CHAPTER 9 - SOIL AND LAND USE POTENTIAL

Chapter 9. SOIL AND LAND USE POTENTIAL

9.0 Background

Papua New Guinea is a country blessed with an abundance of natural resources. Land is one such resource which from the agricultural point of view, comprises of climate, topography, vegetation, soil and geology in that these interact with each other to make it possible or otherwise for its use. Whilst land consists of a number of components, this section, will concentrate on soil as a component of land. Soil textures range from sand to clay. Identifying soil composition is necessary to determine its suitability for upland or lowland rice growing. Soil suitability can be determined through laboratory analysis of soil samples and or observation of the physical characteristics in the respective localities.

The five Provinces covered in this survey were, Central Province, Morobe, Madang, East Sepik and the East New Britain Province. Soil composition and suitability is discussed in the respective sections. An initial observation is made where soil suitability is concerned. This however, can be further substantiated and or otherwise by laboratory analysis of respective samples.

9.1 Central Province

9.1.1 Introduction

In order to ascertain suitability of growing rice as a food crop in selected sites in Kairuku and Abau Districts of the Central Province, soil, land-use (current and potential) and general environment study is necessary. Land-use and environment are components that are just as important as soil and water. Soil however, is the major component of the land resource as far as evaluating suitability of the selected sites is concerned. It is the analysis of the combination of soil, climate and topography that determines land suitability for rice cultivation.

Availability of required site information and specifically adequate and correct information on soils and water is necessary and can only be collected at each selected site.

Rice (upland or lowland) has its soils requirements particularly in (soil drainage, acidity, texture and structure), rainfall, temperature and altitude and this sort of information is readily available (Purseglove 1968, 1972). These soil requirements are matched with the field data and information together with the soils chemical analysis data for land evaluation purposes (refer to Sect. 9.1.6 or Table 9.5).

Information on current land use and environment in general is useful, as the land use practices will have some effects on the surrounding environment.

9.1.2 Objective

Although land and soils physical characteristics may be suitable for rice growing, it is also necessary to have analyzed soils chemical data available to conduct land evaluation for rice cultivation, particularly with regards to the rice nutrient intake requirements. This particular information can be obtained by collecting soil samples at each site for chemical analysis in the laboratory. Available secondary data in this regard will also help immensely.

9.1.3 Survey Methodology

9.1.3.1 Fieldwork

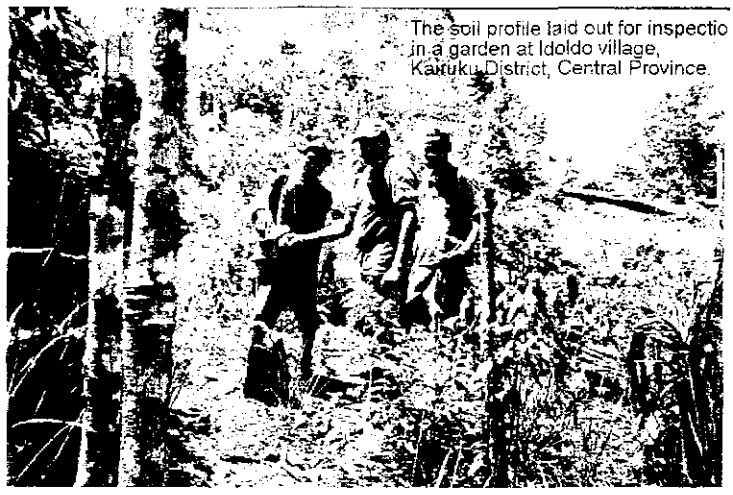
Field data and information is a necessary component of any land and soil survey and this can be obtained through the following activities at each site:

a) Boundary surveys of each site will be done to determine size and area (in hectares). This will also enable the production of soil map that will indicate delineations of different soil types into mapping units (MU);
b) General data and information on vegetation, topography, environment and current land use practices will be collected;
c) Soil profiles will be described randomly (by use of a 120 cm soil auger); and
d) Soil samples from each representative profile will be collected for chemical analysis at the laboratory.

9.1.3.2 Data Collation and Analysis

Preliminary suitability of the soils have been made in the field based on soil physical characteristics only and these are namely: soil depth, soil texture, soil colour and soil drainage. The soils are deep with good clay content for storing moisture during dry periods, have dark brown top-soil layers indicating the presence of organic matter (OM) and are well drained at the garden sites.

Soil samples from each of the study sites were taken for the chemical analysis, but unfortunately, the amount of exchangeable bases such as the calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) will not be known until after the soil analysis have been done.



The soil profile laid out for inspectio in a garden at Idoldo village, Kairuku District, Central Province.

For this purpose the use of the NARI laboratory for soil analysis became handy.

9.1.4 General Characteristics of the Area

9.1.4.1 Area, Location and Access

Tutubu and Amau villages of the Abau District are located to the southeast, while Idoido (Kubuna) and Yumuna (Bakoiudu) villages of the Kairuku District are situated to the northwest of Port Moresby (refer to the locality map). The District Office at Kupiano Station administers Tutubu and Amau, while Idoido and Yumuna come under the District Office at Bereina.

While Amau is accessible by the Magi Highway, Tutubu can be reached by use of an access road that veers off southeast from the main highway before the Merani village. However, Idoido and Yumuna are accessible by a feeder road that veers off northeast of the Hiritano Highway. The District Stations of Kupiano and Bereina can also be reached by sea mainly by the surrounding villages within the vicinity of the two Stations.

9.1.4.2 Physiography, Relief and Drainage

Generally, about 40% of the Abau District is comprised of floodplains and about 50% of mountainous terrain; while, about 40% is floodplains and 40% is mountainous in the Kairuku District. The remainder of the landforms are made up of hills and raised coral reefs and littorals.

Tutubu and Amau sites are located in the flat coastal plain comprising of raised coral reefs and floodplains. Amau sites are well drained, but the Tutubu sites range form well to imperfectly drained.

The sites at Idoido are located on ridges and slopes (3-5°) of undulating topography that extends to Yumuna (further inland), except that the valleys at Yumuna are more pronounced (slopes of > 7°). The ridge tops and slopes are well drained and valleys in most parts are poorly drained.

A stream near a rice plot at Idoido village Kairuku District, Central Province

9.1.4.3 Climate

9.1.4.3.1 Rainfall

The mean annual rainfall provided in Tables 9.1 & 9.2 below are applicable to the four sites investigated. The mean annual rainfall in the Abau area is over 2,200 mm, more than the amount received in the Amazon Bay and Marshall Lagoon areas. Generally, the rainfall increases from the west to east.

Table 9.1. Mean Monthly and Annual Rainfall (mm).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Marshall Lagoon	164	67	118	172	135	98	190	191	91	172	72	79	1525
Abau	141	162	205	225	250	215	206	197	219	113	108	145	2211
Amazon	273	196	249	272	191	133	134	188	183	220	244	244	2197

Source: Climate Tables for PNG; McAlpine, Keig and Short

In the Abau area, dry seasons usually occur during the months of January, February, March, October, November and December and compared to other two stations, it receives the highest annual rainfall.

The mean annual rainfall in the Kubuna area is over 2,600 mm, more than the amounts received at Bereina and Laloki *(refer to Table 9.2 below)*. Generally, the rainfall increases from the coast to inland. The months of June and July are generally the driest months of the year and the rainfall slightly increases to the month of December, in comparison to the first five months of the year.

Table 9.2. Mean Monthly and Annual Rainfall (mm).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Kubuna	276	329	312	254	234	117	81	219	181	227	119	216	2668
Bereina	210	220	210	131	42	28	21	26	55	53	43	172	1182
Laloki	209	143	197	80	42	37	17	26	20	37	30	149	987

Source: Climatic Tables for PNG: McAlpine, Keig and Short

9.1.4.3.2 Temperature

The mean maximum temperature at Tutubu and Amau range from 30 – 32 °C, while the mean minimum temperature ranges from 19 – 23 °C. This range is characteristics of the areas located within the altitude range of 0 – 600 meters above sea level (m.a.s.l).

Temperatures at Idoido are similar to those experienced at Tutubu and Amau, but the nights are cool. However, days are not as hot and nights are cooler at Yumuna because the site is closer to the inland ranges.

Table 9.3. Mean Monthly Annual and Extreme Temp (^{0}C) for Amazon

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	35.3	33.4	34.2	32.8	31.7	31.7	29.4	31.1	31.1	34.0	34.9	34.9	35.3
Mean Max	31.4	31.2	31.3	30.1	28.9	27.9	26.5	27.2	27.8	28.2	30.0	31.7	29.4
Mean	27.0	27.0	27.0	26.0	25.6	24.7	23.7	24.1	24.5	25.1	25.8	27.1	25.6
Mean Min	22.6	22.7	22.6	21.9	22.3	21.4	20.8	20.9	21.2	22.0	21.6	22.4	21.9
Extreme Min	20.6	19.3	18.4	18.6	17.0	16.1	15.0	16.0	15.0	15.6	14.7	19.0	14.7

Source: Climatic Tables for PNG: McAlpine, Keig and Short

Temperature figures for Amazon Bay have been used for the two study areas, as these figures can be used here. The mean monthly temperatures are basically uniform throughout, but temperatures during the months of June, July and August are lower, and the mean annual temperature is about 25.6^{0}C.

Table 9.4. Mean Monthly Annual and Extreme Temp (^{0}C) for Bereina

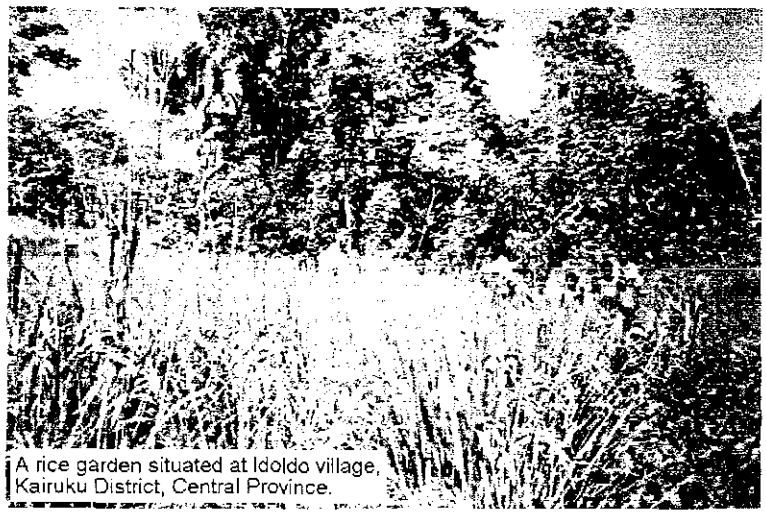
	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	35.4	36.8	34.4	33.3	34.0	33.3	34.2	34.0	33.5	34.4	35.6	35.6	36.8
Mean Max	31.8	31.4	31.1	31.1	30.9	29.9	29.4	29.4	30.1	30.8	31.9	32.1	30.8
Mean	26.7	26.7	26.7	26.5	26.4	25.2	24.9	25.2	25.7	26.1	26.5	26.7	26.1
Mean Min	21.5	21.9	22.2	21.8	21.8	20.5	20.3	20.7	21.3	21.3	21.0	21.3	21.3
Extreme Min	15.6	16.1	17.7	16.1	16.7	15.0	12.8	15.5	12.4	13.9	15.0	15.6	12.4

Source: Climatic Tables for PNG: McAlpine, Keig and Short

Temperature figures for Bereina are applicable for Kubuna area. The mean monthly figures are uniform throughout the year. However, during the months of June, July, August and September, the mean temperatures are lower. The mean annual temperature is around 26.1^{0}C.

9.1.4.4 Vegetation and Land Use

Tropical rainforest and savanna grasslands are dominant in the study areas. Grass species such as *Imperata Cylindrica* (or kunai) and *Saccharum Spontaneum* are dominant in the Abau and Kairuku Districts. Secondary forests and regrowths in the two Districts are mainly associated with gardens. The land is currently used mainly for gardening and commercial crops such as rubber and copra and particularly so in the Tutubu area. Game hunting for fresh meat is a common practice within all areas visited. Some farmers have integrated rice plots of an average of 15m x 20m within the food gardens as a food-crop.



A rice garden situated at Idoldo village, Kairuku District, Central Province.

9.1.4.5 Geology

Alluvial deposits are the dominant lithology while calcareous is the least distributed lithology. Volcanic rocks underlie much of the higher altitude regions.

The geology of the Abau District is described as a submarine basaltic lava, which is a result of plate tectonics. However, the underlying rock type of the ridges of Idoido and Yumuna are volcanic. The valleys are dominated by colluvial and/ or alluvial deposits.

9.1.4.6 Hydrology

There are larger rivers and streams in all sites studied. Some streams however, are seasonal and dry up during the dry seasons but other rivers and streams provide clear water. On the other hand during the wet seasons these waterways hold turbid water containing silt and sand-size particles.

9.1.5 Soils

9.1.5.1 Criteria for Soil Selection

The soil physical and chemical characteristics are important to evaluate it for the envisaged use. Some of the physical and chemical characteristics are soil depth, soil texture and soil consistency, and soil acidity (pH), Cation Exchange Capacity (CEC), and Exchangeable Bases (i.e. Ca, Mg, K., Na) respectively.

In order to do a complete land evaluation for rice (as well as other crops) land and soil characteristics are a critical consideration.

9.1.5.2 Physical and Chemical Characteristics

Generally, the soils are moist and wet because of the swampy conditions with high water table (15-20cm depth) in parts of the surveyed areas.

The physical characteristics of the soil are given in the profile descriptions of the Tutubu Series, Amau Series and Kubuna Series in the annexes provided. The Amau and Kubuna soils are deep and contain good amount of clay in the profiles for storage of moisture. Apart from the other soil series, the Tutubu Series has subsoil comprising of sand that begins at a depth of 40 cm. The thin topsoil is the only source of nutrients for plant growth.

9.1.5.3 Soil Fertility

The soil fertility will not be known until after the soil samples have been analyzed. However, based on visual observations, the Kubuna Series are better soils than soils at other sites. Amau soils were found to lack potassium (K), because of the dried banana leaf edges and immature drying of lower leaves of the rice. The Tutubu soils basically have a physical problem of topsoil depth and may prove to be a problem when farmers consider irrigation for planting of rice during the dry season.

9.1.6 Land Evaluation

9.1.6.1 Criteria for Land Selection

Land as a resource encompasses five (5) environmental components, namely climate, topography, vegetation, soil and geology as these interact with each other to make it possible or otherwise to use as already mentioned.

