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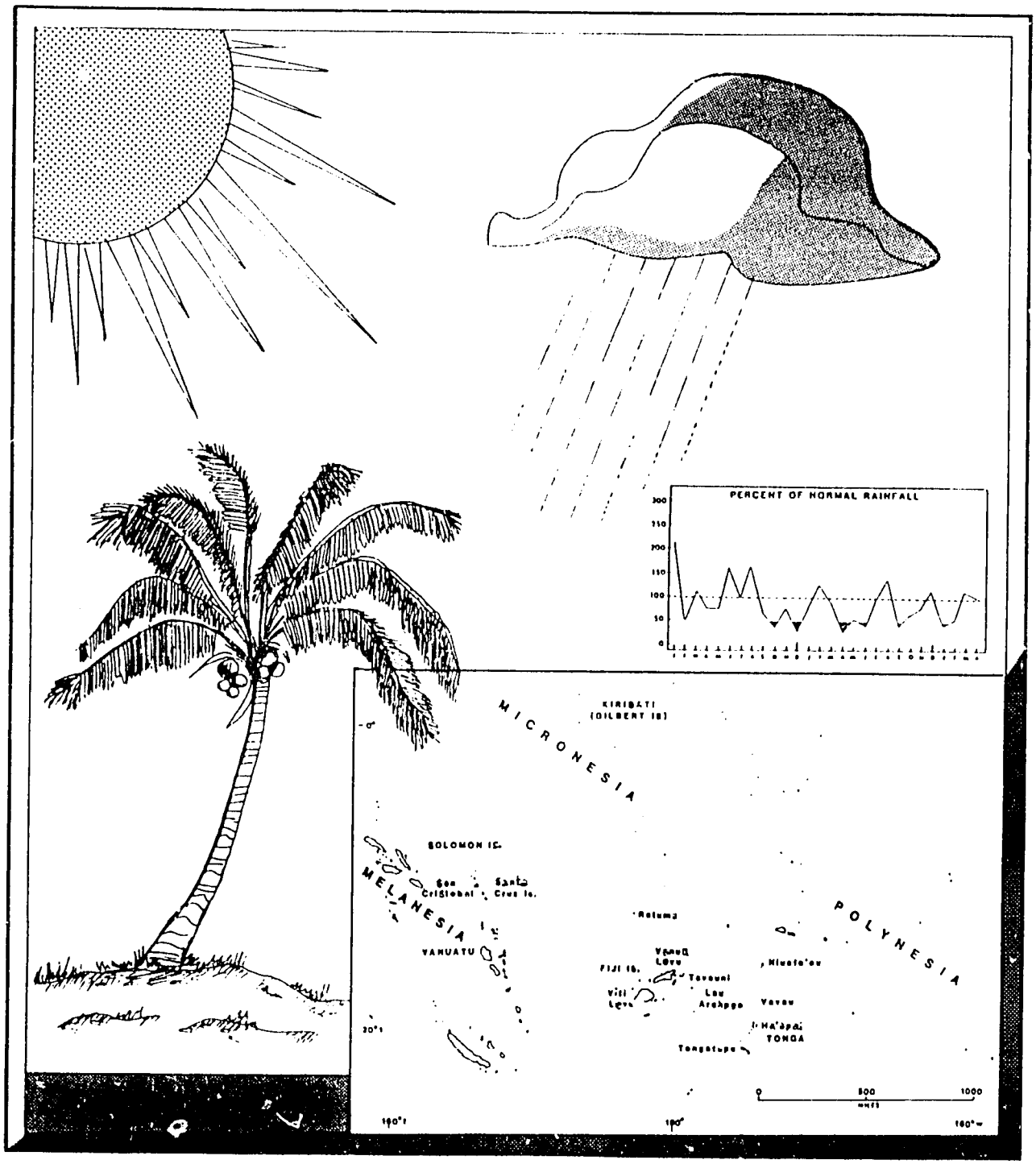
AGROCLIMATIC SURVEY OF THE SOUTHERN PACIFIC ISLAND GROUPS:

Fiji, Gilbert Islands (Kiribati), Solomon Islands, Tonga, Vanuatu



FINAL REPORT

SEPTEMBER 1984

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AGROCLIMATIC SURVEY OF THE SOUTHERN PACIFIC ISLAND GROUPS: FIJI, GILBERT ISLANDS (KIRIBATI) SOLOMON, TONGA, VANUATU[1/]

to

Agency for International Development
Office of U.S. Foreign Disaster Assistance
Washington, D.C.

by

National Oceanic and Atmospheric Administration
National Environmental, Satellite, Data and Information Service
Assessment and Information Services Center
Climatic Impact Assessment Division-Models Branch
Columbia, Missouri 65201

and

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September, 1984

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EXECUTIVE SUMMARY

AGROCLIMATIC SURVEY OF THE SOUTHERN PACIFIC ISLAND GROUPS: FIJI, GILBERT ISLANDS (KIRIBATI), SOLOMON ISLANDS, TONGA, VANUATU

Ana Maria Planchuelo-Ravelo[1/]

The Agency for International Development (AID) needs reliable early warning of potential food shortages to make decisions affecting many of its programs for disaster preparedness, relief assistance and food security in the Southern Pacific Region. To address this need, the NOAA/NESDIS Assessment and Information Services Center Models Branch in Columbia, Missouri, and the Atmospheric Science Department of the University of Missouri-Columbia initially developed agroclimatic background information for selected island groups. The islands included in this project are: Fiji, Gilbert (now part of Kiribati), Solomon Islands, Tonga and Vanuatu (formerly New Hebrides).

The agroclimatic background report for each island group includes a description of: 1) the physical environment including geography, topography, climate, soil and natural vegetation, 2) agricultural practice and crop calendar information for commercial and food crops, and 3) economic activities.

Agroclimatic regions were established for each island group using total annual rainfall, rainfall distribution, wind direction and topographic features. Data bases were developed to systematically study the climate and its relation to agriculture. The meteorological data were computerized for each station. Analysis of potential evapotranspiration estimates was done and a drought index made for selected stations.

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The contribution of Dr. Andres C. Ravelo, Research Associate of the Atmospheric Science Department, University of Missouri-Columbia, was integral to the successful completion of this project by providing valuable support for the agroclimatic analysis. His contribution is greatly appreciated. Dr. Louis Steyaert, Program Manager initiated the project and provided guidance and support.

Other staff members of the Atmospheric Science Department, University of Missouri-Columbia, who contributed to this project included: Joan Darkow, Senior Research Laboratory Technician, typing and editing; Mauricio Hurtado, some of the artwork; Judy Trujillo, data base management assistance; George Lozano, typing; and Jerry Wright, artwork. The constructive comments and review of this report by Dr. Clarence Sakamoto, Chief, Models Branch, Assessment and Information Services Center of NOAA/NESDIS, Columbia, Missouri, are greatly appreciated. Rita Terry, Writer/Editor, NOAA/NESDIS/AISC, Climatic Impact Assessment Division - Models Branch, edited the report.

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CHAPTER I

INTRODUCTION

Agriculture plays an important role in the economy of the South Pacific Islands even though only a small percentage of the land is arable. The year-to-year variations in agricultural output are largely determined by climate, particularly with traditional cultural practices for rainfed crops. Adverse climatic conditions such as severe droughts or tropical storms can lead to crop failures and economic losses. For example, in Tonga a drought from September 1977 to January 1978 had adverse effects on crop production, causing a fall in copra exports and considerable damage to bananas. This event was aggravated by hurricanes Anne and Ernie in November 1977 and February 1978, respectively. In 1983 taro production was reduced by 50 percent in Tongatapu due to a drought. This vulnerability to adverse climate is frequently compounded by other complex factors including increasing population pressure, diminishing natural resources, the rising cost of energy, expansion of agriculture into marginal lands, and less than optimal land conservation practices.

An objective evaluation of all available information related to climate, soil and agriculture must be done to make plans for improvement of agricultural production. Therefore, this report is written to provide background information that can lead to assessing and possibly mitigating the impact of climatic variability. This background is part of a resource analysis to implement a proto-type early warning system for the South Pacific Island group for drought/food production assessment.

Toward this goal, this study seeks to accomplish the following objectives:

1) Provision of reliable information on climate and agriculture.

2) Development of agroclimatic and other data bases which may be used to investigate the impact of weather and non-weather factors on crop failures and food shortages.

Countries and island groups in the South Pacific under study include: Fiji, Gilbert Islands (now part of Kiribati), Solomon Islands, Tonga, and Vanuatu.

Chapter II provides general information on climate and agriculture. Each island group is treated separately in Chapters III to VII. Potential environmental hazards are discussed in Chapter VIII. Climatic and episodic event data are provided in Appendix A and Appendix B, respectively.

CHAPTER II

CLIMATE AND AGRICULTURE

A. Physical Environment

1. Overview

The islands considered in this report are situated in the Pacific Ocean between 3°20'N and 22°20'S latitude and 155°E and 173°W longitude. They are distributed in three ethnic regions: Melanesia, Micronesia and Polynesia. Figure 2.1 shows the major island groups. Melanesia is comprised of a group of archipelagos located northeast of Australia with relatively large islands such Fiji Islands, Vanuatu and Solomon Islands. Micronesia is a group of very small islands located east of the Philippines, including among others the Gilbert, Phoenix and Line islands, all part of Kiribati. Polynesia includes small islands such as Tonga in the Central Pacific.

The islands are often classified into two types, the "high" volcanic and the "low" coral or limestone islands. The high islands often reach elevations over 500 m. The greatest height is found in the Solomon Islands, where Mt. Popomanaseu on Guadalcanal reaches 2,500 m. The low islands rise from no more than a few meters above sea level up to 100 m.

The largest islands are mountainous with relief characterized by volcanic mountains (some of them active), volcanos, high plateaus, rolling hills, narrow valleys, terraces and coastal plains. The river valleys and coastal areas are often the only agricultural lands.

The innumerable small islands in the area vary greatly in structure and form. Some of them, such as the Lau Islands in Fiji and some of the Tonga Islands, are wholly or partly of limestone formation. These islands generally

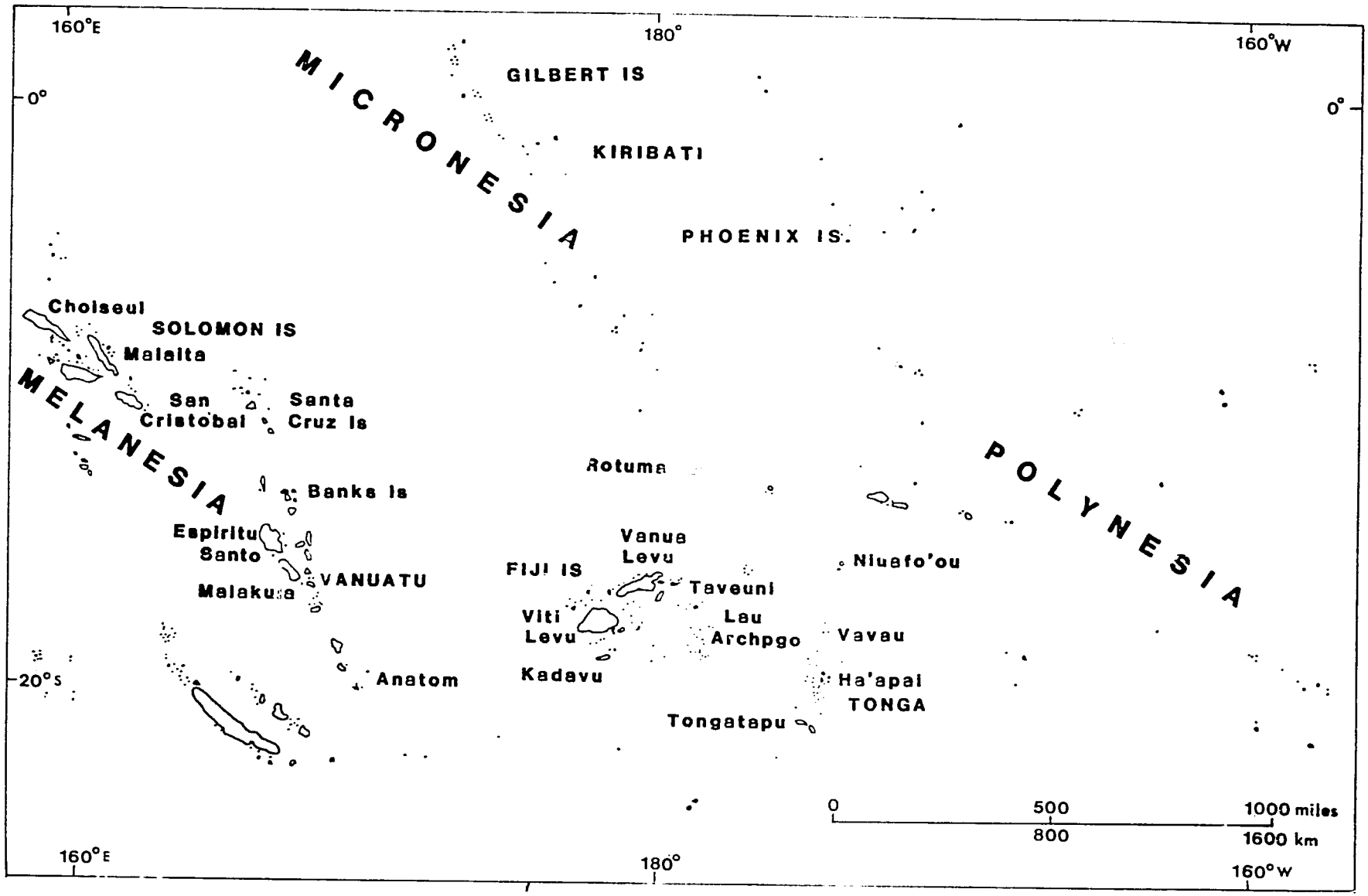


Figure 2.1. Location of the Island Groups.

rise steeply from the shore and have a flat topped profile. The atolls are coral reefs which appear above sea level as a low ring shaped of coral islands or as a chain of close coral islets around a shallow lagoon. These islands often rise no more than a few meters above sea level; the diameter of the lagoon may vary from 1 to 100 km. All the Gilbert Islands of Kiribati are of atoll formation. Other small islands are of volcanic origin such as Parapara in Vanuatu, Kao and Tofua in Tonga, and Mace, Komo and Olorua in Fiji. These small volcanic islands have a rugged and broken relief, with a few flat areas near the shore.

2. Soils

Mature soils with well defined profiles can be grouped according to the dominant factor or factors influencing their formation. The quality of the soil depends on the parent materials, the climate, the topography and the plants and animals living in the soil or on its surface. Figures 2.2 to 2.6 show the soil plant materials for each island group.

In the coral islands, the dry climate and the parent materials do not favor soil development. The parent materials consist of coral rock combined with little more than carbonate of lime. The texture is sandy or gravelly and often contains limestone particles. The shallow soil and its excessive porosity make it unfavorable for plant growth. In general the quality of the soil in the coral islands is poor and not suitable for agriculture. In islands with more rainfall, such as the northern Gilbert Islands of Kiribati and Northern Tonga, yellowish brown latosol has developed. This soil is comparatively more fertile that the coral soil but usually is no more than 20 cm deep and can support only minor agriculture.

The most important soil forming materials in the high islands are volcanic deposits: lava, pumice and ash. To a much smaller extent soils are formed from

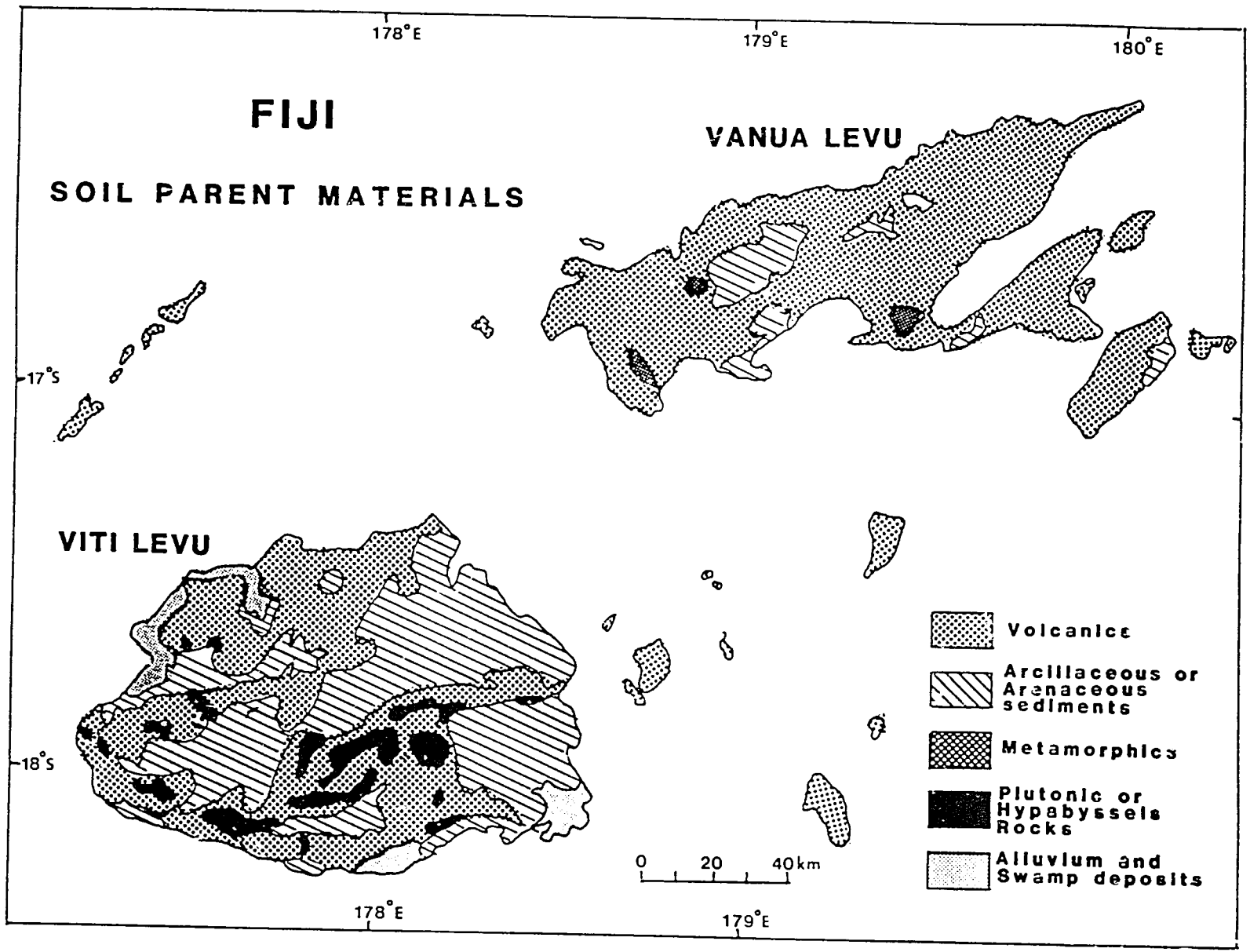


Figure 2.2. Soil Parent Materials for Major Islands of Fiji. Adapted from Brookfield, H. C. and D. Hart (1971).

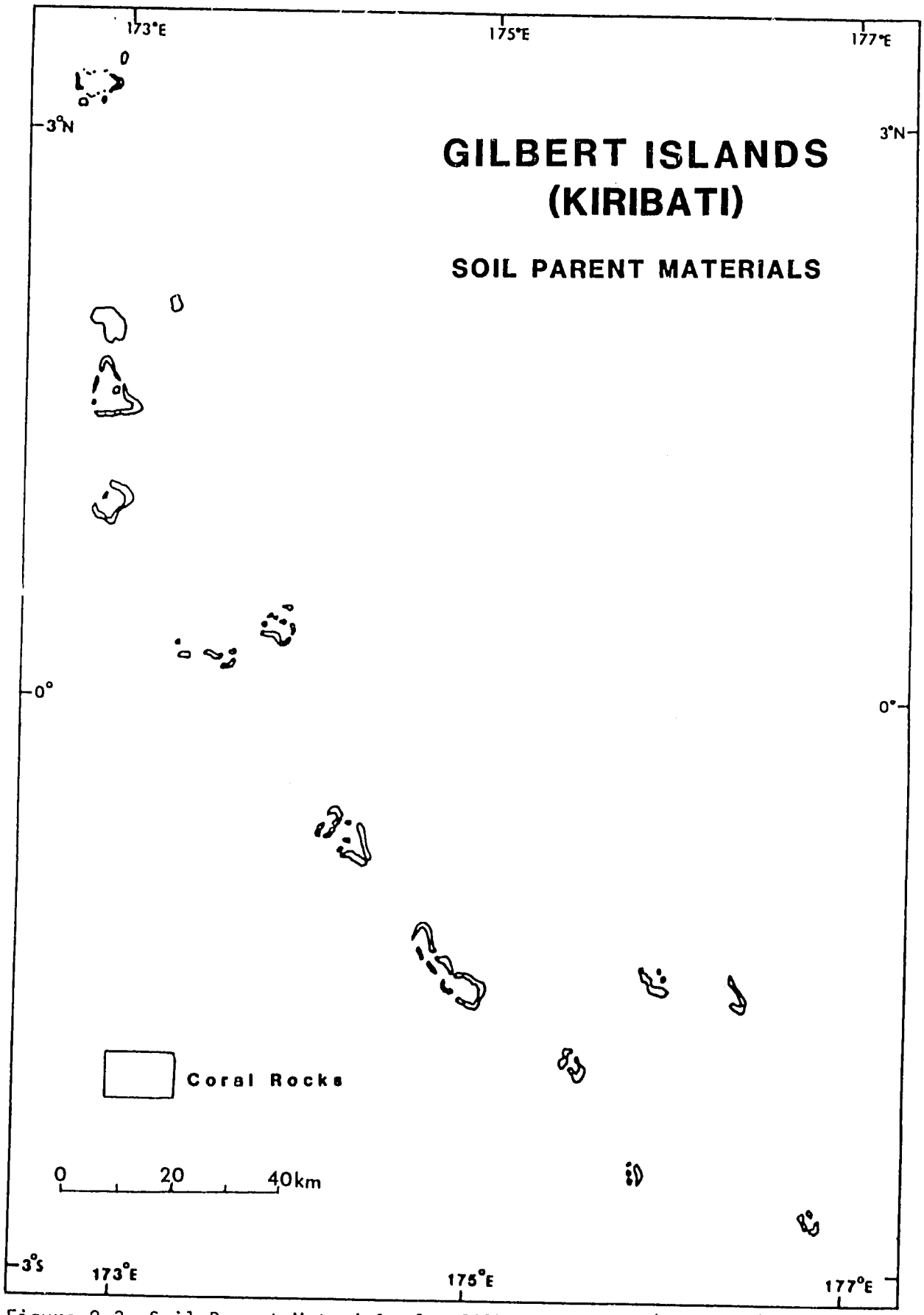


Figure 2.3. Soil Parent Materials for Gilbert Islands (Kiribati).

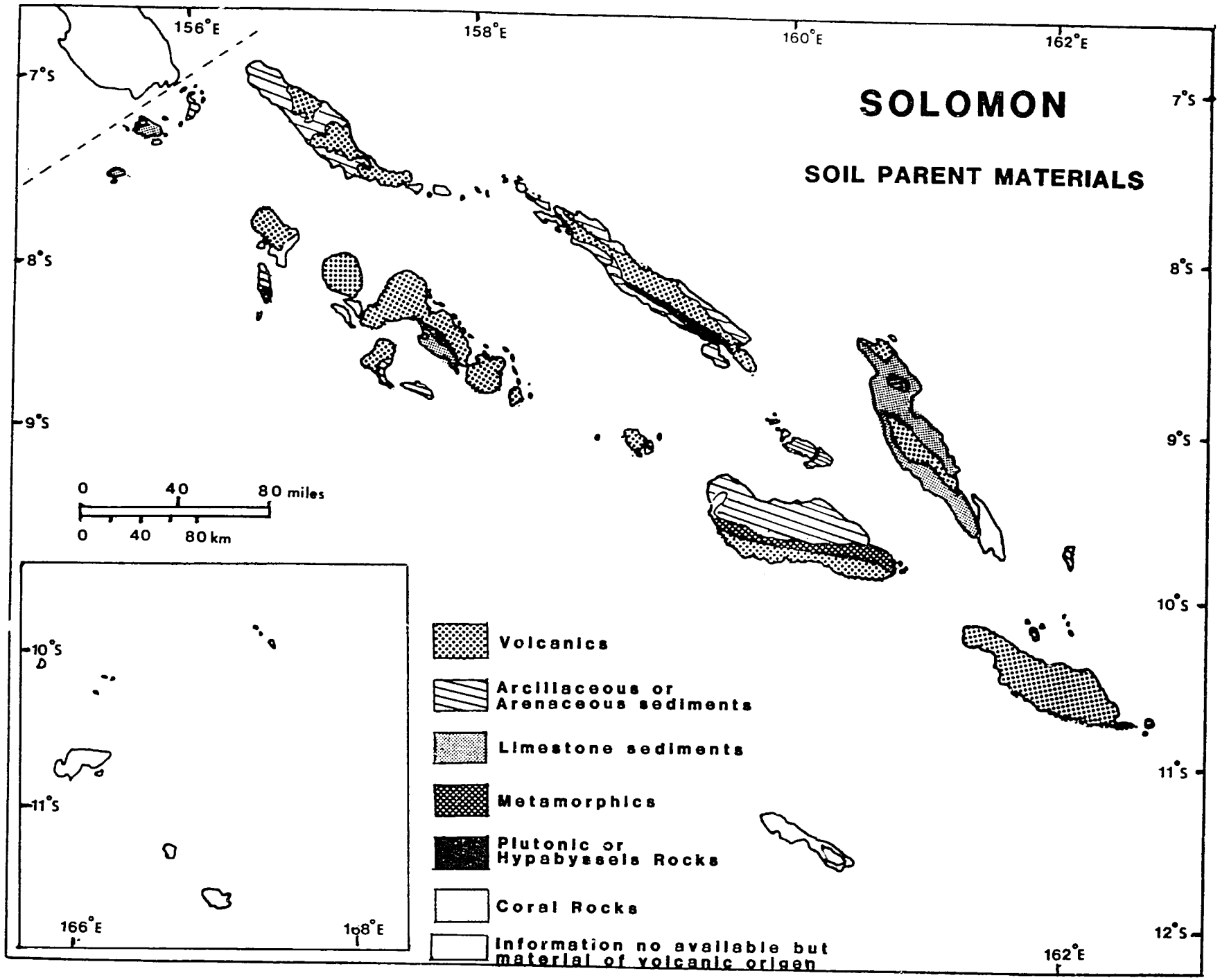


Figure 2.4. Soil Parent Materials for Solomon Islands. Adapted from Brookfield, H. C. and D. Hart (1971).

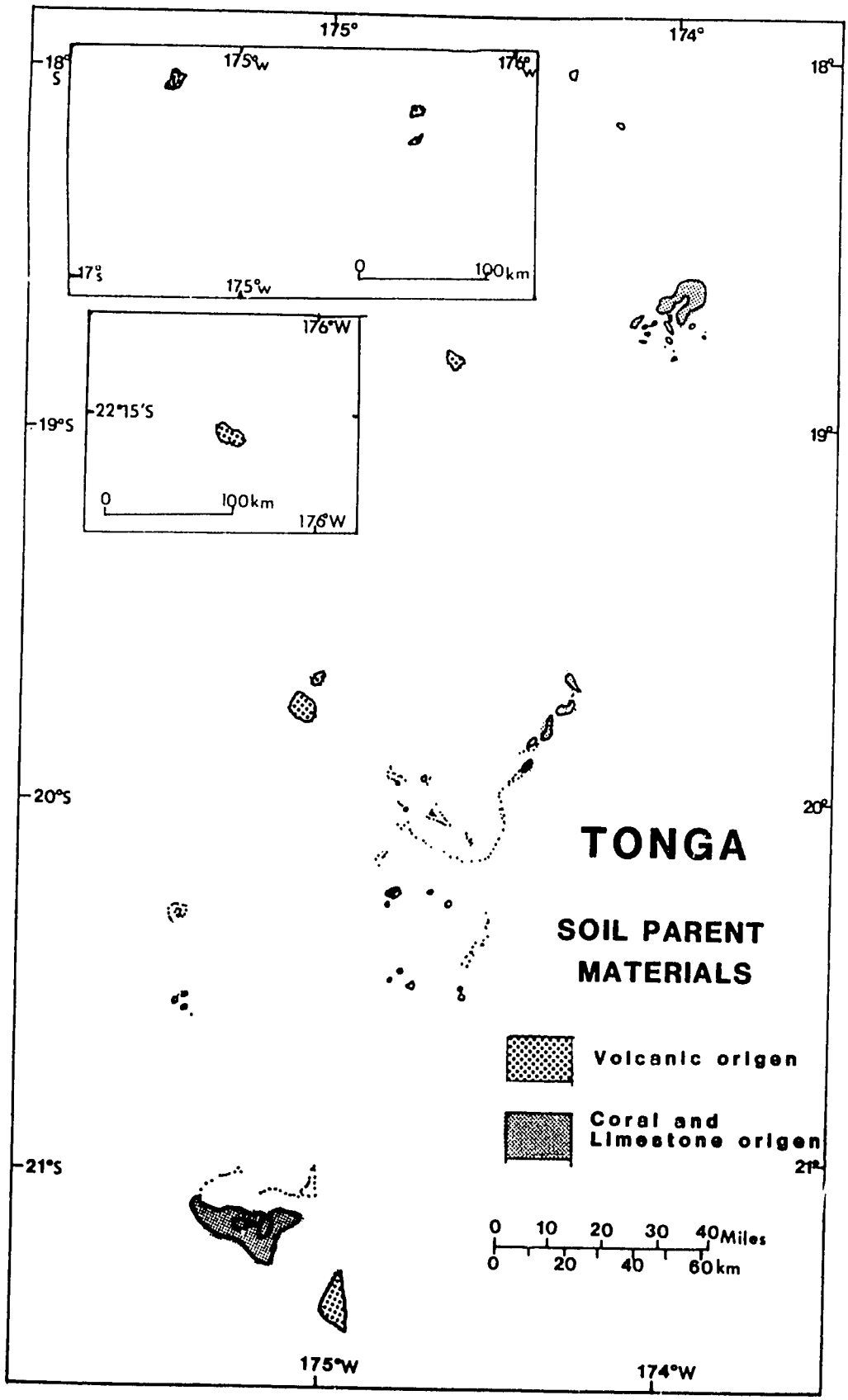


Figure 2.5. Soil Parent Materials for Tonga.

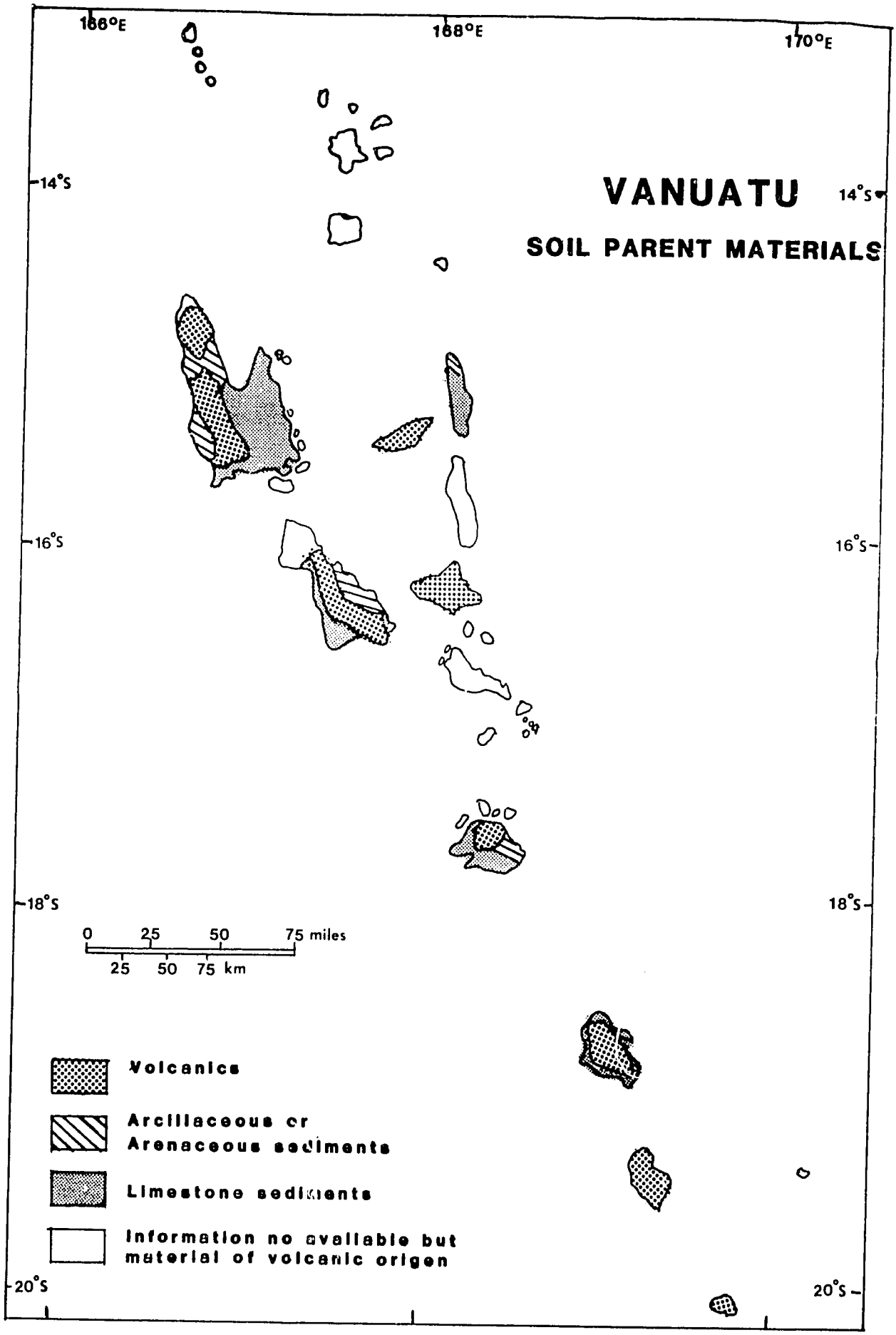


Figure 2.6. Soil Parent Materials for Vanuatu. Adapted from Brookfield, H. C. and D. Hart (1971).

transported materials such as alluvium and wind-blown dust and sand. The only mature soils whose development is controlled solely by parent rock are the rendzinas, which occur in limestone deposits. The others, podzolics, latosolics and humic brown latosols soils, are also dependent on climatic conditions for their formation. Podzolization tends to occur more on acid rock on mountain slopes at high altitudes, where the annual mean air temperature is around 25°C and humus accumulation becomes possible. Podzolic soils are usually found in areas with savanna or grassland vegetation. Laterization usually develops on basic and ultrabasic rocks in places with high and well distributed rainfall and annual mean air temperatures higher than 25°C. Latosols known also as tropical red earths are deeply weathered low-altitude soils. This is the characteristic soil type of most of the tropical rain forest. In areas with continuous heavy rainfall the latosols are yellowish or brownish rather than red. The humic brown latosols may be developed from acid or basic rocks, and seem to be generally associated with the cooler we' climates of highland country such as the wetter uplands on the main islands of Fiji.

3. Natural Vegetation

In considering the types of vegetation in the Pacific Islands a sharp distinction must be made between the low islands and the high islands.

The low islands are poor in species and very uniform in flora; the vegetation consists largely of maritime and drought-resistant plants. Many of the smaller islands are entirely treeless. Apart from the cultivated plants introduced by man, there may be as few as half a dozen species on small islands and under fifty on large ones. Coconut and pandanus (screw pine) are the only useful native plants of the coral atoll islands.

Most of the high islands are covered with forest except for natural limited areas with grassland or where ash from active volcanoes has killed the vegetation; other breaks in the forest reflect villages, plantations and forest clearings either abandoned or harvested for lumber. The lowland forest that occupies the flood plains and deltas is extremely rich with five vegetation layers. Many evergreen trees, palms and epiphytes are found in these areas along with hard-wood species available for commercial exploitation. With increasing altitude the forest structure becomes simplified into two vegetation layers. Most of the montane forest is considered to be virgin forest. Alpine vegetation occurs in the upper limit of the tree level; it is above 2,000 m in the Solomon Islands. Other islands do not rise sufficiently to reach an inversion zone and encounter the high-altitude semi-desert environment of the alpine vegetation.

Because of the global wind pattern in these latitudes the lee areas (in most cases the western and northwestern sides of the islands) are usually drier than the windward. These drier areas are characterized by grassland; rainfall is relatively abundant, ranging from 1,500 to 2,500 mm annually. Typical savanna consisting of open grassland with clumps of trees and bushes is found as intermediate vegetation between degradated forest and grassland. Twyford and Wright (1965) considered the savanna and grassland transition zone, known as Talasiga in Fiji, to be a direct result of man's action of burning the land and destroying the delicate balance of vegetation, thus inhibiting the re-establishment of woody species. Forest and grassland distribution is shown on the agricultural land map included in the chapter on each island group. The vegetation in the coastal communities is probably the most uniform and is present even on the smallest island. Species of pandanus and hibiscus as well as mangrove and sago swamp are typical examples and occupy very narrow strips on the coasts of all islands.

B. Climate

The climate of the South Pacific Islands can be classified as tropical humid (Trewartha, 1968). A brief discussion of air temperature and rainfall regimes is presented here. In addition, climatic diagrams and agrometeorological variables such as evapotranspiration and soil moisture content for the selected stations will be discussed. Drought occurrence as indicated by rainfall analysis and drought indices will be analyzed. More details on climatic conditions are provided in the descriptions of each island group.

1. Air temperature

The principal characteristic of the temperature in the area under study in this report is uniformity, particularly in islands close to the Equator. There is, however, a gradual development of seasonal variation in islands located away from the equatorial zone. The lowest range in mean monthly temperature is less than 1°C (between 28.6° and 28.1°C) registered in Tarawa, Gilbert Islands (Kiribati). The largest variation of mean monthly temperature is 5.2°C (between 26.6° and 21.4°C), observed in Anatom, Vanuatu.

The lowest temperatures in the area are found at high altitudes. For example, in Nandarivatu, Fiji at 835 m of elevation the mean temperature of the coldest month (July) is about 18°C and the mean temperature of the hottest month (February) is 22°C.

