MADAGASCAR VENTURE S.A.R.L.

SOILS SUITABILITY ASSESSMENT D'ANTALAHA PREFECTURE DIEGO-SUAREZ PROVINCE MADAGASCAR FOR AGRICULTURE/MINING AND OTHER INDUSTRIAL DEVELOPMENT

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EXECUTIVE SUMMARY

PURPOSE OF THE SURVEY

This preliminary Soil Survey and Suitability Assessment of an area of 167,500 ha of the Proposed OIL PALM PROJECT in the Prefecture of the Antalaha, Province of Diego-Suarez, Madagascar has been carried out by Param Agricultural Soil Surveys (M) Sdn. Bhd. To determine the potential of the area for oil palm cultivation under estate-level management. The area is currently an area with scattered cultivation by local population. A total of 50,000 ha is to be developed by Madagascar Venture S.a,r,l. into an oil palm plantation. The area which is situated on the northeast part of Madagascar, is accessible by plane from Antananarivo, the national capital. A large number of footpath and a coastal roads area available in the study area.

TOPOGRAPHY AND DRAINAGE

The study area consists of level, undulating, rolling, hilly to steep terrain. The steep terrain (slopes > 38% or 20°) occur often as elongated ridges trending N-S scattered through the central part of the area and to the west. Most of the other areas consists of mainly well drained areas over igneous rocks and alluvia. Poorly drained swamps and water bodies occur in the valleys. Elevation in the study area ranges from 0 to over 1,000 m.

GEOLOGY

The study area dominated by two types of parent materials –igneous rocks and alluvial deposits. The igneous rocks consists of granite, diorites of Precambrian age and basalts of Tertiary to Quaternary age. Three types of alluvial deposits –Marine alluvia, the riverine alluvia and older alluvia occur in the area. The riverine alluvia ranges from imperfect to poorly drained while the older alluvia are well drained. The marine alluvia consists mainly of excessively drained beech sands.

LAND USE

The whole study area is under mosaic of cultivation exept for the step areas which are under jungle.

CLIMATE

The climate of the study area was assessed using the data for Antalaha and Sambava in the study area. Antalaha has an annual rainfall of around 2,500 mm with dry months in September and October. The data for Antalaha and Sambava show that the rainfall is variable with a dry spell in September and October and a rainy period in December and January. The total annual rainfall also around 2,500 mm. The climate in the study area is suitable for oil palm.

SOIL TYPES

A total of eleven (11) soil mapping units have been mapped in the study area. These have been mapped as soil series, soil associations and miscellaneous land units as defined in Peninsular Malaysia. A summary of the main characteristics of the soil mapping units is given in Table 3.1. The soils in the area are suitable for oil palm.

SOIL SUITABILITY FOR OIL PALM

Based on the elevation of the area, the main limitation for oil palm are the steep terrain, sandy textures and surface water in some areas. On the steeper slopes moderate soil depth, soil erosion and low fertility are the main limitations. The current suitability assessment indicates that 115,400 ha or 68.9% of the study area id moderately to marginally suitable for oil palm cultivation.

However with proper soil conservation practices and flood mitigation measures and with proper management most of the area is moderately suitable for oil palm cultivation (see Table 4.6).

CONSTRAINTS AND LIMITATIONS

The major constraints and limitations of the area to the cultivation and agromanagement of oil palm are:

- *Susceptibility of the soils on hilly terrain to soil erosion.*
- *Flooding and poor drainage of the soils in the low-lying areas.*
- *Low fertility status of the soils.*
- *Presence of scattered areas of cultivation in the area.*
- *Scattered nature of the land available for oil palm cultivation.*

SUGGESTED AGRO-MANAGEMENT PRACTICES TO ALLEVIATE THESE LIMITATIONS

- *Carry out proper soil conservation measures such as terracing, cover crop establishment, frond staking on the rolling and hilly terrain.*
- *Carry out drainage and flood mitigation measures.*
- *Proper fertilization of the soils by monitoring leaf levels.*
- *Incorporating the existing formers in the development option by using the nucleus estate concept of development.*

OIL PALM YIELD POTENTIAL

With good management of the soils involving soil conservation, drainage, flood mitigation, soil erosion and fertilizer management an average yield of 20-25 tonnes/ha can be obtained.

LAND OFFERED FOR THE OIL PALM PROJECT

The government of Madagascar has offered seven parcels of land totaling 52,926 ha to the Company for the Oil Palm Project. Of this only 44,593 ha is available and suitable (see Table 5.2). Since the parcels are separated the shortfall of 5,407 ha can be acquired during the development stage in such a way as to link some of the parcels together so that the plantation can be run more efficiently by using a road linkage.

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I. INTRODUCTION

1.1. GENERAL INTRODUCTION

This study consists of Preliminary Soil Survey and Suitability Assessment of the soils totaling 167,500 ha of the Proposed Developed Projects in the Prefecture of the Antalaha, Province of Diego-Suarez, Madagascar. The area is being considered for a verity of development projects. The preliminary soil survey and soil suitability assessment carried out by PARAM AGRICULTURAL SOIL SURVEYS (M) SDN. BHD. At the invitation of MADAGASCAR VENTURES S.A.R.L. who proposed to develop 50,000 ha of this area into an oil palm plantation in 1998. This revised assessment was conducted to evaluate the areas for Agriculture/Mining/Industrial projects.

Essentially, the study objectives are:-

- to carry out a preliminary soil survey of an area totaling 167,500 ha in order to select areas for the proposed Agricultural/Mining and other industrial development projects.
- based on the above soil survey to produce a soil suitability map at a scale of 1:50,000 showing the major soil types and the suitability of the area for these development projects.
- to produce a soil report describing the soils found in the area and to highlight their potential suitability various agricultural, mining and industrial projects.

1.2. LOCATION AND EXTENT

The study area consists of a contiguous parcel of land situated between the Sambawa River in the north and the Onive River in the south. The western boundary is approximately a north-south line about 30 km from the coast while the coastline with the Indian Ocean forms the eastern boundary. The study area which totals 167,000 ha is located in the Prefecture of Antalaha in the Province of Diego-Suarez, Madagascar (see Figures 1.1 and 1.2).

The study area totals 167,000 ha and is situated between latitudes 14° 14’ S and 15° 18’ S and between longitudes 50° 00’ E to 50° 30’ E of the international Meridian. The study area is situated on 1:100,000 topographic sheets Feuille XY-35 Sambava, XY-36 Marombihy, YZ-37 Antalaha and YZ-38 Ambohitralanana. For the central parts of the study area covered by the Maronbihy and Antalaha Sheets, 1:50,000 scale maps were also available (see Figure 1.3). These sheets have a contour interval of 25 meters and were published in 1966 by the Institut Geographique National-Paris, Annexe de Tananarive.

1.3. ACCESS

Access into the area is both by road and footpaths. There are flights from Antananarivo, the national capital to the towns of Antalaha and Sambawa on the northeast coast four times a week. The national highway 53 running from the town of Sambawa along the coast to Antalaha up to the airport at Antsirbato in the south is potholed earth road. The stretch from Antalaha to the airport has been recently metalled. A couple of motorable earth roads into the study area. The roads degenerates south of the airport into a motorcycle or bicycle across these broken bridges.

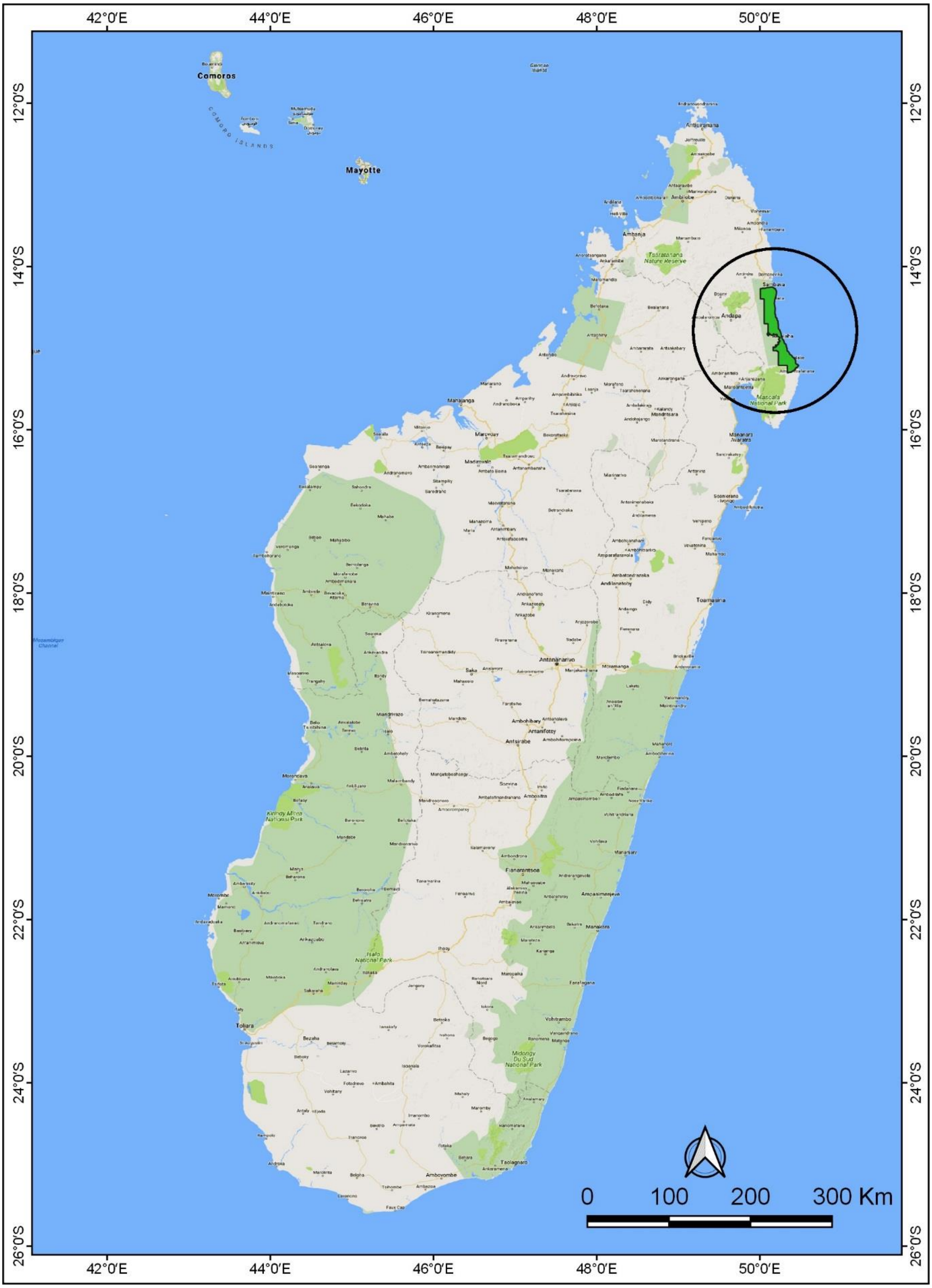


Figure 1.1. Location of the study area in Madagascar.