The physical characteristics of the land such as altitude, temperature, rainfall and soil physical and chemical characteristics such as drainage and texture and acidity (pH) respectively are some of the characteristics that can be used to assess suitability of a tract of land for rice growing (refer to Table 9.5 for range in the characteristics). Meeting all conditions will render high suitability (S1), meeting all but one equals moderate suitability (S2), all but two or three equals marginal suitability (S3) and so on.

Table 9.5. Major factors to be considered when evaluating land for smallholder production.

Major Factors	Land Characteristics
Site Location	Altitude ranges from 0 – 1,200m
Daily Sunlight	Temperature ranges from 20 - 35°C
Moisture Availability	Rainfall ranges from 1,000 – 4,000 mm
Soil Conditions	Well to very poorly drained soils
	Acidity: pH 5.5 – 7.5
	Medium to fine textures

Source: Purseglove 1968, 1972.

9.1.6.2 Land Use Potential Assessment

The soils of the Kubuna area have better physical and chemical conditions than the soils of other sites. Physical observations of crops indicate that the soils at Amau show symptoms of deficiency in potassium, while the Tutubu soils have shallow top-soil. Hence, although the Amau soils have good physical characteristics, the chemical deficiency render the soils moderately suitable (S2); while, the Tutubu soils are marginally suitable (S3) with soil depth (d) as a limiting factor. However, the Idoido and Yumuna soils are highly suitable (S1) for rice production (refer to Table 9.19).

9.1.6.3 Land Tenure and Land Holding

In the Tutubu and Amau villages of the Abau District, land is an important individual and/or family asset vital for the livelihood. Like in most parts of PNG, land is traditionally owned and the indigenous people are culturally attached to.

The land ownership has been passed down from generation to generation and this tradition is continuing today. People live in villages (or communities), but make gardens, do game hunting, and collect materials for housing and other purposes from bushes only on their own land. As the surveyed society is patrilineal in nature, the land is subdivided in each family (or clan) as the family is expected to increase over the years. However, no land-related issues have been detected.

Patrilineal land ownership is also practised in the Kairuku District. In the Idoido and Yumuna villages of the Kuni/Mekeo Local Level Government (LLG) area, the people live on the state lease land that was planted with rubber in the colonial era. The villagers live freely on it as there is no system in place to ensure collection of lease rentals.

The people are aware that they live on the state lease land. Their lifestyle consists of garden making, hunting and collecting bush materials for housing and other purposes from the available bushes.

9.1.7 Conclusion

Of all the sites investigated, Kubuna has all the physical land and soil characteristics suitable for rice growing. The Amau sites have chemical deficiency in potassium (K) and the Tutubu sites are physically shallow. However, in the initial stages of rice growing there will not be any obvious signs in the production amounts, but may become apparent after several years of production if remedial action is not taken in terms of application of fertilizers for instance.

9.2 Morobe Province

9.2.1 Introduction

In order to ascertain *suitability of growing rice* as a food crop in selected sites in Finschaffen and Lae Districts of the Morobe Province, soil, land-use (current and potential) and general environment study is necessary. Land-use and environment are components that are just as important as soil and water. Soil however, is the major component of the land resource as far as evaluating suitability of the selected sites is concerned. It is the analysis of the combination of soil, climate and topography that determines land suitability for rice cultivation.

Availability of required site information and specifically adequate and correct information on soils and water is necessary and can only be collected at each selected site.

Rice (upland or lowland) has its soils requirements particularly in (soil drainage, acidity, texture and structure), rainfall, temperature and altitude and this sort of information is readily available (Purseglove 1968, 1972). These soil requirements are matched with the field data and information together with the soils chemical analysis data for land evaluation purposes (refer to Sect. 9.1.6 or Table 9.5).

Information on current land use and environment in general is useful as the land use practices can affect the surrounding environment.

9.2.2 Objective

Although the physical characteristics of land and soils may be suitable for rice growing, it is also necessary to have analyzed soils chemical data available to conduct land evaluation for rice cultivation, particularly with regards to the rice nutrient intake requirements. This particular information can be obtained by collecting soil samples at each site for chemical analysis in the laboratory. Available secondary data in this regard can also help immensely.

9.2.3 Survey Methodology

9.2.3.1 Fieldwork

Field data and information is a necessary component of any land and soil survey and this can be obtained through the following activities at each site:

a) Boundary surveys of each site will be done to determine size and area (in hectares). This will also enable the production of soil map that will indicate *delineations of different soil types into mapping units (MU)*;
b) General data and information on vegetation, topography, environment and current land use practices will be collected;
c) Soil profiles will be described randomly (by use of a 120 cm soil auger); and
d) Soil samples from each representative profile will be collected for chemical analysis at the laboratory.

Soil samples ACS soil specialist-Apusolo- Wareo, Finschhafen District, MP

9.2.3.2 Data Collation and Analysis

Preliminary suitability of the soils have been made in the field based on soil physical characteristics only and these are namely: soil depth, soil texture, soil colour and soil drainage. All soils observed in the Finschaffen District are deep with good clay content for the storage of moisture during dry periods. They are well drained and have sufficient organic matter (OM) for use by plants. However, most soils observed in the Lae District are poorly drained sandy loams (particularly at 4 and 5 miles), but well drained at Poahum.

Soil samples from each of the study sites were taken for the chemical analysis, but unfortunately, the amount of exchangeable bases such as the calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) will not be known until after the soil analysis have been done.

9.2.4 General Characteristics of the Area

9.2.4.1 Area, Location and Access

Wareo and Salodi villages of the *Finschhafen* District are located to the northeast of Lae, while four and five mile and Poahum village are situated within the Lae District (refer to locality map). Wareo and Salodi villages are administered by the District Office at Finschhafen station, while the other three stations are administered from the Lae District Office.

While the locations within the Finschhafen District are accessible by air (airstrip at Gagidu station) and sea, the other locations are situated within the Lae City. Nazab International Airport is used everyday by flights from major centers of PNG and some from abroad. The Highlands Highway connects Lae with the five Highlands Provinces and another highway connects it with Madang (refer to the locality map).

9.2.4.2 Physiography, Relief and Drainage

Generally, about 90% of the Finschhafen District is mountainous, 5% hilly and 5% raised coral reefs and littorals. Wareo and Salode are located inland in the mountainous terrain with slopes of >15%. The relief is marked by a series of natural terraces from the coast to inland.

Much of the area is well to excessively well drained because of the steep slopes, and about 5-10% is poorly drained, restricted mainly to the valleys.

However, about 80% of the Lae District is mountainous, 10% is hilly and 10% is floodplain. The poorly drained parts are confined to the flood plains.

9.2.5 Climate

9.2.5.1 Rainfall

The mean annual rainfall figures given below in Table 9.6 for Finschhafen and Lae respectively, are applicable to the study areas.

Table 9.6. Mean Monthly and Annual Rainfall (mm).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Finschhafen	140	95	135	301	464	589	655	568	531	402	297	227	4417
Lae Army Camp	305	223	304	253	327	297	410	391	234	417	272	394	3713
Lae Airstrip	267	231	324	403	424	414	501	517	473	386	346	332	4617
Lae Botanical Garden	287	245	368	393	406	359	508	516	391	352	308	329	4419

Source: Climatic Tables for PNG: McAlpine, Keig and Short

In Finschhafen, the monthly rainfall is generally uniform. However, the first three months receive slightly lower rainfall. The three sites in Lae follow similar trend as in Finschhafen. The annual rainfall in all stations is over 3,000mm.

9.2.5.2 Temperature

Temperature figures for Finschhafen and Lae are applicable for the survey sites in the two concerned districts. The mean monthly temperatures range from 25-27^{0}C, while the mean maximum range from 27-30^{0}C (refer to Tables 9.7, 9.8 and 9.9).

Table 9.7. Mean Monthly Annual and Extreme Temp (^{0}C) for Finschhafen

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	33.9	35.9	34.6	33.3	32.7	31.8	31.0	31.7	31.4	34.8	32.8	33.7	35.9
Mean Max	30.8	30.9	30.8	30.3	29.6	28.7	27.7	28.6	28.8	29.1	30.2	30.4	29.7
Mean	27.0	27.2	27.2	26.6	26.2	25.8	25.1	25.5	25.6	25.9	26.5	26.8	26.3
Mean Min	23.2	23.4	23.5	22.9	22.8	22.8	22.4	28.4	22.4	22.8	22.7	23.2	22.9
Extreme Min	20.9	20.0	21.1	19.5	20.0	19.1	19.6	18.4	19.3	19.2	19.4	21.1	18.4

Source: Climatic Tables for PNG: McAlpine, Keig and Short

Table 9.8. Mean Monthly Annual and Extreme Temp (^{0}C) for Lae Airstrip

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	38.2	37.3	38.7	33.9	33.2	33.4	32.2	32.14	32.2	35.2	34.4	35.6	38.7
Mean Max	31.1	31.2	30.8	30.1	29.4	28.6	27.8	27.9	28.7	29.6	30.3	30.7	29.7
Mean	27.5	27.5	27.3	26.7	26.2	25.5	24.9	25.0	25.5	26.1	26.7	27.1	26.3
Mean Min	23.8	23.8	23.7	23.3	22.9	22.4	22.0	22.0	22.2	22.6	23.1	23.5	22.9
Extreme Min	20.7	21.1	21.7	21.3	19.4	19.4	19.3	19.4	19.1	19.1	20.9	20.3	19.1

Source: Climatic Tables for PNG: McAlpine, Keig and Short

Table 9.9. Mean Monthly Annual and Extreme Temp (^{0}C) for Lae Botanical Garden

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	37.2	37.2	35.6	33.4	33.3	32.8	32.5	32.9	35.6	33.3	35.1	36.7	37.2
Mean Max	31.1	29.2	30.9	29.6	28.6	28.0	28.4	28.7	29.7	29.6	30.5	30.9	29.6
Mean	27.1	26.2	27.0	26.0	25.4	24.8	24.8	24.9	25.5	25.	26.4	26.9	25.9
Mean Min	23.0	23.1	23.0	22.4	22.1	21.6	21.2	21.1	21.3	21.9	22.2	22.8	22.1
Extreme Min	21.1	20.0	18.0	20.0	20.0	19.1	19.0	18.0	19.1	20.0	20.0	21.3	18.0

Source: Climatic Tables for PNG: McAlpine, Keig and Short

Unlike in the coastal Finschhafen and the Lae area, the temperatures in the Wareo area are cooler in the evenings and nights. The extreme minimum temperatures in the Wareo area would probably be >18^{0}C.

9.2.5.3 Vegetation and Land Use

Tropical rainforest is the dominant vegetation type in the study area. Where grasslands occur, the main grass species are Imperata Cynlindrica (or kunai) and Saccharum Spontaneum. Secondary forests and regrowths in the two Districts are associated with gardens mainly. Land is currently used mainly for gardening and commercial crops such as coffee (Robusta). Rice plots have been integrated with the food gardens as a food crop by some farmers.

Rainfed lowland rice plots 5 Mile, Lae. Irrigation canal at the right was constructed manually by settler

9.2.5.4 Geology

The geology of the Wareo Area (Finschhafen) is comprised of cavernous reef limestone, interbedded with calcarenite and volcanically derived sandstone.

Alluvium and beach deposits together with gravel, sand, silt and clay dominate the underlying bedrock in the Lae District.

9.2.5.6 Hydrology

In Finschhafen there are many rivers and their tributaries continuously drain the area. All waterways become turbulent during the wet seasons.

There are larger rivers and streams in all sites studied. Some streams however, are seasonal and dry up during the dry seasons but other rivers and streams provide clear water. On the other hand during the wet seasons these waterways hold turbid water containing silt and sand-size particles.

9.2.6 Soils

9.2.6.1 Criteria for Soil Selection

The soil physical and chemical characteristics are important to evaluate for the envisaged use. Some of the physical and chemical characteristics are soil depth, soil texture and soil consistency, and soil acidity (pH), Cation Exchange Capacity (CEC), and Exchangeable Bases (i.e. Ca, Mg, K., Na) respectively.

In order to do a complete land evaluation for rice (as well as other crops) land and soil characteristics are a critical consideration.

9.2.6.2 Physical and Chemical Characteristics

The soil physical characteristics are given in the profile descriptions of the Haiyo Series, Apusolo Series and Wareo Series in the annexes provided. All three soil series are deep and are similar in their profile arrangements, with clay loams topsoils and clay subsoils. These soils are all well drained and cover about 95% of the areas investigated.

On the contrary, majority of the soils investigated in the Lae District are imperfect to poorly drained (particularly at 4 and 5 mile areas), except the Poahum Series

9.2.6.3 Soil Fertility

The soil fertility will not be known until after the soil samples have been analyzed. However, based on visual observations, the Finschhafen soils have better physical properties for growing upland rice than the soils in the Lae District. However, Lae provides better soils conditions for establishing lowlands fields (particularly at 4 and 5 mile areas).

9.2.7 Land Evaluation

9.2.7.1 *Criteria for Land Selection*

Land as a resource encompasses five (5) environmental components, namely climate, topography, vegetation, soil and geology as these interact with each other to make it possible or otherwise for its usage as already mentioned.

The physical characteristics of the land such as altitude, temperature, rainfall and soil physical and chemical characteristics such as drainage and texture and acidity (pH) respectively are some of the characteristics that can be used to assess suitability of a tract of land for rice growing. (refer to Table 9.5 or Sect. 9.1.6.1). Meeting all conditions will render high suitability (S1), meeting all but one equals moderate suitability (S2), all but two or three equals marginal suitability (S3) and so on.

9.2.7.2 Land Use Potential Assessment

The soils of the Finschhafen area have better physical and chemical conditions than the soils of the study sites in Lae. However, slope will be a limiting factor (s) in the Finschhafen area, thus these soils are moderately suitable (S3). The Lae soils are highly suitable (S1) for lowland rice in the 4 and 5 Mile areas, whilst it is also highly suitable (S1) in the Poahum area for the upland rice production (refer to Table 9.19).

9.2.7.3 Land Tenure and Land Holding

In the Wareo and Salodi villages of the Finschhafen District, land is an important individual and/or family asset vital for the livelihood. Like in most parts of PNG, land is traditionally owned and people are culturally attached to.

The land ownership is passed down from generation to generation and continues even today. People live in villages (or communities), but make gardens, do game hunting, and collect materials for housing and other purposes from bushes on their own land. As these societies are patrilineal in nature, land is subdivided into family units or clan group and is further distributed as population increases. No land-related issues was detected during the course of the survey. However, it is envisaged that naturally as families increase in the future, land may become scarce, giving rise to further resource rationalization and perhaps land mobilisation.