The hottest temperatures are reported particularly at lowland islands close to the Equator. In Aorae, Gilbert Islands (Kiribati) the mean temperature of the hottest months (March and May) is 29.1°C and the mean for the coldest (July) is 28.6°C. In Tulagi, Solomon Islands, the hottest month is December with a mean temperature of 28.1°C and the coldest is August with a mean temperature of 27.0°C.

The temperature regime in the South Pacific islands is quite favorable for growing tropical crops. The growing season extends all year-round.

Mean monthly and annual air temperatures for selected stations are included in Appendix A.

2. Rainfall

For the purposes of this survey rainfall is the most important meteorological element. It will be discussed in detail in the description of each island group. Only a general discussion will be made here.

The seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and island topography are the major determinants of rainfall amounts and distribution. Annual rainfall in the region under study ranges from about 380 mm at Beru, Gilbert Islands (Kiribati) to more than 6300 mm at Salia Levu, Fiji.

Three main types of rainfall can be found in the South Pacific islands:

- Convectional rain occurring within the ITCZ. The amount and distribution of rainfall is subject to the seasonal migration of the ITCZ. The rainy season starts with the arrival of the ITCZ.
- Orographic rain occurring in the trade winds zone. This rain occurs all year-round but is heavier during winter because the trades are stronger. This type of rain is characteristic of the windward sides on of the higher islands.
- Hurricane rain occurring during the hurricane season. It can be excessive while it lasts but is infrequent at any one station.

Annual rainfall variability differs from area to area. On some islands, e.g., the Gilbert Islands (Kiribati), the rain is unreliable and droughts of considerable duration are frequently experienced. On lee side of large islands such as Vanua Levu and Viti Levu in Fiji, Erromango in Vanuatu and Gudalcanal in the Solomon Islands, the rainfall regime is highly seasonal with 5 to 7 months of low rainfall that may be associated with severe drought. In areas with moderate rainfall such as the windward areas of Fiji, Vanuatu, Solomon Islands

and the northern islands of the Tonga and Gilbert groups, the rainfall is more evenly distributed throughout the year; the dry season lasts for 2 to 5 months. Excessive rainfall, more than 5,000 mm a year, occurs in some regions such as the Three Sister and Santa Cruz groups in the Solomon Islands and Salia Levu in Fiji.

Agroclimatic regions were established for each island group using rainfall amounts and distribution, island topography and wind direction. A map showing the agroclimatic regions, regional precipitation histograms, wind direction, and meteorological stations is included in the chapter discussing each island group. Rainfall histograms for selected stations are included in Appendix A. The definition and intensity of the dry season for the agroclimatic regions within each island group are relative to the amount and distribution of rainfall. Therefore the seasons, as defined, are not comparable among island groups.

3. Potential Evapotranspiration

Potential evapotranspiration (PET) is the maximum amount of water loss from a soil-crop system when soil water supply is not limited and the ground is completely covered with a short green crop. PET information may be used to develop agroclimatic indices, assessments of agricultural potential and water related problems in agriculture. Evapotranspiration is a process very difficult to measure directly because it is a combination of physical and physiological responses to environmental conditions. Theoretical equations that use more measureable parameters have been developed for estimating PET. Thornthwaite (1948) developed an equation for estimating PET using only mean monthly temperature and daylength. Hargreaves (1975) proposed an equation to estimate PET based on solar radiation and air temperature data.

These two methods were examined to determine the most appropriate to compute PET for selected locations in the South Pacific islands.

Thornthwaite Method

This method is based on the equation:

$$PET = 1.6\ (10T/I)^a$$

where

PET is estimated in centimeters/day,

T = monthly mean air temperature (°C),

I = annual heat index which is a function of T, and

a = polynomial function of I.

An adjustment for latitude is required for locations with daylengths different than 12 hours. This method has the advantage of using only one meteorological element and the local latitude as input. Temperature data are frequently observed at most of the weather stations. This is the main reason it has been used worldwide. However, it should be pointed out that mean temperature is not the only factor affecting the energy balance of the plant/soil system which is closely related to the evapotranspiration process.

Hargreaves Method

Although solar radiation data are not always available, it is possible to estimate solar radiation using the sunshine information that is more commonly observed in weather stations. Hargreaves has developed several empirical formulas to estimate solar radiation from a variety of commonly observed meteorological elements.

The equation for PET is expressed as:

$$PET = 0.0075 (RSM) TF$$

where

PET is expressed in millimeters/day,

RSM = solar radiation (mm/day) and

TF = monthly mean temperature (°F).

Potential Evapotranspiration Analysis

Using available temperature and sunshine data (Wernstedt, 1977; Buxtehude, 1981) for Nadi and Lautoka Bay, Fiji, monthly potential evapotranspiration was estimated using the Thornthwaite and Hargreaves methods (Figure 2.7 and 2.8). Both methods provided very similar PET estimates for May thru August but major discrepancies were observed during October, November and December when differences ranged from 10 to 45 percent. When estimated PET is compared with monthly rainfall, it is evident that different conclusions in water excesses and deficiences can be reached depending on which PET method is used. The Hargreaves method has been shown to be quite reasonable for estimating potential evapotranspiration for locations with tropical humid climates (Ravelo and Steyaert, 1983).

4. Soil Moisture Balance

Soil moisture variability is an important factor in crop production. Direct measurements of soil moisture are seldom available and involve several instrumentation problems. In addition, continuous and repeated soil moisture sampling is needed to determine a representative soil moisture regime for a region. Estimates from climatological water balance methods are more cost-effective for the regional assessment of soil moisture reserves available for crop growth and development. Numerous methods have been developed to estimate

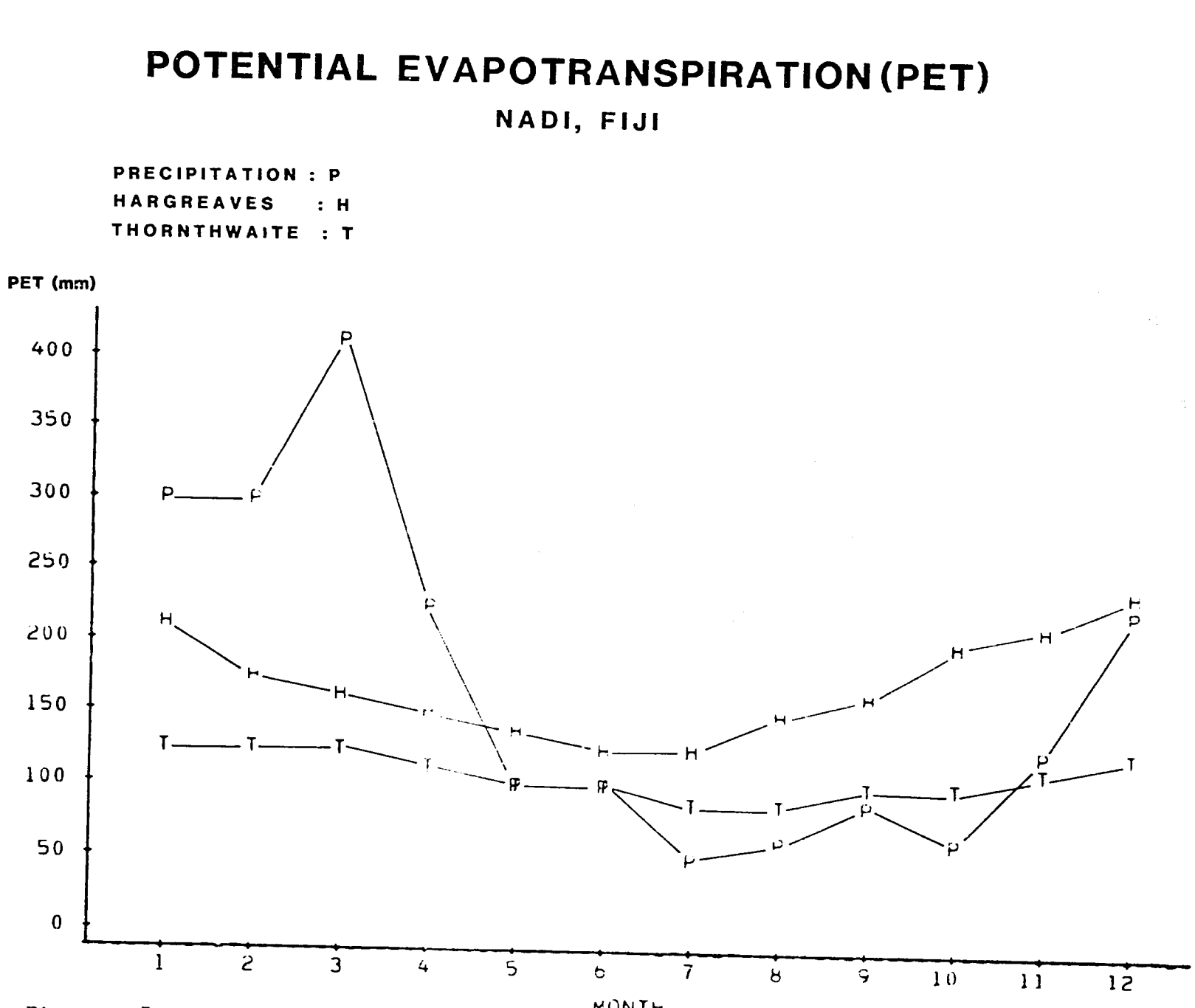


Figure 2.7. Mean Monthly Precipitation (P) and Potential Evapotranspiration Estimates by Thornthwaite (T) and Hargreaves (H) Methods for Nadi, Fiji.

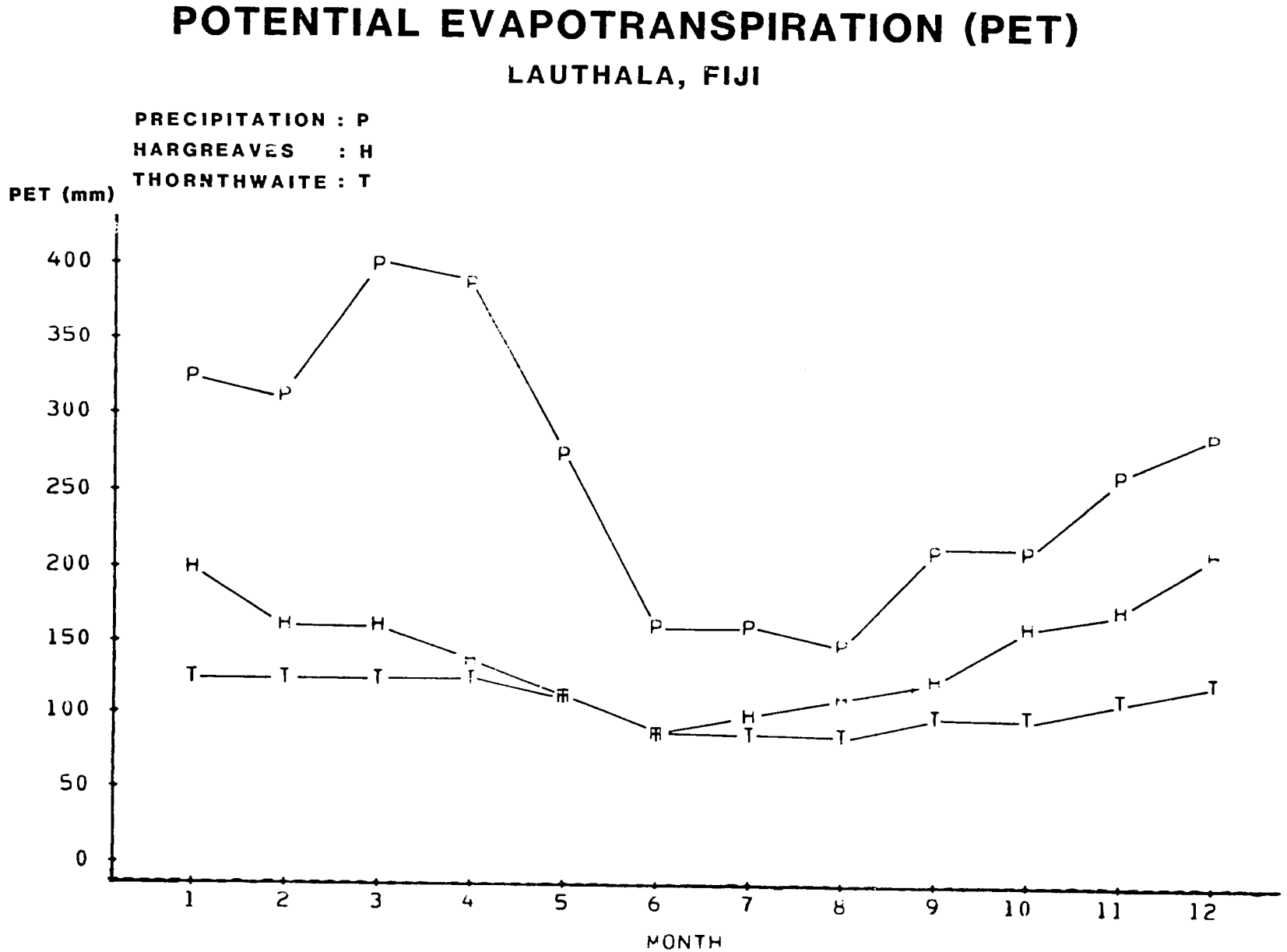


Figure 2.8. Mean Monthly Precipitation (P) and Potential Evapotranspiration Estimates by Thornthwaite (T) and Hargreaves (H) Methods for Lauthala Bay, Fiji.

soil moisture from soil and meteorological parameters. Detailed reviews of climatological soil moisture budgeting techniques are presented in Palmer (1965) and Baier and Robertson (1966). Available soil moisture for this study was estimated by using the Palmer technique (Palmer, 1965).

Monthly rainfall data (WMO, 1980; Todorov, personal communication) and monthly Hargreaves PET estimates for Lauthala Bay and Nadi, Fiji were the major inputs to the soil moisture budgeting technique. In this preliminary stage, the total soil water holding capacity was set at 200 mm. As soil information becomes available, adjustments are made in the soil water holding capacity for individual stations. The soil moisture budgeting technique provided monthly available soil moisture estimates for Lauthala Bay and Nadi. Figure 2.9 shows the mean soil moisture content estimates for both stations. Lauthala Bay shows a near-full soil moisture capacity throughout the year while Nadi shows a depleted soil water reserve from August thru December.

Palmer's soil moisture budget technique can provide estimates for those stations in the South Pacific with monthly rainfall records, mean monthly potential evapotranspiration data and soil water holding capacity information.

5. Analysis of Drought Occurrence

Drought occurrence is not a rare event in many islands of the South Pacific. Rainfall variability is particularly high during the "dry" season. In Nadi, Fiji the Palmer drought index (Palmer, 1965) was computed for 33 years (1951-1984). The index shows that a severe drought started in August, 1977 and ended in December, 1980 (Figure 2.10). Drought conditions were particularly extreme for 1978. Most recently, a drought of several months duration was observed in some islands. For example, in Nadi and Lauthala Bay, Fiji rainfall was well below normal during several months in 1982 and 1983 (Figures 2.11 and 2.12). The soil moisture content and the Palmer drought index verified the

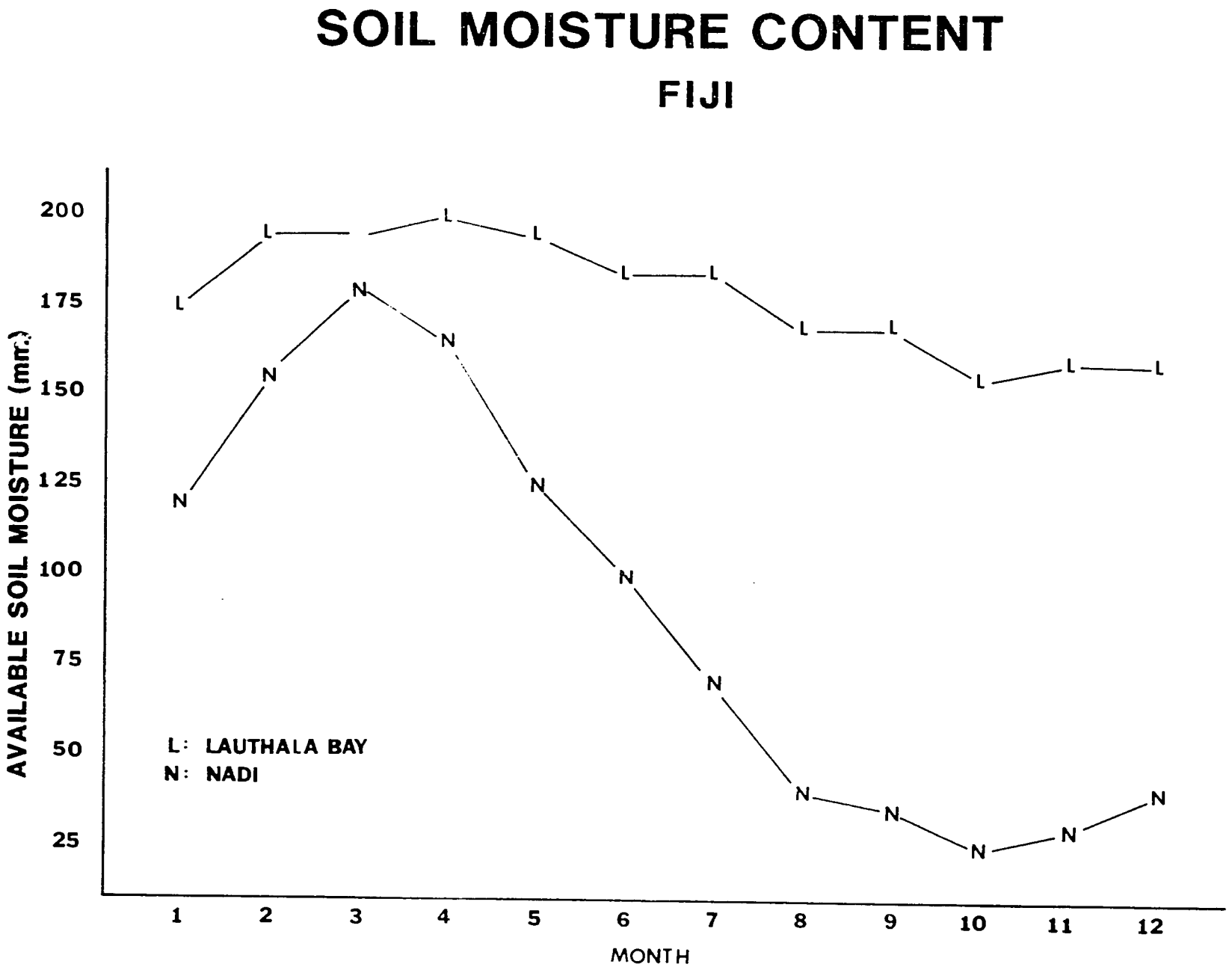


Figure 2.9. Estimated Soil Moisture Content for Nadi (N) and Lauthala Bay (L), Fiji.

PALMER DROUGHT INDEX (PDI)

NADI, FIJI

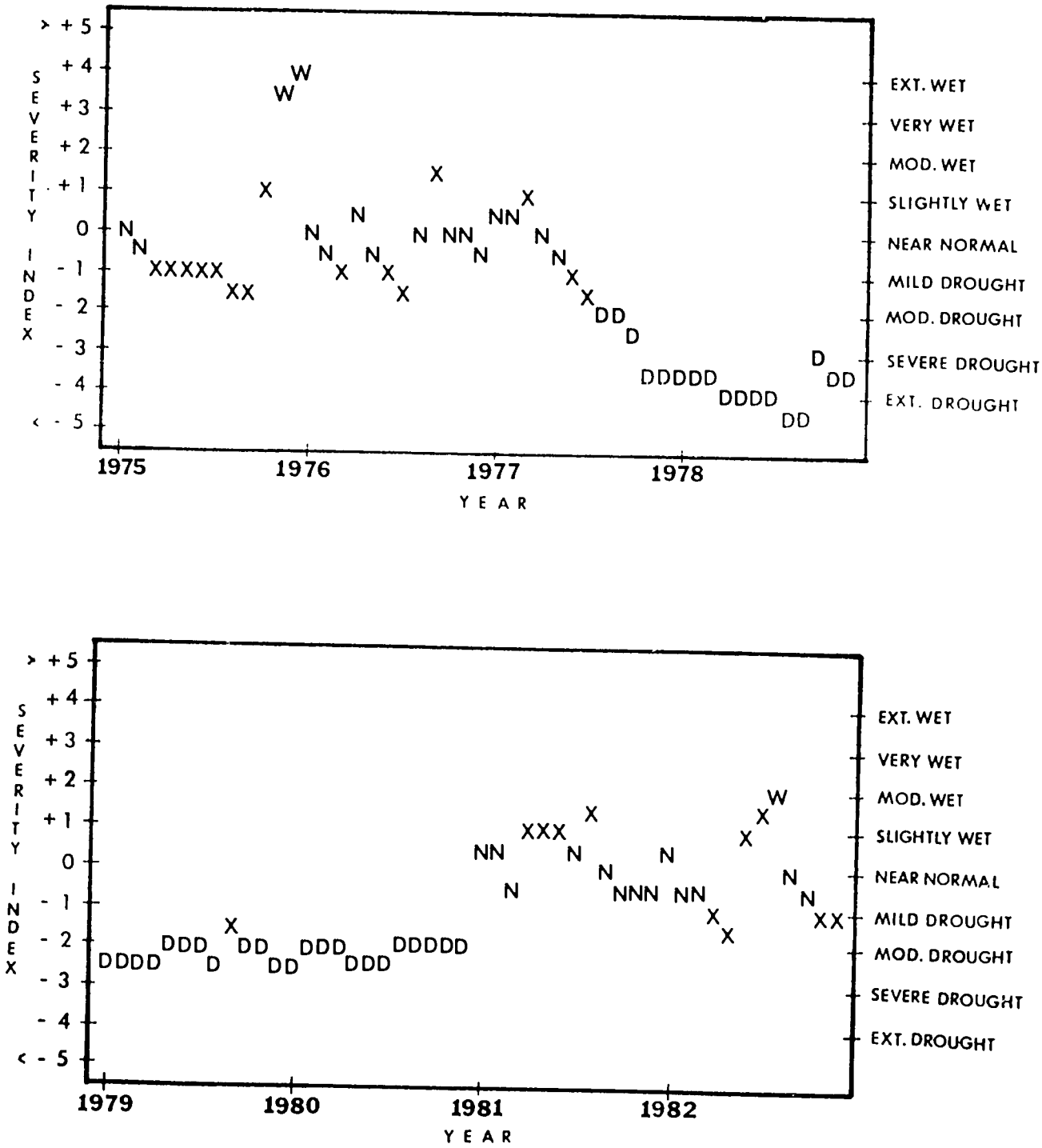


Figure 2.10. Palmer Drought Index (PDI) for Nadi, Fiji.

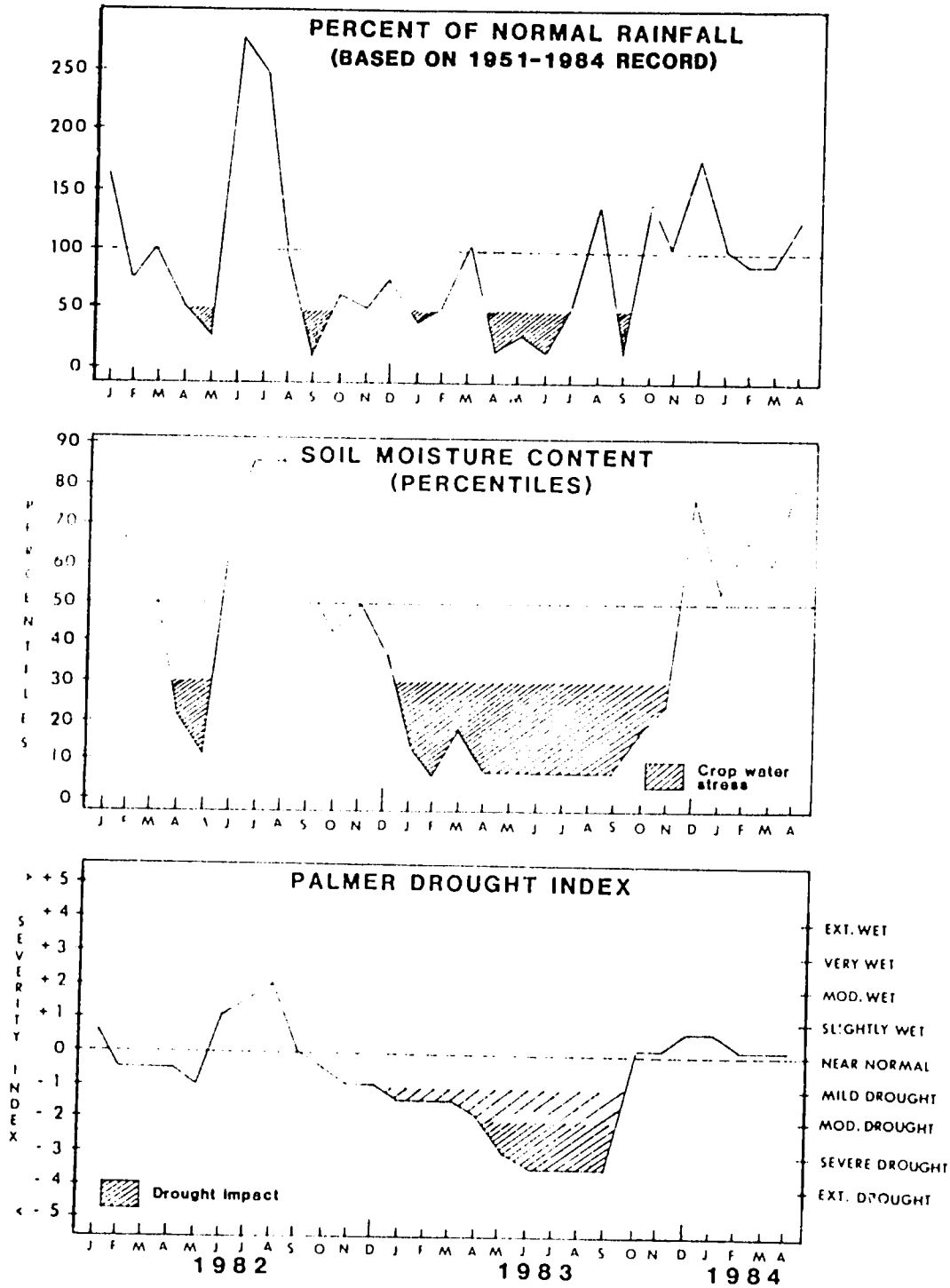


Figure 2.11. Drought Occurrence Analysis Using Percent of Normal Rainfall, Soil Moisture Content and the Palmer Drought Index for Nadi, Fiji.

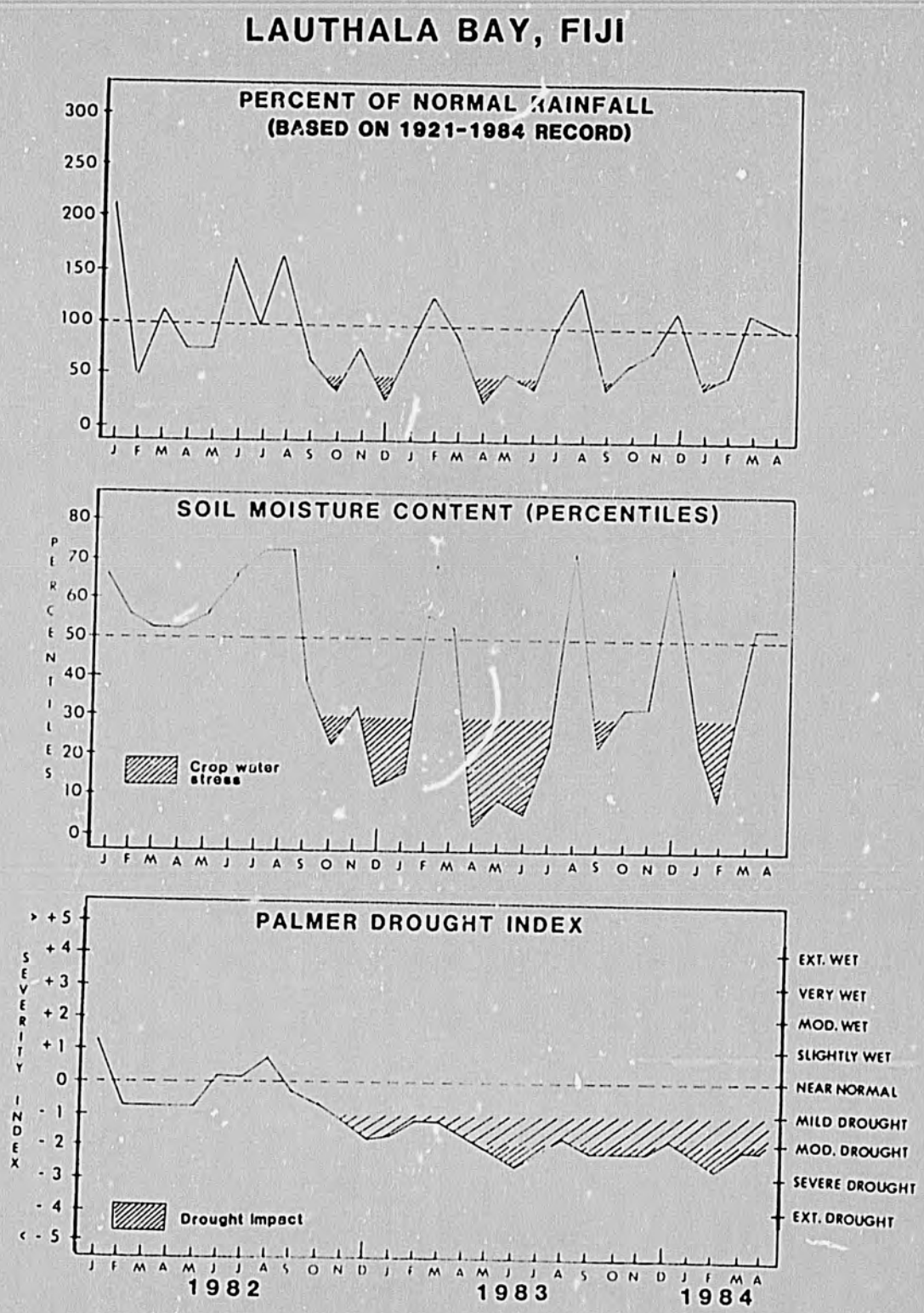


Figure 2.12. Drought Occurrence Analysis Using Percent of Normal Rainfall, Soil Moisture Content and the Palmer Drought Index for Lauthala Bay, Fiji.

occurrence of drought in both locations. In Nadi the drought started in November, 1982 and lasted until October, 1983. During late 1983 and early 1984, rainfall amounts were normal to above normal and soil moisture reserves were restored to near field capacity. In Lauthala Bay, drought conditions began in September, 1982 and lasted until April, 1984. Normal or above normal rainfall for isolated months (February, 1983; August, 1983; December, 1983; March, 1984) was insufficient to break the drought. The below normal rainfall may be associated with the occurrences of "El Nino", a sporadic abnormal warm current in the Pacific Ocean. Severe drought related with "El Nino" was affecting Australia, Indonesia, India, Southern Africa and Central America during 1982 and 1983 (Canby, 1984). More information on drought for each island group is provided in Chapter 8 and Appendix A.

6. Climatic Diagrams

Climatic Diagrams for Nadi and Lauthala Bay showing long-term mean monthly values for rainfall, PET and actual evapotranspiration estimated from soil moisture balance, are shown in Figures 2.13 and 2.14. When the seasonal course of water supply in a rainfed agricultural system is compared with the course of water demand, it is possible to have an insight into the plant-water relationship at a particular place. Quantitative information can be obtained on the many aspects of the soil-plant-atmosphere system such as actual evapotranspiration (AET), differences between actual and potential evapotranspiration, soil water depletion and recharge, and surface runoff.

For example, at Nadi the average monthly values of precipitation and potential evapotranspiration are never equal. The rainfall distribution pattern shows distinct dry and wet seasons. Precipitation varies through the year from a minimum of about 50 mm in July to a maximum of about 350 mm in March. The potential evapotranspiration, varies from a minimum of 130 mm in June to a

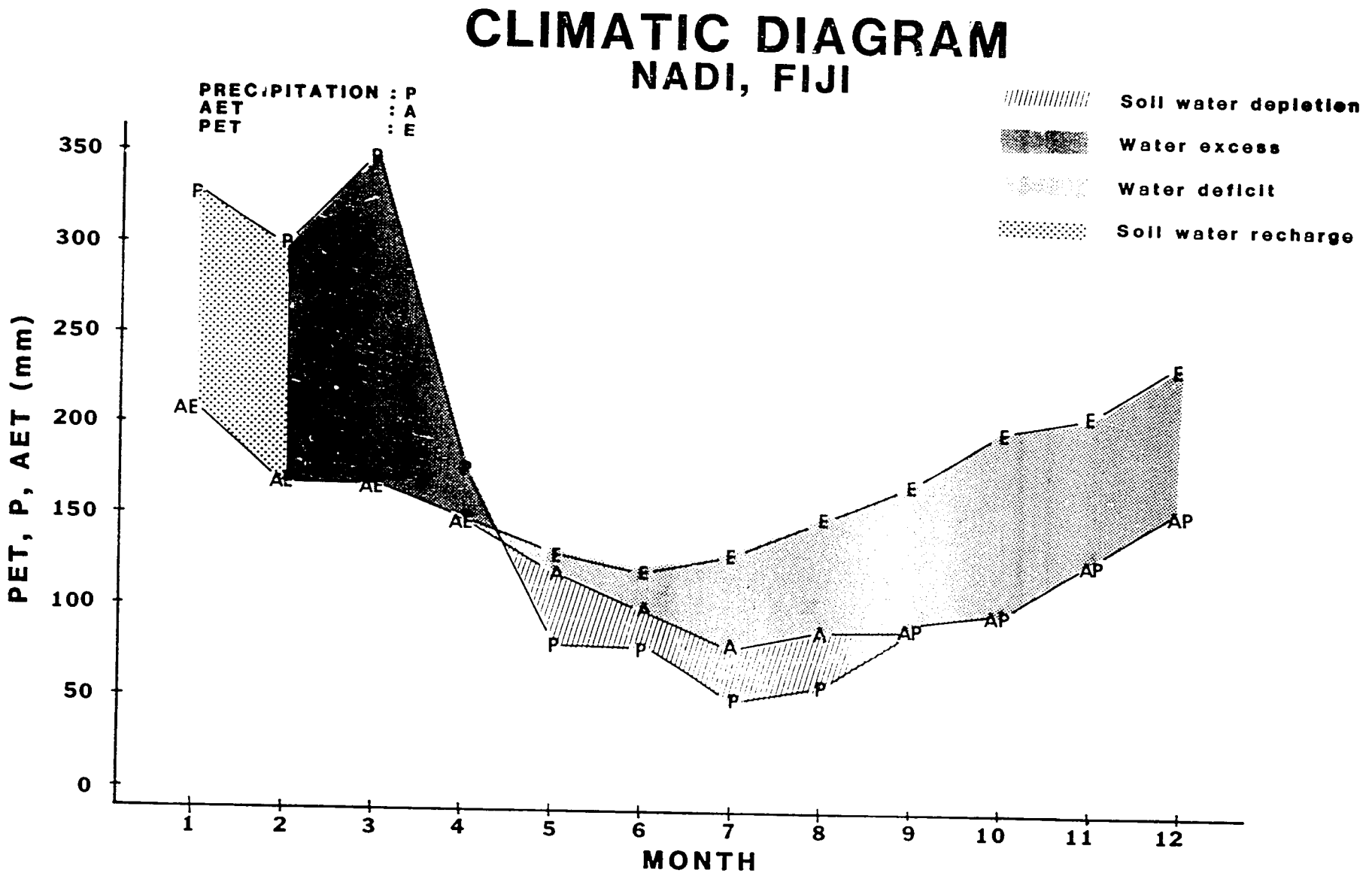


Figure 2.13. Climatic Diagram for Nadi, Fiji.

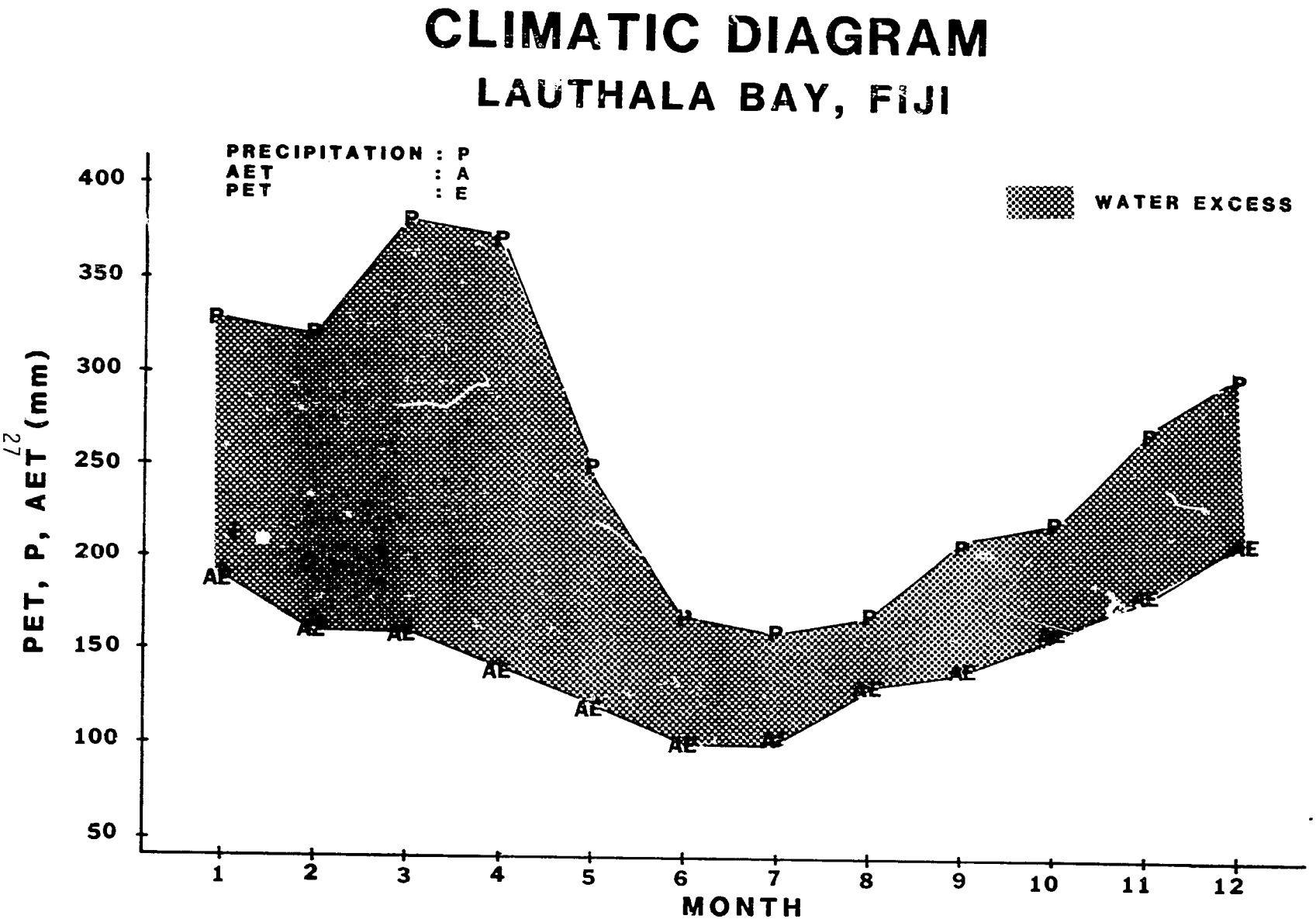


Figure 2.14. Climatic Diagram for Lauthala Bay, Fiji.

maximum of about 250 mm in December. Thus, the seasonal course of both P and PET indicates clearly the periods of water deficit (May through December) and water excess (February through April). Soil moisture storage reaches field capacity by early January and runoff may occur during February and March. There is more water than is needed by the crops during the growing season.

