TAIM HANGRE: VARIATION IN SUBSISTENCE FOOD SUPPLY IN THE PAPUA NEW GUINEA HIGHLANDS

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Except where otherwise acknowledged, this thesis represents my original research. It has not been submitted in whole or in part for a higher degree to any other university or institute of tertiary education.

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ABSTRACT

This research seeks to understand the causes of variation in subsistence food supply in the highlands of Papua New Guinea, particularly the reasons for shortages of sweet potato, the staple food. The study is regional, but the most intensive observations and data are from two provinces and from one community in each of these provinces. Two main indices of subsistence food supply are used: firstly, survey data from food markets and secondly, statements made by villagers about food supply, as documented by outside observers. Particular emphasis is given to long data runs on food availability.

Food shortages have an impact on people's wellbeing. Prior to the colonial period, they resulted in an increased death rate. Body weights of both adults and children are influenced by variation in subsistence food supply. The impact of food shortages is likely to be muted when people have access to cash which they use to buy imported food when subsistence food is scarce. Evidence is brought forward which demonstrates that the frequency of food supply problems has not altered since colonial contact in the 1930s.

Activities associated with cash cropping, labour migration or harvesting of a pandanus nut, which are commonly put forward as explanations for food shortages, are eliminated as causal factors. Disruptions associated with pig killing ceremonies and tribal fighting may be contributing factors at times, but their impact is limited. The food production systems in the highlands are sufficiently flexible to absorb short term fluctuations in planting rate and crop yield.

Long run rainfall records, market price series and crop planting data are used to demonstrate that the major causes of variation in supply are climatic extremes, particularly extended wet periods and frost, and variation in the crop planting rate. Only the most severe droughts cause food shortages, unless a drought is preceded by an extended wet period. In the latter situation, droughts may become a contributing factor. Wet periods appear to be most damaging when the sweet potato tubers are being initiated and droughts reduce yield during the rapid bulking phase. Frost damage sometimes results in food shortages at high altitude locations, but this is uncommon below 2200 m. Villagers vary their planting rates according to the current supply of sweet potato. They plant larger areas when sweet potato is scarce, and a higher proportion of plantings is then made in fallow land. This behaviour initiates a cycle in planting, similar to the well known "hog price cycle", and this may eventually result in another food shortage, particularly if lower planting rates coincide with a climatic extreme. A model is presented that combines these elements to calculate the supply of sweet potato over a five year period in two locations. The calculated food supply is in good agreement with indices of food availability for the same period.

ABBREVIATIONS

AFTSEMU	Agricultural Field Trials, Studies, Extension and Monitoring Unit (Mendi)
ANOVA	Analysis of variance
AWC	Available water capacity
CD	Census division
CPI	Consumer price index
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CUM	Christian Union Mission
DDA	Department of District Administration
DOIC	District Officer-in-Charge
DPI	Department/Division of Primary Industry
EHP	Eastern Highlands Province
ENSO	*El Niño*-Southern Oscillation
FMC	Food Marketing Corporation
GPRI	Growing period rainfall index
HAES	Highlands Agricultural Experiment Station (Aiyura)
Is	Island
K	Kina
kg/ha	Kilograms per hectare
KKB	Kainantu Komuniti Bisnis Ltd
L	Lake
MCH	Maternal and Child Health
MP	Melanesian Pidgin
n	Number
NES	National Emergency Service
NS	Not significant
NSO	National Statistics Office
NSW	New South Wales
OIC	Officer-in-Charge

P	Probability
PNG	Papua New Guinea
PR	Patrol report
r	Correlation coefficient
R	River
SD	Standard deviation
SHP	Southern Highlands Province
SLUP	Simbu Land Use Project (Kundiawa)
SMS	Soil moisture storage
t/ha	Tonnes per hectare
USDA	United States Department of Agriculture
V	Valley
WATBAL	A CSIRO calculator/computer program used to derive soil water balance
wfa	Weight for age
WHP	Western Highlands Province
WP	Western Province
WSP	West Sepik Province

CONVENTIONS

Administrative Units

Papua New Guinea is divided into 19 provinces (previously districts). Each province contains a number of districts (previously sub-districts) and each district a number of census divisions. The boundaries and terms used for administrative units have changed considerably over time, but the present-day administrative terms are used, even when referring to the period before any administrative control existed. Thus the term "Enga Province" refers to what was known as "Enga Sub-District, Western Highlands District" prior to 1973.