Patrilineal land ownership is also practised in the Lae District. While in the Poahum area, the land is traditionally owned by the people who live there. The people who live at 4 and 5 Mile areas are from other parts of PNG and the blocks of land they live on are situated on the State Lease Land.

9.2.8 Conclusion

The land in the Wareo and Salodi areas of the Finschhafen District is mountainous with steep (>15^0) slopes and thus the land and soil are moderately suitable (S2) for upland rice with slope (s) as a limiting factor. Most rice gardens are situated on the sloping natural terraces that have clay soils.

The land at 4 and 5mile areas are highly suitable (S1) for paddy rice mainly, whilst Poahum is suitable for growing upland rice.

Upland TCS 10 Rice Plot. Las Kunai - Lae District -MP

9.3 Madang Province

9.3.1 Introduction

In order to ascertain suitability of rice growing as a food crop in selected sites in Madang and Usino/Bundi Districts of the Madang Province, soil, land-use (current and potential) and general environment study is necessary. Land-use and environment are components that are just as important as soil and water. Soil however, is the major component of the land resource as far as evaluating suitability of the selected sites is concerned. It is the analysis of the combination of soil, climate and topography that determines land suitability for rice cultivation.

Availability of required site information and specifically adequate and correct information on soils and water is necessary and can only be collected at each selected site.

Rice (upland or lowland) has its soils requirements particularly in (soil drainage, acidity, texture and structure), rainfall, temperature and altitude and this sort of information is readily available (Purseglove 1968, 1972). These soil requirements are matched with the field data and information together with the soils chemical analysed data for land evaluation purposes (refer to Sect. 9.1.6 or Table 9.5).

Information on current land use and environment in general is useful as the land use practices will have some effects on the surrounding environment.

9.3.2 Objectives

Although land and soils physical characteristics may be suitable for rice growing, it is also necessary to have analysed soils chemical data available to conduct land evaluation for rice cultivation, particularly with regards to the rice nutrient intake requirements. This particular information can be obtained by collecting soil samples at each site for chemical analysis in any credible laboratory. Available secondary data in this regard will also help immensely.

9.3.3 Survey Methodology

9.3.3.1 Fieldwork

Field data and information is a necessary component of any land and soil survey and this can be obtained through the following activities at each site:

a) Boundary surveys of each site will be done to determine size and area (in hectares). This will also enable the production of soil map that will indicate delineations of different soil types into mapping units (MU);
b) General data and information on vegetation, topography, environment and current land use practices will be collected;
c) Soil profiles will be described randomly (by use of a 120 cm soil auger); and
d) Soil samples from each representative profile will be collected for chemical analysis at the laboratory.

9.3.3.2 Data Collection and Analysis

Preliminary suitability of soils in the field are based on soil physical characteristics only and these are namely: soil depth, soil texture, soil colour and soil drainage. The Lagaha and Umun soils of the Madang District are shallow ad deep and sandy respectively, and are well drained. However, the soils of Danaru and Sausi of the Usino/Bundi District are mostly clayey and well drained.

Soil samples from each of the study sites were taken for the chemical analysis, but unfortunately, the amount of exchangeable bases such as the calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) will not be known until after the soil analysis have been done.

9.3.4 General Characteristics of the Area

9.3.4.1 Area, Location and Access

Lagaha and Umun are located to the southwest of the Madang town; while, Danaru and Sausi are situated to the southeast (refer to the locality map). Lagaha and Umun are administered from Madang District; while, Danaru and Sausi are administered from Usino District Office.

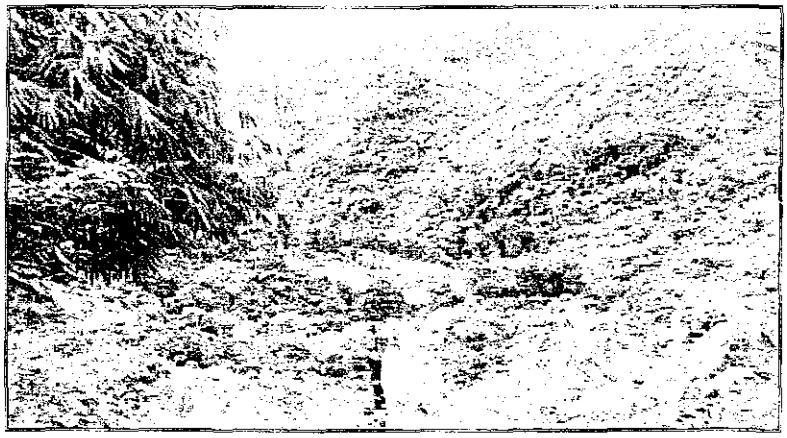
While Lagaha and Umun villages are accessible by Amele Road, Danaru and Sausi are accessible by the Madang/Lae Highway. Seaport ad airport facilities are provided in the Madang town.

9.3.4.2 Physiography, Relief and Drainage

Generally, about 90% of the Madang District is mountainous and 5% hilly; while, about 45% of the Usino-Bundi District is mountainous and 50% floodplain.

Lagaha and Umun sites are located on the mountainous terrain and the floodplain of the Gogol River respectively; while, the Danaru and Sausi sites are situated on the foothills and the floodplain of the Ramu River respectively. There are numerous rivers and their tributaries that continuously drain the study areas during the wet season.

The rugged terrain in Lagaha village



9.3.4.3 Climate

9.3.4.3.1 Rainfall

The mean annual rainfall provided in Tables 9.10 below is applicable to the four sites investigated. The mean annual rainfall for Madang is 3,525m, while, the rainfall at Usino is over 1,700mm.

Table 9.10. Mean Monthly and Annual Rainfall (mm).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Madang Agric.	340	314	373	439	378	235	176	123	152	267	376	375	3533
Madang Airstrip	359	292	344	443	337	200	166	128	144	301	387	379	3518
Usino	780	716	546	157	215	102	74	115	130	182	220	203	1701

Source: Climatic Tables for PNG; McAlpine, Keig and Short

In the Madang area, dry seasons usually occur during the months of July, August, and September; while in the Usino-Bundi District it occurs in the months of June, July, August, September and October.

9.3.4.3.2 Temperature

The mean maximum temperature in the Madang town and Unum village ranges from 29 - 30°C, while the temperature in Lagaha are cooler as it is situated at a higher altitude (refer to Table 9.11 below).

Table 9.11. Mean Monthly Annual and Extreme Temp (^{0}C) for Madang

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	33.2	33.3	33.3	33.7	32.2	32.2	31.5	31.7	33.4	31.7	32.5	33.6	33.7
Mean Max	30.2	30.1	30.1	29.9	30.2	29.8	29.6	29.7	29.9	30.1	30.2	30.1	30.0
Mean	26.2	26.1	26.7	26.6	26.8	26.4	26.2	26.3	26.4	26.5	26.6	26.7	26.5
Mean Min	23.2	23.1	23.2	23.2	23.3	22.9	22.8	22.9	22.9	22.9	23.0	23.2	23.1
Extreme Min	21.0	20.7	20.8	21.1	20.1	19.9	20.0	18.9	20.8	20.3	20.0	19.4	18.9

Source: Climatic Tables for PNG: McAlpine, Keig and Short

Temperature figures for Kaiapit have been used for Danaru and Sausi villages as they are all located in the Ramu Valley. The mean monthly figures range from 24 to over 26^{0}C (refer to Table 9.12).

Table 9.12. Mean Monthly Annual and Extreme Temp (^{0}C) for Kaiapit

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	35.4	35.2	36.1	34.4	36.7	33.3	34.4	35.6	36.2	36.1	37.2	35.6	37.2
Mean Max	32.1	31.8	31.6	31.2	30.5	29.9	29.3	29.9	31.2	31.5	32.4	31.8	31.1
Mean	26.8	26.7	26.6	26.3	25.7	25.2	24.8	25.0	25.8	26.2	26.9	26.4	26.0
Mean Min	21.4	21.5	21.6	21.3	20.8	20.5	20.2	20.0	20.4	20.8	21.3	21.0	20.9
Extreme Min	16.3	15.6	15.0	10.0	10.0	5.6	9.4	14.8	13.9	17.2	18.6	13.3	5.6

Source: Climatic Tables for PNG: McAlpine, Keig and Short

9.3.4.4 Vegetation and Land Use

Tropical rainforest dominates in the four sites studied. Secondary forests ad regrowths are associated mainly with gardens. Imperata Cylindrica (or kunai) is common through-out the area. The land is currently used mainly for gardening and commercial crops such as robusta coffee and cocoa. Game hunting for fresh meat is a common practice within all areas visited. Some farmers have integrated rice plots of an average of 15m x 20m with the food gardens as a food-crop.

Harvested upland rice plot located on a terrace of a mountainside at Lagaha village.

9.3.4.5 Geology

Indurated greywacke is common in the Lagaha area and the hilly parts of Danaru; while, alluvial; gravel, sand, silt, and clay are common in the flat areas of Danaru area and the Umun villages of the Madang District.

9.3.4.6 Hydrology

There are larger rivers and streams in all sites studied, but some streams dry up during the dry seasons. During these times, the rivers and streams provide clear water, but during the wet seasons these waterways contain turbid water containing silt and sand-size particles.

9.3.5 Soils

9.3.5.1 Criteria for Soil Selection

The soil physical and chemical characteristics are important to evaluate it for the envisaged use. Some of the physical and chemical characteristics are soil depth, soil texture and soil consistency, and soil acidity (pH), Cation Exchange Capacity (CEC), and Exchangeable Bases (i.e. Ca, Mg, K , Na) respectively.

Land and soil characteristics are in critical consideration in order to do a complete land evaluation for rice (as well as other crops).

9.3.5.2 Physical and Chemical Characteristics

Generally, the soils are grouped as shallow (15cm deep) mountain soils (Lagaha area), clayey foothill soils (Danaru area), and sandy floodplain soils (Umun and Danaru areas).

The physical characteristics of soil are given in the profile descriptions of the Lagaha Series, Unum Series Danaru 1 Series, Danaru 2 Series, Sausi Series and Benedict Series in the annexes provided. The Danaru 1, St Benedict and Sausi soils are deep and contain good amount of clay in the profiles for storage of moisture; while, the Umun and Danaru 2 soils are sandy with high watertable.

9.3.5.3 *Soil Fertility*

The soil fertility will not be known until after the soil samples have been analyzed. However, based on visual observations, the clayey soils of Danaru 1 foothills, the Sausi Series and the Benedict Series are more suitable than the sandy soils of the floodplains which have low moisture holding capacity.

9.3.6 Land and Evaluation

9.3.6.1 Criteria for Land Selection

Land as a resource encompasses five (5) environmental components, namely climate, topography, vegetation, soil and geology as these interact with each other to make it possible or otherwise for its usage, as already mentioned.

The land physical characteristics such as altitude, temperature, rainfall and soil physical and chemical characteristics such as drainage and texture and acidity (pH) respectively are some of the characteristics that can be used to assess suitability of a tract of land for rice growing. (refer to Table 9.5 or Sect. 9.1.6.1 for range in the characteristics). Meeting all conditions will render high suitability (S1), meeting all but one equals moderate suitability (S2), all but two or three equals marginal suitability (S3) and so on.

9.3.6.2 Land Use Potential Assessment

The soils of Danaru 1, Sausi and St. Benedict areas have better physical and chemical conditions than the soils of other sites, and these soils are highly suitable (S1); while, the soils of the Umun and Danaru 2 areas are moderately suitable (S2) to marginally suitable (S3) with soil texture (t) and soil drainage (w) as limiting factors. The soils at Lagaha are marginally suitable (S3) to not suitable (N), because of limitations posed by steep slopes (s) and shallow soil depth (d) (refer to Table 9.19).

9.3.6.3 Land Tenure and Land Holding

In the study areas, land is an important individual and/or family asset vital for the livelihood. Like in most parts of PNG, land is traditionally owned and people are culturally attached to. However, some people from outside of the Danaru and Sausi areas have come and settled there with permission of the landowners.

Land ownership has been passed down from generation to generation and continues even today. People live in villages (or communities), but make gardens, do game hunting, and collect materials for housing and other purposes from bushes on their own land. As these societies are patrilineal by nature, land is subdivided into family units or clan group and or is further distributed as population increases. No land-related issues was detected during the course of the survey. However, it is envisaged that naturally as families increase in the future, land may become scarce, giving rise to further resource rationalization and perhaps land mobilisation.

9.3.7 Conclusion

The land at Danaru 1, Sausi and St. Benedict areas are highly suitable (S1) for the upland rice growing as the soil physical characteristics in terms of soil texture, soil drainage, soil structure and presence of organic matter (OM) is ideal for smallholder rice cultivation.

The soils at Danaru 2, Umun and Lagaha are moderately suitable (S2) to not suitable (N) and have limitation in soil texture (t), soil drainage (w) and soil depth (d) respectively.

9.4 East Sepik Province

9.4.1 Introduction

In order to ascertain suitability of rice growing as a food crop in selected sites in Wewak and Maprik Districts of the East Sepik Province, soil, land-use (current and potential) and general environment study is necessary. Land-use and environment are components that are just as important as soil and water. Soil however, is the major

component of the land resource as far as evaluating suitability of the selected sites is concerned. It is the analysis of the combination of soil, climate and topography that determines land suitability for rice cultivation.

Availability of required site information and specifically adequate and correct information on soils and water is necessary and can only be collected at each selected site.

Rice (upland or lowland) has its soils requirements particularly in (soil drainage, acidity, texture and structure), rainfall, temperature and altitude and this sort of information is readily available (Purseglove 1968, 1972). These soil requirements are matched with the field data and information together with the soils chemical analysis data for land evaluation purposes (refer to Sect. 9.1.6 or Table 9.5).

Information on current land use and environment in general is useful as the land use practices will have some effects on the surrounding environment.

9.4.2 Objective

Although land and soils physical characteristics may be suitable for rice growing, it is also necessary to have analyzed soils chemical data available to conduct land evaluation for rice cultivation, particularly with regards to the rice nutrient intake requirements. This particular information can be obtained by collecting soil samples at each site for chemical analysis in the laboratory. Available secondary data in this regard will also help immensely.

9.4.3 Survey Methodology

9.4.3.1 Fieldwork

Field data and information is a necessary component of any land and soil survey and this can be obtained through the following activities at each site:

a) Boundary surveys of each site will be done to determine size and area (in hectares). This will also enable the production of soil map that will indicate delineations of different soil types into mapping units (MU);
b) General data and information on vegetation, topography, environment and current land use practices will be collected;
c) Soil profiles will be described randomly (by use of a 120 cm soil auger); and
d) Soil samples from each representative profile will be collected for chemical analysis at the laboratory.