In Lauthala Bay, the average monthly precipitation is always larger than the potential evapotranspiration; there is a year-round water excess. Crop water requirements are normally met and runoff occurs very frequently.

C. AGRICULTURE

1. Overview

Agriculture is the dominant sector of the economy for countries such as Fiji, Vanuatu, Solomon and Tonga in the South Pacific Islands. In the largest islands the agricultural land is generally restricted to coastal areas and river banks. Agricultural production is based on a wide variety of crops grown for export and domestic consumption. Coconut, the source of copra, is the most valuable commercial crop for the region. Cocoa, sugar cane, and banana are also important cash crops on some of the islands. Tobacco and oil palm are also grown for local and export markets.

The major crops grown for domestic food consumption are; rice, yam, sweet potato, cassava, breadfruit, taro and various other vegetables. In the coral atoll islands such as the Gilbert Islands (Kiribati), the agricultural practices are very primitive and centered around copra production and gardens with food crops. One of the major problems in these islands is expanding population pressing on the limited supply of agricultural land.

2. Commercial Crops

a. Coconut (Cocos nucifera)

This palm is widespread in the Pacific Islands. The plant requires a warm climate with little diurnal variation of temperature. The ideal mean annual temperature is around 27°C with an average diurnal variation of no more than 7°C. The palm fails to flourish when grown in places where the mean temperature falls below 21°C. Occasional short spells of temperatures lower or higher than the optimum may be tolerated, but temperatures below 15°C result in fruit abnormalities.

The palm grows best with rainfall between 1,300 and 2,300 mm evenly distributed throughout the year. A total rainfall of 1,500 mm is desirable. The distribution of rainfall, drainage status and moisture-holding capacity of the soil are more important than the quantum of total rainfall. Since water requirements are so high, deficiencies in moisture in the soil and air adversely affect growth.

The inflorescence begins to form about 16 months before the opening of the spathe; severe drought at this point may kill the growing point causing the spathe to abort. The crop could be affected as late as 30 months after the drought; complete recovery occurs only after 3 years.

The coconut is more or less a coastal crop but is not necessarily confined to the sea coasts or to sea level. Coconuts are cultivated on a commercial scale in many places at elevations of over 300 m up to 600 m above sea level.

The palm is semihalophytic; it is able to grow in solutions where roots come into constant contact with salt concentrations up to 0.6 percent that would be lethal for other plants. This permits the use of sea water for irrigation without adverse effects. However, exclusive use of sea water on coconut trees is detrimental, especially with young trees.

The coconut palm grows on many different types of soil provided that they are free-draining and allow unrestricted root development and aeration. The wide and shallow root systems of the palm intercept percolation and enable trees to flourish on shallow coralline and sandy soils in coastal beach and atoll locations where other trees fail. Poor soil drainage is a serious constraint, and heavily leached soils produce low-yielding palms.

The tall palms that generally grow in the Pacific are vulnerable to storm damage; cyclones and hurricanes are a hazard.

The coconut tree begins to bear from 5 to 8 years after germination and reaches maximum yield sometime between 10 and 30 years. The prime years for the palm are between 30 and 40, and it can continue to bear between 50 and 100 years depending on care, fertility of the land and climate.

Copra is a coconut product obtained for export by processing the dried coconut meat before extracting the coconut oil.

Coconut is cultivated under plantation conditions in most of the Pacific Islands.

b. Sugar cane (Saccharum spp.)

Sugar cane is a large, perennial grass, with four cultivated species. The most common sugar cane under cultivation originated in New Guinea. Its cultivars belong to the group of noble canes also called thick because their stems are larger and contain more sucrose than other species.

Sugar cane is a crop which requires high temperatures, plenty of sunlight, and large quantities of water. The crop grows well in places with monthly mean temperatures of 24-27°C or more and an annual rainfall of 1,500 mm. A short dry season is necessary during the later stages of growth when the plant is storing sugar. Sugar cane can be grown on a wide variety of soil types, but heavy soils are usually preferred.

Commercially cultivated cane is always propagated from short stem cuttings. The age at harvest varies from 10 to 15 months or more depending on climate and variety. After harvesting the cane two or three ratoon crops may be harvested before replanting but the yield slowly declines. The yield ranges from 100 to 120 tons of cane per hectare.

Sugar cane is susceptible to the following viruses: Mosaic, Sereh, and Fiji disease. The production of sugar cane for export marketing is confined to Fiji.

c. Banana and Plantain (*Musa* Spp.)

Banana and plantain are large herbaceous perennial plants of Asiatic origin. Many species and varieties are grown under plantation conditions in the tropical zones.

When ripe, all the carbohydrate reserves in bananas are in the form of sugar and the fruits are eaten raw; in the plantain the reserves are starch, requiring cooking before eating. Bananas have a higher commercial value than plantains.

These crops thrive in a wide range of environments between latitudes 30° north and south of the equator, predominantly in the hot, humid lowland zones.

The banana and plantain grow best in areas with monthly mean temperatures around 25-30°C and annual rainfall greater than 2,000 mm. However, there are a range of cultivars that are adapted to high altitudes and lower moisture conditions. These crops require a rich, loamy, well drained and aerated soil with pH between 6.0 to 7.5.

Banana is propagated from suckers which are cut from the parent plant complete with roots when they are about 60 cm in height and several months old. The suckers are planted in holes usually 50 cm in diameter and 50 cm deep. Most bananas bear fruit about one year after planting. As soon as a plant has fruit

the stem should be cut down to about 30 cm from the ground. When suckers are not removed, 3 or 4 plants of different ages grow together so only one banana bunch matures at a time and harvesting extends year-round.

Leaf spot also known as Sigatoka disease, caused by a fungus is the only serious disease threatening bananas and plantains in the South Pacific Islands.

d. Cacao (Theobroma cacao)

Cacao or cocoa is a small tree native to South America. Cocoa is extracted from the dried and partially fermented mature beans.

The climatic requirements for cacao are: temperature varying between 30-32°C mean maximum and 18-32°C mean minimum; and annual rainfall of 1,100 to 3,000 mm, preferably between 1,500 and 2,000 mm with no persistent strong winds. The soil should be porous, rich in organic matter and contain a relatively large amount of clay. The optimum pH is somewhat acid, ranging from 4.0 to 6.0.

Cacao is an expensive crop to grow under plantation conditions because it requires continued maintenance, including pruning, to retain good production. The tree starts to bear at 4 to 5 years and continues for 50 years or more. Harvest starts at the end of the wet season and continues for the first few months of the dry season. The average yield is around 500 kg per hectare but under the best conditions may reach 3,600 kg of dry cocoa per hectare per year.

Cacac is normally propagated from seed but considerable work has been done to vegetatively propagate clones with desirable characteristics.

The South Pacific region remains free of cacao diseases such as the "swollen shoot" malady of West Africa and the "witchesbroom" disease of the Western Hemisphere. Cultivation in the South Pacific area began in 1902 when it was introduced in the Bismarck archipelago as a crop planted under coconut. Cocoa is one of the major commercial crops of Vanuatu.

e. Coffee (Coffea spp.)

Coffee is a small tree or shrub native to the tropical rain forests of parts of Africa and South-east Asia. Coffea arabica and Coffea robusta are two coffee species that are widely cultivated in tropical and subtropical uplands for their cherry-like fruits which contain seeds from which coffee is prepared. The climatic requirements of arabica coffee are moderate mean monthly temperatures ranging between 16-25°C and around 2,000 mm of annual rainfall. In areas where annual rainfall is less than 1,500 mm the crop can be grown only with irrigation. Robusta coffee can be grown in a wider range of environments than arabica. It thrives at generally lower altitudes and is more resistant to leaf disease. The soils in general should be fertile, well drained but retentive of moisture, and slightly acid. The preferred soil acidity ranges from pH 4.5 to 6.0.

Coffee is normally grown from seed which may be planted in nursery beds. The seedling plants are transplanted into the field when 9 to 12 months old. Coffee trees produce the first crop at 2 to 3 years, are in full bearing at 6 to 8 years and continue to give an economic yield for about 30 years.

The most serious disease of coffee is the rust disease caused by the fungus Hemileia vastatrix, for which there is no satisfactory method of control. Varieties resistant to rust have been obtained by inter-specific crossing.

The Arabica variety was cultivated in Vanuatu, Fiji and New Caledonia beginning in 1880. When leaf rust disease appeared in the area the crop was virtually abandoned. The resistant robusta variety is under cultivation in areas where arabica does not thrive.

f. Oil Palm (Elaeis guineensis)

Oil palm is a member of the palm family indigenous to tropical Africa. The plant is an erect tree 10 to 30 m high, terminating in a crown of large pinnate leaves. There are several varieties of palm that vary in fruit thickness and color.

In their natural habitat oil palms are found along the banks of rivers and streams in transition zones between rain forest and savanna where water is plentiful and light has not been shaded by forest trees. These requirements for light and water confine commercial exploitation to groves and plantations in cleared rain forest. The crop grows best and is most productive where the annual rainfall is 2,000 mm or more without a prolonged dry season.

Oil palm is propagated by seed which is obtained from fully ripe fruit bunches of high yielding palms. The seeds are germinated in trays and planted in nursery beds when they have 3 to 4 leaves. After 12 months in the nursery the seedlings are transplanted into the field. The trees begin to bear at 4 to 5 years and reach full yield in 10 to 13 years. The economic life is about 50 years. The yield varies from 7,300 to 18,200 kg of fruits per hectare, according to variety and fertility. The fleshy part of the fruit constitutes 35 to 95 percent of the weight, oil 50 to 65 percent. The oil, rich in protein, fat and vitamin A, is principally used to make soap and margarine and other edible fats.

Oil palm is susceptible to several fungal diseases; serious outbreaks of insect pests have not been observed.

g. Other Commercial Crops

Yaqona or kava is the common name of Piper methysticum, a relative of the well known pepper. The powdered root of the plant, dissolved in water, is the chief beverage of Fiji. It takes from three to seven years to mature, and does

best in deep soils under heavy rainfall. Very high prices and favourable ecological conditions have made it the main cash crop of inland villages in Viti Levu, Fiji.

Tobacco was introduced as a crop by the Germans in Northeast New Guinea in the 1890s. Since then, tobacco has never been more than a subsidiary crop. In Fiji cigarette-type tobacco is grown by smallholder cane-farmers and sold to local factories for curing and manufacture. Tobacco is also grown and marketed on a very limited scale in the Solomon Islands.

3. Food Crops

a. Rice (Oriza sativa)

Rice is native to the Far East. The two subspecies Oriza sativa subsp. japonica from Japan, Korea and North China and Oriza sativa subsp. indica from India, Ceylon, Taiwan, South China and Philippines are separated by geographic and genetic barriers. However, some intermediate types are found in Burma and Java. The varieties of japonica known as short grain rice have narrow dark green leaves and lemmas with well developed awns; the plants are more adapted to long days. The grain softens rapidly and becomes mushy after cooking. The cultivars of indica have broad pale green leaves, awns are absent and the narrow, long grain remains separate and non sticky after cooking.

As a summer crop rice does not need cool temperatures to bloom and is not resistant to freezing temperatures. The plant dies after being exposed to temperatures between 0.5 to 5°C for more than 60 hours. The physiological need of high temperatures required to complete the different growth stages in rice is greater than in corn but less than in cotton. Despite cultivation systems of flooded paddies, rice is not an aquatic plant. It is instead water tolerant and highly sensitive to moisture deficiency between flower initiation and heading.

The total amount of water that the plant needs to produce a pound of grain is no more than wheat or other cereals. Efferson (1952) suggests that one of the main functions of water in rice paddies is to control weeds. However, weeds can be killed with propanill which makes it unecessary to use water for weed control. Kung (1966) summarized the water requirement of rice as follows:

	Average	Extremes
Water requirement from transplanting to harvest	800 - 1200 mm	520 - 2549 mm
Transpiration	200 - 500 mm	132 - 1180 mm
Evaporation	180 - 380 mm	107 - 797 mm
Percolation	200 - 700 mm	32 - 1944 mm

Kung also gave the following desirable water depths for the different growth stages.

	Average	Extremes
During transplanting	2 - 3 cm	Deeper water encourages deeper transplanting which delays the development of new root growth systems.
After transplanting	5 - 8 cm	Drain gradually at maximum tiller stage and fertilize, then return the water as the soil surface starts to crack.
Panicle primordia development state	5 - 8 cm	Shortage at this stages and just following will cause sterility and reduced yields.
After full flowering		Drain gradually.

Rice is a typical crop of temperate zones where the yields are three times greater than in the tropics. Rice was unknown in Melanesia before the colonial period and was introduced by employers as a crop to feed the laborers. To adapt the crop to more tropical conditions the International Rice Research Institute in the Philippines studied 10,000 varieties of rice and through selection and

breeding techniques successfully developed commercial varieties more suitable for cultivation at low latitudes.

b. Yams (Dioscorea spp.)

Yam is the edible starchy tuberous root of various plants of the genus Dioscorea that largely replaced the potato as a staple food in tropical climates. The greater yam, Dioscorea alata, probably originated in Indochina and was introduced into humid regions. This transfer demanded the development of special techniques of soil ridging and draining to keep the tuber in a loose friable soil environment free from excess moisture.

The soil should be a deep, sandy loam free from danger of waterlogging. Ideal conditions for yam cultivation are a tropical climate with temperatures around 30°C, a sharply demarcated dry season of two to five months, and a total rainfall of some 1,500 mm evenly distributed throughout the remainder of the year. It may be advantageous if the beginning of the growing season coincides with a day-length of more than 12 hours, shortening as the crop progresses. The sprout cannot withstand any degree of frost and does not grow well at temperatures below 20°C. Yams can withstand periods of severe drought during which the leafy parts of the plant die away and become dormant. During the dry period the large reserve of water and nutrients stored in the tuber are used and the tuber eventually deteriorates. However, severe drought during the early stage of growth before tuber development can result in the death of the plants. The farming cycle is determined primarily by the beginning and ending of the rainy season. Yams are not grown under irrigated conditions. The normal practice is to plant yams before the beginning of the new rainy season. The growing period is 8 to 10 months when the rainy season is shorter than about eight months. Early planting is desirable to take advantage of the very first rains. The tubers do not suffer by being left in the ground during the dry season. It is

common to harvest only what is required for consumption or sale and leave the remainder of the crop in the ground. The tubers are variable in shape and size; they normally weigh between 5-10 kg.

c. Sweet Potato (Ipomea batatas)

The sweet potato originated in the tropical regions of Central and South America and spread very early from the New World to the Pacific Islands, Asia and Europe.

The sweet potato is a perennial plant with vine-like or trailing stems up to 5 m long. The tubers are enlarged roots that accumulate a large quantity of starch and nutrients. Most cultivars yield well under a wide range of climates and soil conditions, but do best on light, sandy soils where annual rainfall is between 750-1,300 mm. They are not tolerant to drought during the growing season. In dry areas they are grown under irrigation. The crop is propagated vegetatively from stem cuttings that produce new roots on the nodes. Less often it is propagated from shoots which grow from germinated buds on the root tubers. Sweet potato is cultivated in garden plots and is not interplanted with other crops because the plant grows actively and covers all of the ground. A single plant produces from 10-30 root tubers, rarely more than 50. Successive crops may be taken by earthing up the stems after each harvest. Planting normally occurs at the beginning of the rainy season. Harvesting begins 3 to 5 months after planting. Yield, size of the root tuber and percent of starch and protein depends upon the cultivars, climatic variation during the growing period and duration of the storage period.

Sweet potato tubers can be infected by several fungus species which cause them to rot and deteriorate rapidly when stored.

d. Cassava (Manihot esculenta)

Cassava is also known as manioc and tapioca. Cassava is a shrubby, woody, short-lived perennial plant that grows to about 3 m. Dwarf cultivars rarely exceed 1 m in height. The root tubers are the source of tapioca starch.

The crop grows best in a warm climate with deep, rich, well drained soil but it can be grown on a variety of soils from heavy clay to light sand. The tubers deteriorate in soils which are too wet. A heavy well distributed rainfall and average temperatures of 20°C are desirable.

Propagation is done vegetatively from cuttings which root easily. The cultivars of cassava are classified in two groups. The "sweet" cultivars produce a cluster of five to ten tubers that are ready for harvest about 8 to 10 months after planting. The "bitter" cultivars take 18 months to 2 years to mature.

All cassava plants and tubers are to a certain degree poisonous because they contain various amounts of the cyanogenetic glucoside called linamarin. In the "sweet" type the toxic substances are confined to the rind of the tuber; in the "bitter" type the toxic substances are more generally distributed throughout the tuber.

e. Breadfruit (Artocarpus altilis)

Breadfruit is a native plant and staple food in Polynesia. There are several varieties of breadfruit that vary in leaf and fruit shapes, presence or absence of seeds, and fruiting habits. It grows best in hot, humid, tropical lowland islands with annual rainfall between 1,500-2,500 mm and mean monthly temperatures of 22-32°C. The young plants grow better under shade, but later require full sun. It can be grown on a variety of soils that provide sufficient depth and drainage. The crop is propagated by root cuttings, usually planted 90

to 120 cm apart. The tree grows rapidly and begins to bear at 3-6 years. The harvest period starts 60 to 90 days after the emergence of the inflorescence and lasts about 4 months. The fruit is usually harvested while still firm because it lasts for only a few days when fully ripe. Mature trees will yield up to 700 fruit per year, each weighing 1 to 5 kg.

f. Other Food Crops

Taro, eddoe, dashen and cocoyam are the common names of species and varieties of the genus Colocasia. The main cultivated species is Colocasia esculenta, an herb 1 to 2 m tall with underground starchy corms. Taro can be grown under a range of climatic conditions but requires supplementary irrigation where rainfall during the growing season is less than about 1,750 mm. Taro is most productive on freshly cleared rain forest soils where the annual rainfall exceeds 2,500 mm. The corms mature 6-7 months after planting. Although they may be harvested and eaten before they mature, the corms do not store well unless they are harvested fully mature after the leaves have yellowed. The leaves and petioles are sometimes used as a fresh vegetable.

Babai (Cyrtosperma chamissonis), known also as taro, is a herbaceous plant with edible starchy corms, very similar to the true taro. This plant is propagated from suckers and from the top of the corm (tuber). The area to be planted must be weeded and mulched with dry coconut leaves or any other type of organic matter. The planting methods vary from one island to another. In some islands babai is planted in swamp areas, where the soil is soft and watery. On the atolls, where natural swamp is very scarce, it is usually grown in deep pits which have been dug to water table level. Some varieties take many years to reach maturity. Babai is the staple food of many atolls in the Southern Pacific.

Pandanus or screw-pine (Pandanus odoratissimus) is widespread in islands of the Pacific Ocean, where it grows along the coasts producing a belt of dense impenetrable vegetation. Pandanus is a densely branched tree with aereal roots, 6 m high. It is cultivated along river banks, canals or ponds for its edible fruit. The trees produce fruits 3 to 4 years after planting and are harvested year-round. In the Pacific atolls the fleshy base of the fruit is eaten when ripe. The pulp from the fruit is mixed with coconut milk or grated coconut and the paste is baked into flat cakes. The leaves are used for thatching and for making matting, sacks, cordage, baskets, hats, umbrellas and other articles.

CHAPTER III

FIJI

A. Physical Environment

1. Location

The Fiji Islands are situated in the southwestern Pacific Ocean between 15°S and 22°S latitude and 177°E and 175°W longitude. Rotuma and a group of small islands are part of the Fiji territory. Rotuma is geographically separate and lies 354 km north-northwest of Vanua Levu near 12°30'S latitude and 177°10'E longitude. The main archipelago lies entirely within the southern hemisphere midway between Samoa and New Caledonia and 1,660 km north of New Zealand. Fiji is comprised of about 360 islands including two main islands, Viti Levu and Vanua Levu, nearly 260 small islands mostly in the Lau or Eastern group, and numerous islets, atolls and reefs. About a hundred islands are permanently inhabited but many more are used as temporary residences during the turtle-fishing season. The total land area of the country is 18,260 square km, about 90 percent of which is occupied by the two main islands. The international dateline bisects the territory, but for convenience the day is the same throughout the archipelago. Fiji is an independent nation member of the British Commonwealth. The map of the islands is shown in Figure 3.1.

2. Geography and Topography

The largest islands of Fiji are mountainous and of volcanic origin, rising more or less abruptly from two submerged platforms. The western platform is the broader of the two; from it rises Viti Levu, Vanua Levu, Taveuni, Kandavu, Lomaiviti and the Yasawa group. The eastern platform is narrower and elongated, and from it rises numerous small islands of the Lau group. The two platforms are separated by the relatively deep water of the Koro Sea. They are joined by a narrow ridge in the Nanuku passage. North of this passage the ocean floor drops steeply to depths over 1,500 m.

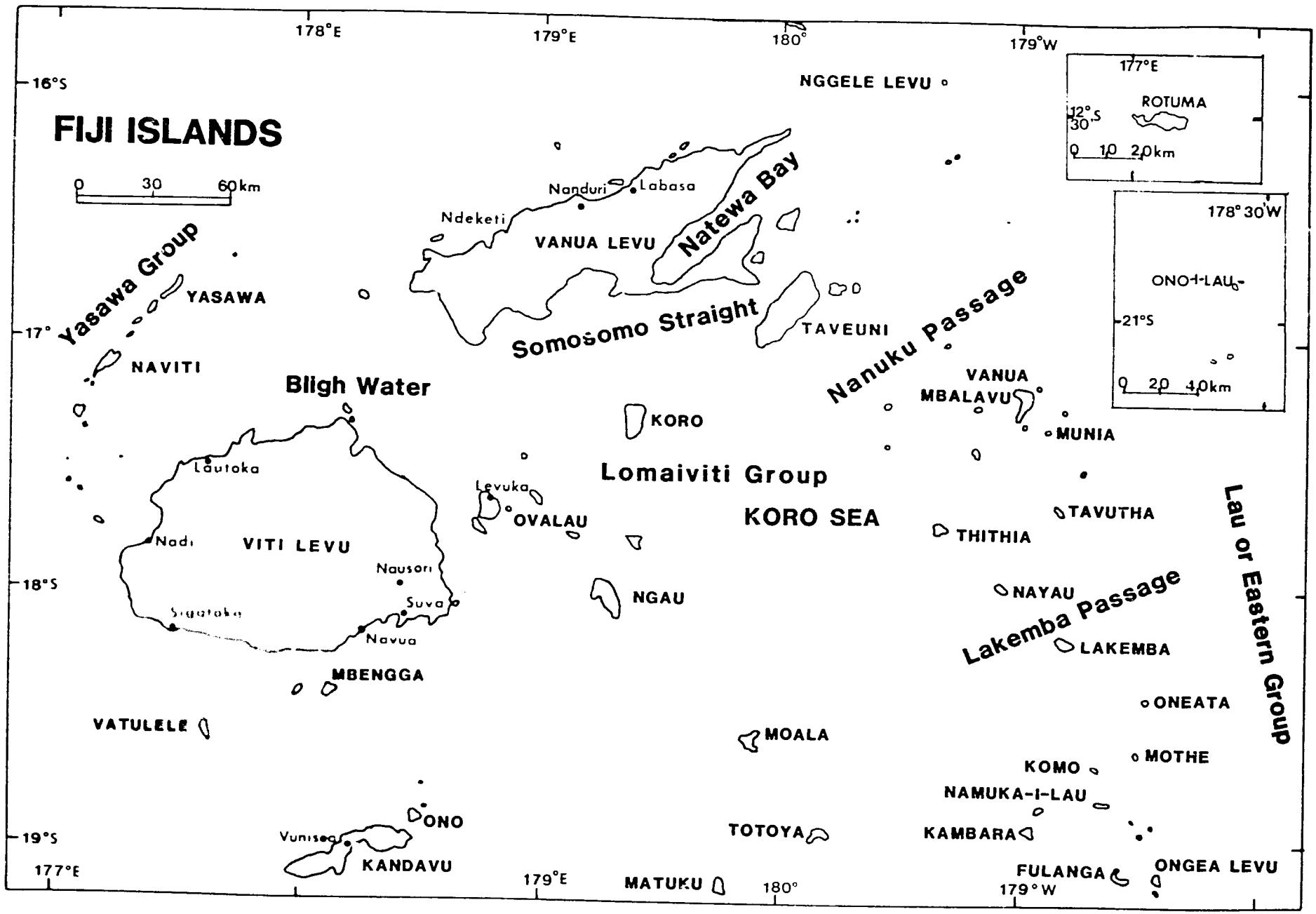


Figure 3.1. Location of Islands and Major Cities of Fiji.

The rocks of Fiji represent a longer period of geological history than those of most Pacific islands and include a great variety of formations. Most of the largest islands are built mainly of ancient volcanic and andesite rocks, with cretaceous and tertiary sediments.

Mount Victoria in Viti Levu is the country's highest peak at 1,323 m. Viti Levu is the largest island with an area of about 10,500 square km, Vanua Levu is the second largest with 5,500 square km. Other large islands are Kandavu, 440 square km, and Taveuni, 435 square km. The rest of the islands have an area under 250 square km.

Viti Levu

Viti Levu measures 80 km from north to south and 145 km from east to west and comprises more than half of the area of the Fiji territory. The island has many different surface features: the high plateau in the central and east area; mountain ranges that include more than 20 mountains with summits ranging from 360 to 1,400 m; areas of hilly uplands, many of which are dissected by rivers; areas consisting of low-lying plains near the coast; deltas of the principal rivers; and low rounded hills.

The Rewa River is the largest in Fiji and is navigable for 97 to 129 km. Its flood plain and portions of the delta, near Suva, are devoted to the cultivation of bananas.

Viti Levu has more than two-thirds of the total population of Fiji. Suva on the southeast side of the island is the capital and seat of the High Commissioner for the Western Pacific. The city is the most important of the three ports of entry of Fiji. Nadi (Nandi) and Lautoka are the major cities of the west coast. In the South, Sigatoka (Singatoka) is the principal city in a very important agricultural area.

Vanua Levu

Vanua Levu is the second largest island of the group. It is 160 km long with an average width of 51 km and a maximum elevation of 1,070 m. The mountain system of Vanua Levu covers four-fifths of its entire area. In many of these mountains are thermal springs with temperatures varying from 38° to 60°C. The eastern extremity is deeply indented by Natewa Bay. The Natewa peninsula is connected with the rest of the island by a very narrow isthmus two and a half miles wide. The western or lee side of Vanua Levu is arid and covered by scanty vegetation. The broken coast of Vanua Levu provides innumerable harbors and sheltered bays. Labasa (Lambasa) and Nanduri on the north coast are important towns in the center of the sugar-growing area.

Kandavu

Kandavu is located south of Viti Levu. The island is about 52 km in length and varies in width from 13 to 1 km. It is of volcanic origin and has some high mountains. The highest point is Mount Washington at 840 m. The land is covered with tropical vegetation, pastures and arable areas. Vunisea is a town located on a small isthmus that nearly divides the island in two.

Taveuni (Somosomo)

Taveuni ranks fourth in size of the Fiji group. Located exactly at meridian 180, it is separated from Vanua Levu by the Somosomo Strait. The island is 37 km long with a coastline of 100 km. The terrain rises symmetrically on both sides at Uluingalau mountain, the highest point at 1,230 m. The island is of volcanic formation covered with luxuriant tropical vegetation and can support cultivation from the sea coast to the summit. Coconut, coffee and tropical fruit are grown on the island. The population is concentrated on the northwest coast.

Ngau

Ngau is 21 km long and 7 km in average width with an area of 140 square km. The north end of the island is dominated by the 705 m twin peaks, Delaico and Delaicoboni, standing little more than 1.5 km apart. The land is fertile and well watered. The high land in the north part and the main ridges running south are covered with dense rain forest. The western peninsula is open and covered with grassland.

Ovalau

The island is 13 by 11 km. The origin is volcanic, with high, rugged, steep hills rising to heights of 915 m. The valleys are narrow and fertile. This island was one of the favorites settled by the earliest Europeans. It possesses numerous safe harbors.

Koro

Koro, 100 square km, is 16 km long and 8 km wide at the northern end. The south tapers to a promontory called Alldin point. The mountains are densely wooded. The highest part rises from the central plateau to 616 m above sea level. Most of the villages are located on the windward coast.

Other Islands

The Yasawa Islands extend in a north-northeasterly direction forming a comparatively narrow chain for a distance of 72 km. The group is located northwestward from the northwest coast of Viti Levu. There are 16 islands with numerous small islets and rocks, making up an area of 130 square km. Naviti is the largest of the group with Yasawa second. The islands are of volcanic origin and their summits range from 230 m to nearly 610 m above sea level. The surface of the islands is rugged and broken, and the area of land suitable for planting is limited.

The islands and atolls of the Lau or Eastern group are scattered over three and a half degrees of latitude between 16° and 19°30'S and two degrees of longitude between 180° and 178°W. Within these limits the islands and reef are unequally distributed, being thickly clustered in the north-eastern and east-central areas. To the south the islands are separated by wide spaces of open sea. The aggregate area of the group is 440 square km distributed among 29 principal islands. One-third of the area is in three islands, Moala, Lakemba and Vanua Mbalavu. There are five other islands above 26 square km. The remaining islands are very small; hundreds of them are only one square km. Of the 29 principal islands, 18 are of pure limestone formation, 8 are limestone invaded by volcanic rocks and only 3 are wholly of volcanic origin.

Rotuma is 12 km long and has a maximum width of 5.6 km. The land is fertile and covered with groves of palm. Copra is the principal export.

3. Climate

The territory of Fiji has a tropical humid climate (Trewartha, 1968). During most of the year the Inter-Tropical Convergence Zone lies to the north, and the prevailing winds are the trades that blow steadily with little interruption from the east, varying east-southeast. Under these conditions the windward sides have relatively high average rainfalls while the central mountains cause rain shadow on the northern and western slopes. All the leeward areas are relatively dry.

From November to March or April the Inter-Tropical Convergence Zone lies south of Fiji and the wind direction is more variable. During these months tropical cyclonic storms or hurricanes are most likely to develop. The association of disturbed conditions with low pressure bring about 250 mm of rain per month to all parts of the islands. February and March are usually the wettest months in both the dry and wet zones. The dry zones have a clearly defined

rainy season from December through April with heavy rains during January and February.

The temperatures in the coastal areas range between 15°C and 32°C with an average annual mean temperature around 25°C. The dry zones are cooler in winter than the wet zones. In the mountains at higher elevations the winter temperatures may fall occasionally to 5°C. The mean monthly relative humidity varies from 73 to 83 percent, with extremes of 60 to 90 percent in the wetter zones and 45-86 percent in the drier areas.

Considering the topography and rainfall distribution throughout the year the territory of Fiji can be divided into three agroclimatic regions. The characteristics of these regions are:

Region I - Strong dry season. Total annual rainfall between 1,800-2,700 mm.

Region II - Moderate dry season.

IIa. Total annual rainfall 1,800-2,000 mm.

IIb. Total annual rainfall 2,000-3,700 mm.

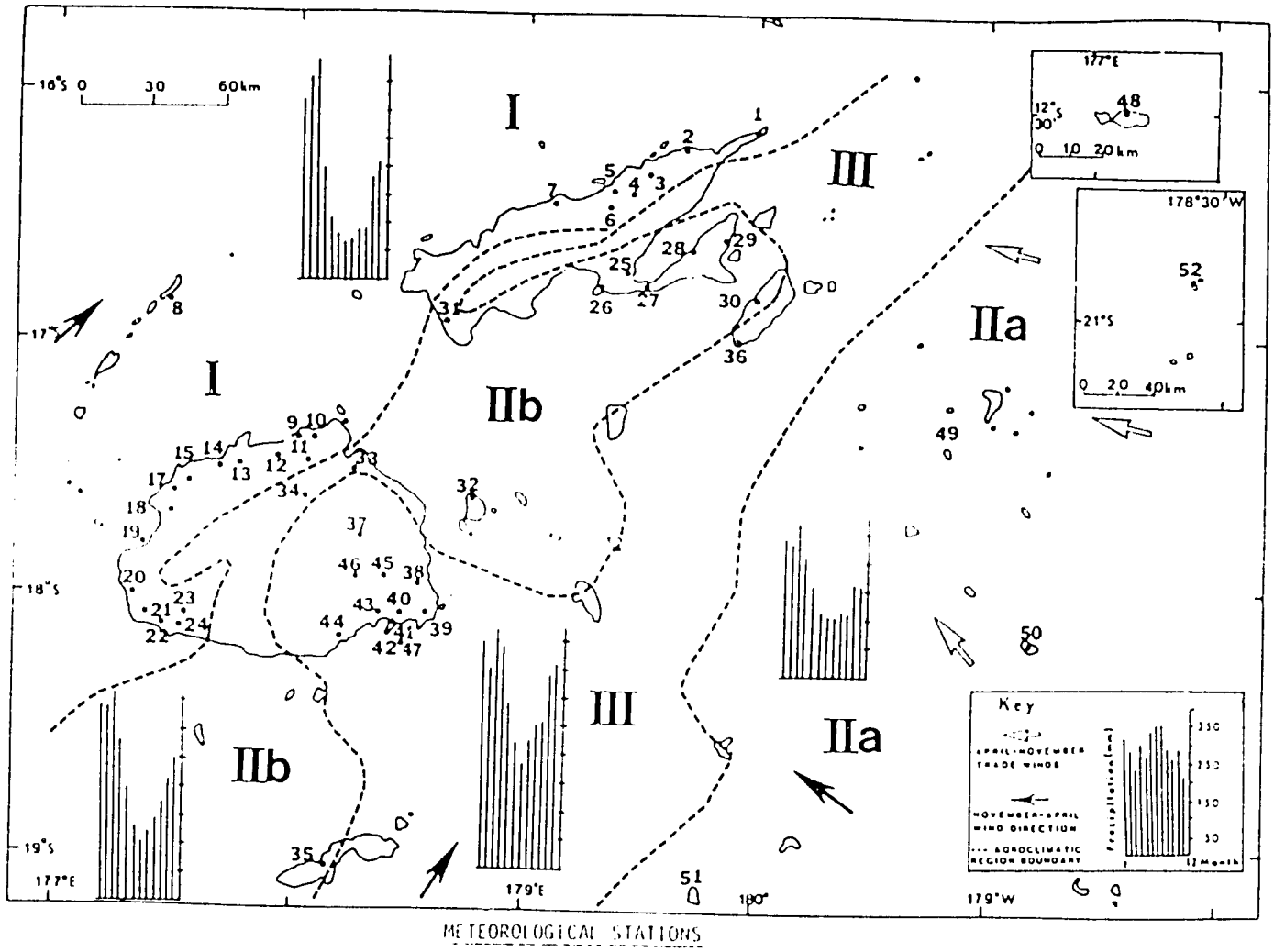
Region III - Weak dry season. Total annual rainfall between 2,600-6,400 mm.

Figure 3.2 shows the location of the weather stations considered in the analysis, the agroclimatic regions, the distribution of the regional rainfall and the wind direction. The distribution of the annual rainfall for selected stations is shown in Appendix A. The mean annual rainfall is shown in Figure 3.3.

Region I includes the west coasts of Vanua Levu and Viti Levu. This region is located in the rain shadow area caused by the mountain range and the high central plateau. The dry season lasts from 6 to 7 months. Rains are very heavy during February and March.

Region IIa includes the eastern island of the Lau group. Region IIb includes the central parts of Vanua Levu and Viti Levu and the west sides of Taveuni, Koro, Ngau and Ovalau Islands. The dry season of these regions lasts

FIJI
AGROCLIMATIC REGIONS



Region I

1. Undo Point (WP,WT,H)
2. Wainikoro (WP)
3. Natova (WP)
4. Waiqele (WP)
5. Labasa Mill (WP,WT)
6. Lambasa Airport (WT)
7. Wailevu (WP)
8. Yasawa-I-Rara (WP,WT)
9. Tavua (WP)
10. Penang Mill (WP,WT)
11. Dobuilevu (WP)
12. Koronubu (WP)
13. Vatukoula (WP)
14. Rarawai Mill (WP,WT)
15. Tagitagi (WP)
16. Veisaru (WP)
17. Lautoka Mill (WP,WT,H)
18. Lautoka Point (WT)
19. Nadi (WP,WT,H)
20. Lomawai (WP)
21. Tau (WP)
22. Navo (WP)
23. Nacocolevu (WP,WT)
24. Lawaqqia (WP)

Region IIa

49. Mango Island (WP)
50. Lakemba (WP)
51. Matuku (WP,WT)
52. Ono-I-Lau (WP,WT)

Region IIb

25. Valeci (WP)
26. Balaga (WP)
27. Vunilangi (WP)
28. Mua (WP)
29. Vanaira (WP)
30. Waiyevo (WP)
31. Nambouwalu (WP,WT,H)
32. Levuka (WP)
33. Nayavu (WP)
34. Nandarivatu (WP,WT)
35. Vunisea (WP,WT)

Region III

36. Salialevu (WP)
37. Vunidawa (WP)
38. Nausori Airfield (WP,H)
39. Nausori Mill (WP,WT)
40. Lauthala Bay (H)
41. Suva (WP)
42. Suva, Tholo-I- (WP,WT)
43. Nakukavesi (WP)
44. Naitonitoni (WP)
45. Wailoku (WP)
46. Tamanua Reservoir (WP)
47. Lauthala Island (WP)
48. Rotuma (WP,WT)

KEY

WP = Wernstedt Mean Monthly Temperature.
WT = Wernstedt Mean Monthly Rainfall.
H = Historical Data Base.