Currency

The Papua New Guinea currency is a decimal one with 100 toea per kina. One kina is worth about A$1.55 in early 1988. Australian currency of pounds (prior to 1966) and dollars (1966 to 1975) was used prior to independence. Throughout, currency is expressed as kina, converted if necessary at a rate of one pound equals two kina, and one Australian dollar as one kina.

Government Departments

The abbreviation DDA (for Department of District Administration) is used throughout to refer to the government department also known as the Department of the Administrator and Native Affairs, Department of the Chief (Prime) Minister and Development Administration. Patrol officers who previously worked for the DDA are now part of the Department of the Eastern Highlands etc.

The abbreviation DPI is used to refer to the Department of Primary Industry and provincial Divisions of Primary Industry. The national DPI has been known as the Department of Agriculture (pre-war Papua and New Guinea Trust Territory); Department of Agriculture, Stock and Fisheries (ca 1947 to 1976); Department of Primary Industry (1976 to 1987); and Department of Agriculture and Livestock (1987 to present). The extension services were transferred to the provincial governments from the late 1970s onwards and are located in provincial units usually known as Divisions of Primary Industry.

Pumberel Health Centre

The Health Sub-Centre on the Nembi Plateau is known as Pumberel to the Southern Highlands Division of Health and I follow this name. It is located at a place known as Hol (or Ol) and Crittenden (1982) and Baines (1983) use the name Ol for the Centre. Prior to 1980 it was located at a nearby location at Embi and Cogill and Clarke (1984) use the name Embi.

Statistical Symbols

The symbols *, **, *** indicate statistical significance at $P < 0.05$, < 0.01 and < 0.001 respectively.

Village/er

The terms "village" and "villager" are used throughout, even when referring to people who live in dispersed hamlets, as the term corresponds to administrative units and people identify themselves by these units. The people of the Nembi Plateau live in dispersed hamlets, as do most people in the western part of the highlands, rather than in a discrete "village". Thus Upa Village on the Nembi Plateau is a government census point for three clans who live within a short distance of the ceremonial ground known as Upa. In the Eastern Highlands, people live in more nucleated settlements.

CHAPTER ONE

INTRODUCTION

This thesis is concerned with variation in subsistence food supply in the highlands of Papua New Guinea (PNG), and in particular with variations of sufficient intensity to bring about periods of felt shortage known as *taim hangre* (hungry time) or *taim bilong hangre* (time of hunger) in Melanesian Pidgin(1). By the standards of the modern famines in the Sahel region of Africa (Glantz, 1987), the Bengal famine of 1943 (Alamgir, 1980), or the famines experienced in medieval Europe, these are minor events. Famine, as defined by Dando (1980:58) or Sen (1981:40), means a prolonged period of food deficiency so serious as to cause widespread death, whether age- and sex-selective or among the whole population. None of the food shortages experienced in the PNG highlands since colonial contact approaches this level. The pattern of subsistence farming in the highlands of PNG, described below, offers considerable buffering capacity against untoward events. Nonetheless, the episodes of *taim hangre* to be described and analysed in this thesis share in common with the larger events elsewhere the same difficulty of interpretation. There is little agreement on the causes of certain *taim hangre* events in PNG. As elsewhere in the world, it has been most common to attribute these events to climatic extremes, and to drought in particular.