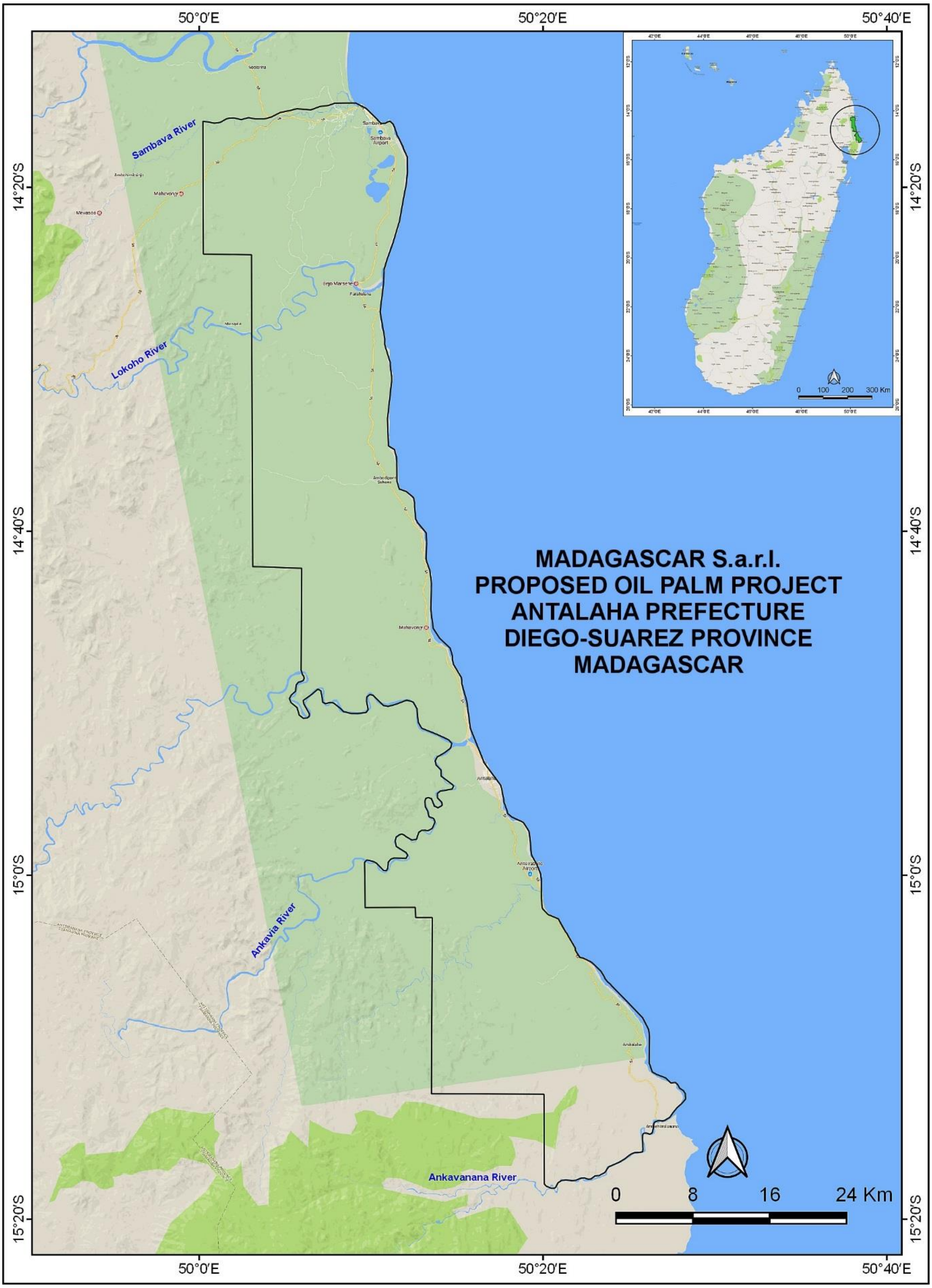


Figure 1.2. Layout Plan of the study area in Madagascar.

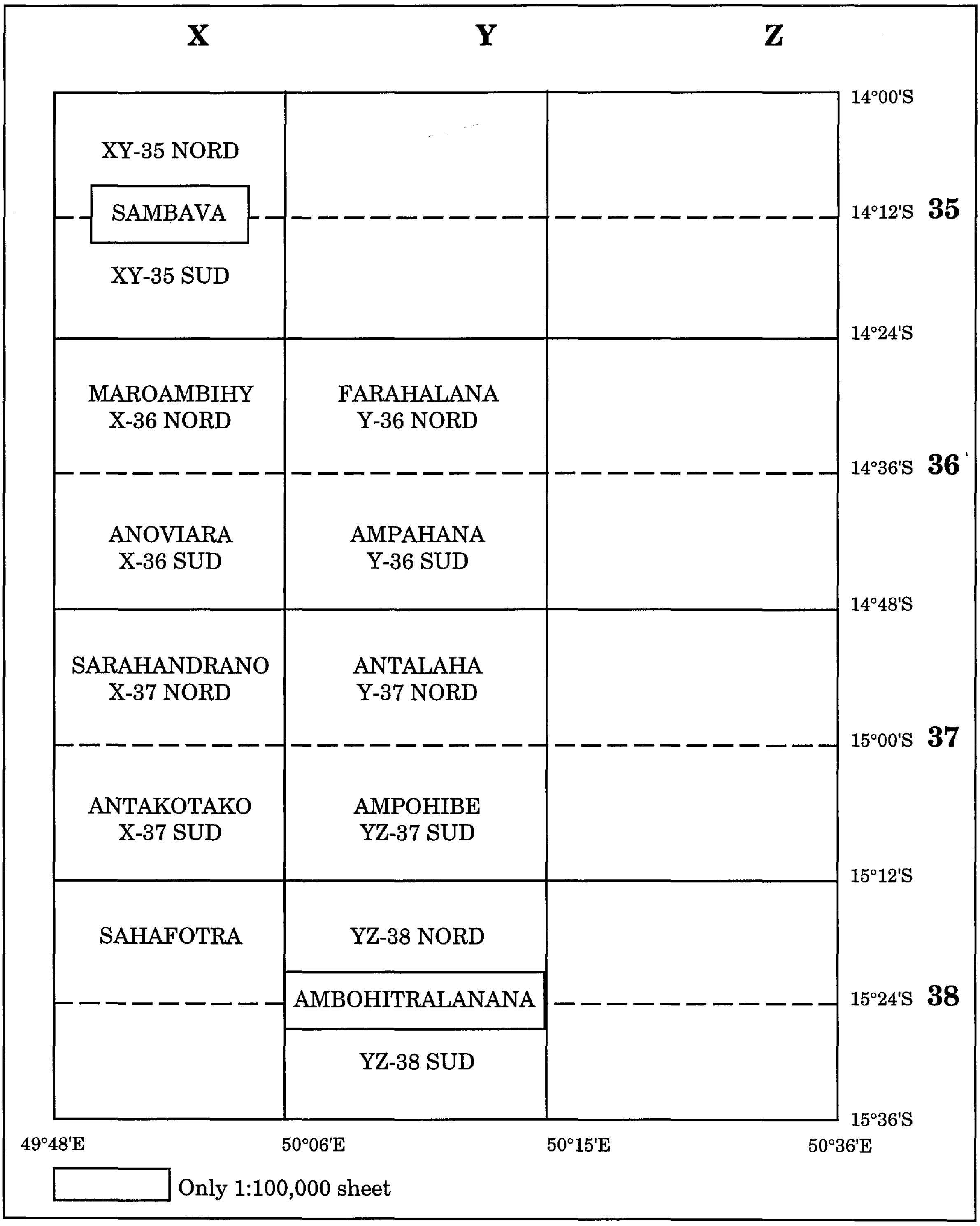


Figure 1.3. Index to topographic sheets (1:50,000).

II. THE ENVIRONMENT

2.1. TOPOGRAPHY AND DRAINAGE

The study area consists of level (0-4% slopes), undulating (4-12% slopes), rolling (12-24% slopes), hilly (24-38% slopes) and steep (>38% slopes) land. Broad alluvial plains occur along the banks of the major rivers such as the Sambava River, the Lokoho River, the Ankavia River, the Ankavanana River and the Onive River. These rivers have a well drained levee and a poorly drained backswamps. Along the coast a broad beach ridge complex exists. These sandy ridges and swales are often planted with coconuts. The undulating, rolling and hilly land is either under forest or other forms of cultivation. Occasionally steep hills occur within the study area. The elevation in the study area ranges from sea level to over 1,000 meters in the steep hills. A few lakes also occur in the study area. A contour map of the study area has been produce with contour interval of 25 meters (see Figure 2.1).

Table 2.1. Slope classes used in Malaysia.

Slope Class		**Description**	**Map Symbol**
(%)	**(°)**		
0–4	0–2	Level	1
4–12	2–6	Undulating	2
12–24	6–12	Rolling	3
24–38	12–20	Hilly	4
38+	20+	Steep	5

2.2. GEOLOGY AND GEOMORPHOLOGY

The geology of the study area has been compiled by Besairie (1970) and a geological map has been produced at a scale of 1:500,000. Part of the map has been reproduces (see Figure 2.2 and Legend). The characteristic future of the study area has been the presence of Pre-Cambrian rocks especially granitic rocks. These granites which consists of two types namely a leucogranite and a monzonitic granite have been metamorphosed to some extent. Strongly metamorphosed rocks of gneiss-mica schists also occur in the area. These two rock types are also Pre-Cambrian age. Lava flows of basaltic composition occur overlying these older rocks. These lava flows consist of Tertiary and Quaternary lava flows. Recent alluvial deposits consist of recent marine alluvial clays and beech sands. The beech sands are quite extensive forming a belt of about one kilometer wide long the coast.

2.3. VEGETATION AND LAND USE

A vegetation and land use map of the area has been produces at a scale of 1:200,000 by the Ministry of Agriculture and Rural Development in 1996. This land use and vegetation map has been produces by interpreting LANDSAT 5 TM images for 1994. This vegetation and land use map has been reproduced here (see Figure 2.3 and Legend).

2.4. CLIMATE

Climatological and hydrological studies are aimed at determining the intensity and distribution of precipitation and other related phenomena with respect place and time. The information thus obtained, coupled with information on soils, terrain etc. is required to determine what crops can be grown in the various locations.

A review of the available climatological data in the area within and adjacent to the study area is possible from the records of the Directorate of Climate and Hydrology in Madagascar. The selected climatic data for Antalaha and Sambava are given in Table 2.2. Unfortunately only means for the period 1961-1990 (30 years) were available. More recent data were either not available or incomplete due to missing values. In addition, rainfall and raindays data for Antalaha (1973-1987) and Cap Est (1988-1993) were available (see Tables 2.3 and 2.4).

2.4.1. Sunshine Hours

The mean monthly sunshine hours for 1961-1990 for Antalaha and Sambava are given in Table 2.2. Antalaha has a mean annual total sunshine of 2,469 hours with low values (< 200 hours/month) in February, June, and August. Sambava also has a low values during the middle of the year when winter is on.