Figure 3.2. Agroclimatic Regions, Distribution of the Regional Rainfall, Wind Direction and Location of the Weather Stations Considered in the Analysis.

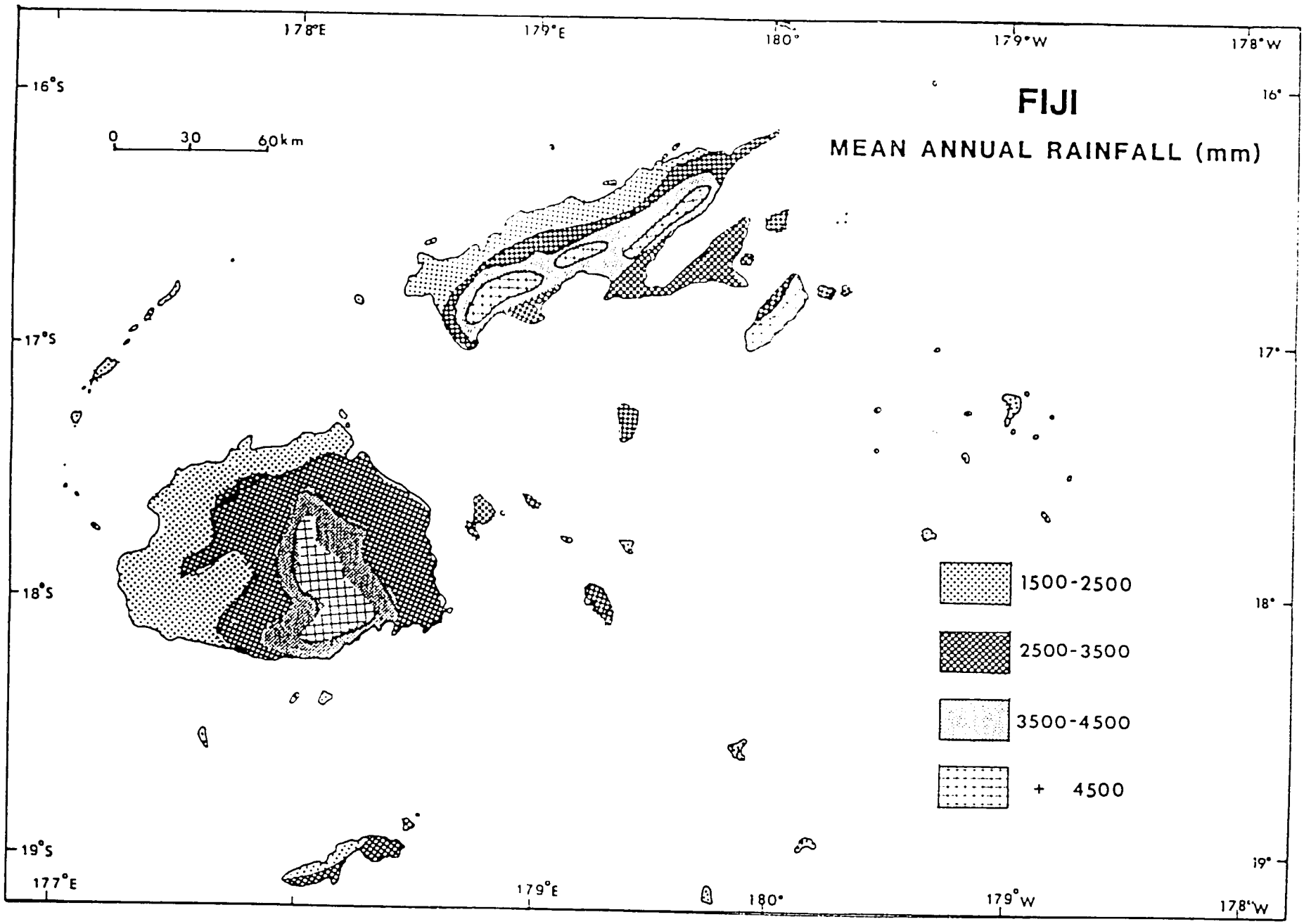


Figure 3.3. Mean Annual Rainfall in mm for Fiji.

for 4 to 5 months and the rainfall is more moderate throughout the year.

Region III includes the windward zones of Vanua Levu and Viti Levu. The rainfall is well distributed throughout the year.

4. Soil and Natural Vegetation

Fiji has a wide variety of soil types, resulting from major differences in the parent or underlying rock, topography, and climatic influences. Most of Fiji's soils are of low fertility. The windward area of the main island has alluvial and colluvial soil in the flat or hilly areas and lateritic soil in the mountainous zones. Soluble soil minerals are usually leached by heavy rains. In lowland areas fine clay particles form a hard pan which prevents water drainage. In the mountain area heavy rainfall and high temperatures cause the formation of lateritic soils. These soils are suitable only for temporary production of food or cash crops. After several seasons of cropping, the land has to be abandoned and left fallow or idle in order to regain the fertility lost by cropping. The leeward zones are less affected by climatic extremes. The soils of the alluvial flat located in the main river valleys are reasonably fertile and cultivated with sugar cane. The soil is stable but requires fertilizing and green manures to maintain fertility. The western hills area of Viti Levu, called Talasiga, has poor soils that support low vegetation. At present these areas are of little agricultural value but they may be improved by using fertilizers to produce crops such as pineapples. Some of the hill slopes, which receive enough rainfall to support forest growth, may be used for plantations of pine forest. Soil types for major islands are shown in Figure 3.4

There is great contrast in the vegetation cover between the windward and leeward sides of the largest islands. In both Viti Levu and Vanua Levu tropical rain forest gives way to grassland often dominated by indigenous reed grass.

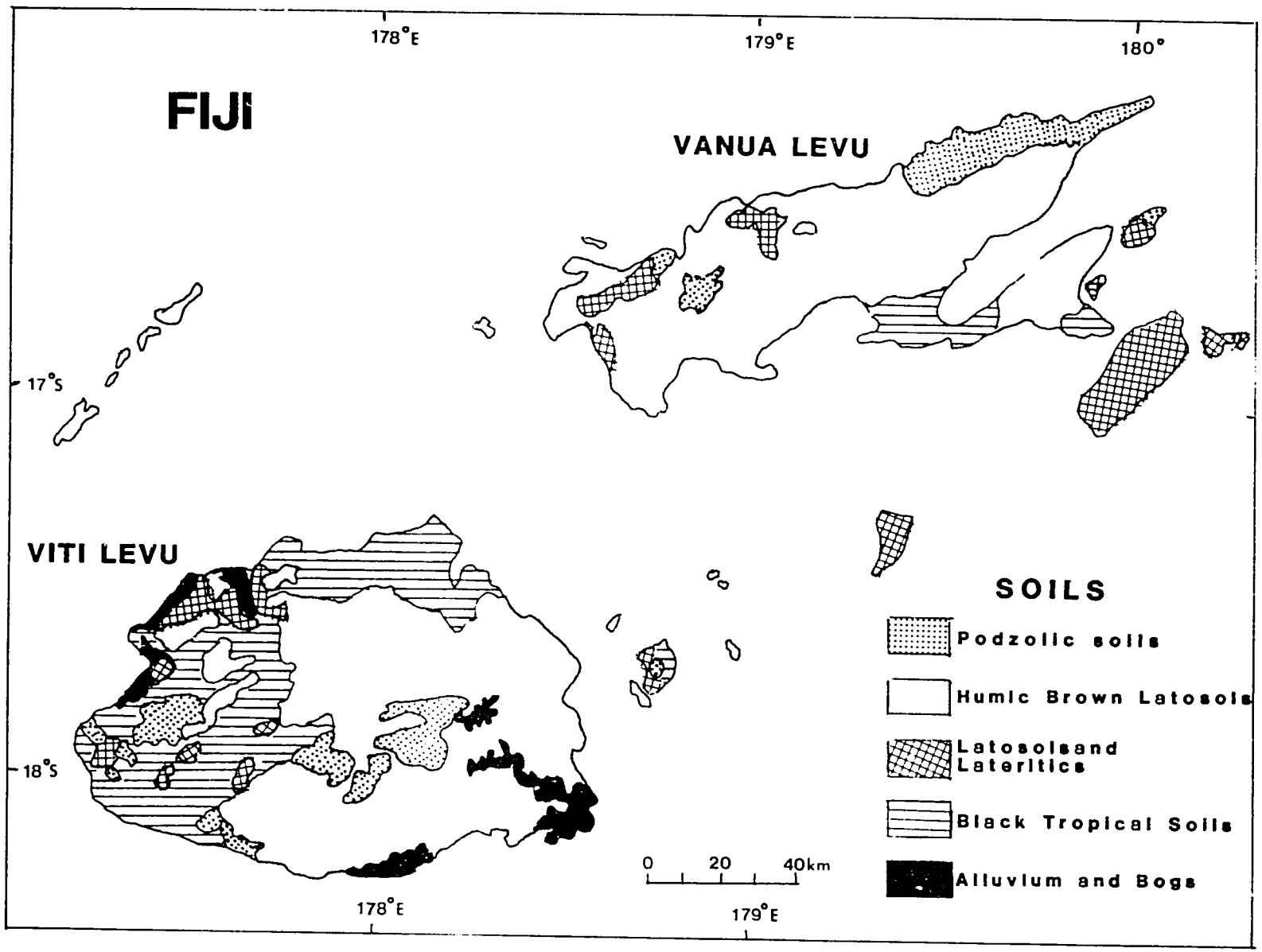


Figure 3.4. Soil Types of Major Islands of Fiji. Adapted from Brookfield, H. C. and D. Hart (1971).

Much of the low hill country is covered with tall grass with scattered trees such as casuarina, pandanus and acacia. More than one half of the total area of the country is covered by tropical rain forest. Mangrove swamps flourish in the deltas and along the shores.

The small coral limestone islands have little spontaneous vegetation due to their thin sandy soils.

B. Agricultural Practices

1. Overview

Fiji is basically an agricultural country. Most of the people employed are directly engaged in agriculture while many others are occupied in processing or handling the agricultural products. In terms of area under cultivation, the most important type of agriculture is village farming. The traditional Fijian villages use communal land. The farming is traditionally done by the land-owning groups called I'tokatoka, Matagali or Yavusa. In this system there is no individual title or ownership.

The I'tokatoka is an enlarged family unit or group descended from brothers that work in communal land. The Matagali is a group of various families with intermarriage linkages. The Yavusa is a combination of several Matagali. These systems of social division, similar to a clan, own 83 percent of the total land area of Fiji. Any member of the unit is entitled to use a part of the land, but the actual division is decided by local custom. Village agriculture varies according to local conditions imposed by slope, soils, climate, relief and access to urban markets.

The traditional cultivation methods are characterized by clearing without the use of fire to rid the garden site of vegetation. Cultivation is repeated at frequent intervals or is maintained continuously for a number of years so

that the period under fallow is shorter than the period under cultivation. Major crops are planted in large one-crop plots; some minor crops are planted in separate and essentially one-crop gardens.

The most important commercial crops in Fiji are: sugar cane, coconut, banana, green ginger and yaqona. Some miscellaneous crops such as mangoes, soybeans, yams, sweet peppers, eggplant and passion fruit are exported to various countries, particularly New Zealand. The principal food crops other than those mentioned are: rice, maize, sorghum, millet, sweet potato, groundnut and beans. Figure 3.5 shows the distribution of agricultural land use and major crops.

2. Commercial Crops

a. Sugar Cane

Sugar cane is Fiji's most important cash-crop. Raw sugar accounts for between 60 and 75 percent of Fiji's income from domestic exports in a normal year.

Early sugar cultivation in Fiji was in the humid southeast area of Viti Levu, but by the mid-1880's the superior ecological conditions of the dry zones of the two main islands were recognized. The main outlines of the present sugar belt were delineated by 1903. Cane farming is now confined to those parts of the western and northern areas of Viti Levu and Vanua Levu with mean annual rainfall between 2,000 and 2,500 mm. Sugar cane was grown in the Rewa Valley until 1959, but extremely wet conditions made sugar production uneconomical.

The pattern of farming activities is closely tied to seasonal climatic changes and to the demands of the harvesting seasons. Planting is from September till November, but small areas are also planted from April to May. The first harvest takes place from 12 to 18 months after planting. Sometimes one or two ratoon crops are taken at slightly shorter intervals before the field

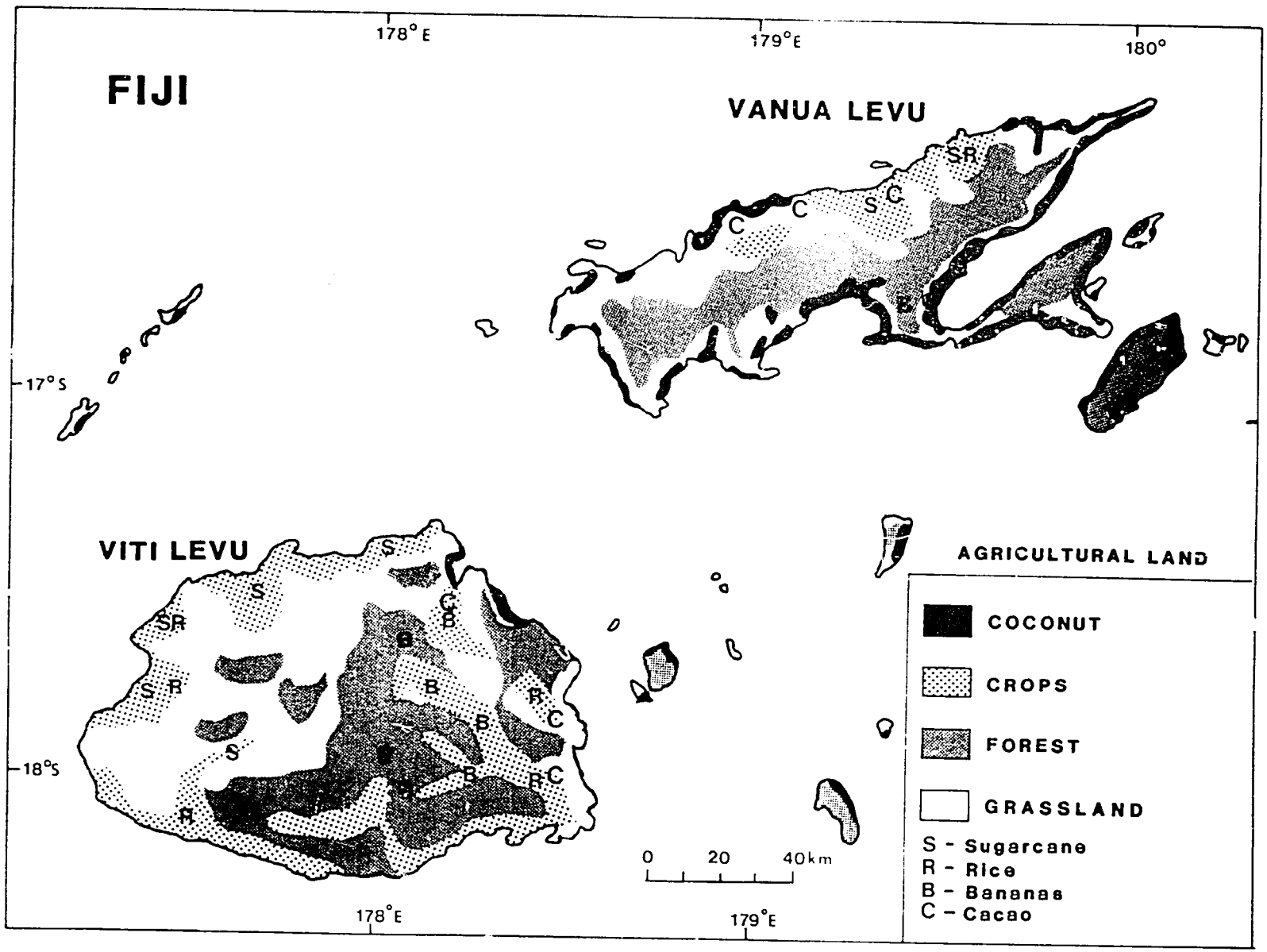


Figure 3.5. Agricultural Land Use for Major Islands of Fiji.

is ploughed and replanted after a rotation period under grass, rice or root crops. About 70 percent of the planted area is harvested each year.

The period of high rainfall in the present cane areas coincides with the hottest months. This provides ideal growing conditions. The marked dry season during the middle of the year helps the development of a high sugar content in the cane stalk before the harvesting season. Sugar cane farms in Fiji have between ten and twelve acres. This area is small enough for a single family to manage without hiring outside labor but large enough to produce a reasonable income. The latest figures in annual production are: 1980-396,000 tons, 1981-470,000 tons, 1982-486,600 tons, 1983-250,000 tons. The production of sugar in 1983 was affected by two hurricanes and severe drought (Carter 1984).

b. Coconut

Copra, a product of coconut, is the second most important agricultural product in Fiji. The sale of copra and copra-products has accounted for between 16 to 25 percent of the domestic export income during the last decades.

Although palms are found in all coastal areas, the main copra producing areas are the eastern and southern parts of Vanua Levu and Taveuni. Other islands with coconut plantations are Kandavu, the Lau group and the Lomaiviti group. The latest figures in copra annual production are: 1980-22,525 tons, 1981-20,371 tons, 1982-22,056 tons (Carter 1984).

c. Other Commercial Crops

Cacao is cultivated in Taveuni, Northern Vanua Levu, and the Eastern region of Viti Levu. Most of the suitable cacao land is used for banana and coconut production.

Tobacco grows well in the Sigatoka Valley and along the Nadi River. Its commercial production is under the control and guidance of the Department of Agriculture. Cigars are manufactured for local consumption, and the Fiji

tobacco company has a factory in Suva. Marketing problems limit production.

Ginger became an important export crop in the 1970's. Raw ginger is exported to Asia, North America and Europe. Passion fruit pulp and juice are manufactured in Sigatoka for export to Australia, New Zealand and North America.

Small quantities of vegetables such as yams, beans, tomatoes, garlic and eggplant are exported to New Zealand. These crops are cultivated on irrigated farms near Nadi. Other crops for export are coffee, tea, rubber, palm oil, pineapple, and citrus.

3. Food Crops

a. Rice

Rice is the staple food of Fiji's population. The rice growing area is confined to the coastal lowlands but is undertaken under varied climatic conditions. Both "wet" and "dry" rice varieties are grown. The land is prepared for "wet" paddy rice from November or December after the first heavy rain until January. The rice seed is planted in nursery beds. After the shoots are about 30 cm high they are transplanted to the wet muddy main fields. At least 300 mm of rain a month are needed during the growing season, which lasts up to five months. "Dry" rice cultivation involves the direct sowing of seed by hand broadcasting, spreading, or drills made by a tractor-drawn implement. This is often done on sugar cane land during the short fallow period after the harvest of the ratoon crop. Dry rice matures quickly but, unlike wet rice, requires weeding. The main concentrations of production outside the cane areas are in Western Viti Levu, in the upper Sigatoka Valley where rice is produced with a wide range of other crops, and on the delta plains of the Rewa and Navua Rivers.

b. Banana

Bananas were an important export crop in the 1890's; 1914 was a peak production year. The closing of the Australian market and internal problems resulted in a steady decline until recent years.

The principal areas producing bananas are confined to the wetter eastern parts of Viti Levu in the valleys of the Rewa River and its tributaries.

Although bananas are a cash crop easily adapted to the traditional pattern of agriculture in the villages, the isolation of the interior valley areas has been a major problem. Until recently, standards of cultivation were poor. In addition, poor handling and packing make it difficult for Fiji to compete with other Pacific island territories. The Waidradra Research Station in Viti Levu was started in the 1970's under an intensive banana project to overcome the problems with diseases. Banana exports, once a big earner of overseas exchange ceased in 1974 (Carter, 1984).

c. Other Food Crops

Maize is cultivated on farms near Nadi (Agroclimatic Region I), and more recently it is grown intensively in the Sigatoka Valley (Agroclimatic Region II). Average maize yield is about 2 tons per hectare.

Sorghum and millet are cultivated on a small scale throughout the western side of Vanua Levu and Viti Levu (Agroclimatic Region I).

Taro and cassava are mostly consumed locally. Both crops are widely cultivated in every agroclimatic region. Taro is more vulnerable to drought than cassava.

4. Crop Calendar

In Agroclimatic Regions I, IIa and IIb, rice is sown from November until January and harvested between March and July. On the east coast of Vanua Levu and Viti Levu (Agroclimatic Region III), 20 percent of the area is irrigated and there are two crops per year. The first crop is sown in December-January and harvested in March-April. The second crop is sown in May and harvested during October-November. In the west and north areas of the main islands (Agroclimatic Region I), rice production suffers from drought about once in five years.

Sugar cane is planted between September and November at the beginning of the rainy season. Small areas are also planted during the hot wet season in April-May. The harvest takes place 15 to 18 months after planting.

Beans are sown between March and May and are harvested in June-July. A second bean crop is harvested in September. Pigeon peas are sown mostly during March-April and harvested after 3-3½ months.

Taro and cassava are planted and harvested year-round. Banana and coconut are harvested throughout the year. Several sources were used to estimate the crop calendar shown in Table 3.1. Further verification is needed before the crop calendar can be used in operational programs.

C. Economic Activities

The most important components of Fiji's economy are agriculture, timber, mining, manufacturing and tourism.

The major crops contributing to export earnings as well as to domestic revenue are sugar cane, coconuts and ginger. Both sugar cane and coconuts are processed locally and provide employment and income for the industrial labor force as well as for farmers.

TABLE 3.1. ESTIMATED REGIONAL CROP CALENDAR FOR FIJI

///Planting/Sowing, ---Vegetative/Flowering, 000 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Region I	Rice	///	---	000	000	000						///	///	Often as a 5 month crop between sugar cane in Vanua Levu Planting Sept-Nov.
	Maize (Corn)	///	---	000	000	00						///	///	
	Sugarcane	---	---	---	---	000	000	000	000	000	000	000	000	Principal crop in the region. Harvest from 15 to 18 mos. Often planting rattoon crop after 12 mos.
		---	---	---	---	---	---	---	---	///	///	///	---	
Region IIa and IIb	Rice	///	///	000	000	000	000	000				///	///	
	Maize	///	///	000	000	000	000	000				///	///	
	Sugarcane	---	---	---	---	---	000	000	000	000	000	---	---	Most planting tape place during hot wet season March-May.
		---	---	///	///	///	---	---	---	---	---	---	---	
	Beans and Peas			///	///	///	000	000	000	000				
Region III	Rice (1st)	///	---	000	000								///	Rainfed rice. About 20% of the land, irrigated.
	(2nd)					///	---	---	---	---	---	000	000	
	Maize (Corn)					///	///	///	---	000	000	000		
	Banana	000	000	000	000	000	000	000	000	000	000	000	000	Principal crop in the region. Rattoon crop is harvested in Sept.
	Beans and Peas			///	///	///	000	000	---	000				
Regions I, IIa, IIb and III	Coconut	000	000	000	000	000	000	000	000	000	000	000	000	Planted and harvested throughout the year. Planted at anytime and harvested year-round.
	Cassava	///	///	///	///	///	///	///	///	///	///	///	///	
		000	000	000	000	000	000	000	000	000	000	000	000	
	Taro	///	///	///	///	///	///	///	///	///	///	///	///	
		000	000000		000	000	000	000	000	000	000	000	000	

The world sugar market is in most years more than well supplied by the joint production of several countries. The proportion of sugar that Fiji supplies to the world market is very small. In 1970, under the Commonwealth Sugar Agreement, Fiji stabilized a quota to supply the United Kingdom at a stable price that was at that time substantially above the world price. Also under the International Sugar Agreement, Fiji has a basic export tonnage to Canada, New Zealand, Singapore and Japan.

The preparation and export of copra was Fiji's earliest industry and still ranks high compared to the sugar industry. The market for copra, although the world price fluctuates, is likely to last into the indefinite future. There is plenty of land available for bananas which at one time occupied a high place among local products.

Altnough timber is one of the principal natural resources, forests have been regarded as a wasted asset. Timber presents the prospect for productive use of very large areas of non-arable land that at present are underutilized and for which it is very difficult to find a productive alternative. For most of the under-developed parts of the island, the land can be used for forests. This applies both to natural forest and to timber plantation.

Mining has a long history in Fiji, though only gold has been mined consistently on a large scale for any substantial period. Other minerals such as iron, copper and manganese are also found in Fiji. The government is a partner in all mining ventures and although the mining industry has not been well developed, it is considered an important source of revenue for the government.

The most important manufacturing operations are the processing of agricultural commodities for export. In addition, enterprises are being encouraged to produce a wide range of commodities for domestic use. Some of the

small-scale manufactured products are concrete blocks, furniture, plywood, clothing, jewelry, plastic articles, paper products, cosmetics, and a great variety of food products.

The tourism industry in Fiji has expanded during the past decade and ranks as the fourth most important industry in the country. However, improvement of interior communication on Vanua Levu and Viti Levu is necessary for the future development of tourist attractions.

CHAPTER IV

GILBERT ISLANDS (KIRIBATI)

A. Physical Environment

1. Location

The Gilbert Islands are part of Kiribati, an independent country that also includes the Phoenix Islands and the Line Islands. The total area of the country is 76 square km distributed among 33 islands scattered over more than five million square km of ocean.

The Gilbert Islands are situated between 4°N and 3°S latitude, and between 172°E and 177°E longitude. The archipelago is composed of 16 islands with a total land area of 272 square km.

The main islands of the Gilbert group are: Tarawa, Butaritari, Tabiteuea and Nonouti. Other islands are Little Makin, Marakei, Abaiang, Maiana, Abemama, Kuria, Aranuka, Beru, Nikunau, Onotoa, Tamana and Arorae. The island of Banaba, also named Ocean Island, that lies near 0.52°S latitude and 169° 35'E longitude was annexed to the Gilbert Islands in 1979 when they became part of the Republic of Kiribati. A map of the islands is shown in Figure 4.1.

2. Geography and Topography

The Gilbert Islands are atolls composed of coral reefs built of ridges from the Central Pacific platform. In most of the atolls the reef encloses a lagoon. The islands often rise no more than 3.6 m above sea level. They are usually higher on the eastern side than on the western because the trade winds that blow from the NE and SE pile up coral fragments and sand. In a few cases the lagoon is filled, becoming a mass of solid limestone surrounded by a reef.

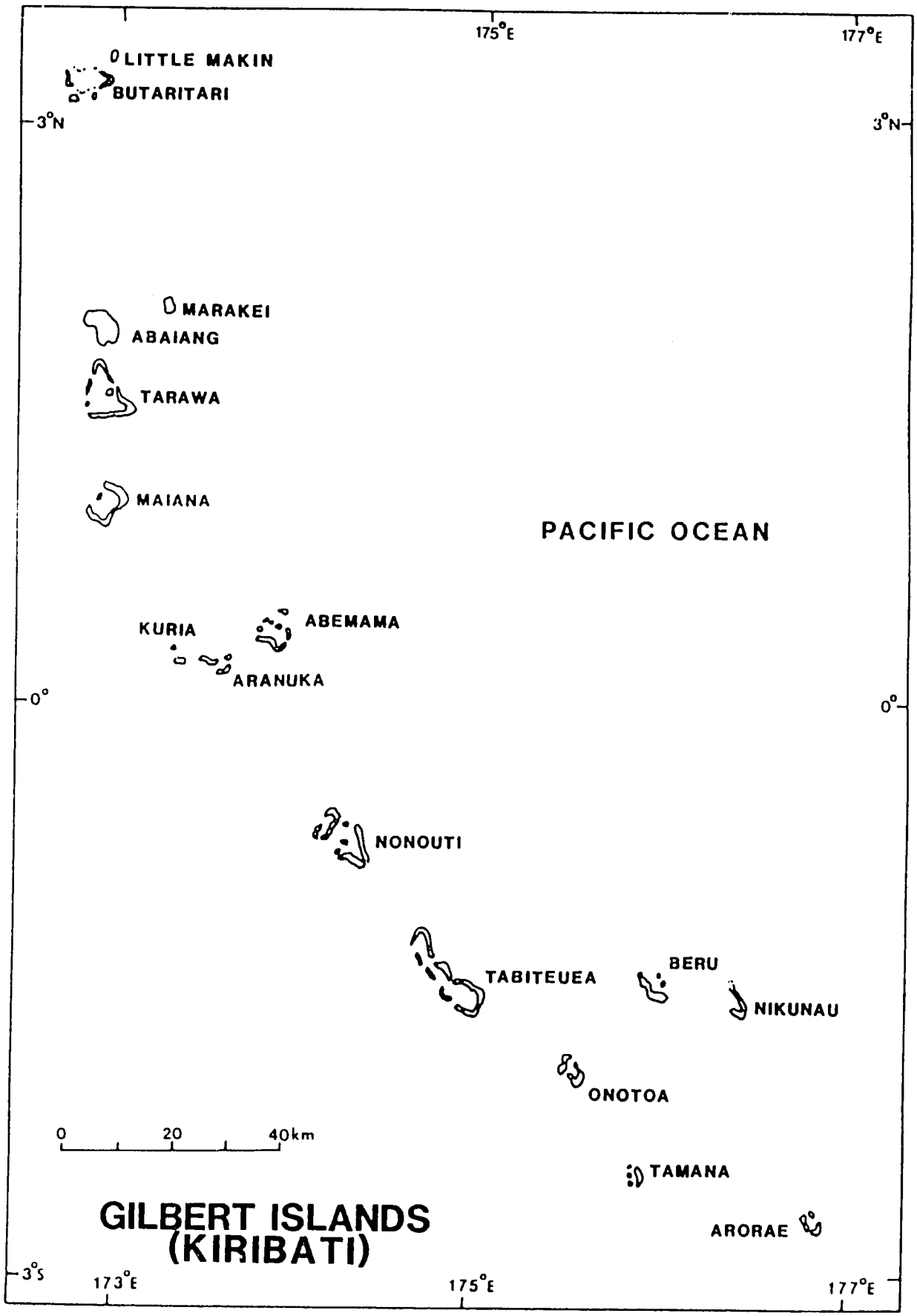


Figure 4.1. Location of the Islands.

Tarawa

Tarawa is a port of entry and is the main center of Kiribati. The atoll is shaped like a triangle with islets on its southern and eastern but not on its western reef. The island's lagoon has one navigable entrance. The perimeter of the atoll is 64 km and the area 920 hectares. This atoll is the most populous in the group. The island has a moderate annual rainfall of around 1,500 mm with a peak during January. Coconut and pandanus are the principal crops. Bananas, babais (taro), sweet potatoes, cassavas and breadfruits are cultivated on a minor scale for domestic markets.

Butaritari

Butaritari has a triangular shape, and is 18 km long from east to west. Its lagoon has two entrances for ships and provides good anchorage. Most of the land is on the south side of the lagoon and is a continuous grove of coconut and pandanus. Butaritari receives around 2,000 mm of well distributed rainfall each year.

Tabiteuea and Nonouti

Tabiteuea, 80 km in length, is the largest island of the group and is second in population. Nonouti is 39 km by 16 km. The lagoon has an entrance for vessels and there is good anchorage. This island receives an annual rainfall of around 1,000 mm with the maximum amount in December. Coconut is the major cash crop.

Other Islands

Abemama is 19 km by 8 km. Aranuka comprises two islets on a 10 km long reef. Banaba is situated 400 km west of the main Gilbert group. It is 10 km in circumference with a maximum elevation of about 78 m. The entire economy of the island was based on phosphate deposits that were worked out; the mining ceased after 1979.

3. Climate

The Gilbert Islands of Kiribati have a tropical wet and dry climate (Trewartha, 1968). The mean temperature is around 28-29°C with little variation during the day and during the year. The lowest temperature ever recorded was 22°C and the highest, 37°C. The trade winds blow throughout the year with a strong northeasterly component and exercise a moderating effect on the temperature. During November to April the westerly gales bring abundant rainfall to the islands.

In spite of their equatorial situation the central and southern islands suffer from severe drought. The driest months are September and October. The wettest months are December and January. The other months are relatively dry.

Taking into consideration the climate throughout the year, the Gilbert Islands can be divided into two agroclimatic regions. The characteristics of the regions are:

Region I: Strong dry season. Total annual rainfall 850-1,300 mm.

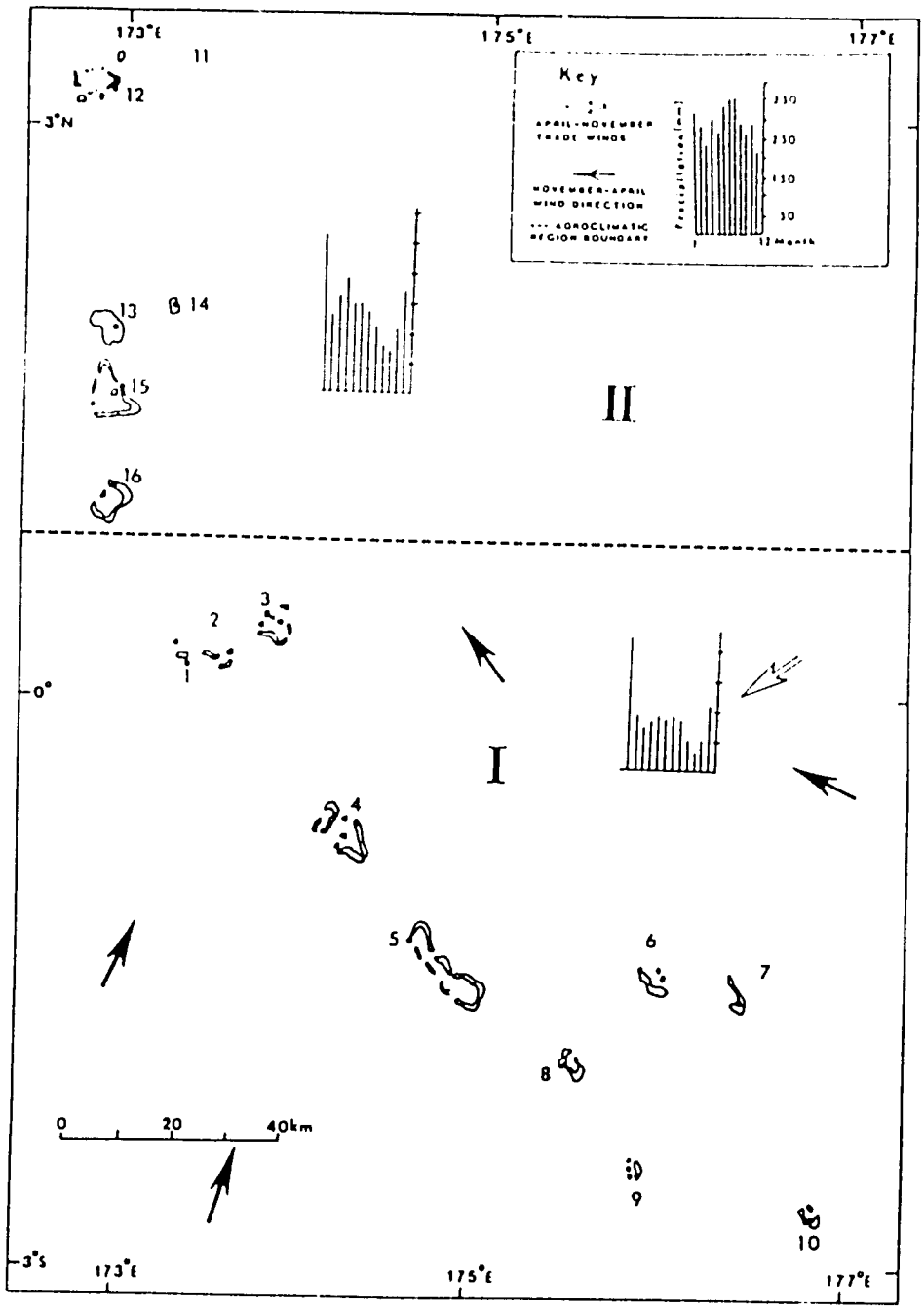
Region II: Moderate dry season. Total annual rainfall 1,300-2,300mm.

Figure 4.2 shows the location of the weather stations considered in the analysis, the agroclimatic regions and the distribution of the regional rainfall and the wind direction. The distribution of the annual rainfall for selected stations is shown in Appendix A.

Region I occupies the central and southern islands. The dry season lasts 4 to 5 months, from July to November. The wettest month is January.

Region II is located in the northern part of the archipelago. The dry season lasts 3 to 4 months, from August to November. The wettest months are January and April.

GILBERT ISLANDS
(KIRIBATI)
AGROCLIMATIC REGIONS



METEOROLOGICAL STATIONS

Region I

1. Kuria (WP)
2. Aranuka (WP)
3. Abemama (WP)
4. Nonouti (WP)
5. Tabiteuea (WP)
6. Beru (WP,WT,H)
7. Nikunau (WP)
8. Onotoa (WP)
9. Tamana (WP)
10. Arorae (WP,WT,H)

Region II

11. Little Makin (WP)
12. Butaritari (H)
13. Abaiang (WP)
14. Marakei (WP)
15. Tarawa (WP,WT,H)
16. Maiana (WP)

KEY

WP = Wernstedt Mean Monthly Temperature.
WT = Wernstedt Mean Monthly Rainfall.
H = Historical Data Base.

Figure 4.2. Agroclimatic Regions, Distribution of the Regional Rainfall, Wind Direction and Location of the Weather Stations Considered in the Analysis.

