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Acid Sand Soil on the Atlantic Coastal Plain of Southwestern Nigeria: Property Variability and Land Evaluation for Agriculture

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Abstract

Acid sand soils that occur along the Atlantic Coastal land of Lagos State of Nigeria were sampled and evaluated for surface soil (0–20cm), property variability, and their potential for pineapple, cashew, mango and coconut crop production. Land was also evaluated for cassava, which is a traditional crop of this area. Soil samples used consist of representative pedons and surface soil horizons from fallow, cultivated and wetland plots.

The least variable (C.V. < 15%) of the properties measured are sand content, pH and base saturation. These soil properties do not seem to reflect the influence of land use types. There is higher correlation coefficient between ECEC and C/N ratio (r = .958) than with organic carbon (r = .436) or clay content (r = .131) for all samples. This trend is repeated on a land-use basis except for those of the wetland where the correlation coefficient between organic carbon and ECEC was higher (r = .773). The correlation coefficient between ECEC and organic carbon for cultivated land use samples is not statistically significant.

Land evaluation indicates that these soils are only moderately suitable for cassava, pineapple and cashew. Nutrient status constitutes the most limiting factor.

Introduction

The coastal area of Nigeria supports rural population whose main occupations are farming and fishing. Recent road development into the coastal area of Lagos State of Nigeria has opened up the hitherto inaccessible coastal lands for multiple use. Land has, therefore, been acquired in large blocks in some instances mainly for cultivation of exportable crops, and, in few instances, for floriculture. There is dearth of data on the properties and distribution of soils located on these coastal sand landforms. The variability and potential of the sandy soils are therefore yet to be evaluated for their worth. This study assesses the productive properties of the soil, especially for exportable tree cash crops.

Materials and Methods

Soils of the Study Area:

Soils evaluated (on latitudes 06^0, 27'N and 07^0. 30'N and longitudes 03^0. 57'E and 04^0.00'E) were from toposequences with non-peat hydromorphic soils on the valley floors. These soils classified as map units A, B and D are all sandy to loamy sand except unit D which has thin humic material at the surface and a shallow water table (Okusami, 1989) (see Table 1 for descriptions).

Samples were collected from surface soils (0–20cm) (composite) of three kinds of land use viz:- cultivated (40 samples), fallow (73 samples) and wet lands (24 samples), and also from the genetic horizons of profile pits (see Table 1) in the different mapping units. The samples were air-dried, and passed through a 2mm sieve. All samples were analysed for particle size distribution (hydrometer method), pH (1:1 and 1:2.5 in H_20 and 0.01M $CaCl_2$ respectively), organic carbon, exchange acidity, total N, exchangeable bases (Ca, Mg, Na and K), available P and electrical conductivity basically using procedures described in Black (1965). Calcium, Mg, Mn, Zn, Cu and Fe were determined by atomic absorption spectrophotometry (Perkin-Elmer 403) while Na and K were by flame photometry. Exchangeable acidity was extracted with 1M KC1 and $A1^{3+}$ and H^+ were determined separately by titration. Effective cation exchange acidity ECEC. Electrical Conductivity (ECe) was measured in saturated (1:1 soil: water ratio) extracts using a conductivity meter.

The FAO method for land evaluation for rainfed agriculture (FAO, 1983) was used to evaluate map units A, B and D. This involved identifying tree cash crops adaptable to soils of low pH and then comparing their requirements with land (soil) qualities of the mapping units. The following crops, Mango *(Mangifera indica* L.), Cashew *(Anarcardium occidentale),* pineapple *(Ananas comusus)* and coconut *(Cocos nucifera)* were considered because of their adaptation to a droughty and acid edaphic environment and also because Mango is found as a common orchard crop around homesteads. Cassava *(Manihot esculenta)* was also evaluated as a current crop under cultivation and crop that would be displaced if evaluation for former crops are positive.

Results and Discussion

Statistical Inference from Surface Soil Properties:

Tables 3 and 4 give summary statistics for relationships between properties of surface soils of the mapping units. The least variability (CV < 15%) is shown by sand content, pH (both in H_20 and $CaC1_2$) and base saturation (BS). These soil properties often show low spatial variability (Wilding and Drees, 1978). Other soil properties exhibit moderate spatial variability but silt size fraction, organic carbon, exchangeable Fe and Zn show CVs greater than 100%.