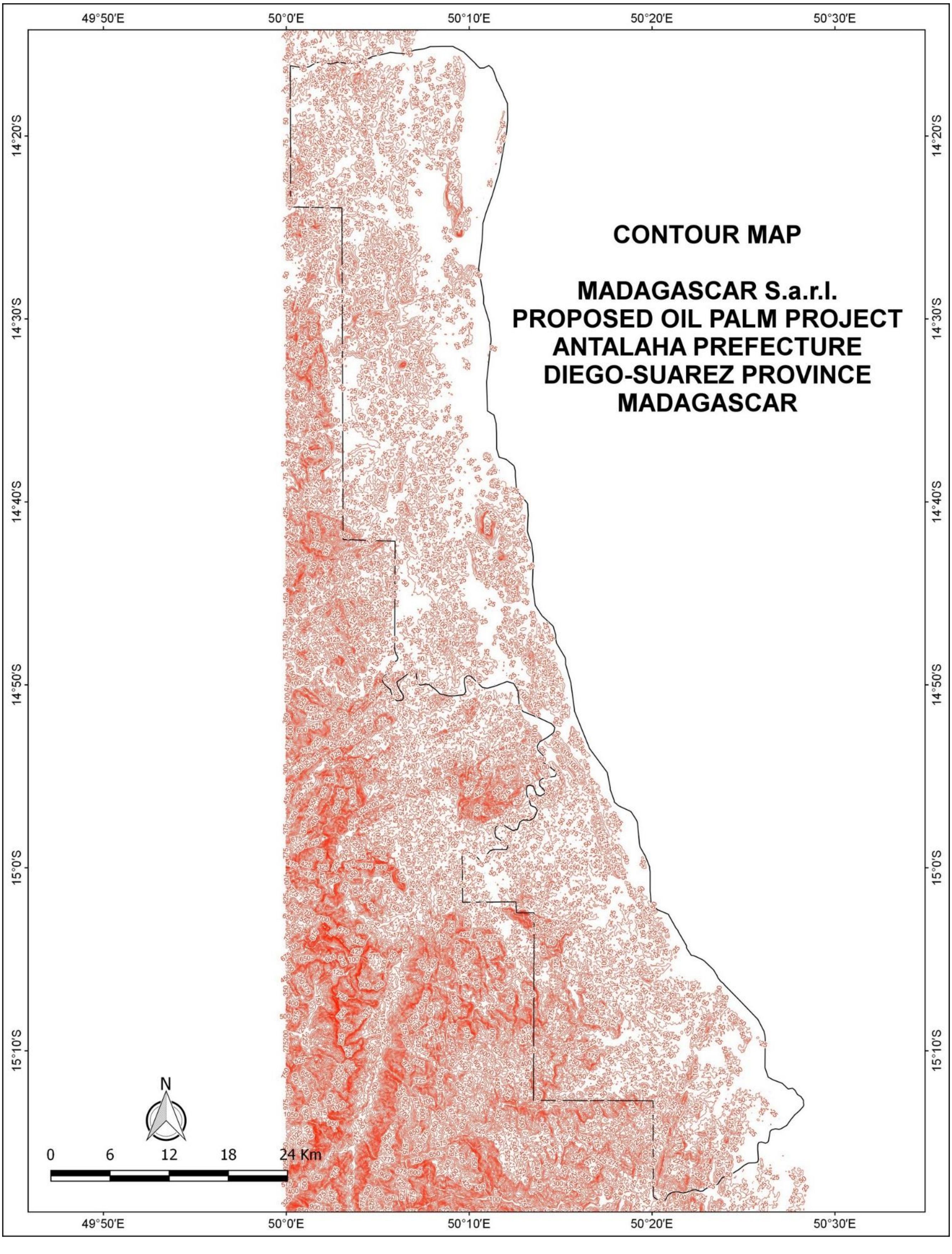


Figure 2.1. Contour Map of the study area in Madagascar.

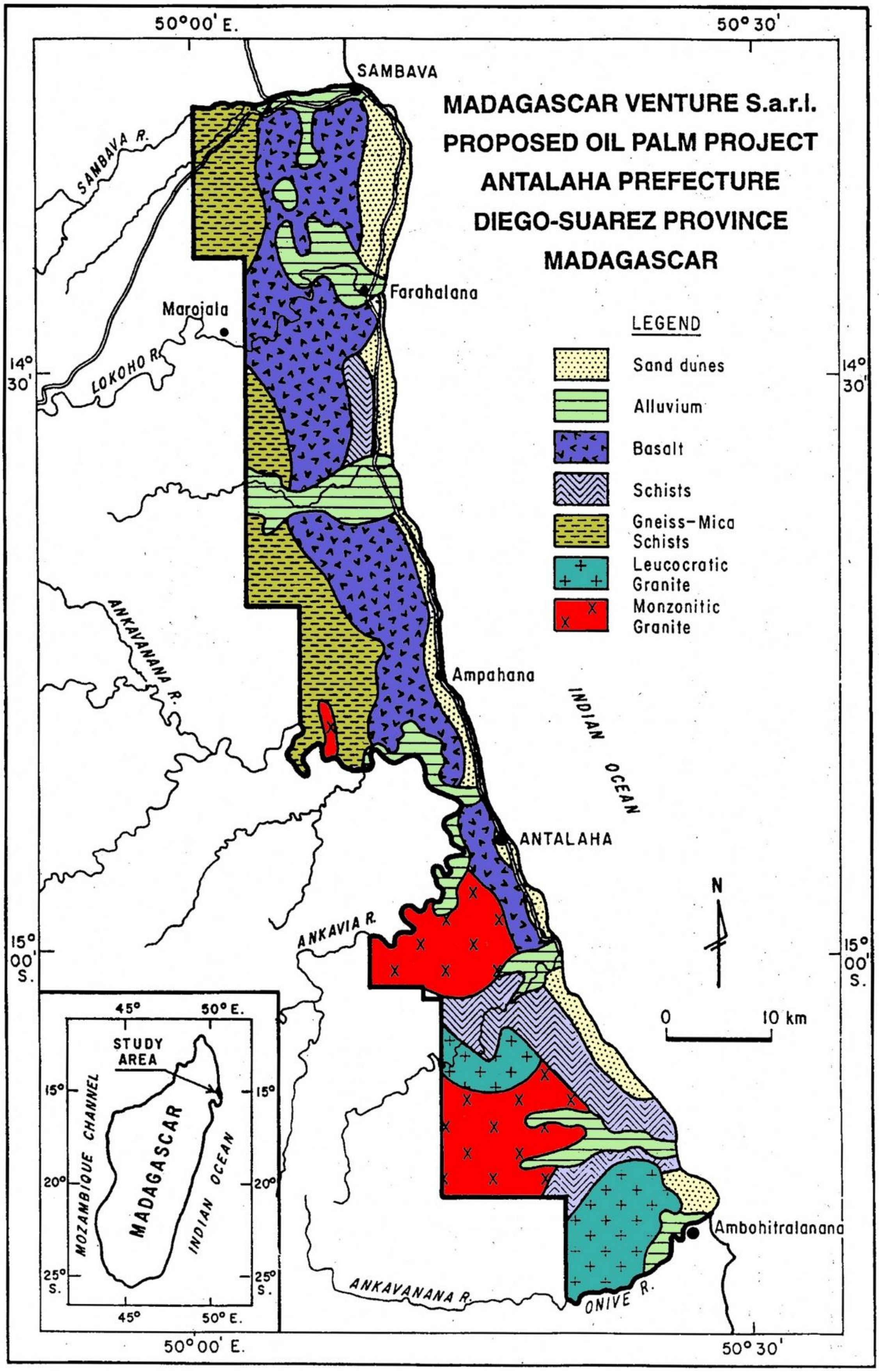
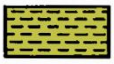
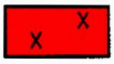
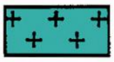


Figure 2.2. Geological map of the study area in Madagascar.

Legend to the study area in Madagascar

MAP SYMBOL	PARENT MATERIAL/ROCK	BRIEF DESCRIPTION	GEOLOGICAL AGE
	Sand Dunes	Sandy Beach Ridges.	Quaternary
	Aluvium	Recent Riverine Alluvium of variable texture.	Quaternary
	Basalt	Fine grained basic lavas.	Tertiary
	Schists	Fine to medium grained mica schists.	Pre-Cambrian
	Gneiss-Mica Schists	High-grade iron-rich metamorphic rocks.	Pre-Cambrian
	Monzonitic Granite	Coarse grained granites probably metamorphosed.	Pre-Cambrian
	Leucogranite	Pale coloured coarse-grained granites probably metamorphosed.	Pre-Cambrian

Geology based on Geological Mao of Madagascar (compiled by H. Besairie, 1970).