9.4.3.2 Data Collation and Analysis

Preliminary suitability of the soils have been made in the field based on soil physical characteristics only and these are namely: soil depth, soil texture, soil colour and soil drainage. The soils of the hills and ridges of the Muschu Island, (Wewak District) and Aupik and Waikakum (Maprik District) are deep with good clay content for storing moisture during dry periods. They range from imperfectly drained to well drained.

Soil samples from each of the study sites were taken for the chemical analysis, but unfortunately, the amount of exchangeable bases such as the calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) will not be known until after the soil analysis have been done.

9.4.4 General Characteristics of the Area

9.4.4.1 Area, Location and Access

Muschu Island is located to the northwest, while Nienguanje is to the west of Wewak town. Sites in the Maprik District (Aupik and Waikakum villages) are located to the southwest of Wewak (refer to locality map). Muschu Island and Nienguanje are situated within the Wewak District, while, Aupik and Waikakum are situated in the Maprik District. While Nienguanje village is accessible by the northcoast road, the Muschu Island can only be reached by sea. Aupik and Waikakum villages are accessible by the Maprik Highway.

9.4.4.2 Physiography, Relief and Drainage

Generally, about 80% of the Wewak and Maprik Districts are under hills and mountains and about 15% under flat floodplains. Muschu Island and two Maprik sites are situated on the hill ridges while the Nienguanje site is situated in the floodplain. The slopes range from 2° to 7°. The hills are well drained, while the floodplains are basically poorly drained.

9.4.4.3 Climate

9.4.4.3.1 Rainfall

The mean annual rainfall provided in Table 9.13 (below) is applicable to the sites investigated in the Wewak and Maprik Districts. The mean annual rainfall for Wewak is 2,199mm; while, for Maprik is 1,848mm.

Table 9.13. Mean Monthly and Annual Rainfall (mm).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Wewak Airstrip	143	128	155	173	219	203	184	195	206	225	207	147	2189
Wewak D.H.Q.	139	119	154	188	227	189	198	161	207	228	106	136	2219
Maprik S.D.H.Q	202	239	210	192	131	88	77	109	119	166	191	191	2027
Maprik	172	223	213	204	121	90	74	94	110	159	155	212	1669

Source: Climatic Tables for PNG; McAlpine, Keig and Short

Rainfall in Wewak is generally uniform throughout the year; while, in Maprik, dry seasons are experienced in the months of June, July and August.

9.4.4.3.2 Temperature

The mean maximum temperature for Wewak ranges from 29 to over 30°C, while; the mean minimum temperature ranges from 22 to over 23°C.

Table 9.14. Mean Monthly Annual and Extreme Temp (^{0}C) for Wewak

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	33.6	32.8	33.3	33.3	36.7	32.8	32.4	32.8	33.2	33.9	34.4	33.1	36.7
Mean Max	30.2	29.8	30.1	30.2	30.8	30.5	30.2	30.3	30.4	30.4	30.4	30.2	30.3
Mean	26.6	26.5	26.6	26.7	27.1	26.7	26.5	26.6	26.3	26.8	26.7	26.7	26.7
Mean Min	23.0	23.1	23.1	23.2	23.4	22.9	22.8	22.8	22.9	23.1	23.0	23.1	23.0
Extreme Min	17.2	19.4	16.7	20.0	20.0	18.3	20.6	19.6	19.4	20.0	18.9	20.6	16.7

Source: Climatic Tables for PNG: McAlpine, Keig and Short

The mean maximum temperature for Maprik ranges from 30^{0}C to over 31^{0}C; while the mean minimum temperature ranges from 20^{0}C to over 22^{0}C (refer to Table 9.15 below).

Table 9.15. Mean Monthly Annual and Extreme Temp (^{0}C) for Maprik

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	34.9	37.3	36.7	32.8	36.7	33.3	32.8	34.1	34.4	34.0	34.4	33.2	37.3
Mean Max	30.8	30.6	30.9	31.1	30.4	30.3	30.7	31.1	31.6	30.7	30.8	30.4	30.8
Mean	26.7	26.6	26.2	26.2	25.9	25.5	25.7	25.7	26.0	26.0	26.0	26.0	26.0
Mean Min	22.5	22.6	21.4	21.3	21.3	20.7	20.6	20.2	20.4	21.2	21.1	21.5	
Extreme Min	16.6	16.7	19.4	19.4	14.1	15.6	15.4	16.8	17.2	18.3	16.7	18.9	14.1

Source: Climatic Tables for PNG: McAlpine, Keig and Short

9.4.4.4 Vegetation and Land Use

Tropical rainforest predominates in the survey areas. Secondary forests and regrowths are associated with gardening and grasslands of Imperata Cylindrica (or kunai) and Saccharcum Spontaneum are common.

The land is currently used mainly for gardening and commercial crops such as cocoa and robusta coffee and copra. Game hunting for fresh meat is a common practice within all areas visited. Some farmers have integrated rice plots of an average of 15m x 20m with the food gardens as a food-crop.

9.4.4.5 Geology

Muschu Island and Nienguanje sites are situated on reef limestone; while, the Maprik sites have calcareous and alluvial materials.

9.4.4.6 Hydrology

There are larger rivers and streams in all sites studied. Some streams however, are seasonal and dry up during the dry seasons but other rivers and streams provide clear water. On the other hand, during the wet seasons these waterways hold turbid water containing silt and sand-size particles.

9.4.5 Soils

9.4.5.1 Criteria for Soil Selection

The soil physical and chemical characteristics are important to evaluate for the envisaged use. Some of the physical and chemical characteristics are soil depth, soil texture and soil consistency, and soil acidity (pH), Cation Exchange Capacity (CEC), and Exchangeable Bases (i.e. Ca, Mg, K., Na) respectively.

In order to do a complete land evaluation for rice (as well as other crops) land and soil characteristics are a critical consideration.

9.4.5.2 Physical and Chemical Characteristics

Generally, the soils are well drained on the hills and ridges, but are poorly drained in the valleys.

The soil physical characteristics are given in the profile descriptions of Muschu Series, Aupik Series and Waikakum Series in the annexes provided. The soils of the hills and ridges of the Muschu Island (Wewak District) and Aupik and Waikakum (Maprik District) are well drained with good clay content for storing moisture during dry periods. They basically range from imperfectly drained to well drained.

9.4.5.3 Soil Fertility

The soil fertility will not be known until after the soil samples have been analyzed. However, based on visual observations of the physical characteristics mainly, the soils of Muschu Island, Aupik and Waikakum have better soil physical characteristics than the sandy soils of Nienguanje.

9.4.6 Land Evaluation

9.4.6.1 Criteria for Land Selection

Land as a resource encompasses five (5) environmental components, namely climate, topography, vegetation, soil and geology as these interact with each other to make it possible or otherwise for its usage, as already mentioned.

The land physical characteristics such as altitude, temperature, rainfall and soil physical and chemical characteristics such as drainage and texture and acidity (pH) respectively are some of the characteristics that can be used to assess suitability of a tract of land for rice growing (refer to Table 9.5 for range in the characteristics). Meeting all conditions will render high suitability (S1), meeting all but one equals moderate suitability (S2), all but two or three equals marginal suitability (S3) and so on.

9.4.6.2 Land Use Potential Assessment

The soils of Muschu Island, Aupik and Waikakum have better physical characteristics than those of Nienguanje. Based on this assessment, the soils of the three mentioned sites will be moderately suitable (S2) to highly suitable (S1); while, those of Nienguanje will be marginally suitable (S3) with soil texture (t) as a limiting factor (refer to Table 9.19).

9.4.6.3 Land Tenure and Land Holding

In the Nienguanje village and Muschu Island of the Wewak District, land is an important individual and/or family asset vital for the livelihood. Like in most parts of PNG, land is traditionally owned and culturally attached to the people.

The land ownership has been passed down from generation to generation and this tradition is continuing today. People live in villages (or communities), but make gardens, do game hunting, and collect materials for housing and other purposes from bushes on their own land. As these societies are patrilineal in nature, land is subdivided into family units or clan group and or is further distributed as population increases. No land-related issues was detected during the course of the survey. However, it is envisaged that naturally as families increase in the future, land may become scarce, giving rise to further resource rationalization and perhaps land mobilisation

9.4.7 Conclusion

Based on the physical characteristics, the soils of Muschu Island, Aupik and Waikakum are better suited for rice growing than the soils of Nienguanje in the Wewak District. Soil texture (sandy) is the limiting factor as the soil will be unable to retain nutrients for plant growth.

9.5 East New Britain Province

9.5.1 Introduction

In order to ascertain suitability of growing rice as a food crop in selected sites of the Rabaul and Kokopo Districts of East New Britain Province, soil, land-use (current and potential) and general environment study is necessary. Land-use and environment are components that are just as important as soil and water. Soil however, is the major component of the land resource as far as evaluating suitability of the selected sites is concerned. It is the analysis of the combination of soil, climate and topography that determines land suitability for rice cultivation.

Availability of required site information and specifically adequate and correct information on soils and water is necessary and can only be collected at each selected site.

Rice (upland or lowland) has its soils requirements particularly in (soil drainage, acidity, texture and structure), rainfall, temperature and altitude and this sort of information is readily available (Purseglove 1968, 1972). These soil requirements are

matched with the field data and information together with the soils chemical analysis data for land evaluation purposes (refer to Sect. 9.1.6 or Table 9.5).

Information on current land use and environment in general is useful as the land use practices will have some effects on the surrounding environment.

9.5.2 Objective

Although land and soils physical characteristics may be suitable for rice growing, it is also necessary to have analyzed soils chemical data available to conduct land evaluation for rice cultivation, particularly with regards to the rice nutrient intake requirements. This particular information can be obtained by collecting soil samples at each site for chemical analysis in a credible laboratory. Available secondary data in this regard will also help immensely.

9.5.3 Survey Methodology

9.5.3.1 Fieldwork

Field data and information is a necessary component of any land and soil survey and this can be obtained through the following activities at each site:

a) Boundary surveys of each site will be done to determine size and area (in hectares). This will also enable the production of soil map that will indicate delineations of different soil types into mapping units (MU);
b) General data and information on vegetation, topography, environment and current land use practices will be collected;
c) Soil profiles will be described randomly (by use of a 120 cm soil auger); and
d) Soil samples from each representative profile will be collected for chemical analysis at the laboratory.

9.5.3.2 Data Collation and Analysis

Preliminary suitability of the soils have been made in the field based on soil physical characteristics only and these are namely: soil depth, soil texture, soil colour and soil drainage. The soils are deep and well drained with high clay content at Raputput village of the Duke of York Island of the Kokopo District; while, the soils are sandy at the other three locations.

Soil samples from each of the study sites were taken for the chemical analysis, but unfortunately, the amount of exchangeable bases such as the calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) will not be known until after the soil analysis have been done.

9.5.4 General Characteristics of the Area

9.5.4.1 Area, Location and Access

The Duke of York Island is situated to the northeast of Kokopo town, while Gelagela and Talvat-Sikut are to the south and Ngunguna village to the west (refer to the locality map). Kokopo District Office looks after Raputput and Ngunguna villages; while, Rabaul District Office looks after Gelagela and Talvat-Sikut areas.

While Raputput is accessible by sea only, Ngunguna is accessible by the Kokopo road and Gelagela and Talvat-Sikut by the Warangoi road.

9.5.4.2 Physiography, Relief and Drainage

The Duke of York Island is comprised of raised coral reefs and littorals, while Ngunguna is under hills. Gelagela and Talvat-Sikut are located also in the hilly terrain. The slopes range from $10^0 - 20^0$.

The sites looked at are all well drained because of the sandy textures of the soils. The small streams that drain the areas become dry during the periods of less rainfall.

9.5.4.3 Climate

9.5.4.3.1 Rainfall

The rainfall figures provided in Table 9.16 is applicable to areas studied. The mean annual rainfall for Rabaul is 2,135mm, while that of Kokopo is 1,946mm.

Table 9.16. Mean Monthly and Annual Rainfall (mm).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Rabaul Airstrip	230	244	256	209	129	114	104	103	94	118	173	238	2003
Rabaul Dept. Works	255	276	312	215	117	101	98	109	94	121	190	255	2138
Rabaul DHQ	352	268	255	245	136	94	131	113	86	118	167	259	2244
Kokopo	219	189	221	170	120	121	168	143	111	116	162	230	1946

Source: Climate Tables for PNG: McAlpine, Keig and Short

The dry season occurs during the months of June, July, August and September in all stations.

9.5.4.3.2 Temperature

Temperature figures provided in Table 9.17 for the Rabaul Airstrip, are applicable for the four sites. The mean monthly temperatures range from 26^0C to 27^0C, and the mean annual temperature is just over 27^0C.

Table 9.17. Mean Monthly Annual and Extreme Temp (^{0}C) for Rabaul

	J	F	M	A	M	J	J	A	S	O	N	D	Ann
Extreme Max	35.4	34.1	36.1	34.4	34.9	35.5	35.0	35.2	36.1	35.9	35.0	34.7	36.1
Mean Max	30.9	30.8	30.7	30.8	31.2	30.9	30.4	30.7	31.4	31.6	31.3	30.9	31.0
Mean	27.1	27.1	27.0	27.1	27.1	27.1	26.8	27.0	27.4	27.5	27.3	27.1	27.1
Mean Min	23.2	23.2	23.3	23.3	23.6	23.3	23.2	23.2	23.4	23.3	23.3	23.2	23.3
Extreme Min	20.2	20.0	20.3	20.0	20.6	17.8	19.4	19.4	19.3	19.3	20.4	16.1	16.1

Source: Climatic Tables for PNG: McAlpine, Keig and Short

The mean maximum temperature ranges from 30^0 to over 31^0C and the mean maximum temperature is $>23^0$C.

9.5.4.4 Vegetation and Land Use

In the Ngunguna and Gelagela areas, the vegetation is a mixture of cash crops and secondary regrowth; while, in the Talvat-Sikut area rainforest dominates. The Duke of York Island is under cash crops.

Except for the Talvat-Sikut area, the rest of the sites are under copra and cocoa, as well as vanilla. Some farmers have integrated rice plots of an average of 15m x 20m with the food gardens as a food crop.

9.5.4.5 Geology

The Duke of York Island has volcanic material overlying coral limestone; while, in the other sites, the parent material is volcanic.

9.5.4.6 Hydrology

The main river is the Warangoi River, but there are numerous smaller rivers and streams, some of which dry up during the dry season.