Table 4 shows correlations between each of ECEC, organic carbon, carbon/nitrogen ratio (C/N) (which are often used as indices of soil fertility) and other soil properties. The low values obtained for the correlation between sand, silt and clay and other properties suggest that soil texture has little or negligible influence on the reactive soil properties, and that organic matter has preferentially accumulated Na ions (r = .814 under fallow and .753 under wetland land-use types). This suggests that during fallow, plants may accumulate Na^+ relative to other measured exchangeable cations on these coastal plain sand. The low correlation (r = .276) between organic carbon and Na^+ under cultivated land-use probably indicates that Na^+ is easily lost on the decomposition of organic matter because it is not a structural component of the plant cell (Wybenga, 1957) and that there is very little reactive surface in this type of soil (Bowen and Lobato, 1988) that could adsorb the released cations. There is a stronger correlation between ECEC and C/N ratio (r = .955) than between ECEC and organic carbon (r = .439) or clay content (r = .131) over all land-use types. This points to the role of organic matter as a dominant source of exchange sites for cation retention and release. The stronger correlation between ECEC and C/N ratio is repeated on individual land use except for the wetland, where the correlation between organic carbon and ECEC attain the highest values. Negative correlation between C/N ratio and Al^{3+} in the upland soils points to the desirability of maintaining organic matter to minimise free A1 ions. A high and unidirectional correlation between C/N and other exchangeable cations (especially Ca^{2+} and Mg^{2+}) also point to the desirability of maintaining organic matter as a reserve if these cations are for gradual release to the soil solution. For these sandy soils therefore, C/N rather than organic carbon predicts better the fertility of the surface horizons.

Land Suitability Classification:

Land qualities: Land qualities deemed relevant to these crops (ILACO, 1981) are oxygen availability (in preference to effective rooting depth), soil moisture availability/drought tolerance, availability of soil nutrients, salinity and erosion hazard.

Effective rooting depth is considered inappropriate for this exercise because the soils that occur on the upland portion of the landscape are sand/loamy sand and very deep (about 250cm). Instead, the groundwater table would control how deep the roots of tree crops would penetrate the soil, so oxygen availability as influenced by the groundwater table is preferable. The drainage classes of the soil survey manual (Soil Survey staff, 1981) were therefore used with slight modification. Four classes equivalent to (1) highly, (2) moderately, (3) marginally, and (4) not suitable, were recognized (Table 5). This division was based on the depth requirements of deep-rooted tree crops. The moderately and marginally suitable soils are on the upper-and lower facets of middle slope respectively. Map unit B is in three of the classes because it occurs along the slope where it is also influenced by high groundwater table. Therefore only map unit D and possibly unit B when temporarily flooded will suffer from oxygen deficit.

Because the soils are very permeable, moisture availability should be directly related to the amount, duration and intensity of rainfall. The emphasis is therefore on perennial crops that can sustain growth and yield despite four to five months' annual drought and the occasional wet season drought. The dry season is needed for ripening and flowering of some perennial crops such as mango and cashew (ILACO, 1981). The rating of the mapping units is therefore a rating for their ability to meet the drought tolerance/ ripening period properties and/or requirements of the crops (Table 6).

Soil pH ranges from strongly acid (5.1 – 5.5) to very strongly acid (4.5 – 5.0). With these ranges, nutrient availability may be affected (McLean, 1973, p. 79), i.e. Zn, Fe, Cu, Mn may be increased while elements like P may decrease. pH ratings (Tale 7) of map units are therefore based on the adjusted pH range of Olson (1981). The pH of these soils may therefore favour release of micronutrients without leading to deficiencies (or toxicities) provided there are replenishing sources within the soil. There are very small amounts of available micronutrients (Table 3). Soil particle size distribution suggest that clays contribute little to the ECEC or the nutrient retention capability of the soils (Tables 3 and 4) (Ahmad, 1988). Although the ECEC is generally low, it is strongly correlated with C/N ratio (Table 4). ECEC is however used instead of C/N ratio as an index nutrient availability because it is more stable and can be measured more readily. Soil texture is included in the rating of nutrient availability because clay content and type will control the exchange properties of subsoil horizons especially those with low organic matter content. The rating in Table 7 was based on the summed subrating concept of Chinene and Shitumbanuma (1988).