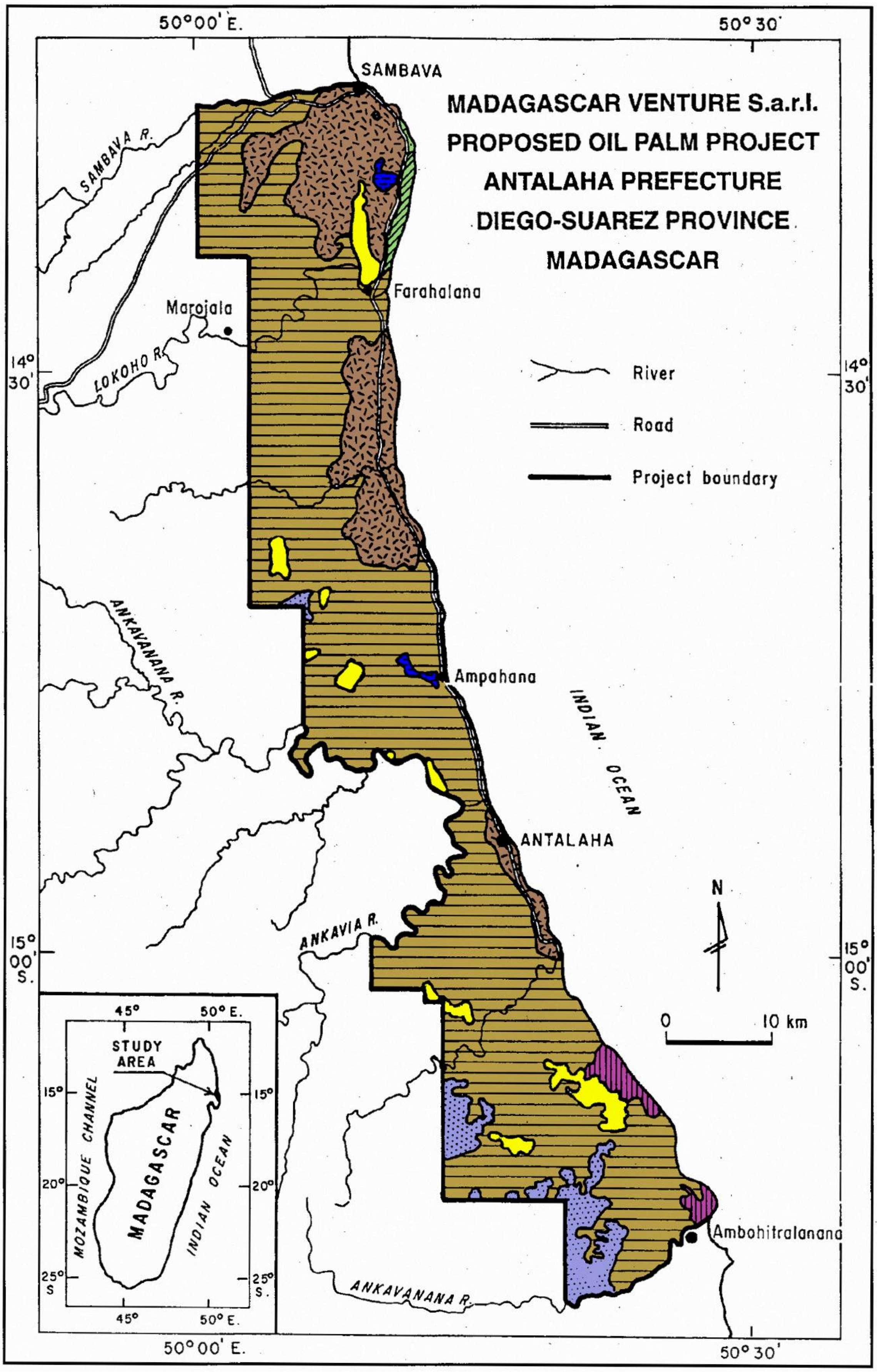
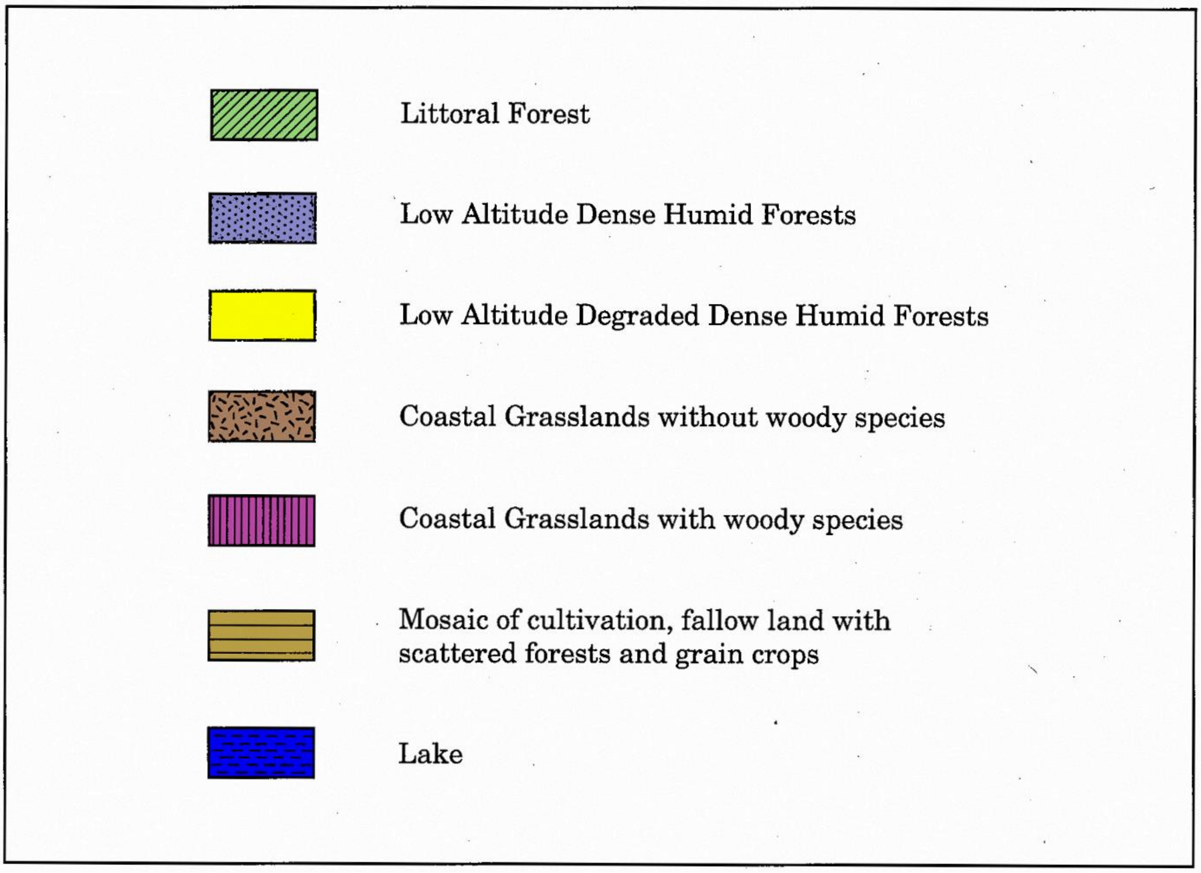


Figure 2.3. Vegetation and land use map of the study area in Madagascar.

Legend for the vegetation and land use map of the study area in Madagascar



2.4.2. Temperature

The mean monthly temperature is always over 21° C in both Antalaha and Sambava. The mean monthly temperature ranges from a low 21.9° C in July to a high of 26.6° C in February in Antalaha.

The lowest mean monthly minimum temperature for both stations is 18.1° C in August while the highest mean monthly maximum temperature is 30.9° C.

2.4.3. Rainfall and Raindays

Antalaha has a mean annual rainfall of 2,376 mm with a total of 236 raindays. A period of low (< 100 mm) occurs in the months of September and October. Heavy rains occur in the months of February and March. This trend of low rainfall in September and October with high rainfall in January, February and March is also seen in the data for Antalaha and Cap Est (see Table 2.3 and 2.4).

Table 2.2. CLIMATIC DATA (1961-1990)

STATION : Antalaha
ELEVATION (metres) : 6

Latitude : 15°00'S
Longitude : 50°20'E

MONTH	AVERAGE MONTHLY					
	Sunshine (hrs)	Rainfall (mm)	Rain Days	Minimum Temp °C	Max Temp °C	Mean Temp °C
Jan	209.2	358.1	20	22.4	30.3	26.3
Feb	198.6	245.8	17	22.5	30.7	26.6
Mar	202.3	306.3	20	22.4	30.2	26.3
Apr	204.1	225.8	19	21.9	29.6	25.7
May	203.3	165.1	19	20.4	28.2	24.3
Jun	178.4	176.9	20	19.0	26.7	22.8
Jul	181.8	170.1	24	18.4	25.9	22.1
Aug	196.5	188.6	24	18.1	25.7	21.9
Sept	208.8	90.9	19	18.4	26.4	22.4
Oct	237.8	92.0	17	19.3	27.5	23.4
Nov	224.9	143.8	18	20.7	28.8	24.7
Dec	223.9	212.6	19	21.9	30.0	25.9
Annual	2,469.6	2,376.0	236	20.5	28.3	24.4

STATION : Sambava
ELEVATION (metres) : 5

Latitude : 14°17'S
Longitude : 50°10'E

MONTH	AVERAGE MONTHLY					
	Sunshine (hrs)	Rainfall (mm)	Rain Days	Minimum Temp °C	Max Temp °C	Mean Temp °C
Jan	220.2	342.2	20	22.6	30.5	26.6
Feb	215.7	257.2	17	22.8	30.9	26.9
Mar	216.4	284.4	20	22.8	30.6	26.7
Apr	215.9	227.1	18	22.1	29.9	26.0
May	223.1	183.3	18	20.7	28.7	24.7
Jun	190.0	182.6	19	19.1	27.2	23.1
Jul	189.4	176.3	22	18.4	26.4	22.4
Aug	199.7	194.9	23	18.1	26.3	22.2
Sept	213.6	100.4	19	18.6	26.9	22.8
Oct	241.3	109.3	18	19.7	27.9	23.8
Nov	228.2	132.0	18	21.1	29.1	25.1
Dec	238.7	219.3	20	22.2	30.2	26.2
Annual	2,592.2	2,409.0	232	20.7	28.7	24.7

Table 2.3. Rainfall and Raindays for Antalaha.

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1973	840.9	439.9	92.0	116.7	152.1	369.8	197.2	201.4	72.3	90.3	31.9	142.9	2,747
1974	481.7	280.2	475.2	452.3	172.9	400.2	208.8	196.9	66.0	155.8	55.4	63.8	3,009
1975	512.5	182.1	235.4	243.1	251.4	190.1	152.2	135.5	116.0	38.0	262.0	612.3	2,931
1976	506.2	352.0	795.7	104.1	36.8	323.0	210.9	85.5	71.3	159.5	90.0	155.6	2,891
1977	276.6	536.3	229.7	185.5	161.0	125.7	137.6	175.7	159.5	65.4	126.6	138.3	2,318
1978	198.9	234.4	636.0	131.7	196.6	144.5	121.9	114.2	106.9	73.0	94.5	181.4	2,234
1979	339.2	101.7	82.9	45.6	204.3	29.8	93.0	210.9	73.1	77.7	80.0	141.3	1,480
1980	207.2	151.7	129.5	161.1	189.5	39.6	108.0	110.1	52.3	48.4	110.2	169.8	1,477
1981	118.9	131.0	210.2	145.0	48.2	64.5	42.0	93.0	79.7	131.2	143.6	242.6	1,450
1982	191.0	84.7	231.2	61.7	138.6	227.8	131.9	192.7	76.9	201.9	72.5	192.7	1,804
1983	289.8	141.8	204.3	191.4	137.4	215.1	69.9	97.6	54.7	87.7	39.4	386.3	1,915
1984	222.2	308.4	353.4	619.4	249.3	260.1	157.1	81.8	89.1	27.0	638.8	158.9	3,166
1985	342.6	223.8	286.0	372.3	94.0	163.9	361.9	271.6	134.4	104.3	67.8	315.8	2,738
1986	220.0	109.6	447.7	210.1	170.8	94.8	90.2	74.2	22.8	224.5	346.3	398.6	2,410
1987	157.8	234.2	241.0	134.4	102.4	52.0	195.0	215.2	75.5	91.4	357.6	57.8	1,919
MEAN	309.6	302.9	325.2	293.9	174.0	197.7	176.0	156.1	96.5	94.2	144.8	220.0	2,491

Raindays

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1973	21	29	18	24	11	27	23	24	15	20	17	18	247
1974	27	25	23	20	23	16	23	23	20	17	17	14	248
1975	22	18	18	24	11	21	24	26	23	14	15	26	242
1976	25	23	29	18	15	23	24	22	19	16	16	16	246
1977	24	20	19	25	15	25	19	21	25	15	21	20	249
1978	14	21	28	20	23	26	24	22	18	13	23	23	255
1979	21	13	18	19	15	17	21	22	22	13	16	19	216
1980	8	11	18	22	22	10	26	22	16	15	21	22	213
1981	19	12	21	13	21	18	18	19	22	18	14	19	214
1982	17	3	20	9	17	25	19	19	17	19	18	15	198
1983	23	17	21	21	19	24	22	22	12	18	10	21	230
1984	16	12	24	25	23	25	22	15	10	17	17	17	223
1985	16	14	21	20	15	14	27	25	23	28	19	24	246
1986	20	15	23	19	23	17	19	15	10				161
1987	17	21	14	15	16	19	23	25	21	10	22	15	218
MEAN	19	17	20	21	18	21	22	21	18	16	17	18	208

Table 2.4. Rainfall and Raindays for Existing Oil Palm Plantation at Cap Est.