4. Soil and Natural Vegetation

The islands are infertile coral atolls with sandy coral soil that has little depth or nutriment. The natural vegetation is very poor; there are only a few species of natural flora.

Apart from coconuts and pandanus, most of the other indigenous trees in the islands are of the low scrub type. Some mangroves grow in lagoons which have become swamps. On some islands there are small natural stands of the hardwood Cordia subcordata, but the quantities are insufficient to warrant commercial milling.

The introduction of cultivated plants is limited because they are not very successful. Failures have been attributed mainly to the calcareous formation and high alkalinity of the soil.

Some salt-tolerant species, mainly casuarinas, have been imported and planted as wind breaks, for firewood or to check erosion. Nearly all introduced plants exhibit the symptoms of chlorosis, from the almost complete lack of chlorophyll to a slight yellowing of the leaves; in all cases growth is stunted. Organic matter in the form of mulch and compost has been supplied and certain fertilizers and trace elements used to help to overcome the deficiencies.

B. Agricultural Practices

1. Overview

The agricultural practices in the Gilberts are very primitive. They are centered around copra production due to the extreme difficulty of growing other crops on a commercial scale. The rainfall is favorable for agricultural production in the northern islands, but other areas are subjected to periodic

droughts. Water shortages result in poorer crop yields during dry years. Agricultural progress is hampered by land fragmentation. Due to the fast population expansion, only 1.2 hectares of land are allowed per person. Unlike the farmers of more fertile islands, Gilbert farmers can do all the cultivation necessary on their farm in one day per week.

2. Commercial Crops

The major part of each island is covered with coconut palms which provide the islanders with an important source of food and drink. The juice from the young flower shoots of the coconut palm is called toddy and is collected by slicing the tip of a shoot with a knife and collecting the drips by bending the lower part of the shoot. The fresh toddy contains up to 16 percent of sugar and is one of the main sources of vitamins on islands where green vegetables and fruits are rare. Coconut palms are mostly uncultivated and generally grow close together. The coconut improvement campaign standardized the spacing of palms for replanting at 7 m on the triangle, giving a population of 190 palms per hectare.

Most of the copra is cut by individual landowners and sold to the local cooperative. It is therefore difficult to obtain actual production statistics. In nearly all the islands the low rainfall permits the production of good quality sun-dried copra. In the northern Gilberts where rainfall is greater a small quantity of copra is hot-air dried.

3. Food Crops

In addition to coconut, other crops which are grown to some appreciable extent are: breadfruit, pandanus and babai. On some northern islands, pawpaws, bananas or plantains and sweet potatoes are also grown on a limited scale.

Babai is the most important crop cultivated in the southern islands. It is grown in the muddy bottom of pits at ground water level. The only care after planting is the addition of leaf compost as manure about every three months. The use of manure is important because the pit is under continuous cropping with no rotation or fallow.

4. Crop Calendar

Most of the crops grown in the Gilbert Islands do not have a fixed planting or harvesting season. In the northern islands, Agroclimatic Region II, sweet potato is the only truly seasonal crop. The planting of sweet potatoes starts in December, immediately after the beginning of the rainy season, and continues until April-May. The harvesting season begins 4 to 5 months after planting and extends for several months.

Taro is cultivated in pits at ground water level. Planting and harvesting are based upon crop water supply and food needs. Bananas or plantains are grown on some islands, but the fruit is of poor quality. The new plants or suckers may be left attached to the parent plant or planted in a separate place any time of the year. Harvest of bananas or plantains is year-round as is coconut. Breadfruit is a perennial seasonal crop, but precise crop calendar information is not available. Several sources were used to estimate the crop calendar shown in Table 4.1. Further verification is needed before the crop calendar can be used in operational programs.

C. Economic Activities

The economy of the Gilbert Islands is dependent upon copra production. The production of copra for export indicates a great annual fluctuation which might be expected in these islands because of their uncertain rainfall. However, the quality of copra produced is good, rated first class in the world

TABLE 4.1. ESTIMATED REGIONAL CROP CALENDAR FOR GILBERT ISLAND (KIRIBATI)

///Planting/Sowing ---Vegetative/Flowering, 000 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Regions I and II	Babai	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	000 ///	Babai is the only root crop which grows in pits at water level.
	Pandanus	000	000	000	000	000	000	000	000	000	000	000	000	The production starts 3 to 4 years after planting.
	Coconut	000	000	000	000	000	000	000	000	000	000	000	000	The palm are almost entirely uncared and grow in every island.
Region II	Banana	000	000	000	000	000	000	000	000	000	000	000	000	
	Breadfruit	000	000	000	000	000	000	000	000	000	000	000	000	The main harvest period is between January and May.
	Papaya (Pawpaw)	000	000	000	000	000	000	000	000	000	000	000	000	The main harvest period is between December and May.
	Sweet Potato	///	///			000	000	000	000	000	000	000	///	

market. The Copra Board sells the bulk of the copra produced to Europe and Australia at current world market prices. No timber of commercial value grows on the islands and forestry plays no important role in the economy. Local industry is confined to small operations such as handicrafts, salting of fish and building small boats. The expansion of the fishing industry and the development of tourism presents possible alternatives for increasing revenues.

CHAPTER V

SOLOMON ISLANDS

A. Physical Environment

1. Location

The Solomon Islands lie in the Coral Sea to the east of New Guinea and north of the Vanuatu Islands. The archipelago comprises a double chain of islands, stretching over 900 miles Northwest to Southeast. The group is located between 5°S to 12°S latitude and 155°30'E to 169°45'E longitude. The area of the country, estimated at 28,530 square km, is comprised of six major islands, between 20 and 30 lesser islands, numerous islets and coral reefs.

The Solomon Islands is a constitutional monarchy member of the British Commonwealth. The head of state is the Governor-General. The country is divided into seven provinces, each with a local government. A map of the islands is shown in Figure 5.1.

2. Geography and Topography

The Solomons are of volcanic origin. The cores of the main islands are of igneous and metamorphic rocks overlain by recent deposits of volcanic and marine sediments.

Many islands in the archipelago are very mountainous but Rennell Island is nearly flat. Mount Popomanaseu (2,550 m) on Guadalcanal is the highest mountain of the island group. The volcanos include one located on the island of Savo, another on the island of Simbo, a submarine volcano on Kavachi and Mt. Tinakula on Santa Cruz.

There are extensive coral reefs and lagoons throughout the islands. A number of atolls are also considered a part of the Solomon archipelago. The most important is Ontong Java. The major islands are Guadalcanal, Santa Isabel, Malaita, San Cristobal, Choiseul and New Georgia.

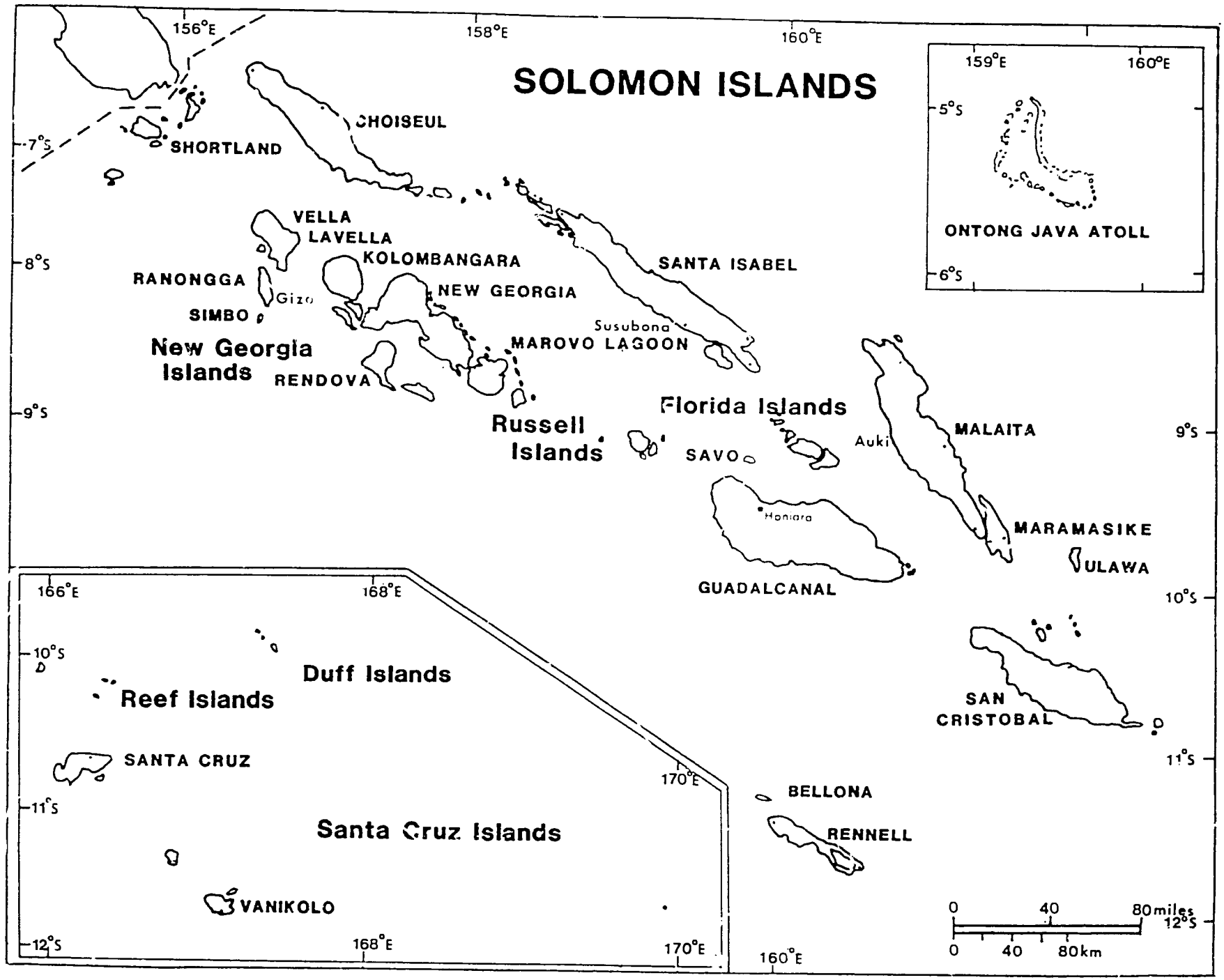


Figure 5.1. Location of Islands and Major Cities of Solomon Islands.

Guadalcanal

Guadalcanal, the largest island in the group, is very mountainous. The highest point is located near the center of the island. On the southern coast numerous rivers follow direct courses to the sea. The whole island is densely wooded with the exception of the western part of the northern plain. The northern coast where the population is concentrated is the most fertile part of the island.

Santa Isabel (Ysabel)

Structurally the island is a single chain of volcanic mountains, which in most parts dip gently to a low-lying coastal strip. The highest point is Mt. Kubonitu at 1,200 m. The whole island is forested. Its leeward side is fertile and nearly covered with plantations. The most important areas of settlement are in the extreme southern and northern parts of the island.

Malaita

The island is basically of volcanic formation with superficial deposits of coral limestone on the lowlands near the coast. Forested mountains, with elevations up to 1,425 m, follow the main axis; the interior is mostly unsurveyed. The island is separated by a narrow passage from Maramasike Island. The two are so closely grouped that they appear to be one island.

San Cristobal (Makira)

The island has many of the characteristics of Guadalcanal but is not so mountainous. The highest altitude is 1,300 m. The settlements are on the "lee" or north side of the island where there are several plantations and trading stations.

Choiseul (Lauru)

Choiseul is a narrow island with a long center ridge. The highest point is Mt. Maitabi (1,660 m). The island is nearly surrounded by reef. The coconut plantations on the coastal belt are separated from each other by stretches of marsh and mangrove swamp.

Other Islands

New Georgia is the largest island of the New Georgia group, which comprises a considerable number of islands with many harbors. Gizo is a port and government station on a little island of the same name and is located near the center of the New Georgia group. Marovo Lagoon is one of the largest island-enclosed lagoons in the world. The southeast peninsula of Rendova Island is dedicated mainly to coconut production. Kolombangara Island situated to the west of New Georgia has an extinct volcano. The islands of this group support good plantations; copra is the principal export.

The Florida group is between Guadalcanal and Malaita. The principal islands in the group are, Negela, Small Negela and Tulagi, a small island west of Negela that is the port of entry and the seat of government.

Rennell and Bellona are two raised limestone islands about 160 km south of Guadalcanal. Rennell is about 80 km long and varies in width from 9 to 20 km. The island is composed entirely of coral limestone that has been uplifted about 130 to 160 m. The population raises yams and taro and collects shellfish and wild fruits for food. Bellona is about 8 km long and fertile. The population of 500 is mostly of Polynesian origin.

The Russell group is comprised of two large islands with a fringe of small islets. The largest is Yandina where one of the finest plantations in the area is located.

The Santa Cruz group is about 380 km east of the southern Solomons. Most of the islands are small and of volcanic origin. The largest island, Santa Cruz, is 46 by 22 km. The maximum elevation is 600 m. The islands are densely wooded with valuable timber such as kauri. There are numerous small islands in the group. One of them, Tinakula, has an active volcano. The economy of these islands is based on the export of copra.

There are other islands associated with the main group of the Solomons. All of them are of atoll formation. Ontong Java is a group of several islets about 250 km north of Santa Isabel. The Shortland Islands are west of Choiseul and south of Bougainville.

3. Climate

According to Trewartha's climate classification (Trewartha, 1968), the Solomon Islands have a tropical climate. The prevailing winds dictate the two main climatic seasons. The dry season extends from the end of April until November and affects the central and northern islands. During this season the southeast trade winds blow almost continuously, but with varying intensity. Periods of up to ten days or more of strong winds with gusts of 25-30 knots and rain squalls are followed by fine days with light southeast winds of 5-10 knots.

Between November and April the weather is more uncertain. The prevailing winds blow primarily from the west or northwest and occasionally from the southeast. In this season there are long periods of calm which may be interrupted by the build-up of cyclones which form in the Coral Sea and Solomon Islands area. The cyclones increase in intensity and move southward, passing through the territories of Vanuatu, New Caledonia, Fiji and Australia; much more damage is caused in these territories than in the Solomon Islands.

The temperature in the Solomons is almost constant throughout the year. The monthly mean temperature is 26° to 27°C. The days are usually hot, but cool land breezes from the mountains make the coastal areas cooler in the evening. The temperatures seldom exceed 32°C during the day or fall below 22°C at night. The major islands are high enough to allow the coastal temperatures to occasionally fall as low as 19°C. The highest temperature ever registered in the Solomon Islands was 36°C in June 1970 in Kirakira; the record low is 14°C recorded in August 1972 in Auki.

Considering the topography and rainfall distribution, the territory of the Solomons can be divided into four agroclimatic regions. The characteristics of the regions are:

Region I - Strong dry season. Total annual rainfall 1,700 - 2,300 mm.

Region II - Moderate dry season. Total annual rainfall 2,300 - 3,200 mm.

Region III - Weak dry season. Total annual rainfall 2,500 - 4,300 mm.

Region IV - Always wet. Total rainfall 4,400 - 6,000 mm.

Figure 5.2 shows the agroclimatic regions, the annual rainfall distribution, the wind direction and the location of the stations considered in the analysis. The distribution of the annual rainfall for selected stations is shown in Appendix A. The mean annual rainfall is shown in Figure 5.3.

Region I is a small area on the northwest coast of Guadalcanal. This area is in the rain shadows caused by the high mountains to the south. The annual rainfall is the lowest of the archipelago; the dry season lasts 6 to 8 months from March to November.

SOLOMON ISLANDS

AGROCLIMATIC REGIONS

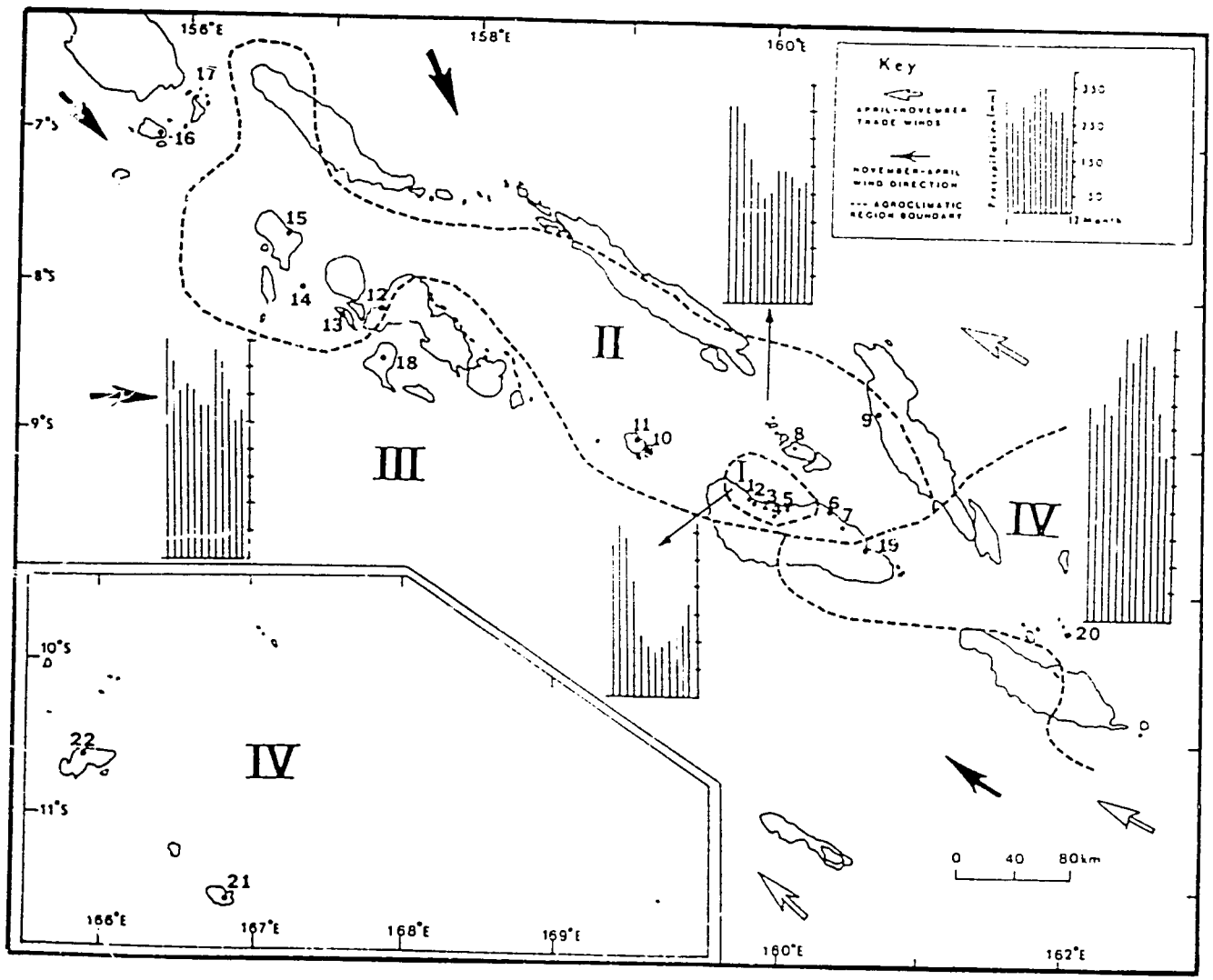


Figure 5.2. Agroclimatic Regions, Distribution of the Regional Rainfall, Wind Directions and Location of the Weather Stations Considered in the Analysis.

METEOROLOGICAL STATIONS

Region I

1. Honiara (WP,WT)
2. Honiara/Henderson (H)
3. Lungga (WP)
4. Kukum (WP)
5. Tenaru (WP)

Region II

6. Ruavatu (WP)
7. Aola (WP)
8. Tulaghi (WP,WT)
9. Auki (WP)
10. Pipisala (WP)
11. Mbanika (WP)
12. Munda (WP)
13. Kohinggo (WP)
14. Gizo (WP)
15. Vella Lavella (WP)

Region III

16. Alu (WP)
17. Mbarakoma (WP)
18. Rendova (WP)

Region IV

19. Kaoka (WP)
20. Three Sisters (WP)
21. Vanikolo (WP)
22. Santa Cruz (H)

KEY

WP = Wernstedt Mean Monthly Temperature.
WT = Wernstedt Mean Monthly Rainfall.
H = Historical Data Base.

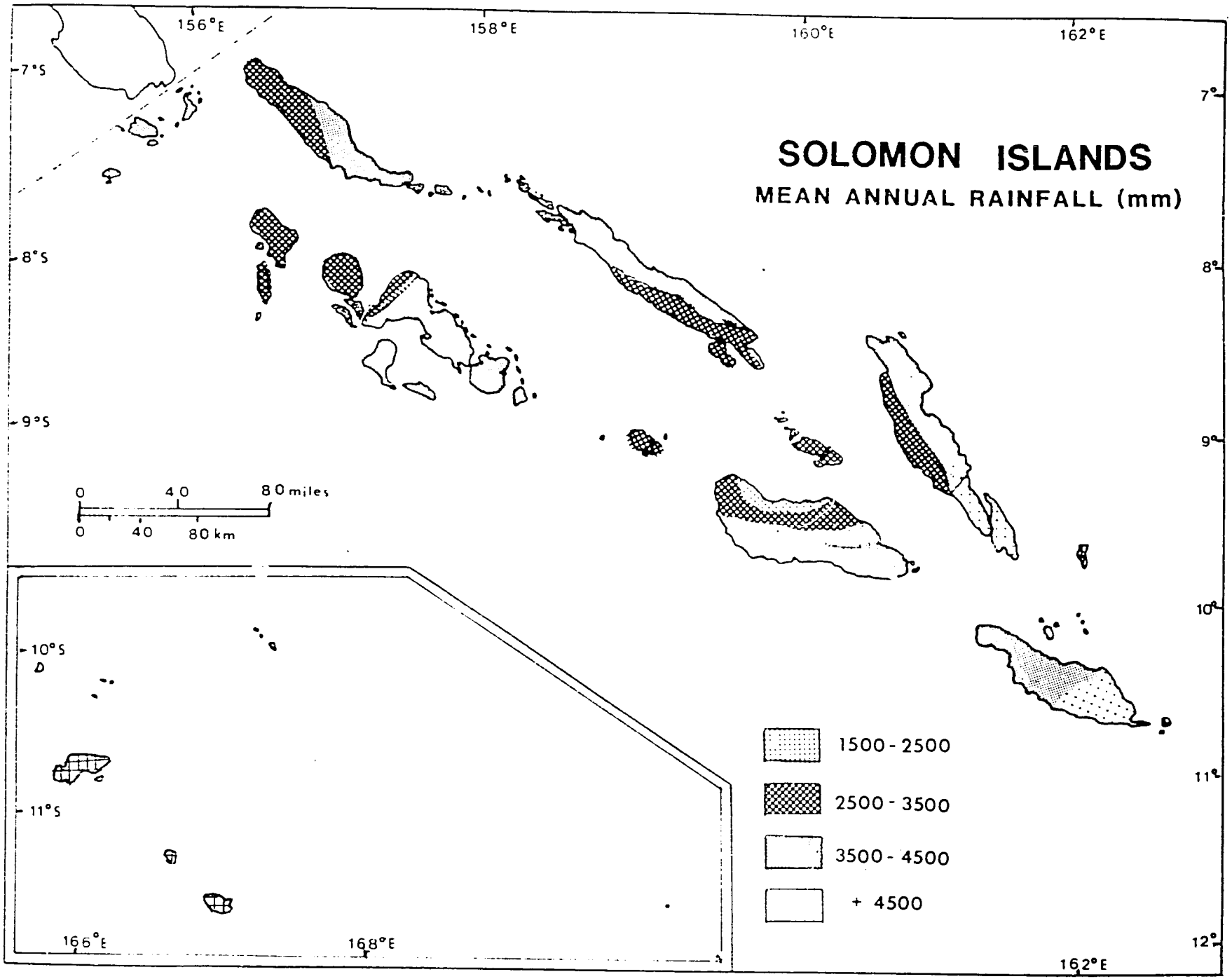


Figure 5.3. Mean Annual Rainfall in mm for Solomon Islands.

Region II occupies the central part of the double chain of the islands. The dry season lasts for 3 to 4 months from May to August-September. January, February and March are the wettest months of the year.

Region III lies at both sides of Region II. The rainfall is evenly distributed throughout the year. In some stations the wettest months are June, July and August.

Region IV is located in Malaita, San Cristobal, the whole region of the Santa Cruz Islands and the southeastern part of Guadalcanal. The rainfall is extremely high and reaches the maximum from June until September.

4. Soil and Natural Vegetation

The soils of the Solomons vary from area to area, but there are three main origins: volcanic rocks, limestone, and alluvial deposits. There are variations on these three main categories. Some of the soils of volcanic origin, particularly those southeast of Rendova (New Georgia group), are extremely fertile. Some soils, however, consist of a coating of volcanic dust over thin coral with a subsoil of clay. The two principal islands of the Russell group have hilly volcanic interiors and gently-sloping limestone terraces. The limestone soil is not very fertile; it becomes waterlogged easily on the plains, but is better on high ground.

More than 90 percent of the land area of the Solomons is covered with trees. The main categories of forest are: coastal, subdivided into beach forest and mangrove swamps; and inland forest, subdivided into lowland, foothill and mountain forest. The mountain forests are very dense, with trees that grow to more than 45 m. Casuarina is one of the best-known trees that grows in the montane forest. In coastal areas free of mangrove swamps, many beaches are relatively clear with only a few coconut palms growing in the shore area. On some beaches where the trees push thickly to the water's edge Cycas plants grow in large numbers.

B. Agricultural Practices

1. Overview

Agriculture is the mainstay of the Solomon Islands. The most valuable exports and principal products are copra, timber and cacao.

Most of the land is held by native people in the traditional kinship groups. According to customary tenure, the land is owned by the group but used by individuals who may own certain objects such as trees or houses. In addition to native customary land, there is also freehold and public land. Land tenure registration was introduced in 1963 with the result that three distinct systems of land tenure exist: the customary system, one derived from the unregistered land that at one time was sold or leased by Solomon islanders, and the land that is under registered title.

Coconut is the most important crop followed by cacao. A major agricultural development in the early 1970's was the establishment of the oil palm which has the potential to become the second major crop in the 1980's. Rice is an important crop in northern Guadalcanal; most of the production is consumed locally.

Several development plans started in the 1970's to improve overall agriculture and marketing. Research and field trial tests continue for new crops, new varieties and soil improvement at the Dala Research Station in Malaita. Research studies are also conducted by joint programs between the Department of Agriculture and private corporations such as Lever Pacific Plantations, the Commonwealth Development Corporation and Guadalcanal Plains Ltd.

The Department of Agriculture assists indigenous farmers with planting subsidies and professional advice from touring agriculture officers and field assistants.

Figure 5.4 shows the distribution of agricultural land use and major crops.

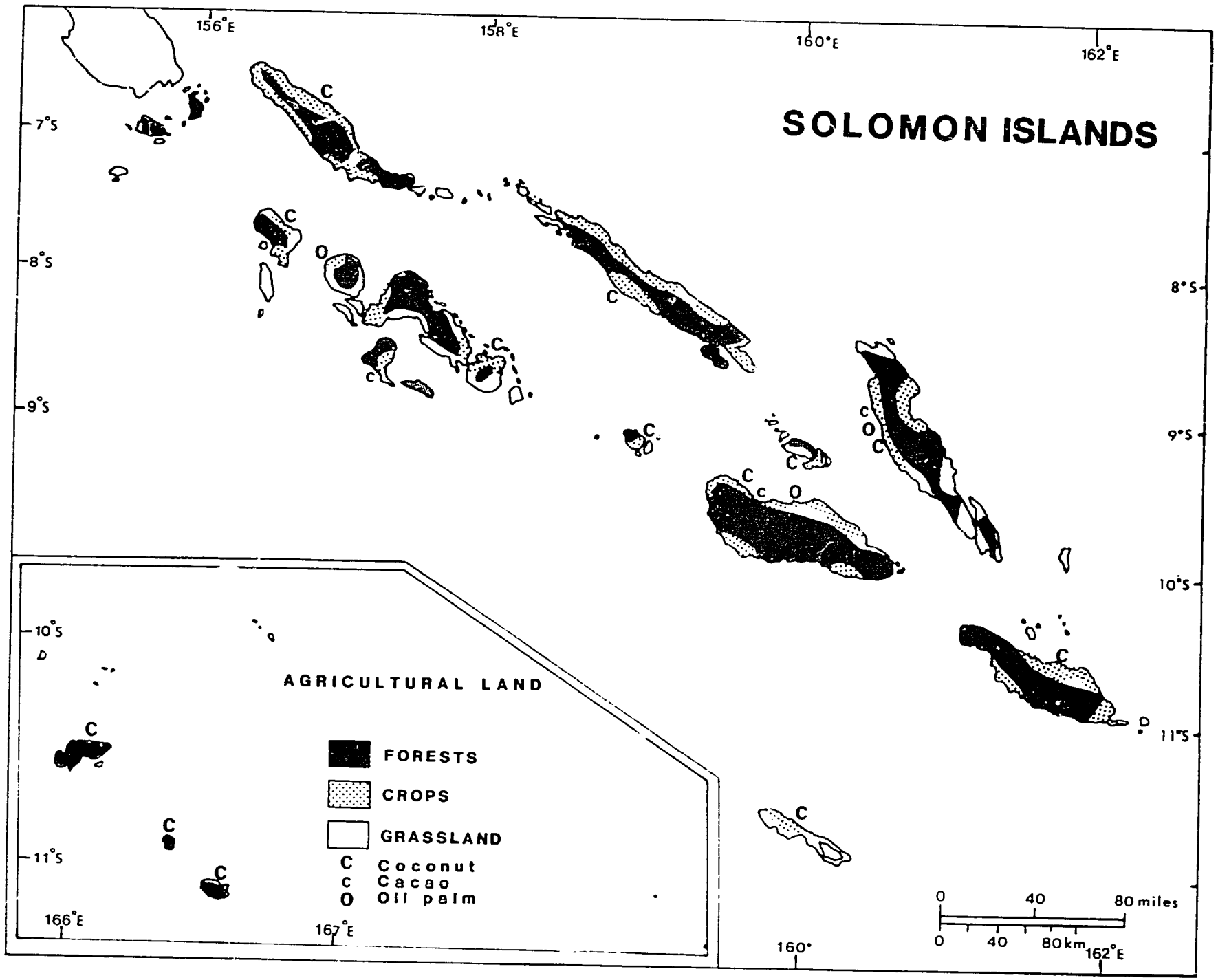


Figure 5.4. Agricultural Land Use for Solomon Islands.

2. Commercial crops

a. Coconut

The production of copra has been the most important industry of the Solomons since about 1900, when Europeans established the first plantation. Before then nearly all production was from native groves. Shortly afterwards, plantation copra became much more important. The Lever Pacific Plantations and Burns Philip Company built large-scale plantations and enterprises for growing and processing coconut into copra.

Coconut plantations are found in northern Guadalcanal, on the leeward slopes of Santa Isabel, and especially on some of the smaller islands in the New Georgia group and the Russell Islands. The early plantations were cleared of coastal forest by native laborers using axes, spades and knives. Today bulldozzers and graders do the work. Sprouting coconuts are planted in long rows. Once the trees are established, weeding is the principal activity. Some plantations are planted with tropical fodder grasses and leguminous plants so that cattle may be kept to aid in the ceaseless fight against weeds. Results obtained by introducing legumes on sandy coralline soils to overcome the serious nitrogen deficiency of these soils have been most promising.

In the Russell Islands a research program to improve planting and care of coconut plantations is in progress between Lever Pacific Plantations and the Department of Agriculture. Two experiments were begun in 1968, one to test a number of varieties and hybrids at different spacings and another to determine the long term effects of seedling selection in ordinary nurseries and use of polyethylene bags at different stages of transplanting.

Each palm tree produces 20-30 nuts a year. The fallen nuts are gathered at intervals of about six weeks and carried by bullock wagon or motor carry to the shed near driers where the copra is cut. Most plantations produce smoke-dried copra, but this is not high-grade. Some of the large plantations have

kiln-driers where the meat is dried over hot steam pipes. Kiln-dried copra brings the highest prices.

b. Cacao

Cacao is also produced on a commercial scale for export. In the 1950's extensive efforts were made to introduce cacao as a major crop. Planting began about 1958 with the encouragement of grants from the colonial development and welfare funds. Cacao is grown commercially by individual farmers and cooperatives in Malaita but the production of cacao has not been notably successful, and research has been carried on by the government to develop better plants and growing techniques. Basic investigation into cacao is carried out at Guadalcanal Plains (Guadalcanal) on Rendova Island and Dala Research Station (Malaita) where trials on shade, spacing, fertilizers and yield of different varieties are done.

Continuous investigations on the relationship between climate, yield and the incidence of black pod disease caused by the fungus Phytophthora palmivora have been conducted to control the disease. Rapid harvesting and corrective pruning have resulted in a very significant decline in losses and better yields have been achieved.

The Department of Agriculture buys and processes the cacao produced by farmers in Malaita. The cooperatives have their own fermentation and drying equipment. Total production for 1981 was 591.8 tons, more than three times the 1977 total of 162.7 tons. The 1980 total was 345.7 tons. Most of the crop is exported to Europe (Carter, 1984).

c. Oil Palm

Experiments on the cultivation of the oil palm as a commercial crop were conducted from the early 1970's. Principal plantation locations are in the islands of Kolombangara, Santa Isabel and Guadalcanal. The seeds were imported from Malaysia and the Ivory Coast. Phosphate deficiency is the major limitation in the upland soils of the islands where the planting of oil palm has been introduced. Plantings in polybags have been maintained without mechanized irrigation as a research trial on a volcanic island in the New Georgia group. The trial results show good seedling growth with almost no losses. The latest figures in production are for 1980: 14,228 tons of oil and 2,349 tons of kernels, 1981: 18,081 tons of oil and 3,163 tons of kernels (Carter, 1984).

d. Other Commercial Crops

Several spice crops have been tested at Dala Research Station in Malaita. High promise is shown by cinnamon, nutmeg, tumeric and all-spice but difficulties have been experienced with cloves and the drying of ginger.

The production of chili attracts small holders because of the intensive style of production which results in a large and rapid cash return from comparatively small acreage. High grade dried chilies, mainly the Tabasco variety, are exported every year. Chili is one of the few crops which can provide a cash income for the people living in the remote inland bush areas.

3. Food Crops

At Ilu Farm on Guadalcanal a wide range of rice varieties were introduced and tested during the middle 1960's. The principal varieties under cultivation are IR 661, IR 22, and IR 8, bred by the International Rice Research Institute in the Philippines.

Prolonged dry weather and the absence of rain at critical growth periods reduce yields of dryland rice in both the rainy and the trade wind seasons. Irrigation at mid-year has been applied to the dryland rice with the result of a clear superiority in yield per hectare. Most of the rice is purchased and consumed locally.

Other crops grown for domestic food consumption are sweet potatoes, yams, taro, cassava, bananas and plantains. The bulk of these crops are grown for marketing near district centers. In addition, pineapples, watermelons, beans, cabbage, sweetcorn and salad vegetables are sent to these markets on a minor scale.

4. Crop Calendar

In Agroclimatic Regions I and II the land is prepared for annual crops at the beginning of the rainy season. The planting starts after the first heavy rain (November or December) and continues until April. Sweet potatoes, cassava and taro are harvested after 4 to 12 months of growing from May until December. Rice is irrigated and two crops are grown each year. The main crop is planted in March-April and harvested in August-September. The secondary crop is planted in September-October and harvested in February-March.

Oil palms, bananas, plantains and coconuts are perennial crops and are harvested throughout the year.

In Agroclimatic Regions III and IV the abundant rainfall allows the growing season to be extended throughout the year, and planting can be scheduled any time. However, excessive rainfall may limit the growth of yams, cassavas and sweet potatoes. Several sources were used to estimate the crop calendar shown in Table 5.1. Further verification is needed before the crop calendar can be used in operational programs.

TABLE 5.1. ESTIMATED REGIONAL CROP CALENDAR FOR SOLOMON ISLANDS

///Planting/Sowing, ---Vegetative/Flowering, 000 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Region I and II	Rice	--- 000	000	/// 000	///	---	---	---	000	000 ///	///	---	---	Main crop irrigated. Secondary crop.
	Corn	---	-00	000	000	000						///	///	
	Sweet Potato	/// 000	///	///	///	/// 000	/// 000	000	000	000	000	000	/// 000	Highest yields occur between August and January.
	Taro	/// 000	/// 000	/// 000	/// 000	000	000	000	000	000	000	000	000	Harvested start 6 to 8 mos. after planting and continue year-round.
	Cassava	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	000	000	000	000	000	/// 000	Harvested anytime after 8 mos. of growing.
Regions I, II, III and IV	Coconut	000	000	000	000	000	000	000	000	000	000	000	000	
	Banana and Plantain	000	000	000	000	000	000	000	000	000	000	000	000	
	Oil Palm	000	000	000	000	000	000	000	000	000	000	000	000	

C. Economic Activities

The economy of the Solomon Islands has been almost entirely based on the production of copra, the timber industry and the export of canned sea products, fresh and frozen fish, turtle shells and crocodile skins.

Coconuts are the most valuable commercial crop. Cacao is also produced for export. Minor cash crop industries have been developed in recent years to provide a cash income for people living in the remote inland bush areas. Tumeric and long red and Tabasco chilies have been grown successfully. The export of spice products to Australia, New Zealand and Europe has improved in the past ten years.

The timber industry is based on the export of logs and sawn timber. The Forestry Department has developed a protective forestry policy for controlling the use and development of the country's commercially valuable timber resources. The direct timber revenue for hard-wood logs and sawn timber exports has increased during the past ten years. However, the forest and timber industry has the potential to make greater contributions to both national and rural development.

The islands are not well endowed with minerals as a source of foreign exchange or as a basis for industrial development. No mining industry of significance has developed, but the full extent of mineral resources is not known. Alluvial gold produced by panning on Guadalcanal by islanders is the only mineral output.

Fishery resources have been exploited for the internal subsistence demand and for exports. The fishing industry has three main centers at Auki, Gizo and Honiara, where the commercial operations are conducted. The exports of marine products include canned fish, turtle shells, crocodile skins, tuna-like fish, shark skin, trochus and marine shells. The canning factory continues to produce

canned skipjack, mainly for the European market. Manufacturing activities are limited to copra, cacao and fishing products for export. Small enterprises, located near population centers, mostly produce items such as furniture, concrete blocks, water tanks, and hot air driers for copra.