All soil horizons are non-saline as shown by EC values less than 15mS cm^{-1} (15 mmhos/cm). The salinity rating of the United States Laboratory Staff (1954) was used for the rating of the land quality, and soil salinity of the mapping units. All mapping units are non-saline and therefore have high suitability to crops. This becomes important because the land utilization types being evaluated for have different levels of sensitivity to salinity (ILACO, 1981) and because of the nearness of the land to the sea.

Erosion hazards is equally not critical because the upland mapping units can absorb almost all the rainfall. Some rills were, however, observed on unit B, and there were also some evidence of past erosion in soil morphology (Okusami, 1989). This is especially expressed in sand content found in the organic soil horizons in the bottom land position during field work.

Requirements for Land Utilization Types: The requirements of the different land utilization types (crops) being assessed are expressed in terms of the land qualities which would determine their productivity and management conditions. Therefore, the requirments of the crops being evaluated are rated (Table 8) in identical forms to those used for the rating of the land qualities for the different mapping units except that desirability should be substituted for suitability in this instance. Thus classes 1, 2, 3 and 4 represent highly, moderately, marginally and not desirable qualities, respectively.

Land Suitability Evaluation: The determination of land suitability involved the comparison of Tables 5 – 7 (see Table 9) against Table 8 to evolve suitability classes for the different mapping units (Table 10). The assumptions under which this determination was made were that:

- there will be good management of the selected land utilisation types;
- accesibility will not be a problem;
- the least favourable of the rated land qualities controls the overall suitability of each map unit.

Table 9 shows that map unit A is well-drained, susceptible to drought, has low fertility status and is non-saline. Map unit B is moderately well drained and moderately drought tolerant, has low fertility status and is non-saline. Map unit D as already discussed, is poorly drained, drought tolerant, has low fertility status and non-saline.

Without exception all crops require a well-drained to moderately well-drained soil environment. Map unit D is therefore not suitable to any of the crops, so it was rated S4 (not suitable) with letter subcripts to show the limiting factors (Table 10). It is however marginally suitable to cassava and could be used if there is a need to increase production of this crop.

Map units A and B allow the cultivation of crops that require well-drained soil. Map unit A is marginally suitable for coconut cultivation because it is sandy and therefore cannot supply moisture all-year round. This is the most limiting factor, as the fertility of the soil can be improved with high inputs. Pineapple, cashew, cassava and mango can all be produced on unit A, though pineapple, cashew and cassava will do better. Cashew requires the drought period for fruiting while pineapple and cassava can tolerate it. Mango also requires drought for fruiting but unit A is rated as marginally suitable for mango cultivation because of its high nutrient requirement, which cannot be met by the sandy soil.

Map unit B is moderately well-drained but may not support good growth of coconut, cashew and mango crops. They all require deep soils for effective rooting. Unit B is therefore classified as marginally capable of producing cassava, coconut and cashew crops with oxygen and nutrient as limiting factors. However, map unit B is considered adequate for pineapple cultivation (at S2f) because this crop requires less rooting depth (ILACO, 1981) and will therefore not be adversely affected by the relatively high ground water table in Map unit B. The only limitation is the poor nutrient status of the soil.

Summary and Conclusions

Map units A and B are considered suitable for cashew and pineapple, respectively. Major problems with these soil types are availability of plant nutrients (soil fertility status) and shallow groundwater table in lower landscape positions of unit B. The influence of organic matter on the physical and chemical properties of these sandy soil is very clear from field and laboratory observations. C/N ratio rather than organic carbon predicts better the fertility of the surface horizons. Soils under cassava have browner surface horizons than those under coconut suggesting lower turnover of organic matter. Surface soil erosion also occurs on land cultivated to cassava, mainly because of crusting. In addition, soil with abundant organic matter was observed to support vehicles with two-wheel drive whereas soils with little or no organic matter (as judged by colour) were suitable only to four-wheel drive vehicles.

Organic matter has an ameliorating role in these Sandy soils. Its generation should therefore be incorporated into the farming systems. Melon plant could be a good source. It is natural to this area, and has the advantages of estbalishing early, growing rapidly with the first rains and decaying rapidly. Its growth habit also means an added advantage towards soil erosion control. Other leguminous crops or grasses can also be tried for improvement of soil physical and chemical properties especially towards successful establishment of the recommended tree crops.