9.5.5 Soils

9.5.5.1 Criteria for Soil Selection

The soil physical and chemical characteristics are important to evaluate it for the envisaged use. Some of the physical and chemical characteristics are soil depth, soil texture and soil consistency, and soil acidity (pH), Cation Exchange Capacity (CEC), and Exchangeable Bases (i.e. Ca, Mg, K., Na) respectively.

In order to do a complete land evaluation for rice (as well as other crops) land and soil characteristics are a critical consideration.

9.5.5.2 Physical and Chemical Characteristics

The soils are deep and well drained, and their physical characteristics are given in the profile descriptions of the Raputput Series, Talvat Series, Gelagela Series and Ngunguna Series in the annexes provided. The Raputput Series have high clay content because they are developed on coral limestone, than others which are sandy.

9.5.5.3 Soil Fertility

The soil fertility will not be known until after the soil samples have been analyzed. However, in the presence of the past and present volcanic eruptions within the area and based on literatures like PNGRIS data base, all soils are volcanic.

9.5.6 Land Evaluation

9.5.6.1 Criteria for Land Selection

Land as a resource encompasses five (5) environmental components, namely climate, topography, vegetation, soil and geology as these interact with each other to make it possible or otherwise for its usage, as already mentioned.

The land physical characteristics such as altitude, temperature, rainfall and soil physical and chemical characteristics such as drainage and texture and acidity (pH) respectively are some of the characteristics that can be used to assess suitability of a tract of land for rice growing. (refer to Table 9.5 or Sect. 9.1.6.1). Meeting all conditions will render high suitability (S1), meeting all but one equals moderate suitability (S2), all but two or three equals marginal suitability (S3) and so on.

9.5.6.2 Land Use Potential Assessment

The Raputput Series of the Duke of York Island have better physical characteristics than soils of other sites. Therefore, these soils are assessed as highly suitable (S1) than the other soils that have sandy textures and are assessed as moderately suitable (S2) with soil texture (t) as a limiting factor (refer to Table 9.19).

9.5.6.3 Land Tenure and Land Holding

In the Rabaul and Kokopo Districts, land is an important individual and/or family asset vital for the livelihood. Like in most parts of PNG; land is traditionally owned and people are culturally attached to.

Matrilineal land ownership has been passed down from generation to generation and this tradition continues even today. Land is subdivided into family units or clan group and is further distributed as population increases. No land-related issues were detected during the course of the survey. However, it is envisaged that naturally as families increase in the future, land may become scarce, giving rise to further resource rationalization and perhaps land mobilisation

Apart from the people living at Ngunguna and Raputput, the people of Gelagela and Talvat-Sikut have been resettled on land that was purchased by the National Government. They are expected to stay for an indefinite period of time.

9.5.7 Conclusion

Based on the physical characteristics of the soils, and because of the fact that the area is in the active geological zone, the soils are volcanic and fertile. The soils of the Duke of York Island will have relatively better physical condition than the soils of the other study sites.

9.6 General Summary for the five surveyed Provinces

Knowing and understanding the method of collecting field data and information is an important asset preceding the actual fieldwork and compilation of the report. The following was done to acquire the needed data and information in the field.

(a) Although boundary surveys of large areas have not been intended for this consulting work, measurements of the household gardens have been taken and most, on the average, measured 15m x 20m;

(b) General data and information on vegetation, topography, environment and current land use practices for each site have been described;

(c) Soil profiles at each site have been described randomly: 3 or 4 soil profiles have been observed (by a use of 120cm soil auger.) before collecting samples from a representative profile; and

(d) Soil samples have been collected for the chemical analysis at the laboratory.

9.6.2 Physiographically, the following general data and information for the ten (10) districts of the five (5) Provinces is given:

(a) In the Central Province, about 40% of the Abau and Kairuku Districts are comprised of the flood plains; while, 50% and 40% is a mountainous terrain respectively;

(b) In the Morobe Province, about 90% of the Finschhafen District is mountainous, while, 80% of the Lae District is also mountainous.

(c) In the Madang Province; about 90% of the Madang District is mountainous; while, about 45% is mountainous and 50% is floodplains in the Usino/Bundi District;

(d) In the East Sepik Province, about 80% of the Wewak and Maprik Districts are mountainous and 15% floodplains; and

(e) In the East New Britain Province, about 85% is hilly and mountainous in the Rabaul District; while, about 90% is also hilly and mountainous in the Kokopo District.

9.6.3 The mean annual rainfall (mm) and mean annual temperature (°C) figures for the respective districts of the five Provinces are as follows:

(a) Abau and Kubuna stations in the Central Province receive >2,000mm and the temperatures of 25.6°C and 26.1°C respectively;

(b) Finschhafen and Lae stations in the Morobe Province receive >4,000mm, and the temperatures of around 26°C;

(c) Madang and Usino stations in the Madang Province receive >3,500mm and >1,700mm respectively, and temperature of around 26°C;

(d) Wewak and Maprik stations in the East Sepik Province receive >2,150mm and >1,600mm respectively, and temperature of around 26°C; and

(e) Rabaul and Kokopo stations in the East New Britain Province receive >2,100mm and 1,900mm respectively, and temperatures of 27°C.

The highest rainfall is received in the Morobe Province; while, the lowest in the Maprik District of the East Sepik Province.

9.6.4 The vegetation distribution and land use for each district are as follows:

(a) In the Abau and Kairuku Districts of the Central Province, the dominant vegetation type is the Tropical Rainforest and Savanna grassland with Imperata Cylindrica (Kunai) and Saccharum Spontaneum. Secondary Regrowths are associated with various land use practices.

The land uses are related mainly to subsistence gardening and commercial cash cropping (like coconut and rubber).

(b) In the Finschhafen and Lae Districts of Morobe Province, Tropical Rainforest dominates with grasslands of Imperata Cylindrica (or Kunai) and Saccharum Spontanem. Secondary regrowths are associated with various land use practices.

The land uses are related to subsistence gardening and commercial cropping (like robusta coffee).

(c) In the Madang and Usino/Bundi Districts of the Madang Province, Tropical Rainforest dominates with Imperata Cylindrica a common grass type. Secondary regrowths are associated with various land use practices.

The land uses are related to subsistence gardening and commercial cropping (like robusta coffee, cocoa and copra)

(d) In the Wewak and Maprik Districts of the East Sepik Province, Tropical Rainforest dominates with Imperata and Saccharum grasses. Secondary regrowths are associated with various land use practices.

The land uses are related mainly to subsistence gardening and commercial cropping (like cocoa and robusta coffee).

(e) In the Rabaul and Kokopo Districts of the East New Britain Province, a mixture of cash cropping (cocoa, copra and vanilla) and secondary regrowths dominate. However, in the Warangoi area, Tropical Rainforest dominates.

The land use practices are mainly related to subsistence gardening and cash cropping.

9.6.5 The geology composition within each district is provided below.

(a) In the Abau District, the underlying geology is submarine basaltic lava and alluvial deposits; while, in the Kairuku District, it is volcanic

material and alluvial deposits;

(b) In the Finschhafen District, the underlying geology is cavernous reef limestone interbedded with calcarenite and volcanically derived sandstone; while, in the Lae District, it is alluvium and beach deposits together with gravel, silt, sand and clay;

(c) In the Madang District, the geology is indurated greywacke; while, in the Usino-Bundi District, it is alluvial deposits together with gravel, sand, silt and clay;

(d) In the Wewak District, the geology is reef limestone; while, in the Maprik District, it is calcareous and alluvial deposits; and

(e) In the Rabaul District, the underlying geology is coral limestone and volcanic deposits; while, in the Kokopo District, it is volcanic deposits.

9.6.6 The physical descriptions of soils in each location in the five Provinces is given both in the profile descriptions and the soil and land suitability table (refer also to the suitability ratings). Most soils are deep and well drained, and suitable for upland rice cultivation. A few soils have physical limitation and these are: (a) shallow soil depth – abrupt textural change (Tutubu – CP); (b) poor drainage (Four and Five Miles – MP); and (c) shallow depth and steep slopes (Lagaha – MP).

The chemical characteristics of the soils is based on the data obtained from the Papua New Guinea Resources Information System (PNGRIS) data base, which gives account of chemical compositions of three (3) major soil groups within a Resource Mapping Unit (RMU). Table 18 provides this chemical data for each location of the five Provinces under study.

Most soils have moderate to high fertility for upland rice except for (a) Tutubu Series (low N, P.), (b) Kubuna Series (low P, K), and Gelagela Series (low, P.).

The soil and land has been evaluated for both upland and lowland rice cultivation, and the suitability ratings for all sites range from highly suitable (S1) to permanently not suitable (N2) (refer Table 9.19).

The soil and land use potential therefore ranges from not suitable to highly suitable corresponding to the suitability ratings (N to S1). The use of this resource is limited by a range of limitations such as soil depth (d), soil fertility (n), slope (e), soil drainage, available soil water holding capacity (m), and so on.

Improvements to the soil can be made, where possible, by attending to all the identified soil and land limitations. For example, where soil fertility is low, adding a fertilizer purchased from stores or simply applying organic humus to the soils can increase the soil fertility.

In most sites, there is space for expansion of rice growing as there is potential land available. It is estimated that there is a total of about 390 hectares available, based on the field conditions experienced at each survey site (refer to Table 9.20).

Table 9.18 Chemical Data - PNGRIS* **Province: Central Province**				
Location	Tutubu (RMU217)	Amau (RMU218)	Yumuna (RMU77)	Idoido (RMU85)
.AWC:				
0 – 25cm	Very low	Low	Low	Low
0 – 50cm	Low	Mod.	Mod.	Mod
0 – 100cm	Mod	High	Very High	High
. Erodibility	Low	Mod	Mod.	Mod.
. Drainage	Well drained	Imp. To well drained	Well Drained	Poor – very poor
. Acidity	Alkaline	Weakly Acid	S/Acid	Weakly Acid
. CEC (meq. %)	<10 – Low	>25 high	10 – 25 Mod	>25 High
. BS (%)	>60 – High	>60 high	20 – 60 Mod	>60 High
%N	<0.2 – Low	0.2 – 0.5 Mod.	0.2 – 0.5 Mod	2 – JM
. Av. P (ppm)	<10 – Low	>20ppm high	<10 Low	>20 High
. Exch. K (meq %)	0.2 – 0.6 – Mod.	0-2 – 0.6 Mod.	<0.2 Low	>.6 High
.Min. Reserv.	High	High	Mod. Low	High

Table 9.18 Chemical Data PNGRIS* **Province: Morobe Province**			
Location	Wareo & Salodi (RMU75)	Poahum (RMU78)	4 Mile & 5 Mile (RMU78)
		SOL1	SOL2
.AWC:			
0 – 25cm	Low	Low	Low
0 – 50cm	Mod.	Mod.	Mod.
0 – 100cm	Mod.	High	High
. Erodibility	Low	Mod	Mod.
. Drainage	Well drained	Poor to Very Poor	Well Drained
. Acidity	Weakly Acid	Weakly Acid	Weakly Acid
. CEC (meq. %)	>25 – High	>25 – High	>25 – High
. BS (%)	>60 – High	>60 – High	>60 – High
. %N	0.2 – 0.5 – Mod.	0.2 – 0.5 – Mod.	0.2 – 0.5 – Mod.
. Av. P (ppm)	>20ppm – High	>10- 20 Mod.	>10 – 20 - Mod.
. Exch K (meq %)	0.2 – 0.6 – Mod.	0.2 - 0.6 – Mod.	0.2 – 0.6 – Mod.
.Min. Reserv.	High	High	High

Table 9.18 Chemical Data PNGRIS* **Province: Madang Province**			
Location	Lagaha (RMU5)	Danaru, Sausi (RMU56)	Umun (RMU2)
.AWC:			
0 – 25cm	Low	Low	Low
0 – 50cm	Mod.	Mod.	Mod.
0 – 100cm	High	High	High
. Erodibility	Mod	Mod	Mod.
. Drainage	Well drained	Well drained	Imp. to poor
. Acidity	Acid	Weakly Acid	Acid
. CEC (meq. %)	Mod. (10 – 25)	High (>25)	Mod. (10 – 25)
. BS (%)	Mod. (20 – 60)	High (>60)	Mod. (0.2 - 0.5)
. %N	Mod. (0.2 – 0.5)	Mod. (0.2 – 0.5)	Mod. (0.2 – 0.5)
. Av. P (ppm)	Mod. (10 – 20	Mod. (10 – 20)	Mod. (10 - 20ppm)
. Exch. K (meq %)	Mod. (0.2 – 0.6)	Mod. (0.2 – 0.6)	Mod. (0.2 – 0.6)
.Min. Reserv.	Moderate	High	Moderate

Table 9.18 Chemical Data PNGRIS* **Province: East Sepik Province**			
Location	Muschu (RMU5)	Nienguanje (RMU21)	Aupik, Waikakum (RMU30)
.AWC:			
0 – 25cm	Low	Low	Low
0 – 50cm	Low	Mod.	Mod.
0 – 100cm	Low	High	Mod
. Erodibility	Low	Mod	Low
. Drainage	Well drained	Well drained	Well drained
. Acidity	Alkaline	Weakly Acid	Weakly Acid
. CEC (meq. %)	High (>25)	High (>25)	High (>25)
. BS (%)	High (>60)	High (>60)	High (>60)
. %N	Mod. (0.2 – 0.5)	Mod. (0.2 – 0.5)	Mod. (0.2 – 0.5)
. Av. P (ppm)	High (>20)	High (>20)	Mod. (10 – 20)
. Exch. K (meq %)	Mod. (0.2 – 0.6)	Mod. (0.2 – 0.6)	Mod. (0.2 – 0.6)
.Min. Reserv.	High	High	High

Table 9.18 Chemical Data PNGRIS* Province: East New Britain Province			
Location	Raputput (RMU1)	Gelagela Ngunguna (RMU10)	Talvat (RMU38)
.AWC:			
0 – 25cm	Low	Low	Low
0 – 50cm	Mod.	Mod.	Mod.
0 – 100cm	High	High	Mod
. Erodibility	Mod	Very low	Mod
. Drainage	Well drained	Well drained	Well drained
. Acidity	Acid	Weakly Acid	Weakly Acid
. CEC (meq. %)	Mod. (10 – 25)	Mod. (10 – 25)	High (>25)
. BS (%)	Mod. (20 – 60)	High (>60)	High (>60)
. %N	Mod. (0.2 – 0.5)	Mod. (>0.5)	Mod. (0.2 – 0.5)
. Av. P (ppm)	Mod. (10 – 20)	Low (<10)	High. (>20)
. Exch. K (meq %)	Mod. (0.2 – 0.6)	Mod. (0.2 – 0.6)	Mod. (0.2 – 0.6)
.Min. Reserv.	Moderate	High	High

* This provides the overall soil chemical status of each site based on Papua New Guinea Research Information System Database (PNGRIS) RMUs kept at DAL, Konedobu.