Rainfall (mm)

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1988										21.9	60.2	80.1	–
1989	264.0	691.9	571.6	177.9	348.3	258.2	307.4	174.0	294.5	70.8	42.4	436.8	3,638
1990	210.4	299.4	249.7	671.9	274.2	275.4	224.4	147.8	63.2	66.2	150.5	104.5	2,738
1991	322.3	674.8	423.8	586.3	113.1	210.7	343.5	196.0	69.4	58.1	47.1	191.5	3.237
1992	362.3	349.3	242.7	789.8	265.6	311.3	191.1	191.8	155.8	91.1	80.0	229.2	3,260
1993	127.8	530.3	365.3	477.0									–
MEAN	257.4	509.1	370.6	540.6	250.3	263.9	266.6	177.4	145.7	71.5	80.0	240.5	3,174

Raindays

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1988											9	6	–
1989	16	13	17	21	21	19	21	16	18	10	9	13	194
1990	16	16	20	23	21	18	17	21	14	6	21	15	208
1991	24	16	21	28	18	21	22	22	12	16	14	15	229
1992	16	20	15	26	22	28	23	21	24	17	16	21	249
1993	16	17	16	22									–
MEAN	18	16	18	24	21	22	21	20	17	12	15	16	190

III. SOILS OF THE STUDY AREA

3.1. SOIL SURVEY METHODOLOGY

The initial approach to the soil survey was to study the existing information available for the area. This included the FAO / UNESCO SOIL MAP OF THE WORLD (FAO, 1974). According to this map a major portion of the study area consist of Orthic Ferrosols while along the coast Dystric Regosols occur. According to the information obtained from the map sales office in Antananarivo, a natural resources map (Carte Des Ressources En Eaux) on a scale of 1:200,000 is being published for the whole Madagascar by the National Centre for Environmental Research in the Ministry of Science and Technology for Development, Madagascar. These maps are mainly being prepared using SPOT satellite imagery with field checks. Unfortunately the two sheets covering the study area, SC-39J-Antalaha and SC38N-Maroantsetra were currently not available. It was thus decided that for this soil suitability study a field reconnaissance soil survey be carried out. Since the study areas was large and the time spent in the field was limited it was decided that the field survey would be confined to examination if the soils along existing roads, tracks and footpaths. Based on this, the geological and topographic maps would be used to extrapolate the boundaries of the soil types.

During the grand survey, the soils were examined along existing roads, tracks and footpaths. At each examination point, the soil was examined using an Edleman soil auger, sampling the soil to a depth of 105 cm (40 inches) or to an impenetrable layer. At each examination point, the depth, the colour, mottling, texture, consistence, presents of rock fragments and roots were described using the terminology of the FAO's *'Guidelines for Soil Description'*. Other characteristics such as slope, drainage class and parent material were also noted. Based on the properties described, the *'Field Legend'* (Paramananthan, 1987) was recorded. From these data the name of the soil series according to the *'Keys to the Identification of Soils in Peninsular Malaysia'* (Paramananthan, 1987) was determined. At the completion of the soil survey soil pits/road cuttings were dug in the major soils mapped. These were described and sampled for analysis. A total of 3 soil types were described and sampled. The results are presented in Appendix-I

The data collected during the field survey were plotted on the 1:50,000 scale contour map and the final soil map were produced. In compiling the map, the geologic, topographic and other features were used in extrapolating the soil boundaries between the examination points.

Only a reconnaissance soil survey was carried out in the study area. Thus in areas where the soils were complex, associations of soil series were mapped but where the soils were more uniform, soils series were mapped. It can therefore be expected that the soil mapping units show on the Soil-Crop Suitability Map (in pocket) will contain certain amount of inclusions of other soils. In addition it was not possible at the scale of mapping used to delineate all the river valleys in the final map.

3.2. DESCRIPTION OF THE SOILS

The unit of mapping currently used in survey was the soil series as defined in Peninsular Malaysia (Paramananthan, 1987). The *soil series* as defined as defined in Peninsular Malaysia as soils having definite set of soil characteristics in terms of diagnostic horizons, moisture and drainage regimes, temperature regimes, soil depth and horizonation but developed over similar parent materials. The advantage of using the soil series as defined in Peninsular Malaysia is that a vast amount of performance and agronomic data on the growth of oil palm on these soil types is available. This would be a tremendous saving in terms of working out fertilizer programs for the soils in the study area when the oil palm are planted. In the soil map of the study area produced at a scale of 1:50,000 (in pocket) a total of eleven (11) soil mapping units consisting three at soil series level, four soil associations and four miscellaneous land units have been identified. A summary of the main properties of the different soil mapping units is given in Table 3.1.

Table 3.1. Characteristics of the soil map units of the study area in Madagascar.

Parent Material	Map Symbol	Soil Series	Slope Class (%)	Description	Extent	
					Ha	%
Acid igneous rocks	Sgt/3	Segamat	Rolling (12-24)	Deep (>100 cm) red clay. Weak fine subangular blocky; friable. No clayskins (oxic). Well drained. Soils over andesite.	16,300	9.7
	Sgt/4		Hilly (24-38)		29,300	17.5
	Jra-Kkm/3	Jerangau-Kampong Kolam Association	Rolling (12-24)	**Jerangau:** Deep (>100 cm) strong brown clay. Weak fine subangular blocky; friable. No clayskins (oxic). Well drained. Soils over acid igneous rocks. **Kampong Kolam:** Deep (>100 cm) red clay. Weak medium to fine subangular blocky; very friable; no clayskins (oxic horizon). Soils developed over diorite.	12,800	7.6
	Jra-Kkm/4				20,800	12.4
	Rgm/Jra/3	Rengam-Jerangau Association	Rolling (12-24)	**Rengam:** Deep (>100 cm) brownish yellow coarse sandy clay. Weak medium subangular blocky; friable. Patchy clayskins (kandic). Well drained. Soils over acid igneous rocks. (granites) **Jerangau:** Deep (>100 cm) strong brown clay. Weak fine subangular blocky; friable. No clayskins (oxic). Well drained. Soils over acid igneous rocks.	5,200	3.1
	Rgm/Jra/4		Hilly (24-38)		15,000	9.0
Older Alluvium	Tpi/3	Tampoi	Rolling (12-24)	Deep (>100 cm) yellowish red to red fine sandy clay loam. Weak to moderate medium subangular blocky; patchy clayskins (kandic). Well drained. Soils developed over Older Alluvium.	2,800	1.7
Colluvium Riverine Alluvium	Rva/1	Riverine Alluvium	Level (0-4)	Variable textured. Soils found along the river bank. Well drained.	13,200	7.9
Beach ridges	Rdu-Rsl/1-2	Rudua-Rusila Association	Level to undulating (0-12)	**Rudua:** Moderately deep (50-100 cm) white to light gray loose, structureless sand (albic horizon) overlying a brown to black strongly cemented spodic horizon between 50-100 cm depth. Well drained. Soils developed over sandy beach ridges. **Rusila:** Deep (>100 cm) structureless sand. Loose friable. High watertable. Poorly drained. Soils formed in depressions between beach ridges.	15,000	9.0
Miscellaneous Land Unit	Stp	Steepland	Steep (>50)	Land with very steep slopes (>50% or 25°). Shallow (<50 cm) variable textured. Moderately well drained. Rock often within 50 cm depth. High conservation area. High potential for soil erosion. Conservation areas.	30,000	17.9
	W	Water Bodies	-	Effluent, ponds, lakes and old mining ponds.	7100	4.2
				Total:	167,000	100.0

3.2.1. Soils Developed Over Basalts

Only one soil series, the Segamat Series has been mapped over the basalts found in the area. Another soil, the Kuantan Series, also occurs over these parent materials but could not be separated from the Segamat Series at the present scale of mapping. The Segamat Series soils occur on rolling (12-24%) to hilly (24-38%) terrain.

Segamat Series. Soils of the Segamat Series are deep, well drained soils developed over basalts. These soils are characterized by their red colours, clayey textures, weak structures and friable consistence. The consistence below 75 cm becomes gradually firmer. These soils have been mapped on rolling to hilly terrain.

The topsoils of the Segamat Series consists of a dark reddish brown (2.5YR3/4) clay with weak fine subangular blocky structures and friable consistence. The subsoils consist of a deep uniform red (2.5YR4/6–4/8) clay with weak medium subangular blocky structures and friable consistence. Consistence become firmer with depth. No clayskins were observed. Rooting to 70 cm is good. Soils of the Segamat Series on rolling terrain occupy 16,300 ha or 9.7% while those on hilly terrain 29,300 ha or 17.5% of the study area.

3.2.2. Soils Developed Over Granites and Related Rocks

Three soil series - the Jerangau, Kampong Kolam and Rengam Series occur over the granites and related parent materials. Due to the intensity of the survey of these soils have been mapped into two soil associations are Jerangau-Kampong Kolam Association and the Rengam-Jerengau Association. The extent of these soils is as follows:-

Jerangau-Kampong Kolam Association/rolling (12-24%)	12,800 ha or 7.6%
Jerangau-Kampong Kolam Association/hilly (24-38%)	12,800 ha or 7.6%
Rengam-Jerengau Association/rolling (12-24%)	5,200 ha or 3.1%
Rengam-Jerengau Association/hilly (24-38%)	15,000 ha or 9.2%

Jerangau Series. Soils of the Jerangau Series are deep, well drained soils developed over acid igneous rocks such as monzonites. These soils are characterized by their strong brown colours, clayey, textures weak structures and friable consistence. These soils have been mapped in association with soils of the Kampong Kolam Series on rolling (12-24%) to hilly (24-38%) terrain.

The topsoils of the Jerangau Series consists of a dark brown (7.5YR3/4) clay with weak medium to fine subangular blocky and very friable consistence. The subsoils consists of deep uniform strong brown (7.5YR4/6) with weak medium subangular blocky structures and friable consistence. No clayskins were observed. Rooting to over 70 cm depth is good.

Kampong Kolam Series. Soils of the Kampong Kolam Series are deep, well drained soils developed over diorits. These soils are characterized by their red colours, clayey textures weak structures and friable consistence. These soils have been mapped in association with soils of the Jerangau Series on rolling (12-24%) to hilly (24-38%) terrain.

The topsoils of the Kampong Kolam Series consists of a dark reddish brown (2.5YR3/4) clay with weak fine subangular blocky structures and friable consistence. The subsoils consists of deep uniform red (2.5YR4/6-4/8) clay with weak to moderate medium subangular blocky structures and friable consistence. No clayskins were observed. Rooting in these soils is good.