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Table 1: **Morphology of Soil Types A, B and D**

Pedon A. LKBL/1110	
	Colour: Moist except otherwise indicated.
0–10cm A1	Dark brown (10 YR 3/3); loamy sand; weak, fine, medium granular; loose (moist); frequent fine, common medium roots; gradual, smooth boundary.
10–33cm A2	Dark yellowish brown (10 YR 4/6); sand; single grain; loose (moist); common fine, medium and coarse roots; gradual, smooth boundary.
33–58cm BA	Brownish yellow (10 YR 6/6); sand; weak, fine, angular blocky; loose (moist); common coarse, few fine and medium roots; diffuse, smooth boundary.
58–105cm BC1	Brownish yellow (10 YR 6/8); sand, single grain; loose (moist); few, medium and coarse roots; diffuse, smooth boundary.
105–148cm BC2	Brownish yellow (10 YR 6/8); loamy sand; weak, fine, medium angular blocky; very friable (moist); few, medium and coarse roots, diffuse, smooth boundary.
148–190cm BC3	Brownish yellow (10 YR 6/8); loamy sand; weak, fine, medium angular blocky; very friable (moist); very few, coarse roots.
190–250cm C	Yellow (10 YR 7/8) with very faint possibly brownish yellow (10 YR 6/8) mottles; sampled with augar.
Variations:	This soil type occupies both the crest and shoulder of the landscape. The Surface horizons could also be very dark brown (10 YR 2/2).

Pedon B. LKBL/1300

	Colour: moist except otherwise indicated
0–14cm A	Dark grayish brown (10 YR 4/2; grayish brown, 2.5Y 5/2, dry); sand; single grain; loose (moist); very frequent, fine and medium, few coarse roots; smooth boundary.
14–38cm 2A	Brown to dark brown (10 YR 4/3); sand; single grain; loose (moist); frequent, fine, common medium and few coarse roots; clear and smooth.
38–80cm 2BCI	Brownish yellow (10 YR 6/6); loamy sand, weak fine, medium angular blocky; very friable (moist); common medium pores; frequent, medium roots; gradual and smooth boundary.
80–114cm 2BC2	Light yellowish brown (10 YR 76/4); loamy sand; very weak, fine, angular blocky; loose (moist); common medium pores; common, medium roots; difuse, smooth bundary
114–142cm 3C1	Pale yellow (2.5 Y 7/4) with few brownish yellow (10 YR 6/8) mottles at lower part of the horizon; sand; weak, fine angular blocky; very friable (moist); few medium roots; diffuse and smooth boundary
142–200cm 3C2	Pale yellow (2.5 Y 7/4) with common medium and district brownish yellow (10 YR 6/8) mottles; sand; single grain, very friable to loose; very few medium roots.
200–220cm 3Cg	Pale yellow (2.5 Y 7/4) with common medium and distinct brownish yellow (10 YR 6/8) mottles. Sampled with auger under water.

Pedon D. 3B/700

	Colour: moist except otherwise indicated. Soil sampled with auger.
0–7cm A0	Organic debris on surface soil
7–15cm A1	Dark brown (10 YR 3/3); loamy sand.
15–26cm A2	Dark brown (10 YR 4/3); loamy sand
26–52cm BC	Brown (10 YR 5/3, wet); sand
52–120cm	Sampled under water.

Table 2: **Weighted averages for selected properties of some profiles**

Profile No.	Depth* (cm)	Sand	Silt	Clay	Texture**	$P^{H}H_{2}0$	ECEC cmol kg^{-1} Soil	BS %	Org. C g kg^{-1}	AV. P mg kg^{-1}	Ece mS cm^{-1}
			%								
				Mapping Unit A - Typic Ustipsamments							
1	210	89	1	10	ls	4.9	1.06	64.8	4.00	13.9	0.77
2	260	87	1	12	ls	5.2	1.06	75.8	7.50	13.6	0.11
6	250	87	2	11	ls	5.7	2.16	67.3	12.30	10.3	0.37
7	230	92	2	6	s	5.4	3.46	80.1	22.10	9.0	0.55
				Mapping Unit B - Typic Ustipsamments							
3	275	84	1	15	sl	5.2	1.46	52.0	6.1	23.5	0.20
4	145	85	1	14	ls	5.7	2.19	67.4	13.9	11.3	0.32
8	200	91	2	7	s	5.3	2.15	82.9	12.4	14.4	0.226
				Mapping Unit D - Aeric Haplaquents							
5	120	94	1	5	s	4.7	1.21	51.9	10.4	17.2	0.24