Table 9.19 Soil and Land Suitability

SOIL SERIES	AREA (ha) **	DESCRIPTION	SLOPE (°)	LAND SUITABILITY		LIMITATION
				Upland Rice	Lowland Rice	
Tutubu	0.0176	Well drained (20-40cm thick) sandy clay loam topsoil overlying sandy subsoil	0	S3	N2	d4 a6
Amau	0.0750	Well drained deep sandy clay loam topsoil overlying sandy clay loam to sandy clay subsoil	0	S2	S3	n2
Kubuna (Yumuna/ Idoido	0.0470	Well drained sandy clay loams to sandy clay overlying heavy clays.	3	S1	N1	e2 n2
Haiyo (Salodi)	0.04	Deep well drained clay loam topsoil overlying clay subsoil.	5	S2	N1	e2 n2
Apusolo		Deep well drained clay loam topsoil overlying clay subsoil.	5	S2	N1	e2 n2
Wareo	0.09	Deep well drained clay loam topsoil overlying clay.	15	S3	N2	e3 n2
Four	0.15	Deep poorly drained sandy clay loam topsoil overlying sandy clay subsoil.	0	N2	S2	w2 n2 a6
Five		Moderately deep poorly drained sandy clay loam topsoil overlying gravely sands and gravels subsoil	0	N1	S2	w2 a6
Poahum	0.08	Moderately deep well drained sandy clay loams overlying sandy loams.	0	S1	S3	n2 a6
Lagaha	0.06	Very shallow soils on steep slopes.	>15	S3	N2	a4 e4 d5
Umun	0.08	Deep imperfect to well drained sandy clay loam topsoil overlying sands to sandy clay loam subsoil.	0	S2	S3	m3
Danaru 1	0.08	Deep well drained clay soils of the foothills.	5	S2	N2	e2
Danaru 2		Deep imperfectly drained clay loam topsoil overlying sands.	0	S2	S3	m3
Sausi (Yagumbu)	0.05	Deep well drained sandy clay loam topsoil overlying light clay subsoil.	0	S1	S1	
Benedict		Deep imperfectly drained clay loam topsoil overlying clay subsoil.	1	S1	S2	e1

SOIL SERIES	AREA (ha) **	DESCRIPTION	SLOPE (°)	LAND SUITABILITY		LIMITATION
				* Upland Rice	* Lowland Rice	
Muschu	0.03 0.015	Deep well drained clay loam topsoil overlying clay subsoil on coral limestone.	2	S1	S2	e2 n2
Aupik	0.18	Deep well drained clay loam to gravely clay topsoil overlying gravelly clay subsoil.	7	S2	N2	e2 n2
Waikakum	0.20	Deep imperfectly drained clays with heavier textured subsoils.	7	S2	N2	e2 a6
Raputput	0.004	Deep well drained clay loam to clay topsoil overlying clay subsoil	2	S2	S3	e2 n2
Talvat-Sikut	0.06	Deep well drained loams topsoil overlying sandy subsoils.	15	S3	N2	e2 a'
Gelagela	0.01	Deep well drained sandy clay loam topsoil overlying sandy subsoil.	0	S1	S3	m3
Ngunguna	0.09	Deep well drained sandy clay loam overlying sandy subsoil.	3	S2	N1	e3

Suitability Rating
S1 - Highly suitable
S2 - Moderately suitable
S3 - Marginally suitable
N1 - Currently Not suitable
N2 - Permanently Not suitable

Limitations
e - slope steepness
m - available soil water
w - soil drainage
d - soil depth
n - soil fertility
a - soil reaction

Limitation Explanation
e1 - very slight erosion hazard
e2 - slight erosion hazard
e3 - moderate erosion hazard
e4 - severe erosion hazard
m3 - low AWC
w2 - poorly drained
d4 - shallow soil
d5 - very shallow soil
n2 - moderately fertile soil
n3 - infertile soil

a4 - alkaline soil
a6 - strongly alkaline soil

* These are current suitability ratings. There is potential for improvement for example: if fertilizer is applied, the fertility status and the suitability of the soil improves.

** Actual garden sizes in hectares.

Table 9.20 Land Area (sq.km)

No.	Location	Province	Area (sq.km) **	Hectares		RMU No.
				Available	Potential *	
1	Tutubu	Central	30	3,000	25	217
2	Amau	Central	422	42,200	50	218
3	Kubuna/Yumuna	Central	498	49,800	10	77
4	Haiyo	Morobe	592	59,200	12	75
5	Apusolo	Morobe				
6	Wareo	Morobe			10	
7	Four Mile	Morobe			15	
8	Five Mile	Morobe	321	32,100		78
9	Poahum	Morobe			75	
10	Lagaha	Morobe	414	41,400	5	5
11	Umun	Madang	105	10,500	40	2
12	Danaru 1	Madang	496	49,600	15	56
13	Danaru 2	Madang				
14	Sausi	Madang			4	
15	Benedict	Madang			100	
16	Muschu Is.	East Sepik	41	4,100	7	5
17	Nienguanje	East Sepik	60	6,100	20	21
18	Aupik	East Sepik	227	22,700	30	39
19	Waikakum	East Sepik			40	
20	Gelagela	East New Britain	424	42,400	5	10
21	Talvat-Sikut	East New Britain			10	
22	Raputput	East New Britain	3	300	5	1
23	Ngunguna	East New Britain	56	5,600	15	38

Source: PNGRIS Database

* Subjective estimations of potential areas in hectares.

** Areas based on PNGRIS RMUs

9.7 Recommendations for improving soil fertility

1. The Soil investigated range from strongly acid to strongly alkaline; have low amounts of some exchangeable elements, base saturation, moderate phosphorus retention and C/N ratio.

2. The following soil series namely Tutubu Series, Four Series, Five Series and Waikakum Series are strongly alkaline soils. It is therefore, recommended that gypsum be used to neutralize the soils as the structure of the clay soil is usually improved by using gypsum.

3. The strongly acid soils of the Apusolo Series can be improved by raising the pH (or acidity) of the soil by adding lime or dolomite.

4. The soils that do not have any pressing nutrient problems are the Umun Series, Danaru 1 Series and Ngunguna Series.

5. The other soils are low in NPK and other exchangeable elements. But the following soils namely Haiyo Series, Apusolo Series, Wareo Series, Four Series, Five Series, Poahum Series, Benedict Series, Raputput Series, Talvat Series and Gelagela Series have problems with Phosphorus retention and/or C/N ratio.

6. Four Series, Five Series and Lagaha Series also have high amounts of sodium (Na).

7. Organic matter or humus can also be used in place of the fertilizers from the stores.

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ANNEX 1 - REPRESENTATIVE SOIL PROFILE DESCRIPTION

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Tutubu Series

Tutubu Series Well to imperfectly drained sandy clay loams overlying sands.

Soil Classification:

Profile Description

Location	:	Tutubu village backyard garden
Landform	:	Flat coastal plain
Slope	:	0°
Vegetation/land use	:	Secondary Regrowth Imperata margin
Drainage Status	:	Well drained
Estimated Permeability	:	Moderate to rapid
Stoniness	:	Nil
Parent Material	:	Recent alluvium

Depth (cm)	Description
0 - 20	Moist very dark brown (10YR 2/2); sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular blocky, many fine roots to:
20 - 40	Moist very dark brown (10YR 2/2); fine sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular blocky, few fine roots to:
40 - 60	Moist very dark greyish brown (10YR 3/2); sand, massive, (loose grain) to:
60 - 120	Moist dark brown (10YR 3/3); sand, loose grain, massive (loose grain).

Range in Characteristics

These are well drained dominant 20 - 40 cm thick, sandy clay loam topsoils overlying sandy subsoils. Roots are concentrated mainly in the topsoils.

Chemical Analysis

Place: Tutubu, Central Province
Soil: Tutubu Series

Site Description

Depth (cm)	0 - 20
pH (H_2O)	8
Exch. Bases (meq. %)	
Ca	36.9
Mg	2.08
K	1.16
Na	0.14
Cation Exchange Capacity (meq. %)	37.8
Base Saturation (%)	105
Olsen P (mg/kg)	35.3
Organic Carbon (%)	4.3
Total Nitrogen (%)	0.37
C/N Ratio	12
Mg:K Ratio	2
P Retention (%)	4.6

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Amau Series

Amau Series — Well drained sandy clay loams topsoil, overlying sandy clay subsoil.

Soil Classification:

Profile Description

Location	:	Amau village garden
Landform	:	Floodplain
Slope	:	0°
Vegetation/land use	:	Secondary Rainforest
Drainage Status	:	Well drained
Estimated Permeability	:	Moderate
Stoniness	:	Nil
Parent Material	:	Recent alluvium

Depth (cm)	Description
0 - 20	Moist very dark greyish brown (10YR 3/2), sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular blocky, few fine roots to:
20 - 40	Moist, dark greyish brown (10YR 4/2), sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular block, few fine roots to:
40 - 60	Moist, dark brown (10YR 3/3), sandy clay loam; firm, sticky and plastic, moderate subangualr blocky, few fine roots to:
60 - 120	Moist, dark greyish brown (10YR 4/2), sandy clay, firm, sticky and plastic

Range in Characteristics

These are deep soils with lighter textured surface layers than heavy textured clay subsoils. These soils have good moisture holding capacities, but may be deficient in some elements, for instance potassium (K).

Chemical Analysis

Place: Amau, Central Province
Soil: Amau Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	6.6
Exch. Bases (meq. %)	
Ca	14
Mg	3.23
K	0.09
Na	0.17
Cation Exchange Capacity (meq. %)	22.6
Base Saturation (%)	77
Olsen P (mg/kg)	3.7
Organic Carbon (%)	2.1
Total Nitrogen (%)	0.16
C/N Ratio	13
Mg:K Ratio	36
P. Retention (%)	38

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Kubuna Series

Kubuna Series — Well drained sandy clay loams to sandy clay overlying heavy clays.

Soil Classification:

Profile Description

Location	:	Anika food garden (30 mins walk from Idoido village)
Landform	:	Undulating Low Hills
Slope	:	3°
Vegetation/land use	:	Grassland and forest margin
Drainage Status	:	Well drained
Estimated Permeability	:	Moderate to slow
Stoniness	:	Nil
Parent Material	:	Cherty

Depth (cm)	Description
0 - 20	Moist dark brown (10YR 3/2); sandy clay loam, friable, sticky and plastic, moderate fine subangular blocky, many fine roots to:
20 - 40	Moist dark brown (10YR 3/4); sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular blocky, few fine roots to:
40 - 60	Moist dark brown (10YR 3/4); sand clay, firm, sticky and plastic to:
60 - 80	Moist yellowish red (5YR 5/8); heavy clay, firm, sticky and plastic to:
80 – 120	Moist yellowish red (5YR 5/8); heavy clay; firm; sticky and plastic.

Range in Characteristics

These are deep well drained sandy clay loam to sandy clay topsoils overlying heavy clay subsoils. The topsoils are dark brown while the subsoils are yellowish red and these soils have good water holding capacity. The brownish colour of the topsoil indicates presence of organic matter. Roots are concentrated mainly in the topsoils.

Chemical Analysis

Place: Kubuna, Central Province
Soil: Kubuna Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	5.5
Exch. Bases (meq. %)	
Ca	3.07
Mg	1.31
K	0.33
Na	0.03
Cation Exchange Capacity (meq. %)	19.3
Base Saturation (%)	25
Olsen P (mg/kg)	4.2
Organic Carbon (%)	2.7
Total Nitrogen (%)	0.27
C/N Ratio	10
Mg:K Ratio	4
P. Retention (%)	50

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Haiyo Series (Finschhafen)
Site No: War 1

Haiyo Series — Well drained clay loam overlying clay.

Soil Classification:

Profile Description

Location	:	Hilltop terrace, rice garden
Landform	:	Coastal Hills and Mountains
Slope	:	5^0
Vegetation/Land use	:	Tropical Rainforest
Drainage Status	:	Well drained
Estimated Permeability	:	Moderate to slow
Stoniness	:	Nil
Parent Material	:	Reef Limestone

Depth (cm)	Description
0 - 20	Moist very dark brown (10YR 2/2); sandy clay loam, moderate fine subangular blocky, friable, sticky and plastic, many fine roots to:
20 - 40	Moist very dark yellowish-brown (10YR 4/4); clay loam, friable, sticky and plastic, moderate fine subangular blocky, many fine roots to
40 - 60	Moist very dark brown (7.5YR 3/2); clay, firm, sticky and plastic; moderate medium, subangular blocky; few fine roots to:
60 – 80	Moist dark brown (7.5YR ¾); clay; firm; sticky and plastic; moderate medium subangular blocky to:
80 – 120	Moist dark reddish brown (5YR ¾); clay; firm; sticky and plastic; moderate medium subangular blocky.

Range in Characteristics

These are well drained clay loam topsoils overlying clay subsoils which are reddish in colour. The roots appear mainly in the top 60cm, and the soil permeability is slow in the subsoil.

Chemical Analysis

Place: Haiyo, Morobe Province
Soil: Haiyo Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	5
Exch. Bases (meq. %)	
Ca	4.12
Mg	3.27
K	0.17
Na	0.14
Cation Exchange Capacity (meq. %)	33.2
Base Saturation (%)	23
Olsen P (mg/kg)	3
Organic Carbon (%)	5.4
Total Nitrogen (%)	0.36
C/N Ratio	16
Mg:K Ratio	19
P. Retention (%)	72

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Apusolo Series: (Finschhafen)
Site No: War 2

Apusolo Series Well drained clay loams overlying clay.

Soil Classification:

Profile Description

Location	:	Hill slope
Landform	:	Inland Hills and Mountains
Slope	:	5^0
Vegetation/land use	:	Tropical Rainforest
Drainage Status	:	Well
Estimated Permeability	:	Fast to moderately slow
Stoniness	:	Nil
Parent Material	:	Reef Limestone

Depth (cm)	Description
0 - 20	Moist yellowish red (5YR 4/6); clay loan; friable; sticky ad plastic; moderate fine subangular blocky; many fine roots to:
20 - 40	Moist, red (2.5YR 4/6); clay; friable; sticky and plastic; moderate fine subangular blocky; many fine roots to:
40 - 60	Moist, red (2.5YR 5/8); clay; friable; sticky and plastic, moderate fine subangualr blocky to:
80 - 120	Moist, red (2.5YR 5/8); clay; firm; sticky and plastic' moderate fine subangular blocky.