Rengam Series. Soils of the Rengam Series are deep well drained soils developed over granitic rocks such as leucogranites. These soils are characterized by their sandy clay textures, brownish yellow to strong brown upper subsoils which become yellowish red at depth. Structures are weak to moderate medium subangular blocky and consistence is friable to firm. Thin patchy coatings occur on ped faces. Soils of the Rengam Series has been mapped in association with soils of the Jerangau Series on rolling (12-24%) to hilly (24-38%) terrain.

The topsoils of the Rengam Series consists of a dark yellowish brown (10YR4/4) to brown (7.5YR4/2) sandy clay loam to clay loam. Structures are weak fine subangular blocky and friable consistence. The subsoils to around 70 cm consist of a brownish yellow (10YR6/6–6/8) to strong brown (7.5YR5/6-5/8) sandy clay to clay with moderate medium subangular blocky structures and firm consistence. Patchy coating occur on ped faces.

3.2.3. Soils Developed Over Older Alluvium

Only one soil series, the Tampoi Series has been mapped over this parent materials. These soils are of limited extent and occupy 2,800 ha or 1.7% and occur on rolling (12-24%) terrain.

Tampoi Series. Soils of the Tampoi Series are deep, well drained soils developed over Older Alluvium. These soils are characterized by their yellowish brown colours, sandy clay loam textures, weak medium to fine subangular blocky structures, and friable consistence and patchy clayskins.

The topsoils of the Tampoi Series consists of a very dark grayish brown (10YR3/2) to dark brown ((10YR3/3) coarse sandy loam to coarse sandy clay loam. Structures are very weak fine subangular blocky to structuresless single grain. Consistence is very friable. The subsoils consists of dark yellowish brown (10YR4/4) to brown (7.5YR4/4) coarse sandy loam to clay loam. Structures are weak to moderate medium subangular blocky and consistence is friable. Patchy clayskins occur on ped faces.

3.2.4. Soils Developed Over Recent Riverine Alluvium

The term *'recent riverine alluvium'* is used to describe all the soils found on level (0-4%) terrain in the valleys and flood plains of the rivers in the study area. Most of these areas have been planted with wetland rice which is cultivated during the rainy seasons. These soils are deep imperfect to poorly drained and have fine sandy clay or clay textures. Structures are weak coarse angular blocky and consistence is slightly sticky to firm. These areas are often flooded during the rainy seasons. These riverine alluvial soils occupy 13,200 ha or 7.9% of the study area.

3.2.5. BRIS Complex

The term *'BRIS Complex'* consists of a series of beech ridges interspersed with swales which occur adjacent to the coast. These soils are sandy with about 95% sand. These sand is often medium to fine and deep. These soils are excessively drained and range in colours from yellowish brown, yellow and white depending on iron and organic matter content. In the depressions between the ridges have a high watertable and flooding is common. At the scale of the present survey it was not possible to separate the various soils in this complex. Soils of the BRIS complex occupy 15,000 ha or 9.0% of the study area.

3.2.6. Steepland

All areas with slopes in excess of 38% or 20° are termed as steepland. These areas often have shallow to moderately deep soils and the weathering rocks often encountered at shallow depths. Such areas, when cleared are prone to soil erosion. Hence steepland areas should be retained as forest. Steepland areas occupy 30,000 ha or 17.9% of the study area.

3.2.7. Waterbodies

All areas with water standing on the surface are placed into this category. These areas were mapped based on the existing topographic maps and occupy 7,100 ha or 4.2% of the study area.

3.3. SOIL CLASSIFICATION

The soils types mapped in the study area have been classified into the FAO/UNESCO FAO/UNESCO Soil Map of the World — Revised Legend (FAO, 1990) and the *Keys to Soil Taxonomy* — Seventh Edition (Soil Survey Staff, 1996). This classification is given in Table 3.2.

Table 3.2. Classification of the Soils

Soil Series	FAO/UNESCO Soil Map of the World — Revised Legend (FAO, 1990)	Soil Taxonomy* — Second Edition (Paramananthan, 2011)
Segamat	Rhodic Ferralsol	Typic Acrudox Very fine, oxidic
Jerangay	Xantic Nitosol	Typic Acrudox Very fine, oxidic
Kampong Kolam	Rhodic Ferrosol	Typic Acrudox Very fine, oxidic
Rengam	Haplic Nitisol	Typic Kandiudult Fine clayey, kaolinitic
Tampoi	Haplic Nitisol	Typic Kandiudult Fine loamy, siliceous
Bris compex Rusila	Haplic Arenosol	Typic Tropopsamment Sandy, siliceous
Bris compex Rudua	Typic Tropohumod	Typic Troporthod Sandy, siliceous

*All soils isohyperthermic

3.4. SOIL CHEMICAL CHARACTERISTICS

A total of three (3) soils were described and sampled for analysis. The descriptions and analytical data of these profiles are given in the Appendix. The three soil types sampled are the Rengam Series (M1), the Tampoi Series (M2) and the Jerangau Series (M3). These resuts are discussed briefly below.

Pedon M1 — Rengam Series
Pedon M2 — Tampoi Series
Pedon M3 — Jerangau Series

Soils of the Rengam Series are represented by Pedon M1. These soils have a low to very low clay content of around 10% in the surface horizons but increases rapidly to 50% with depth. Silt content are low never exceeding 10%. Total sand content decrease from 80% in the surface to 46% in the lower subsoil. The coarse sand : fine sand ratio is over 3 confirming that these soils are derived from coarse grained acid igneous rocks such as granites. As expected these soils are acidic. Organic carbon contents are high in the surface but reduces rapidly with depth. Total nitrogen content are low resulting in a C/N ratio of around 7-10. Available P values are very low (<3 ppm) while total P values are moderate to high (190-270 ppm). Cation exchange capacity values are low with values of 2 to 2.5 cmol. Except for the exchangeable magnesium which is low all the other such as such as calcium potassium are very low. Base saturation values are between 10-20% while exchangeable aluminum values are moderate to low. These results confirm that soils of Rengam Series are of low current fertility status and have a low capacity to retain nutrients. Thus unless a good dosage of fertilizers are added, it will not be possible to obtain and good yields of oil palm.

Soils of the Tampoi Series are represented by Pedon M2. These alluvial soils characterized by very low clay and silt contents (less than 20%). Total sand content are over 90% which major portion of coarse sand. These soils are acidic and organic carbon contents are loe to very low and total nitrogen values are low. Available P values are very low while total P values are moderate. Cation exchange values are very low with values of less than 2 cmol. Exchangeable cations are also very low but base saturation values are moderate. Exchangeable aluminum values are very low.

These results confirm that soils of Tampoi Series are of low fertility status and would require heavy dosage of fertilizers if the oil palm crop is to be obtain good yields. The use of organic mulches such as empty fruit bunches (EFB) and palm oil mill effluent (POME) on these soils would be very beneficial.

Soils of the Jerangau Series are represented by Pedon M3. These soils developed over granodiorites monzonites are characterized by a high clay content but the clays are often aggregated to give high silt values. Thus the silt plus clay values are the actual clay content i.e. over 60%. This aggregation of the clays is probably the result of high iron contents. Both fine and coarse sand contents are equal and total around 30%. These soils are acidic with pH range of 4.1 to 4.5. Organic carbon contents are high in the surface. Total nitrogen values are very low. Available P values are very low while total P values are high to very high again suggesting a fixation of P by the iron. Cation exchange and exchangeable values are high in the surface but low in the subsoil. Exchangeable aluminum values are low while base saturation values are low. These result confirm that soils of the Jerangau Series are of a low fertility status. Special attention should be paid to P values as the P fixation values are high. Thus the use of an organic mulch such as POME of EFB will be beneficial to the crop.

The analytical data of the soils confirm that the three soils sampled suggest that these soils have a low fertility status and hence unless a proper dosage of fertilizer are applied, it will not be possible to obtain and maintain good yields of oil palm.

IV. LAND SUITABILITY EVALUATION (OIL PALM)

4.1. INTRODUCTION

The field survey provide basic information on the soil map units of the area including their characteristics, extent and location. To put the field survey more practical terms in interpretation of this information is required with respect to the use under consideration. This section involves the assessment of the land and soil characteristics in terms of their suitability for the defined land utilization types (LUTs). It is noteworthy that the suitability interpretations are predictions of performance are not necessarily final recommendation for the use of the land. The optimum use of the land involves further considerations of, for example, social, economic, preference of the owner and access to markets.

Performance of suitability rating and response of a soil to management or use depend on its characteristics and quality. Good soil survey interpretations help the soil user to apply the most profitable crop and management for each soil. Although management alone can invariably increase cop yield, optimization of yields depends on manipulating management practices to fit various kind of soils. In some instances certain soils or land limitations can be overcome, or it may not be economic. Permanent soil characteristics such as soil texture, kind of clay, soil depth extra largely determined the response of a soil to a particular crop or to a kind of level management.

4.2. LAND UTILIZATION TYPES

A number of land utilization types were considered in this updated study. This is the cultivation of agricultural crops, mining and other industrial development projects. The fundamental criteria in the suitability determination for the LUT is that of climate and slope. Other characteristics essential in assessing the suitability for the LUT principally concern various soil properties including texture, drainage, depth, flooding, fertility etc. Oil palm is quite a tolerant crop but on steep slopes harvesting may be a problem.

4.3. SUITABILITY CRITERIA – PHYSICAL LAND QUALITIES

The suitability of the land for a specific LUT is governed by a number of physical factors. Each LUT has very specific requirements with respect to these various physical land qualities. These physical land qualities of the soil mapping units in the study area are discussed below with respect to the suitability criteria for oil palm.

4.3.1. Rainfall and Soil Moisture

An examination of the rainfall data for Sambava, Antalaha and Cap Est within the study area indicates that the rainfalll is around 2,500 mm per annum. While this value indicates adequate rainfall for oil palm, the monthly distribution indicates that in January the rainfall is over 300 mm. This high rainfall result in flooding in the valleys and lowlying alluvial plains and may hamper field operations and thereby reduce actual harvested yields. A period of low rainfall occurs at Antalah and Cap Est in the month of September and October. This period of low rainfall is not expected to seriously affect the yield of oil palm but is considered beneficial in controlling pests and diseases.

4.3.2. Slope

The dominant slopes is a fundamental element in the suitability assessment of the land. Steep slopes are associated with severe erosion losses and therefore require particular attention. The potential erosion hazard of the steep areas in the study area is regarded as being severe because of the slopes and the nature of the individual rainfall, the resulting run-off to infiltration ratios are also high. To minimize soil erosion the planting of cover crops and terracing on the steeper slopes is essential. While oil palm can be cultivated on these slopes the difficulty of harvesting and mechanization on such slopes in addition to the cost is obvious. The shallow to moderate soil depths in these areas means that on terracing the parent material will be encountered making soil depth to become another limitation. Thus areas with slopes in excess of 38% or 20° are considered to be marginal for oil palm cultivation.