CHAPTER VI

TONGA

A. Physical Environment

1. Location

The Tonga Islands are located in the south Pacific Ocean between 15°30'S and 23°30'S latitude and 173° and 177°W longitude. The islands are scattered for 800 km in the ocean. The total land area is 747 square km distributed among some 150 islands, 45 of which are uninhabited.

Tonga is an independent constitutional monarchy based on the fusion of traditional chiefs' authority with British parliamentary law. The map of the islands is shown in Figure 6.1.

2. Geography and Topography

Tonga's islands are distributed in two chains that trend roughly north and south following a great submarine ridge that connects New Zealand with Samoa through the Kermadec Islands. The eastern chain consists of numerous limestone islands, formed of raised reef, some rising as much as 200 m above sea level. In contrast, the western chain is formed by a dozen volcanic peaks. The highest, Kao, rises 1,126 m above the sea in a perfect cone shape. Five of the craters are active periodically, six others have been dormant during historic times, but all are recent in the geological sense.

The territory was distributed in four principal groups of islands. From north to south the groups are: Niuatoputapu, located at approximately 16°S latitude and 174°W longitude with two islands; Vava'u group, with five major islands located between 18°-19°S latitude and 174°-175°W longitude; Ha'apai group with three major islands, 30 small coral islands and numerous islets, located at approximately 20°S latitude and between 174°-175°W longitude; and Tongatapu group with two large islands and several islets. The island of

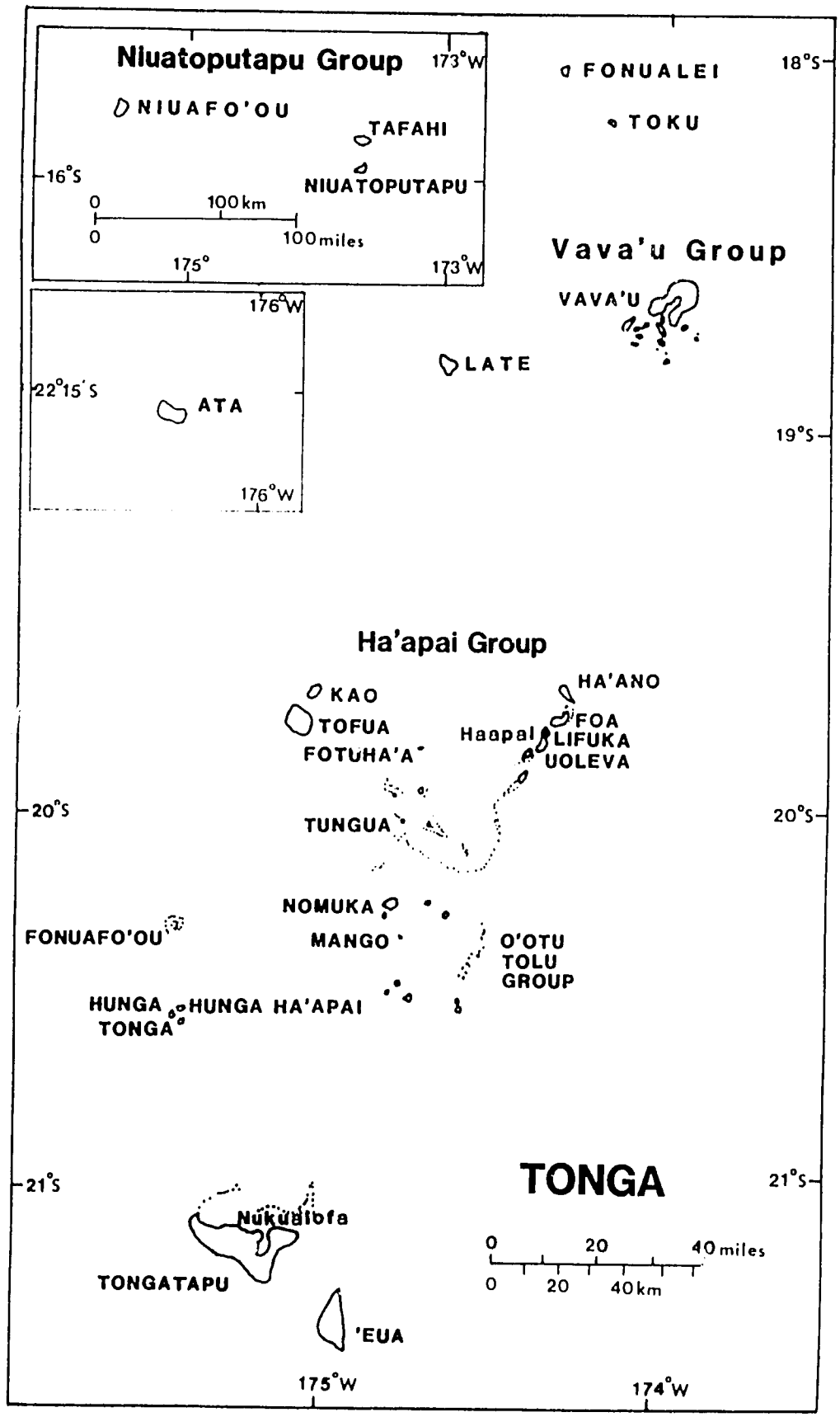


Figure 6.1. Location of Islands and Major Cities of Tonga.

Niuafo'ou located at 15°35'S latitude and 177°38'W longitude is the northern most island separate from the major group and Ata is the southernmost island, located at 22°20'S latitude and 176°12'W longitude.

Tongatapu Group

Tongatapu is located in the southern group. It is the largest island of the country with an area of 260 square km. The city of Nukualofa is the capital of Tonga and is situated on the coast of an immense lagoon on the northern side of the flat coral island. Coconuts, bananas and oranges are cultivated on the island for export.

Vava'u Group

The total area of the group is 120 square km. The island of Vava'u is the largest of the Vava'u group. The island reaches the height of 220 m. Vava'u is famous for its harbor, which is completely land-locked, its caves and for its beauty. The island of Fonualei is 64 km northward of Vava'u and is 183 m high. Late is located southwest of Vava'u. It is 557 m high and has an area of 15 square km. The island is fertile and densely wooded.

Ha'apai Group

Tofua is the largest island in the Ha'apai group. It is over 80 km long, about 6 km wide and 518 m high. Its area is 54 square km, of which over 8 square km is the lake in the crater of the active volcano Lofia.

Kao is an extinct volcano with a perfect cone shape. The summit, 1,126 m, is the highest point in the Tonga territory. The wet side is covered with forest.

The rest of the group is about 30 small islands of coral formation. Lifuka has a small port on the west side of the island and the township Haapai on the east.

Niuatoputapu Group

Tafahi or Boscawen is of volcanic origin and reaches a height of 61 m. This island was the first of the group seen by Europeans in 1616. Niuatoputapu or Keppels Island is about 10 km south of Tafahi and 240 km from Vava'u. A small anchorage is situated on the west side of the island. The main industry is the production of copra.

Other Islands

Niuafo'ou is about 6 km long and 5 km wide. The island is of volcanic origin with a long record of serious eruptions.

Ata Island is 130 km south-southwest of Tongatapu. There are two peaks. The higher is an extinct volcano 350 m high.

3. Climate

The climate of Tonga is cooler than that of most tropical oceanic islands. There are two main seasons. From May until November is the dry season, when the highest temperature rarely exceeds 27°C and the humidity is relatively low. During the dry season the winds blow from the east-southeast and the windward sides of the higher islands receive more rain than the lee sides. December until April is the rainy season; the temperatures are higher, up to 32°C and the humidity is also high. The average rainfall increases from south to north with values between 1,800 to 2,100 mm a year. The wind direction is variable and the northern islands are periodically affected by cyclonic storms.

Taking into consideration the topography and the rainfall distribution of the islands, the territory can be divided into two agroclimatic regions. The characteristics of the regions are:

Region I - Strong Dry Season. Total annual rainfall 1,700-2,000 mm.

Region II - Strong Moderate Dry Season. Total annual rainfall 2,000-2,700 mm.

Figure 6.2 shows the agroclimatic regions, the annual rainfall distribution, the wind direction and the location of the stations considered in the analysis. The distribution of the annual rainfall for selected stations is shown in Appendix A.

Region I is located in the central and southern islands group. These low coral islands of the Ha'apai group are affected by a dry period that lasts between 6-7 months from May to November. In the Tongatapu group the dry period lasts between 4-5 months.

Region II is located in the northern islands group. The total annual rainfall is 2,200 to 2,700 mm. In the Vava'u group the dry season lasts for 4 months and in Niuatoputapu group the dry season lasts for 2 to 3 months.

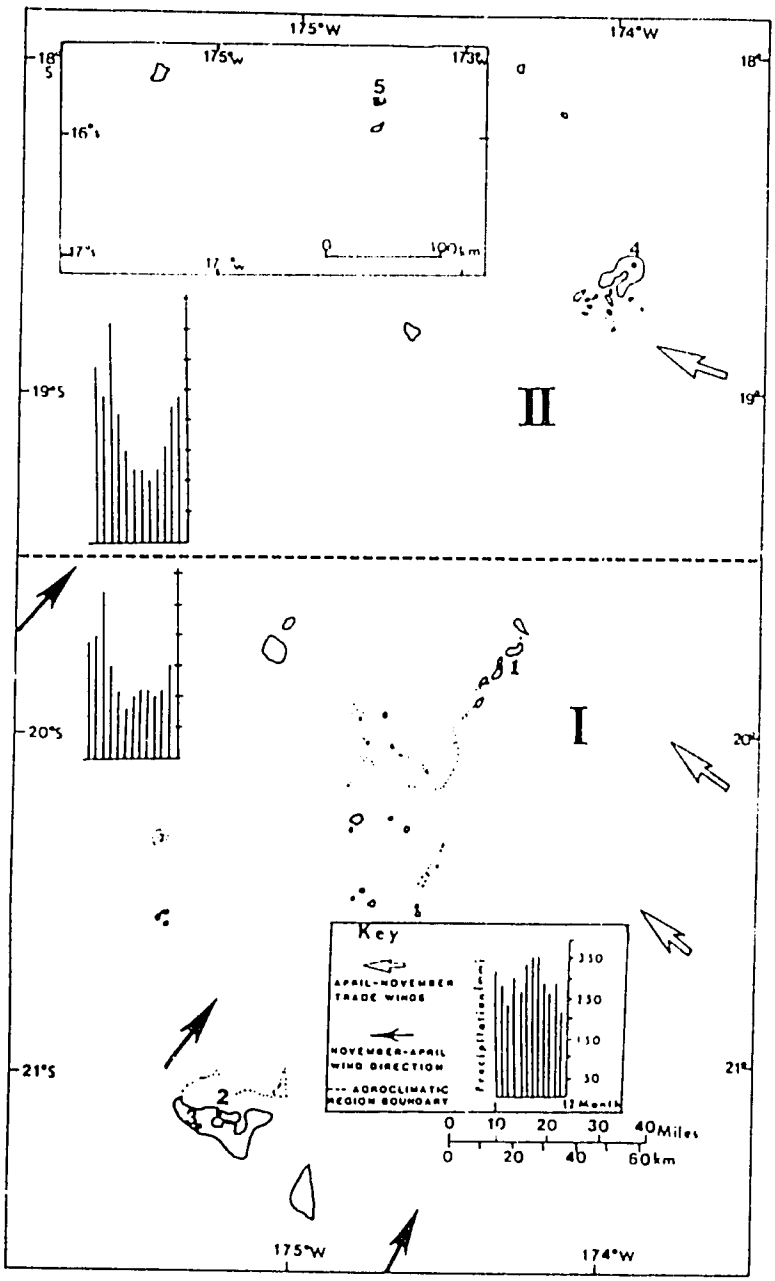
4. Soil and Natural Vegetation

The four main island groups of Tonga are of raised limestone formation. Except for the outlying high volcanic peaks of Tofua and Kao, the islands have a flat to gently undulating surface with only a few small hills or a compact and comparatively hilly surface made up of a series of terraces. The most common soil type on these islands is a fertile, friable soil, which varies in texture from loamy sand to a clay. Although most always underlain by coral limestone, the main parent material of this soil is volcanic ash which gives it a mineral fertility very much higher than usual for soils on raised limestone islands. The other main soil type is a sandy and less fertile soil found at low elevations close to the sea.

The low coral islands have grass and low herbs scattered over gray sand as a sea coast vegetation. Scrubby forest and groves of coconut palm cover the rest of the island. The high islands such as Late, Kao, Tofua and 'Eua, have a luxuriant growth of trees. The rainfall is generally sufficient for good plant growth, and almost all the arable land is under cultivation.

TONGA

AGROCLIMATIC REGIONS



METEOROLOGICAL STATIONS

Region I

1. Ha'apai (WP)
2. Fua'amotu (WMO)
3. Nukualofa (WT,H)

Region II

4. Vava'u (WP,WT,H)
5. Keppel Island (WP)

KEY

WP = Wernstedt Mean Monthly Temperature.
WT = Wernstedt Mean Monthly Rainfall.
H = Historical Data Base.

Figure 6.2. Agroclimatic Regions, Distribution of the Regional Rainfall, Wind Direction and Location of the Weather Stations Considered in the Analysis.

B. Agricultural Practices

1. Overview

The economy of Tonga is dominated by the agricultural sector which contributes over 90 percent of export earnings and accounts for more than 50 percent of the total employment.

The major cash crops are coconuts and bananas. The production of these crops for export has not increased in recent years. The main food crops are yams, taro, cassava, sweet potatoes, plantains and vegetables.

Agriculture is based on a bush fallowing system, a form of shifting cultivation in which the fallow period is shorter. The traditional cultivation method is characterized by clearing and burning the plot, cropping for two to about five years and then bush fallowing from one to ten or more years, depending on the population density of the area.

The land-tenure system of Tonga is highly distinctive compared to systems found in other parts of the Pacific Islands. Each taxpayer is entitled to an allotment of 3.2 hectares of agricultural land, as well as a small piece of land in a village or town for his house. These allotments are inheritable leaseholds from the government for a lifetime, granted to every male of 16 years and above. However, there are more taxpayers than surveyed allotments and about half of the total number of taxpayers do not hold allotments. Although it is illegal, borrowing or buying land from others is becoming a practice in many parts of the island.

In Ha'apai the agricultural system is under pressure from high population density. The cropping period is from three to five years, compared with the usual two or three croppings, while the fallow period is generally from one to three years compared with the usual three to five year period.

In some islands the agricultural system is intensified by the standard of shifting cultivation, with a cropping period/fallow period ratio of around 1:1, to support high population densities of up to about 280 inhabitants per square km.

An examination of possible areas of stress suggests the existence of some minor problems. There has been some deterioration in the fallow vegetation and an increase in the proportion of grasses and other herbaceous plants and weeds which cause a greater problem for farmers than in the past.

Figure 6.3 shows the distribution of the agricultural land use and major crops.

2. Commercial crops

a. Coconut

Production of coconut accounts for approximately 50 percent of arable land (about 36,400 hectares). The coconut palms are grown unevenly, scattered over a part of each allotment, with food-crop gardens rotated among them. Replanting schemes have been in operation for the past decade to replace a large number of coconut trees to improve production. However, the production of coconut suffered great losses due to the rhinoceros beetle in Ha'apai, Tongatapu and Vava'u. Also, variable weather conditions have caused production to fluctuate. The production of desiccated coconut and operation of plants that started in the mid-1960's continued in the 1970's. After a high of 18,400 tons in 1975, copra exports dropped to 12,000 tons in 1977. Tonga ceased to export copra in November 1978. Since then coconut oil has been manufactured for export (Carter, 1984). There are other by-products from coconut, such as coconut fiber which is processed into brushes and sold in domestic markets.

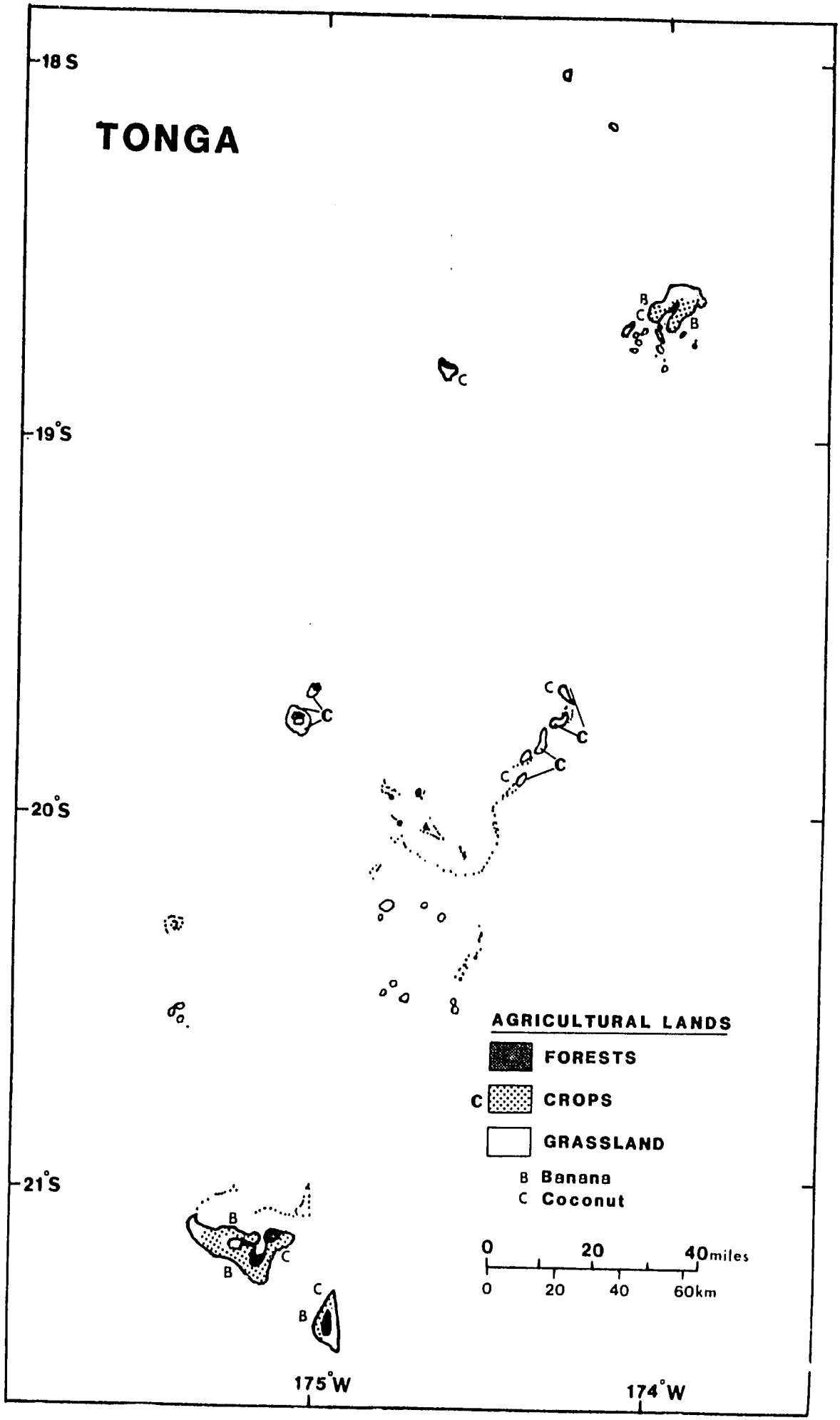


Figure 6.3. Agricultural Land Use for Major Islands of Tonga.

b. Banana

Bananas are the second cash crop of the country, produced on a commercial scale for export. The production of bananas is a part of the cropping sequence which yields for only a few years. They have been increasingly grown in separate plantations. Chemical fertilizers are now being used to improve yield and to extend the life of the plot. However, despite government extension services and subsidiary programs to rehabilitate crops damaged by hurricanes and diseases, the growth in banana production has been slow. The factors contributing to the slow growth in production are: unfavorable weather, irregular shipping and growing competition from other supply sources.

c. Other Commercial Crops

Minor cash crops such as vanilla beans, peanuts and watermelons have been introduced in recent years. Vanilla beans are considered to be the third largest export product.

3. Food Crops

Staple crops include taro, yams, sweet potatoes, fruits and vegetables The food-crop pattern has changed with the increase in population density. In areas of high density, cassava has become the staple food crop while yams, the most preferred tuber for eating, are now much less frequently grown. Cassava yields even on heavily cropped soils, does not require a lengthy fallow and yields more per man-hour of labor than the other food crops.

4. Crop Calendar

Most of the crops are sown or planted during the rainy season, November to March. However, the planting of yams begins in April and lasts until August because the rainfall during that period provides enough water for crop needs. Yams are harvested 8 to 10 months after planting. Pineapples are planted during the dry season from June to July and harvested after one year of growing.

Cassava, taro and sweet potatoes are cultivated in all agroclimatic regions and are harvested year-round. Cassava is harvested 9 to 12 months after planting, taro after 6 to 8 months, and sweet potatoes 4 to 6 months. Taro is less resistant to drought than cassava or sweet potatoes. In 1983 taro production was reduced by 50 percent in Tongatapu and by 80 percent in Ha'apai due to drought occurrence (Todorov, personal communication).

Maize is sown from November to December and harvested between March and April. Bananas and plantains are harvested after a growing period of 12 to 15 months. Coconuts and papayas are perennial crops and the fruits are harvested year-round. Breadfruit, also a perennial crop, has a major harvest period from November to April. Several sources were used to estimate the crop calendar shown in Table 6.1. Further verification is needed before the crop calendar can be used in operational programs.

C. Economic Activities

The economy of Tonga is based on two major export commodities, coconut products and bananas. This leaves the economy vulnerable to the effects of weather conditions and world market changes. Some export diversification was introduced with small quantities of vanilla beans, pineapples, watermelons, and garden vegetables that are exported to supplement income.

Symptoms of stress as a result of population pressure were found in land problems, fallow vegetation, the nutrient status of the soil, cash-crop income and internal migration, particularly in Ha'apai. These problems, however, are as much a result of the failure to adopt the mainland system as coping with rising population densities rather than population growth alone.

Industries include coconut oil mills, plants for desiccated coconut, extracting fruit juices and cement-blocks, and saw mills producing lumber for local building.

TABLE 6.1. ESTIMATED REGIONAL CROP CALENDAR FOR TONGA

///Planting/Sowing, ---Vegetative/Flowering, 000 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Region I, II and III	Maize	---	---	000	000							///	///	
	Yams	---	---	---	///	///	///	///	///	---	---	---	---	Growing period is between 8-10 mos. Harvested all year-round.
	Cassava	/// 000	/// 000	/// 000	--- 000	--- 000	--- 000	--- 000	--- 000	--- 000	--- 000	/// 000	/// 000	The root tubers are harvested upon needs between 9 to 12 mos. after planting.
	Taro	/// 000	/// 000	/// 000	--- 000	--- 000	--- 000	--- 000	--- 000	--- 000	--- 000	/// 000	/// 000	Taro is harvested between 6 to 8 mos. after planting.
	Sweet Potato	/// 000	/// 000	/// 000	--- 000	--- 000	--- 000	--- 000	--- 000	---	---	/// 000	/// 000	Harvest starts 4 to 5 mos. after planting
	Pineapple	---	---	---	---	---	/// 000	/// 000	--- 000	--- 000	--- 000	--- 000	--- 000	Unripe fruits are harvested after 12 mos. of planting.
	Banana and Plantain	000	000	000	000	000	000	000	000	000	000	000	000	Harvest takes place 15 mos. after planting.
	Coconut	000	000	000	000	000	000	000	000	000	000	000	000	
	Papaya	000	000	000	000	000	000	000	000	000	000	000	000	

The country does not have sufficient timber of usable quality to fill all construction needs, consequently lumber must be imported. Forest lands are almost entirely owned by the crown.

The fishing industry provides an important supplement to the food supply for local consumption, but is not large enough to fill the domestic demand. Development of the fishing industry has been assisted by UN agencies, Australia, Japan and other financing projects to provide suitable, motorized, insulated sea fishing boats and cold storage facilities. In 1982, 176 tons of albacore tuna were exported (Carter, 1984).

No important mineral resources are known to exist on the islands. The use of electric power is somewhat limited because energy sources do not exist domestically for power generation and there are no sites for hydroelectric power stations. In the 1970's the tourism industry became an important source of income, but still has to be developed.

The main economic problems are the heavy dependence on primary agricultural products directed toward a fixed market and growing dependence on external aid. Tonga is plagued by an unfavorable ratio of land to man, a system of land-holding that inhibits efficient use and a lack of employment opportunities. No major changes are expected in the near future.

CHAPTER VII

VANUATU

A. Physical Environment

1. Location

The Vanuatu Archipelago, including the Banks and Torres Islands, is located northeast of New Caledonia and southeast of the Solomon Islands in the southwest Pacific Ocean. The archipelago forms an incomplete double chain of islands in the form of a Y, stretching northwest to southeast for 885 km. The group lies between 12°S and 20°S latitude and 165°E and 170°E longitude. The area of Vanuatu proper is estimated at 1,500 square km, comprised of 12 major islands, 18 lesser islands, and between 30 and 40 small islands and islets. The islands were given Spanish, French and English names and most of them appear in maps and books under different names.

Vanuatu (formerly New Hebrides) is an independent republic member of the British Commonwealth. A map of the islands is shown in Figure 7.1.

2. Geography and Topography

The origin of the islands is volcanic. Several active volcanoes are in the group. The principal volcanoes are situated on the islands of Tanna, Lopevi and Ambrym. The continued uplift since the Miocene period and coral reef formations have contributed substantially to the size of most islands. Some islands such as Aniwa are of atoll formation. The larger islands are high and show extensive exposures of volcanic rocks. The smaller islands are often wholly volcanic.

The largest are Espiritu Santo, with an area of about 3,900 square km and Malakula, with 1,160 square km. Other large islands are, from North to South: Vanua Lava (Vannua Lava) and Gaua (Lakon) in the Banks group; Maewo and Ambae in the Santo region; Pentecost, Ambrym and Epi in the Malakula region; and Efate,

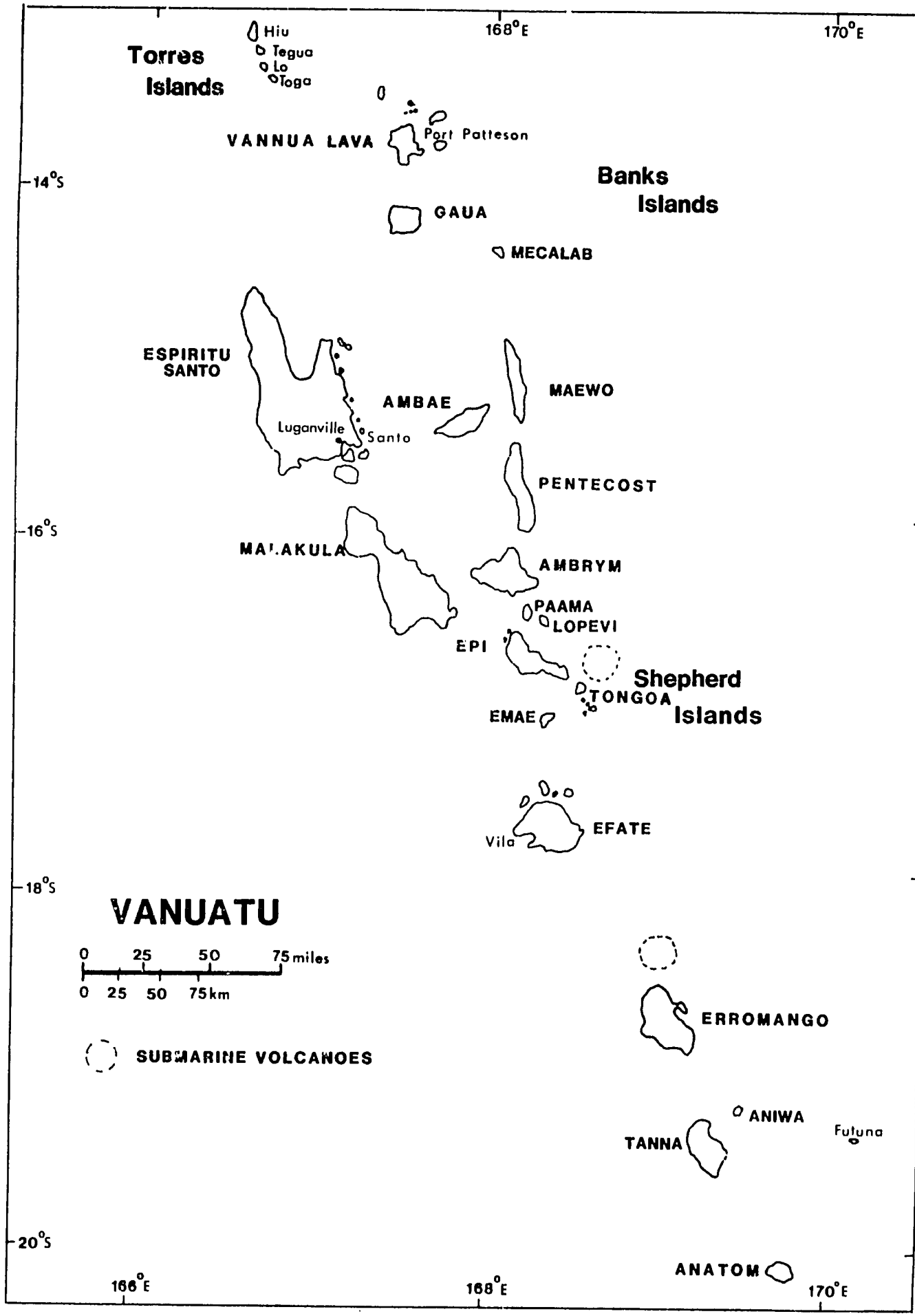


Figure 7.1. Location of Islands and Major Cities of Vanuatu.

Erromango, Tanna and Anatom (Aneytioum) in the Tanna region. There are several smaller islands and islets of little importance.

Espiritu Santo (Santo, Marina)

Espiritu Santo consists of two widely different regions. The eastern half of the island is a plateau with a general elevation of 90 to 180 m culminating in Mt. Turi, 528 m. The western half of the islands is mountainous, rising to 1,669 m at Mt. Santo and 1,858 m at Mt. Talwesmasana. The western side is heavily wooded and has a well developed drainage system. Santo contains numerous small rivers, navigable only by minor crafts. The largest river is the Yora. The forest has openings of arable land on the central and coastal zones and patches of meadows in the southeast. The plantations are in the coastal areas.

Malakula (Malekula, Malekoula, Mallikolo)

Malakula, the second largest island in the group, is about 74 km long and 37 km wide. It is formed by limestone, penetrated in some districts by lava. The surface is hilly. The highest peak is Mt. Penot at 877 m. The coral terraces in the North are thickly covered with cane grass, but the vegetation is dense with forest everywhere. However, there is arable land in the East, North and extreme South of the island. The major plantations are on the east side of the coastal zone.

Erromango (Eromango, Eromango)

The largest of the southern islands, 56.33 km by 40.23 km, it is composed mainly of lava and volcanic agglomerates with terraces of raised coral in the lowlands. The interior is mountainous. The island is fertile but under-developed because of the lack of good harbors. Virgin forest covers almost all of the island. Rough grazing land is present only at high altitudes.

Efate (Vaten)

Efate is of volcanic origin, but is almost completely encrusted with coral limestone. The rivers have eroded the volcanic rock and deposited alluvial materials in the lower reaches to form alluvial flats. The highest peaks in the Northwestern coastal mountains crest at 660 m. The southern part of the islands is a plateau 60 to 90 m high, interspersed with coral ridges. The whole island is densely wooded except for a clear zone in the Northwest and a peninsula mostly covered with grass in the southwest. Small areas on the coastal zone have arable land and plantations. Vila is the port of entry and administrative and commercial center of the group.

Ambrym (Ambrim)

The island is 38.6 km long by 96.5 km wide. The active volcano, Mt. Minnei, dominates the landscape. Its eruption in December 1913, accompanied by a great earthquake destroyed numerous coconut plantations. The eastern slopes are covered with dense forest. The arable land and plantations are restricted to the coastal zone of the island.

Pentecost (Pentecote, Aragh, Aragh-Aragh)

The island is 45.06 km long and 12.07 km wide. There is a central range, numerous fertile valleys and many permanent streams on the western side, where the plantations and arable land are located.

Maewo (Aurora, Maevo)

Maewo is 46.67 km long and 6.44 km wide. It has a lofty central range which probably accounts for the fact that it has the largest rainfall in the group. The island is well-wooded and fertile with numerous streams. The general wetness and numerous swamps have not attracted European settlers. However, some plantations have been established on the western side of the island.

Tanna (Tana)

Tanna is 51.50 km long by 24.14 km across. It is probably the most fertile and attractive island in the group. There are various ranges; the highest rises to 1,020 m at Mount Melen. Tanna is exceedingly well-watered, well-wooded and also well-served by a system of excellent roads, one of which traverses the entire island. Its southerly position gives it a pleasant climate.

Epi

Epi is a very fertile, well-watered island about 43.45 km long and 17.7 km wide. It is mountainous; the highest peak is 810 m. This island has some of the finest plantations of the group.

Anatom (Aneityum, Aneytioum, Aneytum)

Anatom, 56.33 km in circumference, is the most southerly of the group. The mountains rise to 900 m. The valley and the flat lands are fertile and all forms of tropical and subtropical fruit and vegetables grow luxuriantly. The climate is quite suitable for Europeans; it was once a favorite resort for whalers and sandalwood gatherers.

Other Islands

The Banks Islands consist of a scattered group lying 80.47 km northeast of the main island group. In this group the vegetation is luxuriant, the rainfall abundant and soil fertile. The chief island, Vanua Lava (Vannua Lava), is about 24.14 km long and 19.31 km wide. There is a volcano, Mt. Suretematai, still active on this island. Extensive deposits of sulphur cover part of the island; a French company at one time worked the deposits. Port Patteson is an excellent harbour. The eastern most peninsula is occupied by plantations.

Gaua (Lakon) is very broken. There are two peaks of considerable height in the North; Mt. Gharat is an active volcano. Between them a lake, about 6.44 km long, occupies the bed of an ancient crater. Mota (Mota Lava), one of the smallest islands in the group, has a high population density of about 25 persons per square km.

The Torres Islands consist of a chain of small islets (Hiu, Tegua, Lo and Toga) which lie to the northwest of the Banks Islands. The tropical climate with high temperatures and high rainfall has not attracted European settlers. The natives are Polynesians. The islands have been seriously depopulated. Other small islands are: Aore and Malo, south of Espiritu Santo; Paama and Lopevi located between Ambrym and Epi; the Shepherd Islands, Tongoa, Emae and Mataso, south of Epi; and Aniwa and Futuna, east of Tanna.

3. Climate

Vanuatu clearly lies within the tropical climate zone in the North to a subtropical regimen in the South. World scale classifications such as the Koppen and Thornthwaite are insufficient to give much detail about the variations of climate between different parts of the archipelago. The islands lie in the region of the southeast trades. The average annual rainfall ranges from above 3,937 mm in the North to 2,286 mm in the South. The highest temperatures recorded anywhere in the group are around 32°C. At Vila (which may be regarded as the central point) temperatures vary from 28°C to 30°C; the average minimum temperature ranges from 21°C to 23°C. The average year-round humidity is about 83 percent.

The principal characteristic of the lowlands is thermal uniformity over vast areas. The variation of monthly mean temperature at low latitudes in the northern island is negligible. The greatest temperature variations are always encountered between night and day.

The year is divided into two seasons which are less distinct in the northern part of the group. In the winter or dry season from May to October, the Southeast trade winds cause cooler sunny days. The average maximum temperatures vary from 28°C in the North to 24°C in the South, and the average minimum temperatures from 22°C in the North to 18°C in the South. During this period the rain is often associated with troughs in the upper westerlies (anti-trades). At Vila the humidity rate drops to about 75 percent in drier months. The summer or wet season from November to April is the tropical cyclone or hurricane season. The average maximum temperatures in the North vary around 30°C and in the south 28°C. The average minimum temperatures during the summer season in the North are around 23°C and in the South 22°C. At Vila the humidity rate rises to about 88 percent in the wet season.

Taking into consideration the topography and rainfall distribution during the year, the territory of Vanuatu can be divided into three agroclimatic regions. The characteristics of the regions are:

Region I: Strong dry season. Total annual rainfall 1,500-2,200 mm.

Region II: Moderate dry season.

IIa: Total annual rainfall 2,200-2,900 mm.

IIb: Total annual rainfall 2,900-3,500 mm.