Until new forms of analysis began to be applied to the African famines of the 1970s, research tended to focus more on perceptions of climatic hazard and response to its incidence (for example, Kates, 1971; White, 1974a; Wisner and Mbithi, 1974). In the 1970s numerous authors began to challenge the assumption of an automatic nexus between climatic extremes and food shortages. Lofchie (1975), for example, argued that any connection between drought and famine is modified by the political and economic arrangements of a society. He reasoned that decades of over-concentration on export cropping were responsible for the chronic food production problems in Africa and that this rendered people more vulnerable to climatic extremes. His arguments were taken further by, for example, Ball (1976) and Susman *et al.* (1983). Ball stated that Lofchie ignored the "link between politico-economic conditions and the *creation* of drought". She claimed that colonial attempts to integrate peasants and herders into a monetarised, commercialised economy led to ecological degradation which intensified drought conditions. Susman, O'Keefe and Wisner attempted to explain disasters in terms of marginalisation. They argued that poor people are increasingly vulnerable to extreme physical events; that disasters will increase as socio-economic conditions and the physical environment deteriorate; and that the poorest classes will continue to suffer most losses.

(1) While a number of Europeans wrote about food shortages in the highlands in the years following contact, the Rev J. N. Nilles, who worked in Chimbu from 1937 onwards, was the first writer I know of who used the term "time of hunger" (Nilles, 1953:4).

Other authors take less extreme positions but still seek to minimise the relationship between climatic perturbations and food supply problems. Sen (1981) argues that famines are caused by an inability of people to command food (exchange entitlements) rather than a decline in food availability. Following a wide-ranging study of famines, Dando (1980) concludes that natural factors create crop failure, but that people cause famines through political decisions, internal disruptions and cultural restraints. The debate as to the cause of famine in Africa continues. This is illustrated by Sinclair and Fryxell's (1985) argument that recent famines in the Sahel are caused by overgrazing and not simply by lack of rain; by the acrimonious debate between Torry (1986) and Watts (1983; in press) over the roles of colonialism and political ideologies; and by the varied viewpoints in the volume *Drought and Hunger in Africa* in which some authors concentrate on environmental problems, some attribute famine to internal government policies of African states, and others to international economic conditions (Glantz, 1987).

The occurrence of food shortages in the Papua New Guinea highlands provides a good opportunity to examine some of these arguments. Over a million people live in the region; most people are still largely dependent on subsistence agriculture for their livelihood; there is no class of landless peasants; cash cropping is widespread and is dominated by one commodity (Arabica coffee); there is a single dominant staple food (sweet potato) in the region; and the people have experienced colonial rule, albeit shorter and more benign than in many other parts of the world(2).

The same problems of interpretation, though without the philosophical overtones of the African debate, have begun to emerge in recent literature on *taim hangre* events in PNG. This is well illustrated by the lack of agreement on the causes of food shortages which were widely reported in 1984. These shortages were variously attributed to people's neglect of food gardens during the coffee harvest season (Korugl, 1984), or neglect during the harvest of a pandanus nut and fruit (Muwanli, 1984; Senge, 1984); unspecified failure of sweet potato crops to bear (Levett, 1984; Tai, 1984; Gunther, 1985); excessively intensive land use (Levett, 1984); damage to gardens by enlarged pig herds prior to pig kills (Gunther, 1985); inadequate garden planting rates and premature harvesting (Crittenden *et al.*, 1985). Other explanations recorded, but not endorsed, by two agronomists included excessively wet periods reducing sweet potato yields; drought having the same effect; a change in seasonal climatic patterns; damage to gardens by pigs and rats; severe soil erosion; poor planting methods for sweet potato; poor soils; and an eclipse of the sun (Levett, 1984; Gunther, 1985). Clearly such a plethora of explanations, many of which only apply in restricted locations, cannot explain a phenomenon which operates at a regional level.

(2) The botanical names for crops referred to in the text are given in Appendix 1.