4.3.3. Soil Physical Characteristics

The physical properties of the soil are an important consideration in the suitability assessment and directly affect crop performance. A minimum rooting depth of 50 cm is requires for most crops and the presence of stones and gravels is not desirable. Most crops do not tolerate poor drainage and/or flooding. Sandy soils do not have tha ability to retain moisture and fertilizers. Sandy soils are common along the coastal areas. These soils are not suitable for oil palm cultivation.

4.3.4. Soil Chemical Characteristics

The fact that the soil chemical characteristics can be ameliorated is the notable difference between these and soil physical characteristics. Nevertheless, the soil chemical characteristics are an equally important consideration in assessing the suitability of the soil.

4.4. SOIL SUITABILITY EVALUATION

The soil survey carried out in the study area has identified **______** different soil mapping units of which

4.4.1. Classification System

The land/soil suitability classification system utilized corresponds to that of FAO (1976). The framework in this system consists of three hierarchal categories: orders, classes and subclasses.

At the highest level two orders are used defined as follows:

Table 4.1. Land evaluation classification system for oil palm.

ORDER	CLASS	DEFINITION
S Suitable	S1 Highly Suitable	Land having no or only minor limitations to the sustained cultivation of oil palm.
	S2 Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained cultivation of oil palm. Productivity will be significantly lower and/or inputs will be significantly greater than the S1 land.
	S3 Marginally Suitable	Land having limitations which in aggregate are severe for the sustained cultivation of oil palm. Productivity will be so reduced and/or the required inputs will be so high that the use of this land will be only marginally justified.
N Not Suitable	N Not Suitable	Land giving qualities that appear to preclude its sustained use for the cultivation of oil palm.

Suitable (S): Land on which sustained use for the defined purpose and manner is expected to yield benefits that will justify recurrent inputs without unacceptable risk of damage to the resource base.

Unsuitable (N): Land having qualities that appear to preclude its sustained use for the defined purpose and manner.

The classes reflect degrees of suitability within the above orders. Three classes are recognized under the order suitable and single class under the unsuitable order. An outline of the suitability classification system is presented in Table 4.1.

Subclasses indicate specific limitations within the classes a total of six limitations were recognized and considered in the evaluation as follows:

c - climate limitation consisting of rainfall, dry periods, sunshine etc.

d - drainage and flooding limitation.

f - fertility limitation associated with low inherent fertility status.

p - physical soil quality limitation such as weak structured, organic soil material (peat).

s - soil depth limitation often due to presence of thick gravel layer.

t - topographic limitation of excessive slopes; also implies a potential soil erosion hazard.

4.4.2. Suitability Assessment Procedure

The individual land characteristics for each of the soil mapping units are summarized in Table 4.2. These qualities are in turn evaluated for oil palm - the crop considered in this study. This rating is assign to the land characteristics based upon criteria and class limits set out for oil palm (Table 4.3, Paramananthan, 1998 in press)

The evaluation and assessment of the climate of the study area for oil palm is given in Table 4.4. The evaluation for each of other land qualities of the soil mapping units with respect to oil palm is presented in Table 4.5. These individual ratings are summarized at the bottom of the same table with each soil mapping unit being assigned an overall rating for oil palm cultivation.

In assigning an overall suitability rating to each soil mapping unit for a particular crop the lowest suitability rating determines the overall rating.

4.4.3. Overall Suitability Rating

From the evaluation of the climate summarized in Table 4.4, it can be seen that the climate in the study area is moderately suited for oil palm cultivation. Some field operation problems may be encountered in the rainy season due to flooding especially in the poorly drained soils.

Table 4.2. Land characteristic of the soil map units.

Land Characteristic	SOIL MAP UNIT									
	SGT/3	**SGT/4**	**JRA-KKM/3**	**JRA-KKM/4**	**RGM-JRA/3**	**RGM-JRA/4**	**TPI/3**	**RVA/1**	**BRIS/1–2**	**STP/5**
Slope (%)	12–24	24–38	12–24	24–38	12–24	24–38	12–24	0–4	0–12	38+
Drainage Class	well	well	well	well	well	well	well	Imperf. to Poor	Excessive to Poor	well
Flooding	None	None	None	None	None	None	None	Moderate	None	None
Texture/Structure	c	c	c	c	sc-c	sc-c	scl	sc-c	s	sc-c
Gravel Layer Depth (cm)	None	None	None	None	None	None	100+	None	None	None
Depth to Hard Rock (cm)	100+	100+	100+	100+	100+	100+	100+	100+	100+	50+
Thickness of Peat (cm)	–	–	–	–	–	–	–	–	–	–
Fertility Status	Low	Low	Low	Low	Low	Low	Low	Low to moderate	Very low	Low

Table 4.3. Evaluation of land characteristics for oil palm.

SOIL SUITABILITY CLASS	**Highly Suitable (S1)**		**Moderately Suitable (S2)**	**Marginally Suitable (S3)**	**Not Suitable (N)**
LAND/SOIL CHARACTERISTIC / **DEGREE OF LIMITATION**	**Not Limiting**	**Minor Limitation**	**Moderate Limitation**	**Serious Limitation**	**Very Serious Limitation**
CLIMATE					
• Total annual rainfall (mm)	2,500–3,500	3,500–4,000 1,700–2,500	4,000–5,000 1,450–1,700	5,000–6,000 1,250–1,450	6,000 + – 1,250
• Length of dry season (months)	None	1	1–2	2–3	3 +
• Mean Daily Solar Radiation(MJm^{-2})	13–15	15–17 11–13	17–19 9–11	19–21 7–9	21 + – 7
• Mean Annual Temperature (°C)	25–29	29–32 22–25	32–35 20–22	35–37 16–20	37 + – 16
• Wind (m/s)	5–8	8–10 3–5	10–15 – 3	15–20 –	20 +
TOPOGRAPHY					
• Slope (%) (°)	0–4 0–2	4–12 2–6	12–23 6–12	23–38 12–20	38 + 20 +
WETNESS					
• Drainage Class	Moderately well to imperfect	Well to somewhat excessive	Excessive or somewhat poorly drained	Poorly drained	Very poorly drained
• Flooding	Not flooded	Not flooded	Minor flooding	Moderate flooding	Severe flooding
PHYSICAL SOIL CONDITIONS					
• Texture/structure	Cs, SC,CL	Co, L, SCo SiCL	SCL, Cm, SiCs	SiCm SL, LfS	LcoS S
• Depth to root restricting layer (cm)	100 +	75–100	50–75	25–50	– 25
• Depth to acid sulfate layer (cm)	100 +	–	75–100	50–75	–50
• Thickness of organic soil (cm)	–	0–50	50–200	200–500	500 +
SOIL FERTILITY CONDITIONS					
• Weathering stage (effective CEC) cmol(+)/100 g clay	24 +	16–24	– 16		
• Base saturation (%) A horizon	50 +	35–50	– 35		
• Organic carbon (%) A horizon	1.5–2.0	2.0 + – 1.5			
• Salinity (millimohs) 50 cm depth	0–1	1–2	2–3	3–4	4 +
• Micronutrients		Deficiency	Toxicity		

Table 4.4. Climatic evaluation of land characteristics for oil palm

Characteristic	Climatic Evaluation for Oil Palm
Total Annual Rainfall (mm)	S2
Length of Dry Season (months)	S2
Mean Daily Solar Radiation (MJm^{-2})	S1
Mean Annual Temperature (°C)	S2
Overall Climatic Evaluation	S2

Table 4.5. Suitability evaluation for oil palm.

Characteristics	**SUITABILITY RATING OF SOIL MAP UNIT**									
	SGT/3	**SGT/4**	**JRA-KKM/3**	**JRA-KKM/4**	**RGM-JRA/3**	**RGM-JRA/4**	**TPI/3**	**RVA/1**	**BRIS/1-2**	**STP/5**
Climate	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
Slope	S2	S3	S2	S3	S2	S3	S2	S1	S1	N2
Drainage Class	S1	S1	S1	S1	S1	S1	S1	S3	S3	S1
Flooding	S1	S1	S1	S1	S1	S1	S1	S3	S1	S1
Texture/Structure	S2	S2	S2	S2	S1	S1	S3	S1	N1	S1
Gravel Layer	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Depth to Rock	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2
Depth of Peat	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Fertility	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
OVERALL RATING										
Current	S2cfpt	S3t	S2cfpt	S3t	S2cft	S3t	S3p	S3d	N1p	N2t
Potential*	S2c	S2c	S2c	S2c	S2c	S2c	S3p	S2c	N1p	N2t

Suitability Class:
S1 = Highly Suitable
S2 = Moderately Suitable
S3 = Marginally Suitable
N1 = Currently Not Suitable
N2 = Permanently Not Suitable

Limitations:
c = climate
d = drainage/flooding
f = fertility status
p = physical soil quality
s = soil depth
t = topography

* Economics not considered.

Table 4.6. Overall soil suitability for oil palm.

SOIL MAP UNIT	SOIL SUITABILITY SUBCLASS		REMEDIAL MEASURES REQUIRED	EXTENT	
	Current	Potential*		Ha	%
SGT/3	S2cfpt	S2c	Fertilization.	16,300	9.7
SGT/4	S3t	S2c	Terracing, soil conservation, fertilization.	29,300	17.5
JRA-KKM/3	S2cfpt	S2c	Fertilization.	12,800	7.6
JRA-KKM/4	S3t	S2c	Terracing, soil conservation, fertilization.	20,800	12.4
RGM-JRA/3	S2cft	S2c	Fertilization.	5,200	3.1
RGM-JRA/4	S3t	S2c	Terracing, soil conservation, fertilization.	15,000	9.0
TPI/3	S3p	S3p	Fertilization, soil conservation, EFB application.	2,800	1.7
RVA/1	S3d	S2c	Drainage, fertilization.	13,200	7.9
BRIS/1–2	N1p	N1p (S3p)	Fertilization, EFB application.	15,000	9.0
STP/5	N2t	N2t	–	30,000	17.9
W (water)	N2	N2	–	7,100	4.2
			TOTAL:	167,500	100.0

Suitability Class:
S1 = Highly Suitable
S2 = Moderately Suitable
S3 = Marginally Suitable
N1 = Currently Not Suitable
N2 = Permanently Not Suitable

* Economics not considered.

Limitations:
c = climate
d = drainage/flooding
f = fertility status
p = physical soil quality
s = soil depth
t = topography

Based on the current soil suitability evaluation carried out 8 out of the 11 soil mapping units are either moderately or marginally suitable for oil palm cultivation (see Table 4.6) The suitable soil map units are SGT/3, SGT/4, JRA-KKM/3, JRA-KKM/4, RGM_JRA/3, RGM-JRA/4 TPI/3 and RVA/1 which total 115,400 ha or 68.9% of the study area. The suitability status of many of the marginally suitable land can be upgraded by simple remedial measures outlined in Table 4.6. All the remaining soil map units viz. RDU-RSL/1-2, STP/5 and W (water bodies) are not suitable for oil palm cultivation. The unsuitable land total 52.100 ha or 31.1%. These soil map units are unsuitable for oil palm cultivation due to sandy textures, steep slopes and water on soil surface.