*Depth of soil profile sampled

**ls = loamy sand; sl = sandy loam; s = sand.

Table 3: **Summary of Statistics for surface soil sample of studied acid sand.**

	Sand	Silt	Clay	ST[a]	pH		Ca	Mg	Na	K	Al	H	ECEC	BS	Org.	Total	C/N	Avail	Fe	Mn	Cu	Zn
		%			H_2O	CaCl			$cmolkg^{-1}$ Soil					%	C gkg^{-1}	N		P	$mgkg^{-1}$			
										FALLOW LAND (N = 73)												
Mean	89.68	1.81	8.51	1.47	5.11	4.47	2.14	.49	.17	.16	.24	.22	3.40	83.94	18.0	1.8	11.38	19.70	.04	.18	.01	.04
Min.	61	0	4	1	4.7	2.85	.27	.01	.09	.05	.05	.05	.89	52.9	1.60	0.30	1.10	2.5	.01	.01	.01	0
Max.	96	21	18	3	6.65	5.85	5.71	1.29	.63	.59	1.65	.75	7.66	96.7	117.8	10.2	22.6	80	.66	.77	.04	.31
C.V.	5	141	30	38	10	12	58	73	40	53	84	54	48	11	29	76	65	63	217	84	55	126
										CULTIVATED (N = 40)												
Mean	89.18	2	8.83	1.58	5.06	4.39	1.83	.51	.17	.14	.29	.22	3.18	80.26	19.4	1.8[e]	11.42[g]	15.33	.05	.20	.02[e]	.05[e]
Min.	82	0	5	1	3.8	3.12	.25	.01	.05	.03	.05	.05	.67	52.4	1.6	3.0	0.6	4	.01	.01	.01	0
Max.	94	6	15	3	6	5.25	5.07	1.45	4	.37	1.65	.4	7.83	95.3	141.2	9.8	19.6	32	.2	1.2	.06	.22
C.V.	3	75	28	37	8	10	61	66	38	49	90	34	48	14	117	93	42	44	112	111	69	104
										WETLAND (N = 24)												
Mean	86.38	2.85	10.79	1.88	5.12	4.48	2.12	.57	.18	.16	.35	.20	3.58	79.74	15.7	1.3[d]	11.12	16.32[d]	.04	.18	.20	.06
Min.	56	0	5	1	4.05	3.6	.27	.01	.01	.02	.1	.05	.86	53.5	0.40	0.3	0.18	5	.01	.01	.01	0
Max.	92	22	22	3	5.95	5.35	6.67	1.76	.52	.46	1.75	.5	10.76	95.5	117.9	3.9	31.9	39	.16	.5	.05	.18
C.V.	10	179	37	35	10	11	71	76	59	78	100	55	63	18	146	70	55	55	104	79	67	77
										ALL LANDS (N = 137)												
Mean	88.96	2.04	9	1.57	5.10	4.45	2.05	.51	.17	.15	.27	.21	3.37	82.13	18.1	1.7	11.35[f]	19.99[e]	.04	.04	.02[b]	.04[c]
Min.	56	0	4	1	3.8	2.85	.25	.01	.01	.02	.05	.05	.67	52.4	0.40	0.3	0.18	2.5	.01	.01	.01	0
Max.	96	22	22	3	6.65	5.85	6.67	1.76	.63	.59	1.75	.75	10.76	96.7	141.2	10.2	31.9	8.0	.66	.06	.06	.31
C.V.	6	145	33	38	9	11	62	72	44	58	93	49	52	14	105	82	46	59	167	66	66	108

[a]ST = soil texture quantified, 1 = sand, 2 = loamy sand, 3 = sandy loam; [b]N = 135; [c]N = 136; [d]N = 23; [e]N = 39; [f]N = 134; gN = 38.