Food supply problems may arise for several basic reasons, which operate singly or in combination. These reasons are a change in crop yield or crop planting rate; an overall decline in food production combined with changes in either crop yield or crop planting rates; or a change in the balance between supply and demand. There are numerous statements in the academic and popular literature on the causes of food shortages in PNG and all of these reasons are implied. There are only a limited number of major studies on the causes of food supply problems in the highlands. Some attribute shortages to climatic extremes and their effects on crop yield (for example, Shannon, 1973; Powell and Powell, 1974; Waddell, 1975; Wohlt, 1978; Wohlt *et al.*, 1982). Crittenden (1982, 1984) proposes that food supply varies annually because cultivators vary their planting rate regularly according to their perception of climatic extremes. Activities associated with commodity production for cash, that is, coffee growing and cattle raising, are given as the prime cause of subsistence food deficits by Grossman (1984). These arguments and assertions are examined in an attempt to establish the most important causes of food shortages in the PNG highlands.

APPROACH AND METHODOLOGY

The study is located within the traditions of cultural geography, concerned as it is with rural societies undergoing change and with a historical orientation (Brookfield, 1973b; Mikesell, 1978). The methodology used is to examine possible relationships between climatic, social and economic phenomena and food supply problems. Considerable attention is given to the behaviour of plants and people, in particular, the relationship between sweet potato and soil moisture, and villagers' crop planting patterns. The study also focusses on mechanisms through which political and economic changes associated with colonialism and post-colonial governments may affect food production. In the PNG context, these changes include a possible overall decline in subsistence food production per person, the influence of cash cropping, and male migration.

Attention is directed at food supply problems which occur at the level of several census divisions and wider, not those which affect only a few households or communities. The term "widespread" is used throughout as a shorthand for "widespread at a district level, that is, affecting many communities in at least two census divisions of a district" (see Conventions). Particular emphasis is given to long data runs as, it will be argued, the use of short data runs is partly responsible for the varied explanations offered for food supply problems in PNG. The study is conducted at a range of scales, from intensive work in two communities through to data sets covering the entire highlands region. Numerical data are presented in less aggregated form in appendices to facilitate reanalysis and use of data for other purposes.

It is almost an academic "tradition" in PNG to undertake intensive village studies, for up to 24 months. Such studies have much to offer an understanding of food production at the village level, but they can also lead to merely local explanations of regional phenomena. This study seeks general, universally applicable explanations for a phenomenon which occurs irregularly over much of highlands PNG. It does not, therefore, pursue questions such as the locus of decision making on food production within households, and certain questions raised by this work must be addressed by more intensive studies at a household level. Change in demand for food associated with variation in pig numbers is another important component of the balance between supply and demand; however attention here is concentrated on food supply rather than on the supply/demand balance.

The reason it is possible to take a broader and longer term approach than much Ph.D. research in PNG is that in early 1978 I took up employment as a research agronomist with the PNG Department of Primary Industry (DPI) and was based at Aiyura in the Eastern Highlands Province for five years(3). Later in 1978 I participated in a multi-disciplinary team study which sought to understand the very high rates of child malnutrition on the Nembi Plateau in the Southern Highlands Province (Allen, 1984b). Our fieldwork coincided with a food shortage there. The highlands literature suggested that annual or irregular climatic extremes, particularly frost and drought, or distraction of food producers during harvests of the cash crop coffee or an edible nut (karuka pandanus) were responsible for food shortages. The situation on the Nembi Plateau was intriguing as drought, frost, coffee cultivation and karuka nut pandanus harvests were not important factors and could not be held responsible for subsistence food shortfalls.

Stimulated by the Nembi experience, I commenced a research project entitled "Seasonality of subsistence food production in the highlands". Field sites were firstly in Asiranka Village, on the Highlands Agricultural Experiment Station at Aiyura and in the Kainantu area, and secondly, on the Nembi Plateau. A research horticulturist, Euclid D'Souza, was employed to work under my direction. I collected data in the Aiyura area, and D'Souza on the Nembi Plateau. D'Souza lived on the Plateau and also worked on another of my projects entitled "Intensification of subsistence agriculture, Nembi Plateau" (D'Souza and Bourke, 1983; 1986). Regular data collection for the seasonality project extended from February 1979 until May 1983 in the Aiyura/Kainantu area and on the Nembi Plateau between September 1979 and June 1982. Some of the data from both locations are used here.