Range in Characteristics

These are well drained clay loam topsoils overlying clay subsoils which are red in colour. The roots appear mainly in the top 60cm, and the soil permeability is slow in he subsoil.

Chemical Analysis

Place: Apusolo, Morobe Province
Soil: Apusolo Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	4.9
Exch. Bases (meq. %)	
Ca	2.39
Mg	1.13
K	0.24
Na	0.12
Cation Exchange Capacity (meq. %)	31.7
Base Saturation (%)	12
Olsen P (mg/kg)	3.3
Organic Carbon (%)	6.4
Total Nitrogen (%)	0.46
C/N Ratio	14
Mg:K Ratio	5
P. Retention (%)	68

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Wareo Series: (Finschhafen)
Site No: War 3

Wareo Series Well drained clay loams overlying clay.

Soil Classification:

Profile Description

Location	:	Hillslope
Landform	:	Inland Hills and Mountains
Slope	:	15°
Vegetation/land use	:	Tropical Rainforest
Drainage Status	:	Well
Estimated Permeability	:	Fast to slow
Stoniness	:	Nil
Parent Material	:	Reef Limestone

Depth (cm)	Description
0 - 20	Moist dark brown (7.5YR 3/4); clay loam, friable, sticky and plastic, moderate fine subangular blocky, many fine roots to:
20 - 40	Moist strong brown (7.5YR 4/6); clay loam, friable; sticky and plastic; moderate fine subanular blocky; many fine roots to:
40 - 60	Moist reddish brown (5YR 4/4); clay, friable, sticky and plastic; moderate fine; subangular blocky; few fine roots to:
60 - 80	Moist reddish brown (5R 5/4); clay; firm; sticky and plastic; massive to:
80 –120	Moist reddish brown (5YR 5/4); clay; firm; sticky and plastic; massive.

Range in Characteristics

These are well drained clay loam topsoils overlying clay subsoils. These are dark brown to reddish brown soils, and the permeability slow in the subsoil.

Chemical Analysis

Place: Wareo, Morobe Province
Soil: Wareo Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	5.2
Exch. Bases (meq. %)	
Ca	1.73
Mg	0.59
K	0.53
Na	0.11
Cation Exchange Capacity (meq. %)	25.6
Base Saturation (%)	1.2
Olsen P (mg/kg)	1.3
Organic Carbon (%)	4.3
Total Nitrogen (%)	0.33
C/N Ratio	13
Mg:K Ration	1
P. Retention (%)	89

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Four Series: (Lae)
Site No: For 1

Four Series — Poorly drained sandy clay loam topsoil overlying sandy clay subsoil.

Soil Classification:

Profile Description

Location	:	Four Mile
Landform	:	Depositional Valley (Flood plain)
Slope	:	0°
Vegetation/land use	:	Secondary/Rice Garden
Drainage Status	:	Poor
Estimated Permeability	:	V/Slow
Stoniness	:	Nil
Parent Material	:	Alluvium/Colluvium

Depth (cm)	Description
0 - 20	Moist very dark grey (10YR 3/1); sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular blocky, many fine roots to:
20 - 40	Moist very dark greyish brown (10YR 3/2); few fine and distinct mottles, yellow mottles (10YR 7/8); sandy clay loam; firm; sticky ad plastic; moderate fine subangular blocky; few fine roots to:
40 - 60	Wet very dark grey (10YR 3/1); few common ad distinct yellow (10YR 7/8) mottles; sandy clay; firm; sticky and plastic; massive coherent to:
60 - 80	Wet grey (2.5YR 5/0); gleying; sandy clay; weakly developed; non-sticky and non-plastic; massive coherent to:
80 –120	Wet grey (2.5YR 5/0); gleying; sandy clay; weakly developed; non-sticky and non-plastic; massive coherent.

Range in Characteristics

These soils are deep and poorly drained with high watertable. They are sandy clay loam topsoil overlying sandy clay subsoil. The subsoil has gley horizons.

Chemical Analysis

Place: Four Mile, Morobe Province
Soil: Four Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	8.2
Exch. Bases (meq. %)	
Ca	34.51
Mg	6.01
K	0.76
Na	1.07
Cation Exchange Capacity (meq. %)	36
Base Saturation (%)	118
Olsen P (mg/kg)	7.5
Organic Carbon (%)	1.9
Total Nitrogen (%)	0.1
C/N Ratio	19
Mg:K Ratio	8
P. Retention (%)	36

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Five Series: (Lae)
Site No: Fiv 1

Five Series — Poorly drained sandy clay loam topsoil overlying gravelly sands and gravels.

Soil Classification:

Profile Description

Location	:	Four Mile
Landform	:	Depositional Valley (Flood plain)
Slope	:	0°
Vegetation/land use	:	Secondary/Rice Garden
Drainage Status	:	Poor
Estimated Permeability	:	Slow
Stoniness	:	Nil
Parent Material	:	Alluvium/Colluvium

Depth (cm)	Description
0 - 20	Moist very dark grayish brown (10YR 3/2); sandy clay loam, slightly firm, sticky and plastic, moderate fine subangular blocky, many fine roots to:
20 - 40	Moist very dark brown (10YR 3/3); gravelly loams, sand; loose; non sticky non plastic; structureless-single grain to:
40 - 60	Wet light olive brown (2.5YR 5/6); gravelly sand; loose; non sticky non plastic; structureless–single grain.

Range in Characteristics

These are gravelly poor drained soils with high watertable (at 25cm). They are sandy clay loam topsoil overlying gravelly sands in the subsoil.

Chemical Analysis

Place: Five Mile, Morobe Province
Soil: Five Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.7
Exch. Bases (meq. %)	
Ca	23.46
Mg	3.57
K	0.63
Na	1.04
Cation Exchange Capacity (meq. %)	31.3
Base Saturation (%)	92
Olsen P (mg/kg)	5.4
Organic Carbon (%)	5.2
Total Nitrogen (%)	0.31
C/N Ratio	17
Mg:K Ratio	6
P. Retention (%)	22

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Poahum Series: (Lae)
Site No: Poh 1

Poahum Series Well drained sandy clay loams overlying sandy loams.

Soil Classification:

Profile Description

Location	:	Pohaum Rice Field
Landform	:	Depositional Valley
Slope	:	0°
Vegetation/land use	:	Secondary Regrowth, Imperata
Drainage Status	:	Well drained
Estimated Permeability	:	Fast
Stoniness	:	Nil
Parent Material	:	Alluvium, gravel, sand silt, clay

Depth (cm)	Description
0 - 20	Moist very dark brown (10YR 2/2); very fine sandy loam; weak friable; crumb; sticky and plastic; few roots to:
20 - 40	Moist very dark greyish brown (10YR 3/2); fine sandy clay loam; weak friable; subangular blocky; sticky and plastic; few fine roots to:
40 - 60	Moist very dark brown (10YR 2/2); sandy loam; loose; massive-single grain; non-sticky non-plastic to:
60+	Gravel/Stone

Range in Characteristics

These are well drained very dark brown moderately deep sandy loam soils. Gravels appear at 60-70cm depth.

Chemical Analysis

Place: Poahum, Morobe Province
Soil: Poahum Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	5.6
Exch. Bases (meq. %)	
Ca	0.69
Mg	0.41
K	0.28
Na	0.03
Cation Exchange Capacity (meq. %)	52.8
Base Saturation (%)	3
Olsen P (mg/kg)	8.4
Organic Carbon (%)	1.7
Total Nitrogen (%)	1.0
C/N Ratio	17
Mg:K Ratio	1.0
P. Retention (%)	97

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Lagaha Series: (Madang)
Site No: Lag 1

Lagaha Series Well drained very sallow gravelly clay loams.

Soil Classification:

Profile Description

Location	:	Mountain slope, food garden
Landform	:	Mountains
Slope	:	15°
Vegetation/land use	:	*Tropical Rainforest/Food Garden*
Drainage Status	:	Well drained
Estimated Permeability	:	Fast
Stoniness	:	Few (10% ground cover)
Parent Material	:	Indurated grewacke

Depth (cm)	Description
0 - 15	Moist very dark grayish brown (10YR 3/2); gravelly clay loam; moderate fine subangular blocky; friable; sticky ad plastic; many roots to:
15+	Gravel/Stone.

Range in Characteristics

These are very shallow soils on steep slopes (>15^0). They are basically gravelly clay loams developed on greywacke parent material.

Chemical Analysis

Place: Lagaha, Madang Province
Soil: Lagaha Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7
Exch. Bases (meq. %)	
Ca	25.04
Mg	4.23
K	2.88
Na	1.7
Cation Exchange Capacity (meq. %)	43.4
Base Saturation (%)	78
Olsen P (mg/kg)	5
Organic Carbon (%)	7.7
Total Nitrogen (%)	0.63
C/N Ratio	12
Mg:K Ratio	1.0
P. Retention (%)	54

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Umun Series: (Madang)
Site No: Umu 1

Unum Series Imperfect to well drained sandy clay loams.

Soil Classification:

Profile Description

Location	:	Food/Rice Garden
Landform	:	Flood plain
Slope	:	0°
Vegetation/land use	:	Floodplain forest
Drainage Status	:	Imperfect to well drained
Estimated Permeability	:	Moderate to fast
Stoniness	:	Nil
Parent Material	:	Alluvium

Depth (cm)	Description
0 - 20	Moist very dark grayish brown (10YR 3/2); sandy clay loam, friable; sticky and plastic, moderate fine subangular blocky, many fine roots to:
20 - 40	Moist very dark brown (10YR 3/3); sandy clay loam; friable; sticky and plastic; moderate fine subangular blocky; few roots to:
40 - 60	Moist dark brown (10YR 3/3); sand; loose; non sticky and non plastic; massive – single grain to:
60 - 80	Moist dark yellowish brown (10YR ¾); with few fine faint brownish yellow (10YR 6/6) mottles; loamy sand; loose; slightly sticky slightly plastic; massive-single grain to:
80 –120	Moist dark brown (10YR 3/3); with few fine faint brownish yellow (10YR 6/6) mottles; sandy clay loam; firm; sticky and plastic; massive-coherent.

Range in Characteristics

These are imperfect to well drained sand clay loams with a more massive-coherent layer in the subsoil. Mottling appears at about 60cm depth indicating fluctuations of the watertable.

Chemical Analysis

Place: Umun, Madang Province
Soil: Umun Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.4
Exch. Bases (meq. %)	
Ca	29
Mg	6.1
K	1.34
Na	0.14
Cation Exchange Capacity (meq. %)	42
Base Saturation (%)	87
Olsen P (mg/kg)	12.2
Organic Carbon (%)	4.8
Total Nitrogen (%)	0.4
C/N Ratio	12
Mg:K Ratio	5
P. Retention (%)	25

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Danaru Series: (Madang)
Site No: Dan 1

Danaru 1 Series Well drained clay loam overlying clay.

Soil Classification:

Profile Description

Location	:	Danaru 1. Garden
Landform	:	Foothills
Slope	:	3° - 10°
Vegetation/land use	:	Tropical Rainforest, Imperata, Food Garden
Drainage Status	:	Well drained
Estimated Permeability	:	Moderate
Stoniness	:	Nil
Parent Material	:	Indurated Greywacke

Depth (cm)	Description
0 - 20	Moist very dark grey (10YR 3/2); clay loam, moderate fine subangular blocky, friable, sticky and plastic, many fine roots to:
20 - 40	Moist dark brown (10YR 3/3); light clay; moderate fine subangular blocky; friable; sticky and plastic; few roots to:
40 - 60	Moist dark yellowish brown (10YR 4/4); clay; moderate fine subangular blocky; slightly firm; sticky and plastic to:
60 - 80	Moist dark yellowish brown (10YR 4/4); clay; moderate fine subangular blocky; firm; sticky and plastic to:
80 –120	Moist dark yellowish brown (10YR 4/4); clay; moderate fine subangular blocky; firm; sticky and plastic.

Range in Characteristics

These are clay soils of the foothills. They are well drained and the clay content increases with depth, thus, the consistence gets firm as well.

Chemical Analysis

Place: Danaru 1, Madang Province
Soil: Danaru 1 Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.4
Exch. Bases (meq. %)	
Ca	28.98
Mg	7.94
K	2.69
Na	0.06
Cation Exchange Capacity (meq. %)	36.9
Base Saturation (%)	107
Olsen P (mg/kg)	29.5
Organic Carbon (%)	6.3
Total Nitrogen (%)	0.53
C/N Ratio	12
Mg:K Ratio	3
P. Retention (%)	46

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Danaru 2 Series: (Madang)
Site No: Dan 2

Danaru 2 Series Imperfectly drained clay loams overlying sands.

Soil Classification:

Profile Description

Location	:	Food/Rice Garden
Landform	:	Flood plain
Slope	:	0°
Vegetation/land use	:	Secondary Rainforest
Drainage Status	:	Imperfect
Estimated Permeability	:	Fast to Moderate
Stoniness	:	Nil
Parent Material	:	Alluvium, gravel, sand, silt, clay

Depth (cm)	Description
0 - 20	Moist very dark grayish brown (10YR 3/2); clay loam, moderate fine subangular blocky, friable, sticky and plastic, many roots to:
20 - 40	Moist very dark grayish brown (10YR 3/2); clay loam; moderate fine subangular blocky; friable; sticky and plastic; many roots to:
40 - 60	Moist dark brown (10YR 3/3); loamy sand; loose; non sticky and non plastic; structureless-single grain to:
60 - 80	Moist dark yellowish brown (10YR 3/4); sand; loose; non sticky and non plastic; structureless-single grain to:
80 –120	Moist dark yellowish brown (10YR 3/4); loamy sand; loose; non sticky and non plastic; structureless-single grain..

Range in Characteristics

These are imperfectly drained clay loams overlying sands. They are alluvial soils.

Chemical Analysis

Place: Danaru 2, Madang Province
Soil: Danaru 2 Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.4
Exch. Bases (meq. %)	
Ca	34.51
Mg	6.58
K	1.36
Na	0.43
Cation Exchange Capacity (meq. %)	49.8
Base Saturation (%)	86
Olsen P (mg/kg)	22.8
Organic Carbon (%)	2.4
Total Nitrogen (%)	0.3
C/N Ratio	8
Mg:K Ratio	5
P. Retention (%)	22

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Sausi Series: (Usino)
Site No: Sau 1

Sausi Series Well drained sandy clay loam overlying light clay.