Table 4: **Correlation values for selected surface soil properties of studied acid sand.**

	Fallow (N = 73)			Cultivated (N = 40)			Wetland (N = 24)			All Samples (N = 137)		
	ECEC	Org. C	C/N	ECEC	Org. C	C/N	ECEC	Org. C	C/N	ECEC	Org: C	C/N
Sand	–.225	.736	–.034	.072	.458	.270	.607	.427	–.391	–.320	–.481	–.108
Silt	.042	.189	.049	.175	.225	.025	.659	.491	.449	.352	.291	.205
Clay	.073	.386	–.056	–.193	.422	–.344	.407	.252	.232	.131	.317	–.030
Ca	.961	.288	.999	.953	.008	.999	.963	.766	.999	.957	.305	.999
Mg	.835	.475	.740	.943	.123	.868	.965	.694	.937	.891	.397	.811
Na	.440	.814	.238	.611	.276	.404	843	.753	.745	.609	.600	.422
K	.394	.385	.326	.775	.046	.673	.870	.642	.795	.1247	.323	.474
Al	.172	.707	–.038	.072	.449	–.188	.395	.235	.146	.213	.452	–.030
H	.166	.197	.120	.198	.050	.098	.534	.492	.348	.250	.212	.160
Fe	.210	.712	–.000	.059	.289	–.152	.220	.073	.059	.166	.430	–.027
ECEC		.494	.962		.127	.954		.773	.963		.436	:958
Org. C	.494	.704	.291	.127		.015	.773		.763	.436		.308
Total N	.347	.704	.210	.196	.024	.024	.546	.599	.497	.311	.379	.218
C/N	.962	.291		.954	.015		.963	.763		.958	.436	
Avail. P	.559	.110	.605	.426	.038	.363	.629	.510	.523	.311	.148	.534
	r <.230, not statistically significant at 5%			r <. 313, not statistically signifiant at 5%			r <. 404, not statistically significant at 5%			r <. 167, not statistically significant at 5%		

Table 5: **Rating of Oxygen availability using drainage classes**

Drainage Classes	Depth (cm)	Rating	Mapping Units	
Well drained	greater than 150	1	A:	B *
Moderately well-drained	101–150	2	B	
Somewhat poorly drained	51–100	3	B *	
Poorly drained/Very poorly drained	0–50	4	D	

*Proportion of mapping unit not appreciable.

Table 6: **Rating for Soil Moisture availability (drought tolerance/Ripening period).**

Dry Season/Ripening Period (Drought tolerance) (months)	Ratings	Mapping Units
4/5	1(4)	A
3	2 (2,3)	B
2	3(1)	B *
Less than 2	4(1)	D

( ) Rating for drought tolerance;

* Proportion of mapping unit not appreciable.

Table 7: **Rating of nutrient availability/retention.**

Factor	Sub-rating	Mapping Units
pH (H_2O)		
6.6 – 7.5	1	
5.6 – 6.5	2	
4.5 – 5.5	3	A, B, D
Less 4.4	4	
ECEC		
cml kg^{-1} soil		
greater than 15	1	
10 – 15	2	
4 – 9	3	
less 4	4	A, B, D
Soil Texture		
Sandy loam	1	
Loamy sand	2	A, B
Sand	3	A, B, D
Clay	4	
Sum of sub-ratings	Final Ratings	
3	1	
4 – 6	2	
7 – 9	3	
10 – 12	4	A, B, D

Table 8: **Rated Soil requirements of crops for optimum productivity**

Crop	Land Qualities			
	Oxygen availability	Drought Tolerance	Nutrient availability	Salinity
Coconut	1	4(4)	2	2
Pineapple	2	2(–)	2	4
Cashew	1	1(1)	3	2
Mango	1	1(1)+	2	4
Cassava	1	2	2	4

( ) Rating for ripening period;
(–) not applicable;
(+) rating for flowering/fruiting.

Classes 1 – 4 represent highly, moderately, marginally, and not desirable qualities respectively.

Table 9: **Summary Ratings of (very important) land qualities for the mapping units**

Mapping Units	Oxygen availability	Drought Tolerance	Nutrient availability	Salinity
A	1	4(1)	4	1
B	2	2,3(2)	4	1
D	4	1(4)	4	1

Figures in parenthesis indicate rating for ripening period.

Table 10: **Land suitability determination.**

Mapping Units	Land Utilizaition Types				
	Coconut	Pineapple	Cashew	Mango	Cassava
A	S3t	S2f	S2f	S3f	S2f
B	S3of	S2f	S3of	S3of	S3of
D	S4ot	S4ot	S4otf	S4ot	S3of

Classes 1 = highly suitable (S1)
2 = moderately suitable (S2);
3 = marginally suitable (S3);
4 = not suitable (S4).

Limiting Factors: o = oxygen availability;
t = drought tolerance;
f = fertility status.