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(3) I had previously worked on food crops and subsistence agriculture as a Research Agronomist in the PNG lowlands for the DPI between 1970 and 1977. Food supply problems are also an issue in the PNG lowlands where outsiders commented on subsistence food scarcities as early as 1849 (Laracy, 1973:136-138).

Other projects that I worked on between 1978 and 1983 included one that gathered data on the altitudinal limits of some 270 crop species in PNG; and another that mapped subsistence food production systems at a scale of 1:500,000 for all of PNG. Both projects involved extensive field trips in all parts of the highlands region and elsewhere. They provide the basis for generalisations made about subsistence food production at a regional level within the thesis.

In May 1983 I moved to Canberra to undertake a Ph.D. study programme and elected to continue the study of food shortages and crop seasonality. The emphasis changed during my stay in Canberra to variation of food supplies. A three week visit was made to Goroka, Aiyura and Mendi in November 1983. The major period of additional fieldwork for the thesis was the four months between August and December 1984. A brief visit was made to Port Moresby in April 1985, when further data were collected. In 1984 I spent over a month in Port Moresby, mainly extracting material from patrol reports in the National Archives. Then I lived for over a month in Asiranka Village (September-October 1984) where I slept in a small abandoned trade store and ate with the family of Apolis Paibiko and his wife Naniso. A similar period (October-November 1984) was spent in Upa Village where I lived in a permanent material house owned by Pei. In both field sites, I communicated in Melanesian Pidgin, a language in which I am fluent, not in local languages. The remainder of the fieldwork was spent collecting data on food shortages in the five highlands provincial capitals.

THE ARGUMENT

Evidence for variation in subsistence food supply comes from two primary sources. The first is documented observations by outsiders, including the author, mostly based on statements by villagers about food supply. These observations are available in a number of forms, including patrol reports by government officers and government correspondence files. The second source of evidence comes from surveys in periodic food markets. An inverse relationship between supply and price exists in these markets and, it is argued, this reflects subsistence supplies in the market catchment and can be used as a record of village production. Based on these data sources, evidence is presented in Chapter 3 on variation in the supply of sweet potato and other foods over time at a number of locations.

The supply of sweet potato varies over time, but not on a regular or an annual basis, although paired food shortages about two years apart are not uncommon. The supply of other food crops in aggregate generally varies irregularly, but it does vary in a regular annual cycle in some parts of the highlands. The variation in production of supplementary foods depends more on the farming system in which they are grown than on climatic seasonality. These data also show that the frequency of episodes of food scarcity has not altered since contact between highlanders and foreigners.

The study of food shortages in PNG is of more than academic interest. For one location where good data are available on children's bodyweight, it is shown that there is a close relationship between food shortages and variation in the rate of child malnutrition. This is significant because highlands children who fall below certain international standards of weight for age have a greatly increased rate of morbidity and mortality (Heywood, 1982). Thus food shortages do affect people's wellbeing, particularly where cash incomes are very low. The available data does not indicate that variation in subsistence food supply affects infants' birthweight. Food deficits have resulted in increased death rates in the past in parts of the highlands, most recently in 1941-42. There is no unequivocal evidence for hunger-related deaths since then, although claims for this by villagers are not uncommon (Chapter 4).

The impact of subsistence food shortfalls has been greatly reduced since contact by access to cash and imported food. Where cash incomes are greater, the impact of subsistence food deficits on peoples' body weight is likely to be much weaker.

The data do not support the argument that a decline of food production per person since the PNG highlands have been incorporated into the world economy is a contributing factor to food supply problems. All available evidence clearly indicates that there is no causal relationship between activities associated with coffee or karuka pandanus nut harvests and food shortages. The available evidence, whilst incomplete, does not suggest that diversion of villagers' labour by wage labour or migration is responsible for food shortages. Other factors, such as tribal fighting and disruptions associated with pig killing ceremonies which have applied prior to colonial contact, probably do result in some shortages, but the scale of disruption is restricted (Chapter 5).