4.4.4. Main Limitations to Oil Palm Cultivation

A major portion of the study area consists of land with rolling, hilly and steep slopes. The soils such as Rengam and Tampoi Series are prone to soil erosion if these soils are exposed to the rain after clearing. Thus it is imperative that proper soil conservation works be carried out throughout the development of the area. The soil conservation work such as time of land clearing, proper soil terracing, cover-crop establishment, stacking of oil palm fronds and the use of silt-traps along roads are essential if high yields of oil palm are to be obtained and maintained. A river reserve should also be established along the rivers to ensure that siltation of the rivers is minimal.

Flooding during rainy seasons particularly in the poorly drained soils (RVA/1) can create problems especially when the palms are young. Young palm cannot tolerate flooding-especially if the water is stagnant. Thus in these areas proper drainage needs to be applied.

Low fertility status is a common problem in tropical soils and the soils in the study area are also generally of low fertility status. Thus the use of fertilization are mandatory if high yields of oil palm are to be obtained and maintained. The loamy soils of the Tampoi Series particularly require special attention. The use of empty fruit bunches (EFB) and application of palm oil mill effluent (POME) are particularly useful on these soils. Such practices will also minimize if not completely prevent pollution or contamination of the rivers after development.

A number of wildlife such as the Zebu, snakes etc. occur in the study area and the habitat for these should be retained wherever possible. Fishing at the deltas of the rivers are a source of income for many people. Conservation measures such as the creation of river reserves to prevent pollution and siltation of rivers will ensure that these resources are maintained. The creation of wildlife reserves of the unsuitable land will also ensure that the habitat for wildlife is maintained.

Many of the steep hills in the area are a potential source of road-fill material. Most of the 'hard rocks' found in the study area are basalts and granites which can be used as road fill material. A small quarry occur near Antalaha airport. Here the rocks are broken manually. A proper quarry can be establish to supply road fill material for upgrading the roads in the area. The amount of stones available could not be assessed during the present study.

4.5. OVERALL YIELD POTENTIAL

Generally the soils in the area have a low fertility level but with proper fertilization and soil management measures and average yield of about 25-28 tonnes/ha is possible. On selected soils such as Segamat and Jerangau Series a potential yield of over 30 tonnes/ha is also possible with good management.

V. REFERENCES

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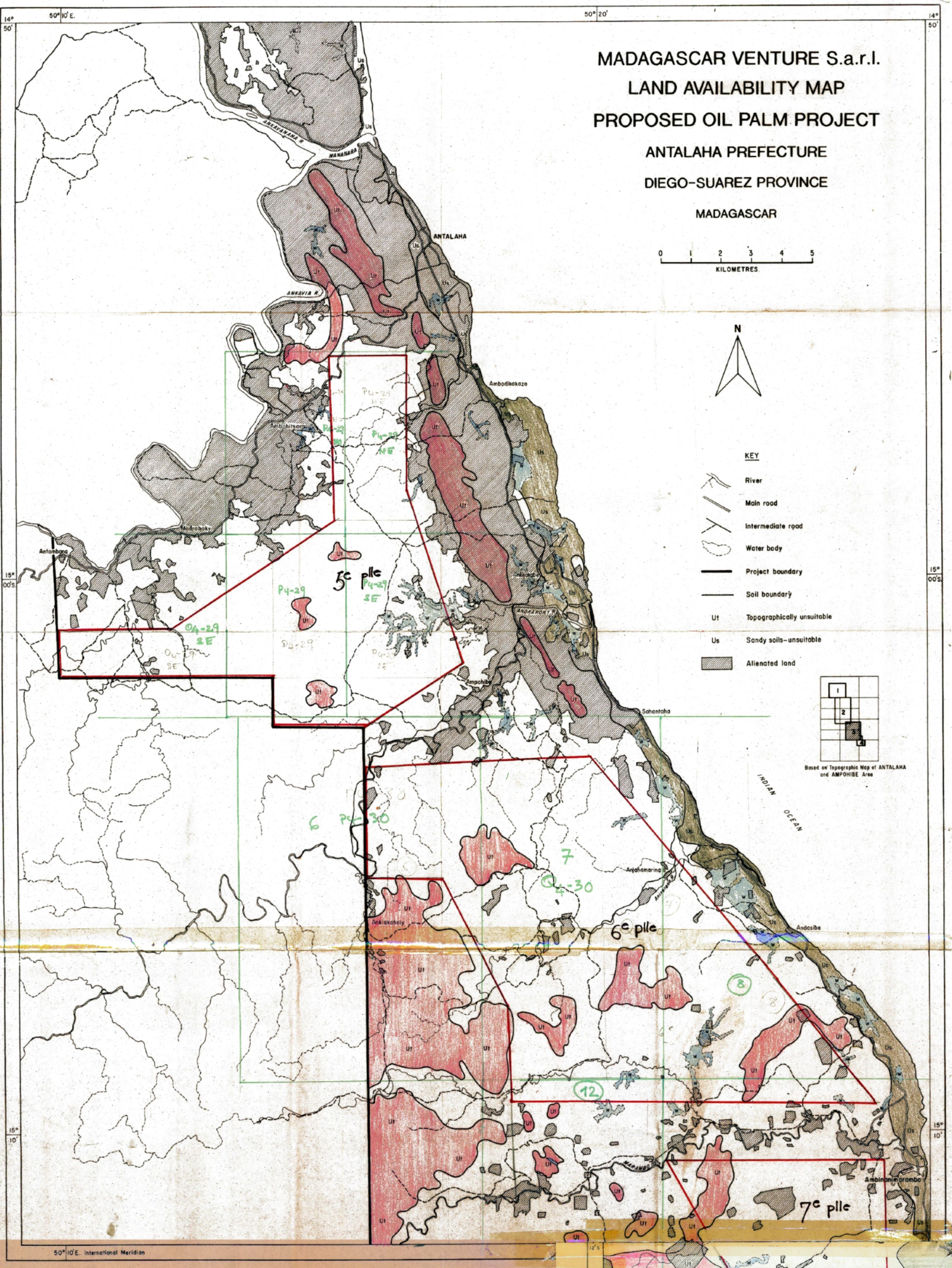
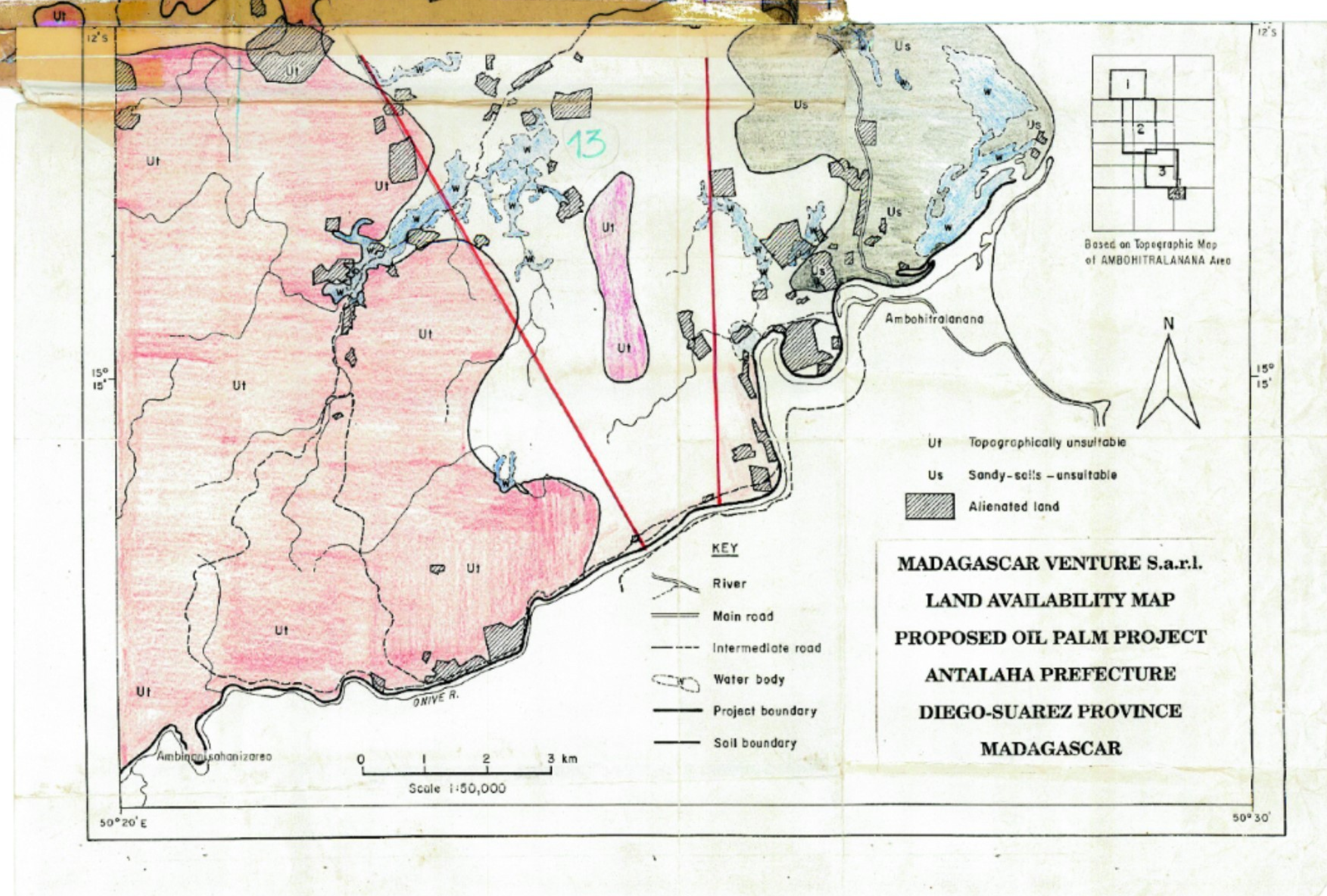


MADAGASCAR VENTURE S.a.r.l.
LAND AVAILABILITY MAP
PROPOSED OIL PALM PROJECT
ANTALAHA PREFECTURE
DIEGO-SUAREZ PROVINCE
MADAGASCAR
0 1 2 3 4 5
KILOMETRES
N
KEY
River
Main road
Intermediate road
Water body
Project boundary
Soil boundary
Ut Topographically unsuitable
Us Sandy soils-unsuitable
Alienated land
Based on Topographic Map of ANTALAHA and AMPOHIBE Area
ANTALAHA
Ambodiakakazo
Ambohitsara
Antombana
Sahantaha
Anjahamarina
Ankiakahely
Andasibe
Ambinanindramba
INDIAN OCEAN
5e plle
6e plle
7e plle
50°10'E. International Meridian



Ambohitralanana
Based on Topographic Map of AMBOHITRALANANA Area
N
Ut Topographically unsuitable
Us Sandy soils-unsuitable
Alienated land
KEY
River
Main road
Intermediate road
Water body
Project boundary
Soil boundary
MADAGASCAR VENTURE S.a.r.l.
LAND AVAILABILITY MAP
PROPOSED OIL PALM PROJECT
ANTALAHA PREFECTURE
DIEGO-SUAREZ PROVINCE
MADAGASCAR
0 1 2 3 km
Scale 1:50,000