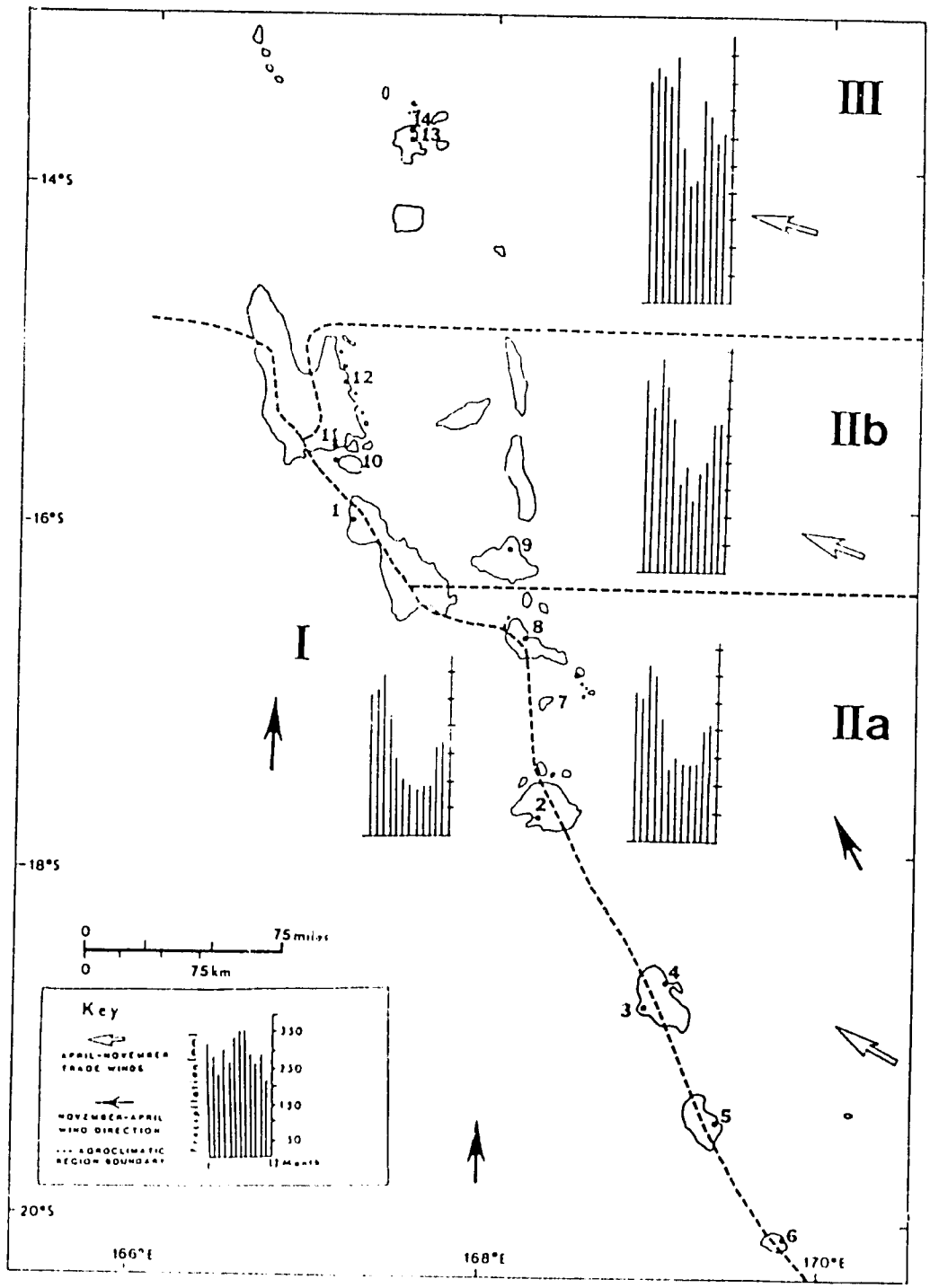
Region III: Weak dry season. Total annual rainfall more than 3,500 mm.

Figure 7.2 shows the agroclimatic regions, the annual rainfall distribution, the wind direction and the location of the stations considered in the analysis. The distribution of the annual rainfall for selected stations is shown in Appendix A. The mean annual rainfall is shown in Figure 7.3.

Region I is located on the west side of the islands. The dry season lasts for seven months, from May until October. The rainy season starts in November and ends in May.

VANUATU

AGROCLIMATIC REGIONS



METEOROLOGICAL STATIONS

Region I

1. Atchin Island (WP)
2. Vila (WP,WT,H)
3. Dillon Bay (WP)

Region IIa

4. Erromango (WP)
5. White Sands (WP)
6. Aneityum (WP,WT,H)
7. Tongoa (WP)
8. Epi (WP)

Region IIb

9. Ambrym (WP)
10. Tangoa (WP)
11. Luganville (WP,WT,H)
12. Santo East (WP)

Region III

13. Port Patteson (WP,WT)
14. Sola (H)

KEY

WP = Wernstedt Mean Monthly Temperature.
WT = Wernstedt Mean Monthly Rainfall.
H = Historical Data Base.

Figure 7.2. Agroclimatic Regions, Distribution of the Regional Rainfall, Wind Direction and Location of the Weather Stations Considered in the Analysis.

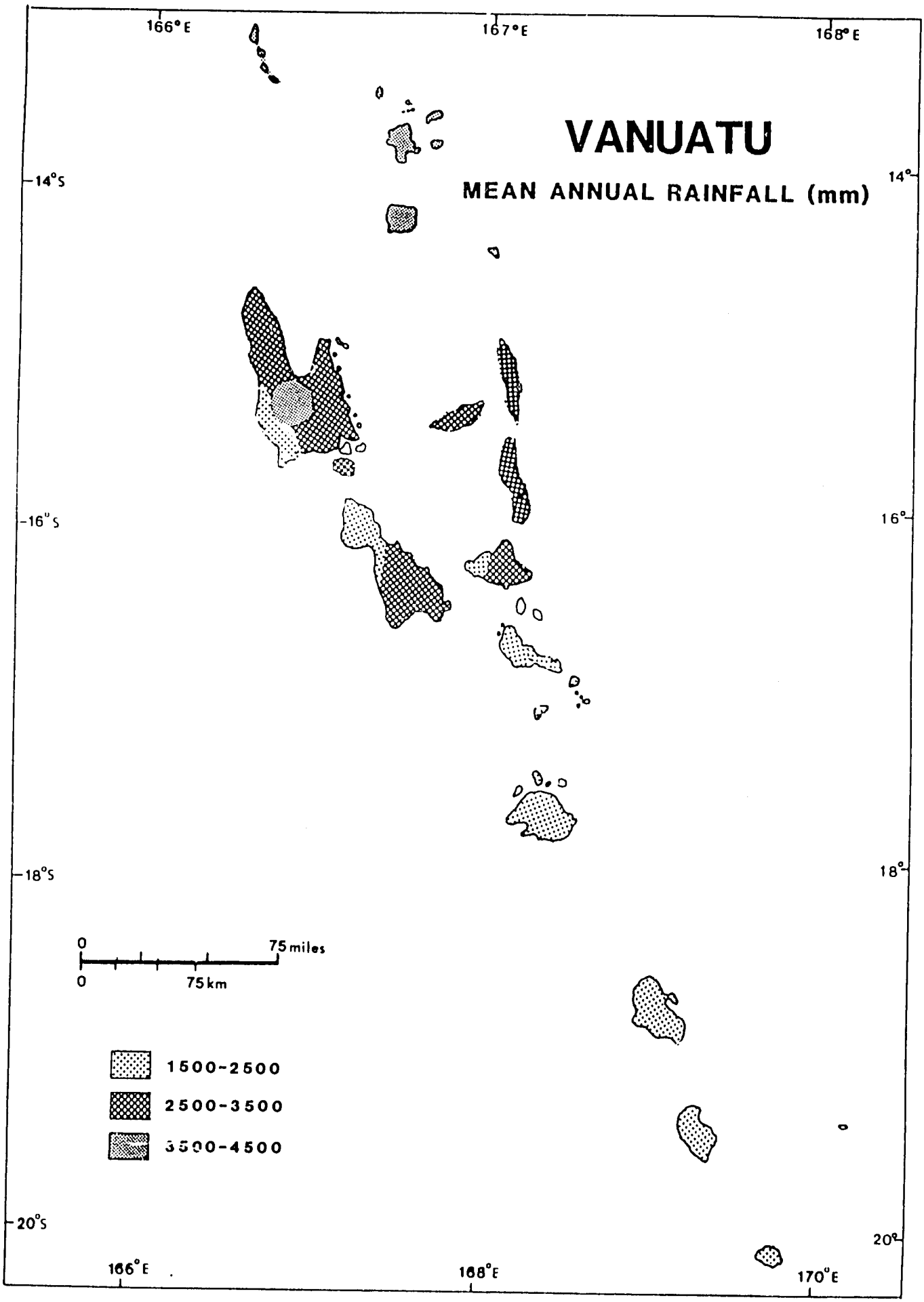


Figure 7.3. Mean Annual Rainfall in mm for Vanuatu.

Region II lies on the east side of the island. The dry season lasts for five months from June to October. The rainy season starts in December and ends in May. Region IIa and IIb differ in the total amount of rainfall during the year more than in the rainfali distribution.

Region III occupies the northern islands and the central region of Santo. The rainfall is more moderate throughout the year and there is no clear dry season.

4. Soil and Natural Vegetation

The New Hebrides Islands generally have fertile soil developed from volcanic material. Most of the islands have sediments in which limestone is prominent. The soil in Erromango is composed mainly of lava and volcanic agglomerates with terraces of raised coral located on the lowlands. In islands where rivers have eroded the volcanic rock, deposits of alluvial materials are found in the lower lands and alluvial flats. The fertile soil, the abundant rainfall and warm temperatures favor the growth of a heavy forest. The only breaks in the forest are villages, gardens, patches of grassland and abandoned clearings. The flora include trees of useful timber such as kauri pine (Agathis obtusa), tamanu (Calophyllum neo-ebudicum) and species of the valuable sandalwood. Savannah grasslands are found in some porous coral terraces.

B. Agricultural Practices

1. Overview

Agriculture is the main sector of the Vanuatu economy. Because of the mountainous, forest-covered nature of the land, cultivation is generally restricted to the coastal plains and the low plateau. In some relatively populous small islands, cultivation is necessarily more intensive and the available land is insufficient for cash crops.

The traditional system of subsistence agriculture is based on shifting cultivation with a long-term rotation of ten to fifteen years. In the more advanced coastal villages where cash crops have been introduced, fixed cultivation with a rotation of three to five years is now often practiced for food crops. The most important commercial crops in Vanuatu are coconut, cacao, coffee and rubber. Cacao and coffee are not as well-suited for cultivation on the coastal soils as coconut palms. These crops were mainly cultivated by European planters before World War II. The Agricultural Department has attempted to encourage native production of these crops but with only moderate success. The major food crops are: yams, taro, sweet potatoes, manioc, corn, bananas, breadfruit, citrus, mangoes and pawpaws. The first two are the staple food stuffs. Figure 7.4 shows the distribution of agricultural land use and major crops.

2. Commercial Crops

a. Coconut

Conditions in Vanuatu are particularly favorable to cultivation of the coconut palm. The temperature range and the rainfall are suitable for coconuts even on the southernmost island of Anatom.

The plantations are concentrated on coastal plains because the light soil on a coral base provides the good drainage that coconut requires. The total area under cultivation is 69,000 ha (Carter, 1984). The major center of production are the central and northern islands, particularly, Espiritu Santo, Malakula and Ambrym.

On Espiritu Santo there is a coconut research station engaged in a long-term program to improve the yield of coconut plantations in Vanuatu. The station also studies the wind tolerance of 18 coconut varieties and hybrids and nitrogen deficiencies of soil. Several species of legumes were introduced with the dual

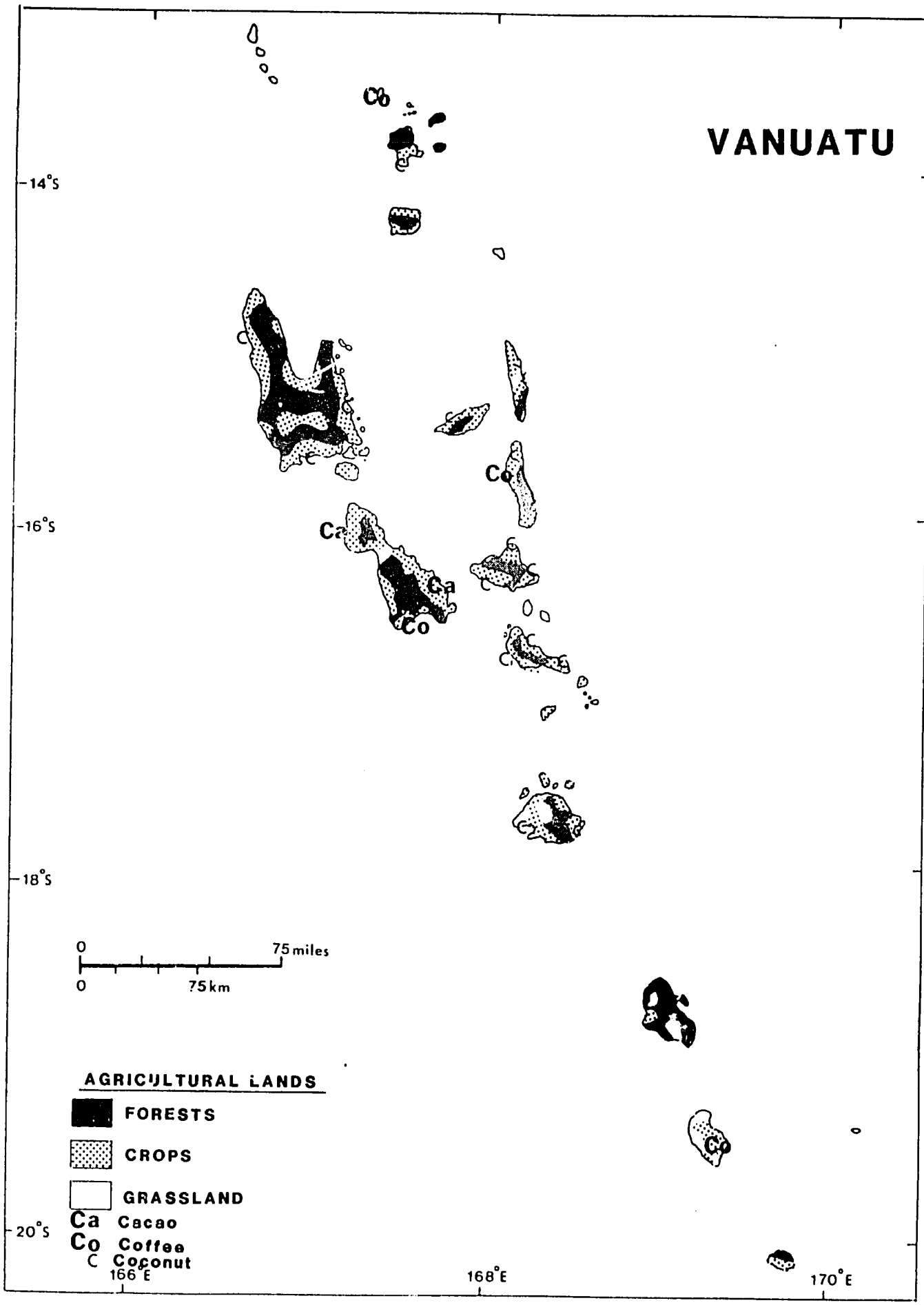


Figure 7.4. Agricultural Land Use for Vanuatu.

purpose of increasing the nitrogen content of the soil and producing better grazing conditions for the cattle.

The copra of Vanuatu is generally of a lower quality than that produced elsewhere. Efforts have been made to improve the quality of the smoke-dried copra and to introduce the use of other techniques such as hot air-drying. Insect damage on coconut plantations is listed in Appendix B.

b. Cacao

Cacao is the second most important cash crop in Vanuatu. It was introduced in the Vanuatu archipelago at the beginning of the century. By 1910 there were already 240 hectares on 30 plantations. Since World War II, cacao production has fallen to only about 15 percent of pre-war levels. The rising production costs forced the planters to abandon production.

Cooler temperatures and low soil fertility characterize the ecological environment for cacao in Vanuatu. Under these conditions yield averages only 0.22 ton/ha; however, the cocoa is of high quality.

c. Coffee

Coffee is the third most important cash crop but there has been no significant increase in production over the last few years. Like cacao, coffee was planted with or under coconut on some 25 plantations.

In 1962 the Agricultural Department began to encourage coffee growing in the middle bush area on Tanna, which was considered to be well-suited to the cultivation of the Arabica variety. From 1962 to 1971 about 50 hectares of land owned by natives was planted. In 1970, 91 tons of coffee beans were exported, but since that peak year the production and exports have declined.

3. Food Crops

The cultivation of vegetables for sale in the domestic market is restricted to the coastal plains near the villages. The production and distribution of subsistence foods is a major economic activity. All households have access to one or more gardens located varying distances from the village. Women are normally the garden workers.

Root and tuber crops grown for domestic market are: yams, taro, sweet potatoes and manioc. The first two are the staple food stuffs. Fruit tree crops include: banana, breadfruit, citrus, mango and pawpaw. Other crops for consumption are corn, pineapple and vegetables such as tomatoes, cabbage and watercress.

4. Crop Calendar

Root and tuber crops have two planting seasons in Agroclimatic Regions I, IIa and IIb. Sweet potatoes, taro, and cassava are planted during the rainy season (November-April). Harvesting takes place 3 to 5 months after planting for sweet potatoes, after 6 months for taro, and after 9 months for cassava. The land preparation for yam planting starts in July or August. Planting is usually spread over 3 to 4 months, between August and December. The tubers take between 7 to 9 months to mature and harvesting begins in March. The harvesting of all root and tuber crops usually extends throughout the year. The general practice is to leave the tuber in the ground until it is needed.

In Agroclimtic Regions I, IIa and IIb maize is sown from November until January and in Agroclimatic Region III the sowing starts during February-March to avoid heavy rains during the last stage of maturity. The harvesting begins 3 months after sowing for sweet corn and after 4 to 5 months for grain corn.

Coconut and banans or plantains are perennial crops harvested year-round.

Breadfruit and citrus fruit are seasonal perennial crops and crop calendar information is not available.

Several sources were used to estimate the crop calendar shown in Table 7.1. Further verification is needed before the crop calendar can be used in operational programs.

C. Economic Activities

The economy of the islands that make up the Vanuatu nation has been almost entirely based on agriculture. Small contributions are made by forestry, deep-sea fishing and mining. The major cash crops are coconuts, cocoa and coffee. The production and quality of the crops are low in relation to the quality elsewhere. In recent years great efforts have been made to improve the quality of the copra for export.

The forests on the islands of Erromango, Anatom and Efate have timber of commercial value. Exploitation is partially impeded by lack of transportation facilities, and only minor quantities have been exploited for domestic and external use. Deep-sea fishing is carried on in adjacent waters. The catch, mostly tuna, is frozen and exported to the United States, France and Japan by the South Pacific Fishing Company which has American, British, French and Japanese capital. Manganese adds to the known resources of the islands. The deposit occurs at Forari on the east coast of Efate.

Cattle are raised for grazing on coconut plantations to add to the domestic food supply and for meat processing for export although domestic demand is absorbing an increasing amount of the available supply.

There is very little manufacturing and that which does exist is directed toward the home market. There is also a small meat-canning plant that produces good beef in aspic and corned beef for sale domestically and for export, mostly to New Caledonia. Few native handicrafts that can be sold abroad are produced in the islands.

TABLE 7.1. ESTIMATED REGIONAL CROP CALENDAR FOR VANUATU

///Planting/Sowing, ---Vegetative/Flowering, 000 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Region I, IIa & IIb	Yams	---	---	000	000	000	000	000	/// 000	/// 000	/// 000	///	///	
	Taro	/// 000	/// 000	/// 000	000	000	000	000	000	000	000	/// 000	/// 000	The harvest starts 6 mos after plant- and continues year-round.
	Cassava (Manioc)	/// 000	/// 000	/// 000	/// 000	000	000	000	000	000	000	/// 000	/// 000	The root tuber is ready for harvest after 9 mos.
	Sweet Potato	/// 000	/// 000	/// 000	/// 000	000	000	000	000	000	000	/// 000	/// 000	Harvesting take 5 place from 3 to 5 mos. after planting.
	Maize (Corn)	///	---	000	000	000						///	///	
Region I, IIa, IIb & III	Coconut	000	000	000	000	000	000	000	000	000	000	000	000	Commercial production is concentrated in Northern and Central islands.
	Banana or Plantain	000	000	000	000	000	000	000	000	000	000	000	000	
Region III	Maize		///	///	---	---	000	000						
	Taro	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	
	Cassava	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	
	Sweet Potato	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	/// 000	

CHAPTER VIII

POTENTIAL ENVIRONMENTAL HAZARDS

A. Overview

The island countries and territories of the Pacific region represent some of the most ecologically vulnerable nations in the world. Most of the islands lie within the seismic region of the Pacific Basin. Tremors and earthquakes are frequent, especially along the Tonga trench and throughout Melanesia. Strong earthquakes are sometimes accompanied by tsunamis.

The high islands of the area have active or potentially active volcanoes. Fiji, Vanuatu and Tonga lie within the hurricane zone and are affected by an average of 2 to 3 storms a year. The Gilbert Islands (Kiribati) and many islands of other countries are made up of coral atolls with irregular rainfall and are thus subject to drought. For example part of Kiribati, Fiji and Tonga experience droughts from time to time. Nauru suffers from a state of perpetual drought and has to import water.

Pacific Islands are vulnerable to natural disasters that affect not only the ecological balance but also the economic well-being. Lives lost, homes and buildings destroyed, crop loss, infrastructure damage, and environmental effects produce an unfavorable impact on the economy. A detailed listing of historical episodic events by island groups is shown in Appendix B.

Natural disasters can be divided into three main events: terrestrial, including volcanic eruptions and earthquakes; atmospheric, including typhoons (hurricanes), tropical storms, and climatic extremes such as drought; and oceanic, including tsunamis and associated storm surges.

B. Terrestrial Events

1. Volcanic Eruptions

The great majority of the volcanos in Melanesia are of the explosive type yielding very little lava but great quantities of ash. The outstanding exception is Mt. Benbow on Ambrym (Vanuatu) which erupts balsaltic lava from flank fissures. The immediate consequences of ash falls are serious destruction of crops and trees. If heavy and prolonged they may bring about the temporary evacuation of the area, as has happened several times in the last 100 years. Except where falls are very heavy and frequent, the recent ash is often of high fertility and enriches the soil of surrounding areas.

Vanuatu has several craters on the list of active volcanos of the world. They include: Karua and Epi (submarine); 2 volcanoes on Ambrym which produce showers of ash occasionally, accompanied by lava; Yasur on Tanna Island producing periodic ash showers; Lopevi and Hunter which have erupted intermittently; four centers of submarine activity on the east coast of Epi, north of Tongoa Island, Mount Gharet on Lakon; and Mt. Suretemati on Vanua Lava in the Banks group.

There are four volcanos in the Solomons Islands one on the island of Savo which erupted in 1849; one on Simbo Island; a submarine volcano Karachi south of New Georgia and Tinakula in Santa Cruz which erupted in 1971.

In Fiji no volcanic activity has been recorded recently. Hot spring activity is common throughout the group and is caused by subterranean volcanic activity in some places and by structure displacements in others. There have been periodic volcanic eruptions on Tonga. Niuafo'ou, Late, Tofua, Falcon and Fonualei islands all have active volcanos.

The Gilbert Islands (Kiribati) are of atoll formation and are not affected by volcanic eruptions.

2. Earthquakes

The zone of high seismicity that runs along the western edge of the Pacific Border through Melanesia is part of the Circum-Pacific Active Zone, characterized throughout by both earthquakes and volcanism. The two activities are frequently linked, but earthquakes are both more widespread and more frequent than volcanic eruptions (Brookfield, 1971).

Earthquakes are a regular phenomenon in Vanuatu, but those of high magnitude are considerably fewer. The most seismically active areas lie between Espiritu Santo and Torres Islands and between Anatom and Erromango.

The Solomon Islands lie in a seismically active region. There were serious earthquakes in 1959 and 1977 which produced landslides, flooding, and tidal waves in the South Guadalcanal area.

Numerous earthquakes occur east of Fiji where the Pacific plate is subducted under the Tonga trench. There are two active seismic zones offshore, one north of Vanua Levu and the other between Suva and Mbengga.

Tonga is located in a region of very high seismic activity. Earthquakes in the Tonga trench in 1917 reached 8.7 on the Richter scale and in 1919 reached 8.4; both were felt in Tongatapu and Ha'apai.

C. Atmospheric and Oceanic Events

1. Atmospheric

a. Storms

Typhoons or hurricanes are a hazard in the southwest Pacific. Violent tropical cyclones are associated with the equatorial zone of convergence. The cyclonic depressions usually develop between 15 degrees south and 185-190 degrees east and intensify only after they have moved southward from this latitude. They follow erratic paths, but most frequently move in the area between the Solomon and Society Islands. Occasional storms sweep along the Queensland coasts and even as far south as north of New Zealand.

Typhoons usually occur during the wet season from November to April. The very strong winds sometimes exceed 100 knots. The chance of any one island being seriously affected is fairly small; the frequency of occurrences over any one place is of the order of two storms a year and one hurricane every two years. In general, four to six tropical depressions occur during the warm season, of which one out of four might reach hurricane proportions. However, in some islands as many as three hurricanes have occurred in a single year and sometimes there have been three years without a hurricane.

For Vanuatu, 22 hurricanes were reported during a 26 year period from 1867-1893 and 75 notable tropical storms and hurricanes between 1800-1981. (Franco et al, 1982).

There is a period of eight years for which there are no records and other years with incomplete information. The Solomon Islands recorded 14 notable storms from 1951 through 1982. Lack of information, particularly immediately following the war years, precludes any possibility of dealing fully with hurricanes in the Solomon Islands. Hurricanes and tropical cyclones are the most common types of natural disasters in Fiji, occurring on an average of once a year over the last 100 years. From 1880-1975, eastern Fiji experienced 75 hurricanes. Hurricanes are the most common type of disasters in Tonga. Notable storms affect the islands every 2 to 3 years, but sometimes more than one storm can occur in the same year. Most of the storms travel east, southeast, or south when they reach Tonga; a few of them proceed west. The Gilbert Islands (Kiribati) are located north of the area where tropical storms usually develop. However, the storms travel erratic paths and the lack of records does not mean that the area is not affected.

b. Drought

Drought has long been a problem throughout some of the Pacific Islands such as Nauru and the Southern Gilberts, the Phoenix Islands and Christmas Island in Kiribati. Drought may, however, occur anywhere, even in those regions which experience high annual rainfall.

Details of drought occurrence in Fiji have been presented in Chapter 2. The climatic diagram for Lauthala Bay (Figure 2.16) shows water excess year-round under normal conditions. However, a drought occurrence was reported for 1954 which affected sugar and copra export and in 1968 a severe drought caused a fall of 17.2 percent in the production of sugar cane. In addition, the Palmer Drought Index estimated for a series of 63 years (from 1921 to 1984) shows occurrences of moderate drought during 1931, 1933, 1938, and 1940. From January 1943 to September 1945 a prolonged drought affected the region, reaching an extremely severe condition in August 1943. Other drought spells occurred in 1965, 1967 and from June 1977 to August 1978. More recently, moderate drought was recorded for the same area from 1982 to 1984.

Other islands such as the Gilberts in Kiribati, are subject to frequent drought conditions. Losses in copra production due to drought were reported in Tarawa during 1934, 1954-55, 1963 and 1973-74. The records of drought occurrence in Tonga show adverse effects on crop production during 1930, 1951-52, 1953, 1977 and 1978. More recently, in 1983 taro production was reduced by 50 to 80 percent due to an occurrence of severe drought. Drought occurrence are not recorded the Solomon Islands and Vanuatu.

2. Oceanic

The most important oceanic disaster events are storm surges resulting from very low air pressure and wind closely linked to the occurrence of hurricanes and tsunamis. Storm surges often cause drastic coastal landform changes and considerable inundation of large expanses of lowland. Oceanic episodic events are usually recorded as part of other major events such as earthquakes or tropical storms.

CHAPTER IX

SUMMARY

This report is written to provide background information that can lead to assessing and possibly mitigating the impact from climatic variability. The islands included in this report are: Fiji, Gilbert (now part of Kiribati), Solomon Islands, Tonga and Vanuatu (formerly New Hebrides).

A complete agroclimatic background report of each island group included a description of: 1) the physical environment including geography, topography, climate, soil and natural vegetation, 2) agricultural practices information for commercial crops and food crops and crop calendar, and 3) economic activities.

Agroclimatic regions were established for each island group using total annual rainfall, rainfall distribution, wind direction and topographic features. Data bases were developed to systematically study the climate and its relation to agriculture. The meteorological data were computerized for each station. Analyses of potential evapotranspiration estimates and a drought index were also made for selected stations.

The climatic requirements of commercial and food crops in the Southern Pacific Islands were discussed in detail.

Episodic event data on occurrences of tropical storms, earthquakes, volcanic eruptions, tsunamis, drought and other disaster experiences related to crop failures were documented for each island group.

The background information on climate and agriculture for the Southern Pacific Islands provided in this report may be used for developing drought early warning and land use planning resource in the island groups.

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APPENDIX A

METEOROLOGICAL DATA

TABLE A.1.

MEAN MONTHLY AND ANNUAL AIR TEMPERATURE IN °C FOR

SELECTED STATIONS IN SOUTH PACIFIC ISLAND GROUPS

Island Group	Agroclimatic Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Fiji	Region I													
	Labasa Mill	26.8	26.8	26.6	26.2	25.3	24.4	23.8	24.2	24.7	25.4	25.9	26.4	25.5
	Lambasa Airport	26.8	26.7	26.6	26.3	25.1	24.3	23.4	23.9	24.8	25.4	25.7	26.3	25.4
	Lautoka Mill	27.2	27.3	26.9	26.6	25.6	24.6	24.0	24.3	24.8	25.7	26.2	26.8	25.8
	Lautoka Point	26.8	26.8	26.7	25.9	25.1	24.0	23.3	23.7	24.3	25.0	25.6	26.3	25.3
	Nacocolevu	26.4	26.5	26.2	25.6	24.0	22.9	22.1	22.5	23.3	24.1	25.1	25.9	24.6
	Nadi	27.0	26.9	26.7	26.2	25.0	24.0	23.3	23.8	24.5	25.2	25.9	26.6	25.4
	Penang Mill	27.6	27.6	27.3	26.8	25.9	24.9	24.2	24.6	25.1	25.9	26.6	27.1	26.1
	Rarawai Mill	27.2	27.1	26.9	26.5	25.3	24.1	23.3	23.8	24.7	25.5	26.1	26.6	25.6
	Undo Point	26.6	26.7	26.6	26.3	26.0	25.3	24.6	24.7	25.0	25.6	25.9	26.6	25.8
	Yasawa-I-Rara	27.0	26.9	26.6	26.4	26.0	25.3	24.6	24.8	25.1	25.7	26.1	26.7	25.9
	Region IIa													
	Matuku	26.8	27.0	26.8	26.3	25.1	24.1	23.1	23.6	24.2	25.0	25.7	26.4	25.3
	Ono-I-Lau	26.3	26.6	26.4	25.7	24.3	23.4	22.4	22.4	22.7	23.6	24.5	25.3	24.5
	Region IIb													
	Nambouwalu	26.9	27.1	26.7	26.3	25.5	24.7	23.9	24.0	24.4	25.2	25.4	26.3	25.5
	Nandarivatu	21.6	22.0	21.5	21.0	20.0	18.9	18.3	18.8	19.0	20.1	20.6	21.1	20.2
	Vunisea	26.4	26.8	26.1	25.4	24.2	23.2	22.4	22.6	23.1	23.9	24.7	26.1	24.6
	Region III													
	Lauthala Bay	26.3	26.3	26.1	25.7	24.7	23.9	22.9	23.5	24.2	24.9	24.9	25.8	24.8
	Nausori Mill	26.2	26.5	26.4	25.6	24.3	23.3	22.6	22.6	23.1	23.9	24.7	25.6	24.6
	Rotuma	27.4	27.3	27.2	27.4	27.2	26.8	26.4	26.5	26.7	26.8	27.0	27.2	27.0
	Suva	26.8	26.9	26.8	26.1	24.8	23.9	23.1	23.2	23.7	24.4	25.3	26.2	25.1
Gilbert	Region I													
	Arorae	28.8	28.9	29.1	28.9	29.1	28.8	28.6	28.8	28.8	29.0	29.0	29.0	28.9
	Beru	28.2	28.3	28.3	28.3	28.5	28.4	28.2	28.0	28.6	28.5	28.4	28.4	28.3
	Region II													
	Tarawa	28.2	28.1	28.1	28.2	28.4	28.3	28.2	28.3	28.4	28.6	28.3	28.3	28.3
Solomon	Region I													
	Honiara	26.8	26.7	26.5	26.6	26.7	26.4	26.2	26.3	26.5	26.7	26.8	26.7	26.6
	Region II													
	Tulaghi	27.7	27.7	27.7	27.7	27.5	27.1	27.1	27.0	27.2	27.4	27.8	28.1	27.5
Tonga	Region I													
	Nukualofa	25.6	25.9	24.1	23.2	21.4	21.3	21.4	21.7	22.4	23.8	24.8	25.4	23.4
	Region II													
	Vava'u	26.4	26.7	26.0	24.8	24.2	23.2	23.1	23.7	24.3	25.1	25.9	26.0	25.0
Vanuatu	Region I													
	Vila	26.4	26.8	26.1	25.2	24.0	23.2	22.4	22.7	23.2	23.9	25.0	25.9	24.6
	Region IIa													
	Aneityum	26.0	26.6	26.0	24.9	23.4	22.5	21.5	21.4	22.0	23.1	24.2	25.3	23.9
	Region IIb													
	Luganville	25.5	25.8	25.4	25.3	24.1	23.6	22.8	23.3	23.8	24.1	24.8	25.4	24.5
	Region III													
	Port Patteson	26.6	26.9	26.6	26.3	26.1	25.8	25.2	25.2	25.5	25.7	26.1	26.6	26.1

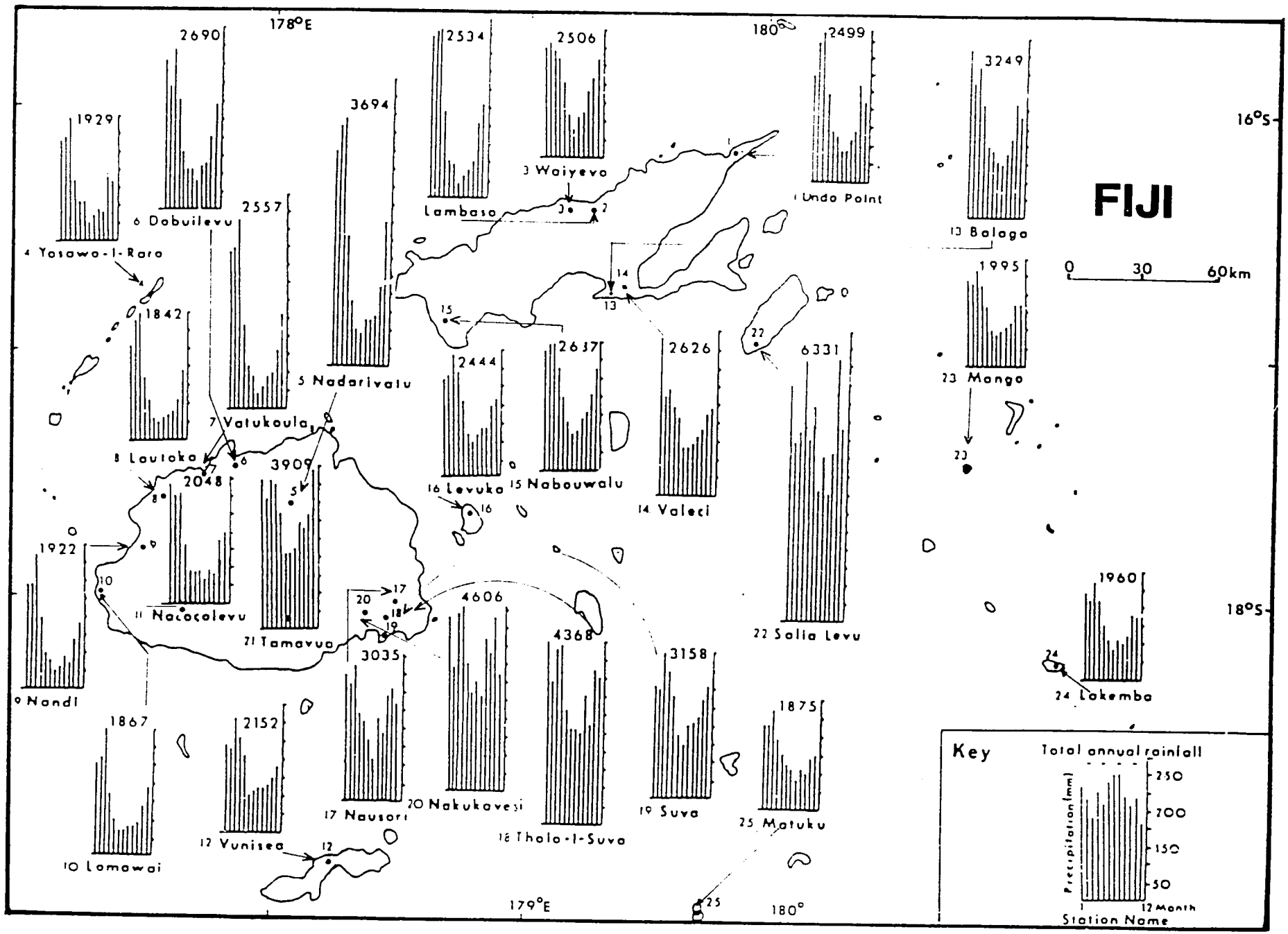

Figure A.1. Rainfall Distribution for Selected Stations in Fiji.