Soil Classification:

Profile Description

Location	:	Sausi Village, Food Garden
Landform	:	Flood plains
Slope	:	0°
Vegetation/land use	:	Imperata Cylindrica/Garden
Drainage Status	:	Well drained
Estimated Permeability	:	Fast to moderate
Stoniness	:	Nil
Parent Material	:	Alluvium

Depth (cm)	Description
0 - 20	Moist very dark grayish brown (10YR 3/2); sandy clay loam; weak fine crumb; friable; sticky and plastic; many roots to:
20 - 40	Moist yellowish brown (10YR 5/4); light sandy clay loam; moderate fine subangular blocky; friable; sticky and plastic; few roots to:
40 - 60	Moist yellowish brown (10YR 5/4); light sandy clay; moderate fine subangular blocky; friable; sticky and plastic to:
60 - 80	Moist yellowish brown (10YR 5/6); light sandy clay; moderate fine subangular blocky; slightly firm; sticky and plastic to:
80 –120	Moist yellowish brown (10YR 5/6); light sandy clay; moderate fine subangular blocky; slightly firm; sticky and plastic.

Range in Characteristics

These are well drained sandy clay loams overlying light sandy clay. They are soils of the alluvial plain.

Chemical Analysis

Place: Sausi, Madang Province
Soil: Sausi Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	6.5
Exch. Bases (meq. %)	
Ca	14.26
Mg	4.78
K	1.41
Na	0.05
Cation Exchange Capacity (meq. %)	34.4
Base Saturation (%)	60
Olsen P (mg/kg)	8.2
Organic Carbon (%)	4.8
Total Nitrogen (%)	0.41
C/N Ratio	12
Mg:K Ratio	3
P. Retention (%)	57

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Benedict Series: (Madang)
Site No: Ben 1

Benedict Series Imperfectly drained clay loam topsoil overlying clay subsoil.

Soil Classification:

Profile Description

Location	:	St. Benedict College, Garden
Landform	:	Coastal Foothills
Slope	:	1°
Vegetation/land use	:	Secondary Regrowth/Garden
Drainage Status	:	Imperfectly drained
Estimated Permeability	:	Moderate
Stoniness	:	Nil
Parent Material	:	Coral Limestone

Depth (cm)	Description
0 - 20	Moist very dark grayish brown (10YR 3/2); clay loam; moderate fine subangular blocky, friable; sticky and plastic; many fine roots to:
20 - 40	Moist dark brown (10YR 3/3); clay loam; moderate fine subangular blocky; friable; sticky and plastic; few fine roots to:
40 - 60	Moist dark brown (10YR 4/3); clay; moderate fine subangular blocky; slightly firm; sticky and plastic to:
60 - 80	Moist yellowish brown (10YR 5/6); clay; moderate fine subangular blocky; firm; sticky and plastic to:
80 –120	Moist yellowish brown (10YR 5/6); clay; moderate fine subangular blocky; firm; sticky and plastic.

Range in Characteristics

These are imperfectly drained clay loams overlying clay subsoils formed on coral limestone.

Chemical Analysis

Place: St. Benedicts - Madang
Soil: Benedicts Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	6.8
Exch. Bases (meq. %)	
Ca	11.71
Mg	3.97
K	0.09
Na	0.12
Cation Exchange Capacity (meq. %)	22.3
Base Saturation (%)	71
Olsen P (mg/kg)	1.6
Organic Carbon (%)	2.4
Total Nitrogen (%)	0.16
C/N Ratio	15
Mg:K Ratio	44
P. Retention (%)	30

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Muschu Series: (Wewak)
Site No: Muschu 1

Muschu Series Well drained clay loam topsoil overlying clay subsoil.

Soil Classification:

Profile Description

Location	:	Muschu, Food Garden
Landform	:	Low Hills
Slope	:	2°
Vegetation/land use	:	Secondary Regrowth/Food Garden
Drainage Status	:	Well drained
Estimated Permeability	:	Moderate
Stoniness	:	Nil
Parent Material	:	Coral Limestone

Depth (cm)	Description
0 - 20	Moist very dark greyish brown (10YR 3/2); clay loam; moderate fine subangular blocky; friable; sticky and plastic; many small roots to:
20 - 40	Moist brown (7.5YR 5/4); clay; moderate fine subangular blocky; slightly firm; sticky and plastic many small roots to:
40 - 60	Moist strong brown (7.5YR 5/6); clay; moderate fine subangular blocky; firm; sticky and plastic to:
60 - 80	Moist strong brown (7.5YR 5/6); clay; moderate fine subangular blocky; firm; sticky and plastic to:
80 –120	Moist strong brown (7.5YR 5/6); heavier clay; moderate fine subangular blocky; firm; sticky and plastic.

Range in Characteristics

These are well drained clay loam topsoil overlying clay subsoil on a coral limestone subsoil.

Chemical Analysis

Place: Muschu, East Sepik Province
Soil: Muschu Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	6.9
Exch. Bases (meq. %)	
Ca	10.12
Mg	2.41
K	0.19
Na	0.06
Cation Exchange Capacity (meq. %)	25
Base Saturation (%)	51
Olsen P (mg/kg)	2.2
Organic Carbon (%)	2.1
Total Nitrogen (%)	0.18
C/N Ratio	12
Mg:K Ratio	13
P. Retention (%)	58

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Aupik Series: (Maprik)
Site No: Aup 1

Aup Series — Well drained clay loam to clay topsoil overlying gravelly clay subsoil.

Soil Classification:

Profile Description

Location	:	Low hill ridge, Food Garden
Landform	:	Low Hills
Slope	:	7°
Vegetation/land use	:	Tropical Rainforest/Food Garden
Drainage Status	:	Well Drained
Estimated Permeability	:	Fast to Moderate
Stoniness	:	Nil
Parent Material	:	Alluvium

Depth (cm)	Description
0 - 20	Moist very dark grayish brown (10YR 3/2); clay loam; moderate fine subangular blocky; friable; sticky and plastic; few roots to:
20 - 40	Moist dark grayish brown (10YR 4/2); gravelly clay; moderate fine subangular blocky; friable; sticky and plastic; few roots to:
40 - 60	Moist dark grayish brown (10YR 4/2); gravelly clay; moderate fine subangular blocky; slightly firm; sticky and plastic to:
60 - 80	Moist light yellowish brown (10YR 6/4); gravelly clay; moderate fine subangular blocky; firm; sticky and plastic to:
80 –120	Moist brownish yellow (10YR 6/6); gravelly clay; moderate fine subangular blocky; firm; sticky and plastic.

Range in Characteristics

These are well drained clay loam to gravelly clay topsoil overlying gravelly clay subsoil. They have been developed on the alluvial parent material.

Chemical Analysis

Place: Aupik, Maprik District, East Sepik Province
Soil: Aup Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	6.5
Exch. Bases (meq. %)	
Ca	3.75
Mg	1.2
K	0.11
Na	0.03
Cation Exchange Capacity (meq. %)	9.2
Base Saturation (%)	55
Olsen P (mg/kg)	5.6
Organic Carbon (%)	1.6
Total Nitrogen (%)	0.17
C/N Ratio	9
Mg:K Ratio	11
P. Retention (%)	10

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Waikakum Series: (Maprik)
Site No: Wai 1

Waikakum Series: Imperfectly drained clays with heavier textures in the subsoil

Soil Classification:

Profile Description

Location	:	Waikakum, Food Garden
Landform	:	Low Hills
Slope	:	7°
Vegetation/land use	:	Secondary Regrowth/Food Garden
Drainage Status	:	Imperfectly Drained
Estimated Permeability	:	Moderate
Stoniness	:	Nil
Parent Material	:	Alluvium

Depth (cm)	Description
0 - 20	Moist black (2.5Y 2/2); clay; moderate fine subangular blocky; friable; sticky and plastic; many fine roots to:
20 - 40	Moist very dark grayish brown (2.5Y 3/2); heavy clay; firm; sticky and plastic; few roots to:
40 - 60	Moist light yellowish brown (2.5Y 6/4); heavy clay; firm; sticky and plastic to:
60 - 80	Moist olive yellow (2.5Y 6/6); heavy clay; firm; sticky and plastic to:
80 –120	Moist light yellowish brown (2.5Y 6/4); heavy clay; firm; sticky and plastic.

Range in Characteristics

These are imperfectly drained clays with heavier texture in the subsoil formed on alluvial parent material.

Chemical Analysis

Place: Waikakum, East Sepik Province
Soil: Waikakum Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.9
Exch. Bases (meq. %)	
Ca	29.15
Mg	6.08
K	1.45
Na	0.10
Cation Exchange Capacity (meq. %)	38.03
Base Saturation (%)	97
Olsen P (mg/kg)	26.1
Organic Carbon (%)	5.2
Total Nitrogen (%)	0.4
C/N Ratio	13
Mg:K Ratio	4
P. Retention (%)	18

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Raputput Series: (Kokopo)
Site No: Rap 1

Raputput Series: Well drained clay loam to clay topsoil overlying clay subsoil

Soil Classification:

Profile Description

Location	:	Raputput (Duke of York), Food garden
Landform	:	Low Hills
Slope	:	2°
Vegetation/land use	:	Secondary Regrowth/Food garden
Drainage Status	:	Well drained
Estimated Permeability	:	Fast to moderate
Stoniness	:	Nil
Parent Material	:	Coral Limestone (Volcanic)

Depth (cm)	Description
0 - 20	Moist very dark brown (10YR 2/2); clay loam; moderate fine subangular blocky; friable; sticky and plastic; many small roots to:
20 - 40	Moist very dark grayish brown (10YR 3/2); clay; moderate fine subangular blocky; friable; sticky and plastic; few small roots to:
40 - 60	Moist dark reddish brown (5YR 3/2); clay; moderate fine subangular blocky; firm; sticky and plastic to:
60 - 80	Moist dark reddish brown (5YR 3/3); clay; firm; sticky and plastic to.
80 –120	Moist dark reddish brown (5YR 3/3); clay; firm; sticky and plastic.

Range in Characteristics

These are well drained clay loam to clay topsoil overlying clay subsoil. These are volcanic soils developed on the coral limestone parent material.

Chemical Analysis

Place: Raputput, East New Britain Province
Soil: Raputput Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.5
Exch. Bases (meq. %)	
Ca	15.38
Mg	3.9
K	1.64
Na	0.21
Cation Exchange Capacity (meq. %)	29.5
Base Saturation (%)	72
Olsen P (mg/kg)	14.8
Organic Carbon (%)	6.9
Total Nitrogen (%)	0.35
C/N Ratio	20
Mg:K Ratio	2
P. Retention (%)	57

Chemical Analysis

Place: Talvat-Sikut, East New Britain Province
Soil: Talvat Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.8
Exch. Bases (meq. %)	
Ca	19.77
Mg	2.9
K	5.76
Na	0.09
Cation Exchange Capacity (meq. %)	33.9
Base Saturation (%)	84
Olsen P (mg/kg)	15.8
Organic Carbon (%)	12
Total Nitrogen (%)	0.64
C/N Ratio	19
Mg:K Ratio	1.0
P. Retention (%)	67

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Gelagela Series: (Rabaul)
Site No: Gel 1

Gelagela Series: Well drained sandy clay loam topsoil overlying sandy subsoil.

Soil Classification:

Profile Description

Location	:	Gelagela, backyard garden
Landform	:	Low Hills
Slope	:	0°
Vegetation/land use	:	Secondary/garden
Drainage Status	:	Well drained
Estimated Permeability	:	Fast
Stoniness	:	Nil
Parent Material	:	Volcanic

Depth (cm)	Description
0 - 20	Moist black (7.5YR 2/0); sandy clay loam; weak crumb; friable; sticky and plastic; few fine roots to:
20 - 40	Moist black (7.5YR 2/0); sandy clay loam; weak fine subangular blocky; friable; sticky and plastic; few roots to:
40 - 60	Moist brown (7.5YR 4/2); loamy sand; loose; structure-single grain; non sticky ad non plastic to:
60 - 80	Moist yellowish brown (10R 5/4); sand; loose; structureless-single grain; non sticky and non plastic to:
80 –120	Moist light brownish grey (2.5Y 6/2); sandy loam; loose; structureless-single grain; non sticky and non plastic.

Range in Characteristics

These are well drained sandy clay loam topsoil overlying sandy subsoil. They are formed on volcanic parent material.

Chemical Analysis

Place: Gelagela, East New Britain Province
Soil: Gelagela Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.0
Exch. Bases (meq. %)	
Ca	12.05
Mg	3.11
K	0.82
Na	0.07
Cation Exchange Capacity (meq. %)	38.8
Base Saturation (%)	41
Olsen P (mg/kg)	5.6
Organic Carbon (%)	12
Total Nitrogen (%)	0.95
C/N Ratio	13
Mg:K Ratio	4
P. Retention (%)	86

ANNEX 1
REPRESENTATIVE SOIL PROFILE DESCRIPTION

Ngunguna Series: (Kokopo)
Site No: Ngu 1

Ngungna Series: Well drained sandy clay loam overlying sandy subsoil.

Soil Classification:

Profile Description

Location	:	Ngunguna Village, Food garden
Landform	:	Coastal Hill
Slope	:	3°
Vegetation/land use	:	Secondary Regrowth/Garden
Drainage Status	:	Well drained
Estimated Permeability	:	Fast
Stoniness	:	Nil
Parent Material	:	Volcanic

Depth (cm)	Description
0 - 20	Moist black (7.5YR 2/0); sand clay loam; weak fine crumb; friable; slightly sticky and slightly plastic; few fine roots to:
20 - 40	Moist black (7.5R 2/0); sandy clay loam; weak fine crumb; friable; slightly sticky and slightly plastic; few fine roots to:
40 - 60	Moist brown (7.5YR 4/2); loamy sand; loose; structureless-single grain; non sticky and non plastic to:
60 - 80	Moist very dark grayish brown (10YR 3/2); sand; loose; structureless-single grain, non-sticky and non plastic to:
80 –120	Moist light yellowish brown (2.5Y 6/4); loamy sand; loose; structure less-single grain; non sticky and non plastic.

Range in Characteristics

These are well drained sandy clay loam topsoils overlying sandy subsoils. These are formed on volcanic parent material.

Chemical Analysis

Place: Ngunguna, East New Britain Province
Soil: Ngunguna Series

Site Description

Depth (cm)	0 – 20
pH (H_2O)	7.4
Exch. Bases (meq. %)	
Ca	15.4
Mg	2.55
K	2.63
Na	0.17
Cation Exchange Capacity (meq. %)	31.1
Base Saturation (%)	67
Olsen P (mg/kg)	13.5
Organic Carbon (%)	5
Total Nitrogen (%)	0.53
C/N Ratio	9
Mg:K Ratio	1.0
P. Retention (%)	38