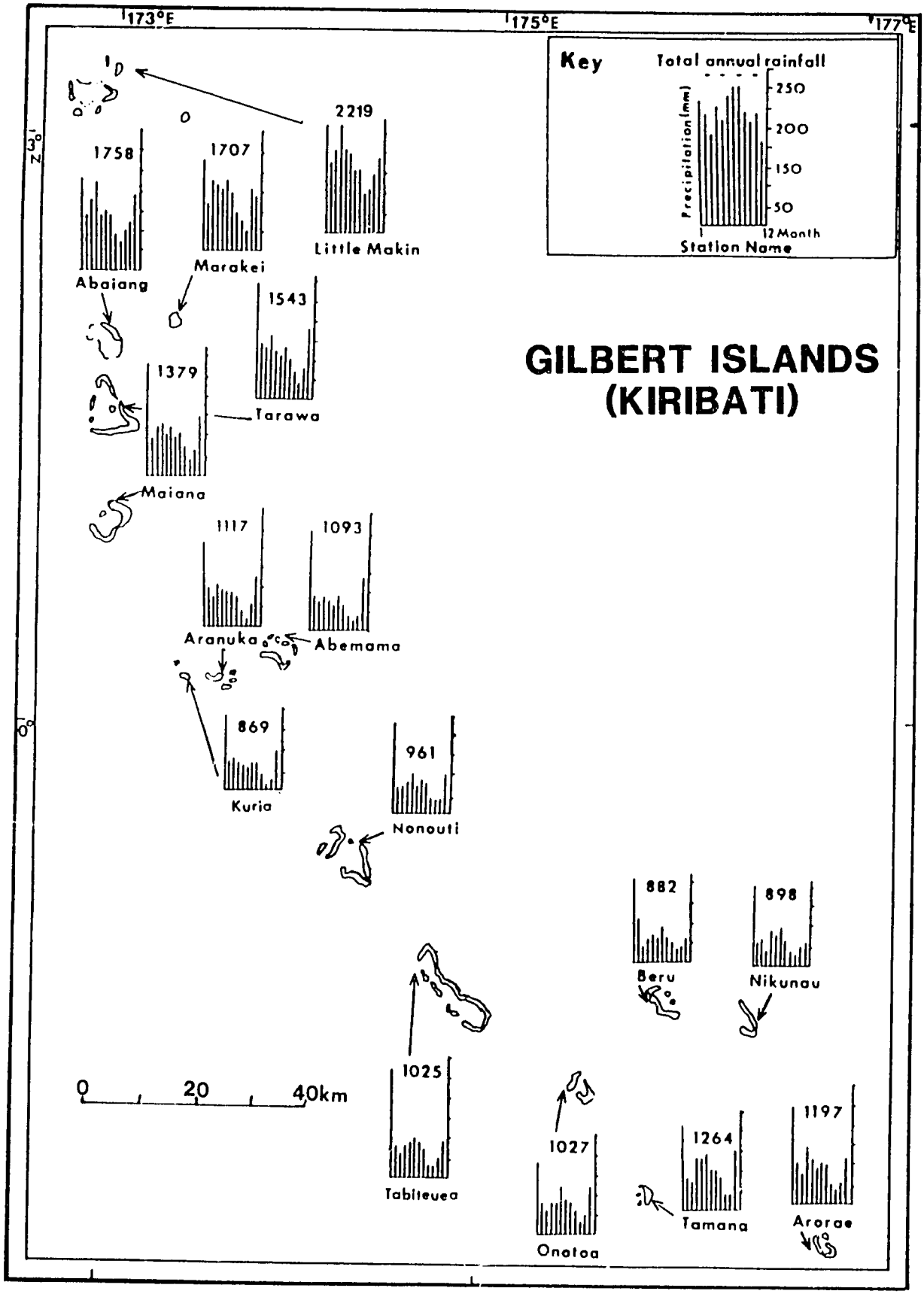

Figure A.2. Rainfall Distribution for Selected Stations in the Gilbert Islands (Kiribati).

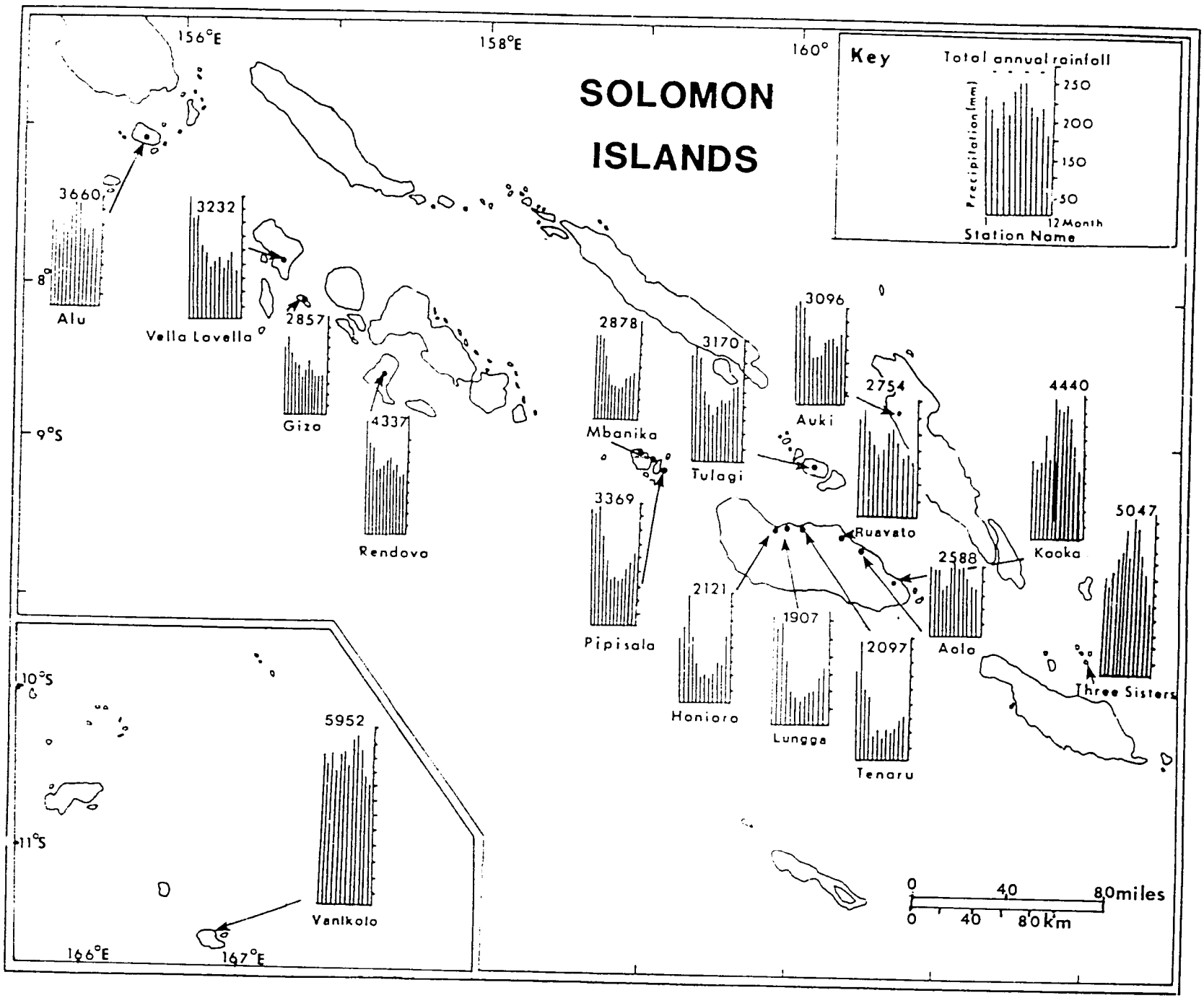

Figure A.3. Rainfall Distribution for Selected Stations in the Solomon Islands.

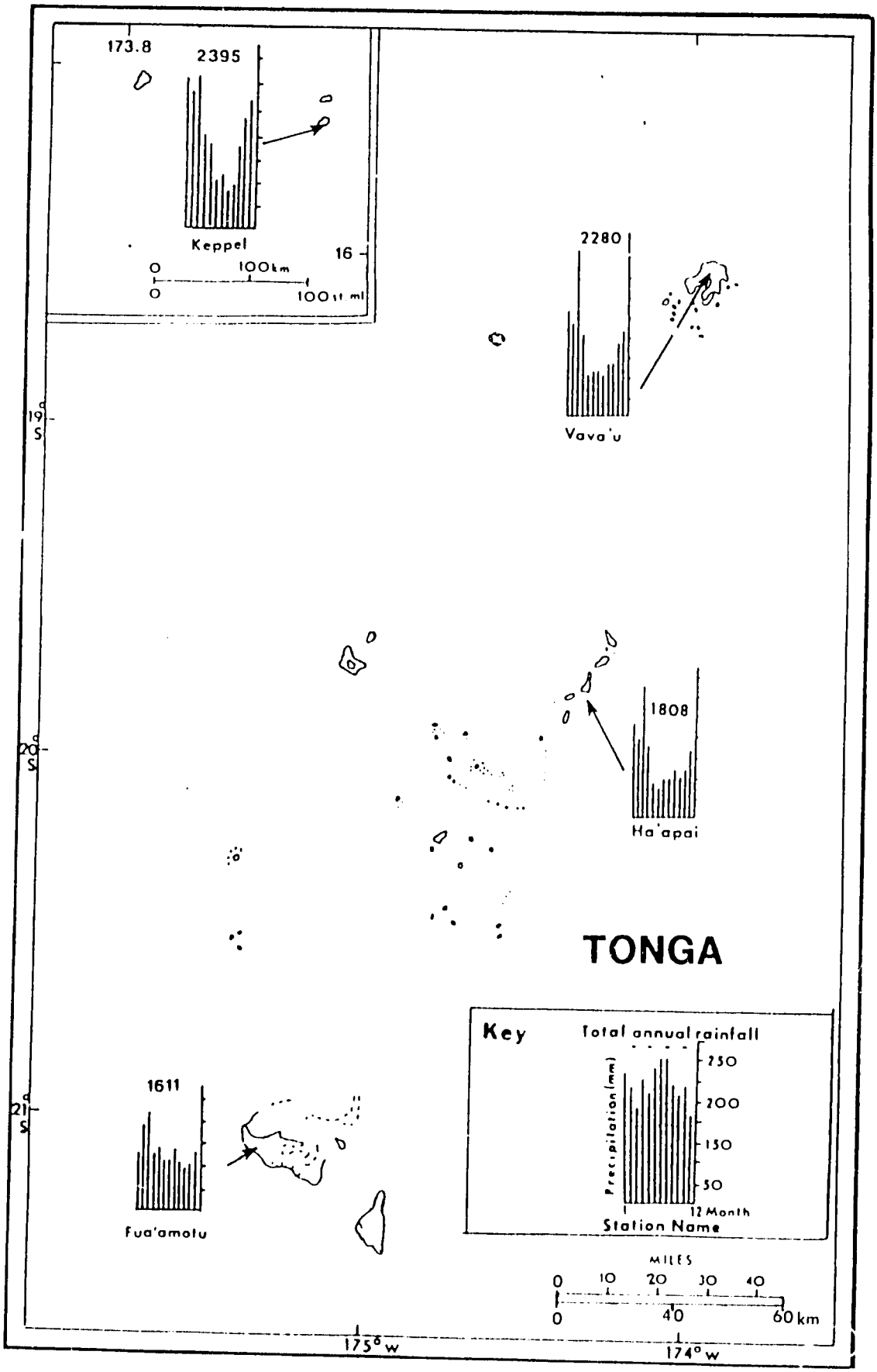

Figure A.4. Rainfall Distribution for Selected Stations in Tonga.

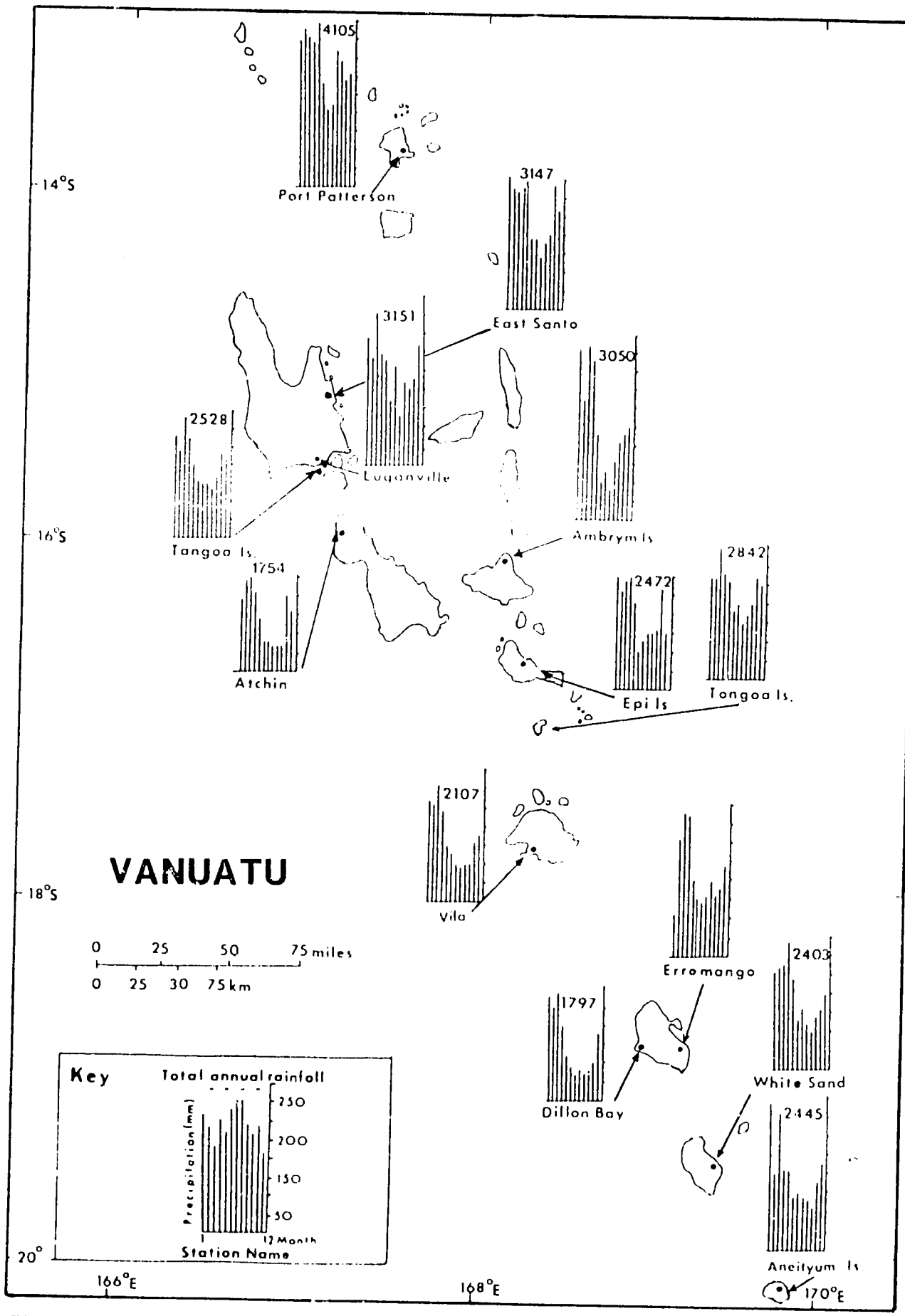

Figure A.5. Rainfall Distribution for Selected Stations in Vanuatu.

APPENDIX B

EPISODIC EVENTS DATA

TABLE B.1

FIJI DISASTER EXPERIENCE PROFILE[1/]

1. TERRESTIAL EVENTS

a. Earthquakes

1921, Earthquake was reported at Tuvaloa and Cakaudrove area.
1932, The southern tip of Koro Island was affected by an earthquake.
1953, An earthquake in the Suva-Mbengga zone reached 6.75 on the Richter scale.
1961, Suva zone was affected by earthquakes.
1970, An earthquake was reported in the Suva-Mbengga area.
1975, Suva-Mbengga zone reported an earthquake.
1976, During the month of July and August 30 minor earthquakes were recorded in the Suva region.
1979, In November, two earthquakes registered 6.9 R. and 6.3 R., respectively.

2. ATMOSPHERIC EVENTS

a. Hurricanes, Tropical Storms and Cyclones

1939, December 28 minor storm damage to roads and power lines.
1941, February 19-20 severe hurricane: Central Lau, Lomaitivi and Viti Levu; Suva's worst hurricane since 1910, 3 lives lost.
1941, April 7 moderate: SSE east of Vanua Levu and through the Lau Group.
1941, December 26 minor storm; southeastward between Vanua Levu and Viti Levu, southern Lau; slight damage in Savusavu district and Taveuni.
1943, January 1, moderate storm; SSE over eastern Vanua Levu and Lau Group; severe in southern Lau.
1943, March 17 minor storm southeastward and through Lau group.
1944, January 8-10 minor storm erratic, passed through southern Lau.
1948, December 7-8 moderate to severe storm; SSE east of Vanua Levu and through the Lau Group; considerable damage to plantations, food crops, houses in Taveuni, Lau Group; Lauan airlift of RNZAF.
1950, February 2 minor: southwestward through northern Lau Group; gales but no significant damage.
1950, February 25-27 moderate storm; westward between Vanua Levu and Viti Levu, then southward.
1950, March 30 moderate storm; Viti Levu.
1952, January 24 minor cyclone: southeastward over Vanua Levu and Lau Group.
1952, January 28 severe hurricane: near Suva; 23 lives lost, new banana plantations wiped out, drop in production.
1954, April 22-25 storm: moved southeast over Vanua Levu, Lakeba, and Tonga, causing strong winds in Lau.
1955, January 5-6 moderate storm: Yasawas.
1955, January 27-28 minor storm: eastward south of Viti Levu.
1957, February 26 minor storm: southwestward through Koro Sea.

1/ Information quoted from: Franco, et al (1982).

1958, January 7 moderate to severe cyclone: southward through Lau Group.
1958, April 9 minor storm: moved southeast over Yasawas.
1958, December 2-3 severe storm: southeastward over central Viti Levu; center passed over Ono-I-Lau.
1959, December 30 moderate cyclone: south of Fiji; coastal villages destroyed by flooding.
1964, November 22-23 minor cyclone: moved southeastward east of Vanua Levu and through northern Lau.
1964, December 6-7 minor storm: east of Vanua Levu and through northern Lau, trees uprooted at Katafaga Island.
1964, December 21 moderate to severe storm.
1965, February hurricane: wind damage not severe, widespread floods.
1966, December 4-5 minor storm: southeastward over Viti Levu and Southern Lau.
1967, April 9-10 severe cyclone: southward over Vanua Levu and just east of Viti Levu, passing near Ono-I-Lau; considerable damage to houses and food crops.
1970, January 11 minor cyclone: gale force winds in Kia, Vanua Levu, and Taveuni.
1970, October 29-30 cyclone "Nora": gale force winds in Yasawa and Mamanutha Groups, Viti Levu, Lomaiviti Group, Moala, and Toyota.
1970, December 17-18 cyclone "Priscilla": gale force winds in Yasawa and Mamanutha Groups, extreme southwestern section of Viti Levu, Vatulele, and Kadavu.
1972, October 23-29 hurricane "Bebe": severe hurricane affected much of the country; 18 dead, 120,000 homeless, 6,500 houses destroyed.
1973, February 2 "Henrietta": moderate storm in extreme eastern tip of Vanua Levu (Undu Point), Thikombia Island, and Nggele Levu.
1973, April 3-4 cyclone "Juliette": affected Savusavu and Bua; 160,000 homeless; later passed over Ha'apai, Tonga.
1973, December 18 cyclone "Lottie": affected Kadavu and Lau Group; 74 deaths, 1373 houses destroyed, 15,000 people rationed.
1974, April 26 "Tina": minor gale force winds in extreme eastern tip of Vanua Levu, Taveuni, Thikombia Island, Naitaumba (Northern Lau).
1975, January 30-February 2 cyclone "Val": affected the Lau Group; 75% of the houses destroyed, 23,000 mass fed for 6 months.
1975, April 5-6 "Betty": moderate hurricane in western Kadavu, Ono Island, Vatulele, and Ono-I-Lau; extensive damage in some Kadavu areas.
1977, December 25-26 "Anne": moderate hurricane affecting Naitaumba, Vanua Mbalavu, Munia Katafanga, and Thikombia-i-Lau.
1978, January 4-5 "Bob": moderate hurricane in strip of Viti Levu west of line from about Tavua to Lomeiwai, Yasawa, and Mamanutha Groups; one death in Sambeto, near Nadi, where several houses were demolished.
1978, February 4 storm: several islands affected.
1978, February 18-19 minor cyclone "Ernie": storm force winds in Thikombia Island, northeastern tip of Vanua Levu (Undu Point).
1978, December 29-30 moderate cyclone "Fay": storm force winds in Kia, Thikombia, eastern Vanua Levu, Taveuni; coastal damage from combined storm surge and heavy surf to some islands in Lau Group.
1979, March 26-28 severe hurricane "Meli": running in a straight line from the Eastern through parts of the Central and Western Divisions, traversing parts of the Lau, Kadavu, Rewa, and Nadroga provinces;

heavy storm surge on March 27, reaching between 2-3 m. on the island of Nayau with wave wash reaching 6 m. in places; severe devastation, 53 persons dead, 300 injured, 15,000 homeless; at least 11 vessels lost, damaged, sunk, or aground; 1,324 families left homeless and 263 school units destroyed.

1980, January 2-5 minor hurricane "Peni": gale force winds in Mamanutha Group, extreme western strip of Viti Levu west of line from about Sigtoka to Nadi.

1980, March 24 moderate storm Tia: moderate storm, western Vanua Levu, southern Koro, Vathata, Thithia, Thuvutha, southern half of Vanua Mbalavu, and Nggamea; moderate flooding in Vanua Levu and Taveuni, storm surge in Savusavu area, landslides in Koro and Nggamea; 4 deaths, extensive damage to dwellings in Nggamea and Vanua Mbalavu, 504 homes and 31 school units destroyed.

1980, April 3-5 cyclone "Wally": affected Vanua Levu and Viti Levu; severe gale, coastal and inland area between Korolevu and Navua, Vatulele, Kadavu, Mbegga; severe flooding in Navua, Rewa, and other coastal rivers of Viti Levu from Korolevu eastwards; 18 deaths, 10,000 homeless, 269 homes and 31 school units destroyed; heavy damage from flooding and landslides, extensive damage to Queen's Road between Korovisilou and Suva; severe loss of livestock, pasture, and crops especially in Navua.

1981, January cyclone "Arthur": severe damage to sugarcane industry; 952 homes and all schools in the Yasawa/Mamanuca Group, Lautoka, Nadi, and Nadroga areas destroyed.

1982, January "Hettie" caused three deaths.

1983, Two hurricanes, "Oscar", early in March, and Seru-later in the same month, devastated large sugar-growing areas. (CARTER, 1984)

b. Drought

1926, Drought affected crops.

1957, Drought affected sugar and copra exports.

1968, There was a fall of 17.2% in the production of sugarcane that was affected by severe drought.

1983, Severe drought, along with hurricane damages has cut sugar production by about 50 percent. Also will affect the 1984 harvest as it has prevented much of the replanting. (Carter, 1984).

TABLE B.2

GILBERT ISLANDS (KIRIBATI) DISASTER EXPERIENCE PROFILE[1/]

1. ATMOSPHERIC EVENTS

a. Hurricanes, Tropical Storms and Cyclones.

1914, Hurricane: Kiribati and Tuvalu; damage to cultivation, suspension of copra industry for two years; loss of a few lives.
1928, Hurricane: Kiribati and Tuvalu; considerable damage to houses and coconut trees.
1972, October 21 "Bebe" severe hurricane: Funafuti devastated by winds of 180 mph, with 95% of the houses destroyed, 5 killed, 700 homeless; Fiji and Tonga also affected.

b. Climatic Extremes

Drought

1934, Drought and epidemic affected part of the islands.

1954-55, Long periods of drought affected copra production.

1963, Copra production was affected by drought.

1973-74, Copra exports were seriously affected by severe drought.

1/ Information quoted from : Franco, et al (1982).

TABLE B.3.

SOLOMON ISLANDS DISASTER EXPERIENCE PROFILE[1/]

1. TERRESTRIAL EVENTS

a. Volcanic Eruptions

1971, Tinakula in Santa Cruz erupted and poured lava for two months, leaving 6,000 homeless and causing extensive damage, including the loss of the San Cristobal bridge.

b. Earthquakes

1959, Serious earthquake in South Guadalcanal area produced landslides, flooding, and tidal waves.
1977, Serious earthquake occurred on July 7, with epicenter at 160 km southwest of Bougainville, with a force of 7.3 on the Richter scale, resulting in 13 deaths.
1978, Earthquake with epicenter at 320 km south of Guadalcanal, reached 7.3 on the Richter scale.
1980, On July 8, an earthquake with the force of 7.3 R. was reported near Santa Cruz Islands. On July 9 in the same area other earthquakes reached 6.8 on the Richter scale.

2. ATMOSPHERIC EVENTS

a. Hurricanes, Tropical Storms and Cyclones

1951, March 24-25 storm.
1952, January 23-24 cyclone: developed south of the Solomon Islands but caused much damage from high seas.
1955, March 23 storm.
1959, March 7-8 storm south of main islands
1959, December 20-22 severe storm at Choiseul Bay.
1966, March 28 cyclone "Glenda": widespread damage in Guadalcanal and San Cristobal, mostly from high seas.
1966, November 14 cyclone "Angela": small, violent cyclone over Malaita and Guadalcanal caused extensive damage.
1967, November 11-12 storm "Annie": caused widespread and heavy damage especially in the more western islands; winds of 100 mph.
1968, December 11-12 cyclone "Becky": widespread damage in central islands, especially Malaita and San Cristobal.
1971, "Ursula": violent storm over Santa Anna, 1 dead, 2,500 homeless.
1972, "Carlotta": loss of lives, serious damage to buildings and agricultural areas.
1972, Hurricane "Ida": destroyed valuable timber.

1/ Information quoted from: Franco, et al (1982).

1979, February 20 "Kerry": affected eastern Solomon Islands; 6,000 homeless, 2 dead, and several seriously injured.
1982, April 2-4 cyclone "Bernie": winds of 35-40 knots and gusts of 70-75 knots; heavy surf and falling trees caused much damage.

3. OCEANIC EVENTS

a. Tsunamis

1926, A tsunami in Guadalcanal inundated the port and island with waves of 2-6 m high.
1931, A tsunami destroyed 18 villages and killed 50 persons.
1939, Heavy damage and 12 people were killed by a tsunami in April.
1960, An earthquake in Chile caused a tsunami which damaged the wharf.

TABLE B.4.

TONGA DISASTER EXPERIENCE PROFILE[1/]

1. TERRESTIAL EVENTS

a. Volcanic Eruptions

1925, Volcanic eruption on Falcon Island.
1930, A volcano of Niuafo'ou erupted, destroying a town and one third of the cultivated land on the island.
1939, Volcanic eruption on Fonua Lei.
1946, Niuafo'ou volcano erupted again causing considerable damage to crops and the total population of 2,500 persons was evacuated to Nuku'Alofa.
1974, Fonua Lei volcano erupted.

b. Earthquakes

1977, An earthquake of 7.2 R. or 7.4 R. on June 23 caused extensive structural damage on Tongatapu and Eua. The earthquake lasted approximately 2.5 minutes. On October a tremor was felt in the Tonga-Kermadec region but caused no damage.
1980, Earth tremor that reached 6.3 R.
1981, An earthquake of 7.5 R. had its epicenter in the Tonga Islands and also affected Samoa.
1982, An earthquake that reached 6.5 in the Richter scale.

2. ATMOSPHERIC EVENTS

a. Hurricanes, Tropical Storms and Cyclones

1944, January 30 southeastward between Niuafo'ou and Keppel Island.
1949, December 20 moderate: SSE between Ha'apai and Tongatapu ; damage to coconuts.
1957, December 7-8 moderate cyclone: southeastward to south of Vava'u.
1960, January 17-18 storm: eastward north of Niaufoou on night of January 17 and near Keppel Island next morning.
1960, March 19-20 moderate storm: southwestward to north of Vava'u.
1961, March 16-17 severe cyclone: southward close to Vava'u and Ha'apai Groups and to east of Tongatapu; 2 dead and 50% of housing destroyed, leaving 8,000 homeless; banana crop wiped out; coconuts stripped and uprooted, setting back the copra industry two and a half years.
1963, March 11 moderate hurricane: WSW about 100 km southeast of Keppel Island.
1963, March 12-14 moderate: severe in Nomuka.
1964, November 24-25 moderate: almost stationary west of Tongatapu for 24 hours, then between Ha'apai and Tongatapu.
1972, October storm "Bebe".

1/ Information quoted from: Franco, et al (1982).

1973, April 12 hurricane "Juliette": Ha'apai Group; severe damage to crops, housing, water tanks, schools, churches on 7 islands and in 17 villages. Three deaths, 700 affected, 33% of copra lost.
1974, Storm on Niuafo'ou.
1977, December 27 "Anne": damaged crops and structures in Ha'apai.
1978, February 21 storm "Ernie": substantial damage in Ha'apai. Five injured, 10,000 affected, and damage estimated at US$1.1m (OFDA).
1979, Storm on Niautoputapu.
1982, March 3 cyclone "Isaac": severe tropical cyclone; violent winds, heavy rain, and sea surge devastated Tonga leaving thousands homeless and 6 dead.
1982, June cyclone: Tongatapu, severe damage to more than 30 houses, crops almost destroyed, especially bananas in the eastern division.

b. Climatic Extremes

Drought

1926, Drought depressed trade and affected the copra output adversely.
1930, Severe drought affected adversely the copra production.
1951-52, Drought adversely affected crops.
1953, Drought had adverse effects on crop production, causing a fall in copra exports and considerable damage to bananas.
1977, Effects of a severe drought were aggravated by the hurricane "Anne".
1978, Prolonged drought affected crop production; the damage was aggravated by the hurricane "Ernie".

Floods

1982, Several villages on the northwest coast of Tongatapu were evacuated in February following the worst floods to strike the area in 20 years.

4. OCEANIC EVENTS

1917, Two tsunamis were generated by earthquakes in the Tonga trench.
1919, Tsunami was recorded in the Ha'apai group.

TABLE B.5

VANUATU DISASTER EXPERIENCE PROFILE[1/]

1. TERRESTIAL EVENTS

a. Volcanic Eruptions

1952, On March a volcano erupted throwing out ash and cinders in Southeast Abrym. All bushes, trees and ferns were killed. All coconuts fell from the palms and most of them had only a central leaf left on them. Port Veko and Craig were covered with ashes.

1960, On July 10th, the volcano on Lopevi, a small island rising steeply 1200 m out of the sea a few miles north of Epi in the central Vanuatu, erupted with a violent explosion after being dormant since 1939.

1961, The existing volcanoes in the group, Ambrym and Yasour were continously active producing frequent volcanian type ash showers but without major eruptions.

1962, Four center of submarine activity noted to the east of Epi and north Erromango. Mathew Island also periodically active. It increased considerably in size during the past few years.

1963, In Lopevi a volcano erupted violently, producing numerous lava flows and large quantities of ash. Mt. Gharat, a dormant volcano beside a crater lake on Lakon Island in the Bank group, erupted briefly but only ash was emitted.

1964, Lava and ash clouds from Mt. Lopevi erupted intermittently through the year. Four center of submarine activity noted to the east of Epi and north of Toupoa, and one recorded north of Erromango.

1965, Activity of the existing volcanoes diminished during the year, although Yasour on Tanna and the two Ambrym volcanoes continued to produce ash showers periodically sometimes accompanied by lava fountaining. By the end of 1965 activity ceased at Lopevi which had been erupting intermittently since July 1963.

1966, Activity increased on Mt. Gharat on Lakon and Suretematai on Vanua Lava in the Banks group. The latter volcano characterized only by fumaroles and solfataras erupted in August, emitting ash from a new crater on its northwest slopes. Spasms of an emission were also recorded at Mt. Gharat. Report of the development of new volcanic center within the summit caldera on Aoba were incorrect; this proved to be a small solfatara.

1/ Information quoted from: Franco et al (1982), and New Hebrides, Report For the year (1959-1960, 1961-1962, 1963-1964, 1965-1966, 1967-1968, and 1969-1970).

1967, The fumarolic activity of Mt. Suretematei on Vanua Lava continued, and there was a small eruption of ash in mid-1967. Mt. Gharat on Lakon also erupted a little ash but more commonly emitted white smoke. After periods of relative quiescence both Ambrym and Lopevi became active again. Marum on Ambrym belched forth greath quantities of gas and fine ash. A turbulent white cloud was characteristically present reaching 3,000 to 4,500 m above the volcano. On at least three occasions in 1967, Mt. Lopevi's activity consisted of the emission of small quantities of smoke from both the summit and northwest craters, with the eruption of basaltic lavas.

1968, Marum on Ambrym continued to belch great quantities of gas and fine ash. On at least four occasions, Mt. Lopevi erupted with emission of basaltic lavas that lasted for only a day or so, with the lava coming from the north-west crater and reaching the sea on the west coast. Yasour on Tanna continued its mild eruption of gas and ash towards the end of 1968.

1969, Volcanic activity was recorded on five islands. In the Banks Islands mild solfataric activity continued on Vanua Lava, and Mt. Gharat on Lakon erupted a little ash, although more commonly only a small gas cloud was emitted. The two volcanoes, Marum and Benbow on Ambrym were mildly active throughout the period with periodic increases resulting in ejection of large ash clouds. The strongest of these ash eruptions in August 1967 caused extensive minor damage to garden areas on the northwest side of the island where much of the green foliage was burned and died. The activity of Lopevi decreased during the first quarter of 1969.

1970, There was generally only a little eruption of gas on Mt. Lopevi, apart from a culmination in April-May 1970 when renewed emission of gas and lava occurred. Yasour on Tanna was mildly active throughout 1967-1970 showing small fluctuations in activity and a constant small eruption of ash.

1971, Volcanic activity was recorded from most of the ten center; the most notable eruptions were those of the submarine center Karva in the Central island in February.

1972, The volcanic activity continued in most of the center which are in the list of active volcanoes of the world. In August, a notable eruption was recorded on the submarine center of Ambrym. In addition, another submarine center, of the east coast of Epi, was mildly active, the first time it has been so for at least ten years. A number of these eruptions followed closely on strong shallow-focus earthquakes in their vicinity.

b. Earthquakes

1901, A big earthquake was reported in Santo.

1966, In Vanuatu 1629 earthquakes were reported for 1966, but those of high magnitude were considerably fewer.

1966-67, The number of earth tremors recorded as having originated in Vanuatu increased compared with the previous two years but none were strong and no damage was sustained.

1969-70, The number of seismic shocks recorded as having originated in Vanuatu decreased appreciably. There were a total of 4185 in 1969 and 1706 in 1970. Fortunately, none were severe. Although a number of shocks with magnitude greater than 6 on the Richter scale occurred, no damage was reported (New Hebrides, report 1969-1970).

1971, There was a general decrease in the number of earthquakes compared with the previous year. For 1971 764 earthquakes were reported. Six of them were recorded as having magnitudes of 6 or more on the Richter scale and included one on October 28th that reached 7.1 which resulted in three deaths and caused extensive damage in southeast Santo.

1972, Large earthquakes which occurred in 1972 included one of magnitude 7.2 near the Torres Islands in February and another of magnitude 7.5 near Tanna in November; little damage was caused by these shocks.

1979, An earthquake measuring 6.7 on the Richter scale was reported in Vanuatu on May 1st, 1979.

1980, On July 17 a major earthquake occurred on Vanuatu measuring 8.0 on the Richter scale.

1981, A major earthquake shook Vila on Santo at 1:59 a.m. on 15 July measuring 7.0 on the Richter scale. There were no reports of damage or casualties at the time.

2. ATMOSPHERIC EVENTS

a. Hurricanes, Tropical Storms and Cyclones

1940, February 8-9 hurricane: severe in restricted area, North Efate, Nguna Island, Mataso Island; many houses and plantations destroyed; Tongoa devastated.
1940, February 18-19 severe in restricted area; southwestward over central Vanuatu.
1947, January 13 storm: Tanna.
1948, January 24-25 moderate hurricane: Santo, Malakula, Abrym, and Epi; most damage to housing and plantations in Santo and Malakula.
1951, December 24-25 severe hurricane: northern Vanuatu, Epi, Ambrym, Malekoula; almost all villages and plantations destroyed in Epi and Abrym; 100 dead, 9 small ships sunk.
1952, November 30 storm and hurricane affected Efate and southern islands.
1954, February 15 storm caused some damage from Banks to Malekoula.
1956, March 2 storm and hurricane affected Efate and southern island; damage to plantations.
1957, March 29 storm: Aneityum.
1959, December 28-29 hurricane "Amanda": from Epi to Aneityum; severe damage in Vila and southern Efate: winds of 75-85 knots with gusts up to 100 knots.
1960, January 1 storm and hurricane from Malekoula to Efate, where damage caused by "Amanda" was aggravated.

1963, November 18 storm and hurricane from Pentecost to Tanna; one village destroyed on Tongoa, Furari mining installations damaged in Efate.
1963, November 18-19 moderate storm.
1964, March 31 storm "Henrietta": Banks and Santo.
1968, March 4 "Florence": affected southern islands.
1968, December 14 storm "Becky" affected area from Santo to Efate; severe damage on Malekoula and Shepherd Islands.
1971, December 9 storm "Ursula": affected central islands; floods on Efate.
1972, January 18 "Carlotta": Santo to Aneityum; severe damage on Efate and Aneityum.
1972, February 2 "Wendy": Banks to Malekula; severe damage on Banks and Santo, 4 dead.
1972, March 20 storm "Yolanda": Aneityum.
1972, April 17 "Gail": Efate, Shepherd; severe damage on Tongoa, Emae, Mataso, Makura, and North Efate.
1974, February 3 "Pam": central and southern Vanuatu; heavy rains, damage on Efate and Tanna.
1975, March 5 storm "Alison": from Malekoula to Efate; severe damage on Tongoa and Emae.
1976, January 14 storm "David": from Banks to Efate; heavy rains, some damage by wind on Malekoula.
1977, January 15 "Marion": southern islands; subsistence crops destroyed.
1977, January 20 "June": Efate, severe damage to housing and agriculture on Mataso, estimated winds of 80 knots in east Efate.
1977, March 16 storm "Norman": southern islands, winds of 45 knots, damage to subsistence agriculture on Aneityum, Futuna, Aniwa; landslides on Tanna and Futuna.
1978, January 5 storm "Bob": southern islands; tidal storm wave caused damage from Emae to Tanna; winds at Aneityum of 60 knots.
1979, January 6 "Gordon": Torres, Banks, Santo, Malekoula; most of the houses destroyed in Loh (Torres); gardens destroyed on Banks Island; tidal wave on north Santo where sea reached 200 m. inland, severe damage to plantations and to 8 villages on the west coast; 65 houses destroyed in Malekoula and wharf destroyed in Norsup.
1981, February 11 cyclone "Cliff": extensive damage: houses destroyed on Pentecost, Malekoula, Ambrym, Epi, Efate and other islands; trees blown down in the capital and Vila blacked out for several hours; half of Air Club hangar's roof blown off and sheets of corrugated iron flung onto fence 50 m. away.
1981, December 12, "Gyan": northern groups and west Santo; heavy rains, floods on north Malekoula; estimated housing damage V100 million (US$1m).

3. OTHER DISASTER EXPERIENCE

1960, Copra production of many Vanuatu coconut plantations was at various times seriously affected by the insect Axiagastus campbelli which damaged the coconut flower and caused nuts to fall prematurely with the result that size of the nuts and copra content were reduced.

1964, Some coconut plantations on Efate suffered considerable damage of a temporary nature fro. the cochineal insect Aspidiotus destructor which forms a scale on the underside of coconut leaves and, by extracting the sap, can gradually kill the palm unless is controlled. A predator (Lindorus lophantes) was found shortly after the cochineal attack began. The introduction of the predator proved to be very successful in controlling Aspidiotus.

1965, Aspidiotus was considered to present no serious economic threat to coconut plantations.