The major causes of food supply shortfalls are climatic problems and variation in the crop planting rate over time; and it is not unusual for both factors to combine to produce a food shortage. The relationship between climatic variation and food supply is examined, using firstly agronomic experiments and village yield surveys (Chapter 6) and secondly the calculated soil moisture storage (Chapter 7). Frost sometimes has a major negative influence on crop yield, but only in restricted locations. The most important climatic influence on sweet potato yield is found to be very extended periods of high rainfall, particularly in the weeks following planting when tubers are being initiated. This contributes to the problem of interpreting the cause of food shortages because the effects of the extended wet spell are not apparent until many months later. Very intensive rainfalls over short periods may also be damaging. Drought by itself rarely results in food deficits.

However, when a drought is preceded by an extended wet period some months earlier, this combination reduces crop yield.

Villagers may make a number of responses to food shortages, including altering pig management strategies, eating alternative foods, migrating, and if they have access to cash, buying imported food (Chapter 8). An extremely important response, that influences future food supplies, is variation in the planting rate. Planting rates for sweet potato vary over time, although not in a regular manner. When food is scarce, people plant larger areas with food crops and a greater proportion of food gardens is planted in previously fallowed land. This results in a period of abundant food supply some six to eight months later. The planting rate is then reduced below the long term average. This may result in a second food shortage, particularly if it coincides with a second climatic extreme. This combination of climatic perturbations and cycles in planting rate produces food shortages which have no obvious cause, but which are attributed to a wide range of different and often contradictory local causes.

The import of these findings for PNG is at a practical level: the need for better informed extension workers, for extension advice to villagers to try to reduce variation in planting rate, and for greater emphasis on the collection of data which would allow monitoring of present and prediction of future food supply problems. For the international literature, the findings suggest that, however applicable political and economic factors are in assigning the causes of famine, environmental parameters must not be ignored. Further, it can be argued that in some parts of the world where the international economy is, as yet, muted, environmental factors may be more important causes of variation in food supply than economic or political factors.

CHAPTER TWO

THE HIGHLANDS REGION AND THE STUDY COMMUNITIES

In this chapter, background information is given on the physical and social environment, and on food production systems in the highlands region in general and in the two communities where the most intensive observations were made. Emphasis is given to data that relate to possible causes of food shortages, such as climatic classification and involvement of villagers with cash cropping. The two study communities share some common features, but they contrast in other ways. It will be argued that the sample households studied in each community are representative of the community as a whole, and that the two communities are reasonably representative of others in their respective parts of the region.

THE HIGHLANDS

The study region is the central highlands and highlands fringe of PNG, that is, the inhabited parts of New Guinea above 1000 m, from Menyamya-Kaintiba in the east to the Irian Jaya border in the west (Figure 2.1). The study is concentrated within two provinces, the Eastern Highlands (EHP) and the Southern Highlands (SHP); and within those two provinces on Asiranka Village in the Aiyura Basin, south-east of Kainantu, EHP; and on Upa Village on the Nembi Plateau, Nipa District, SHP.

Most people in the highlands live in nucleated villages or in dispersed hamlets ("villages"), and a small proportion live in small towns and institutions such as high schools(1). These villagers produce most of their daily food needs in their own food gardens. Some money is obtained from cash crops, mainly Arabica coffee, some from remittances from relatives employed out of the village and some from casual or seasonal wage labour. Only a very small sector of the highlands village population is involved in business or wage employment and does not grow the bulk of its food supply.

The organisation of household living arrangements and production units varies somewhat within the region and these are influenced by Western values. Polygyny, which was very widespread, is being replaced by monogyny and nuclear family residence. For the purposes of collecting and presenting information, it is useful to make a distinction between "households" and "women's cooking hearths" (Crittenden, 1982:386). A household is usually a male-headed unit whereas a woman's cooking hearth centres around a married woman and consists of those who depend on her for food. Where monogynous marriages are the norm, as in Asiranka Village, a household usually contains one cooking

(1) See Conventions for use of the term "village".

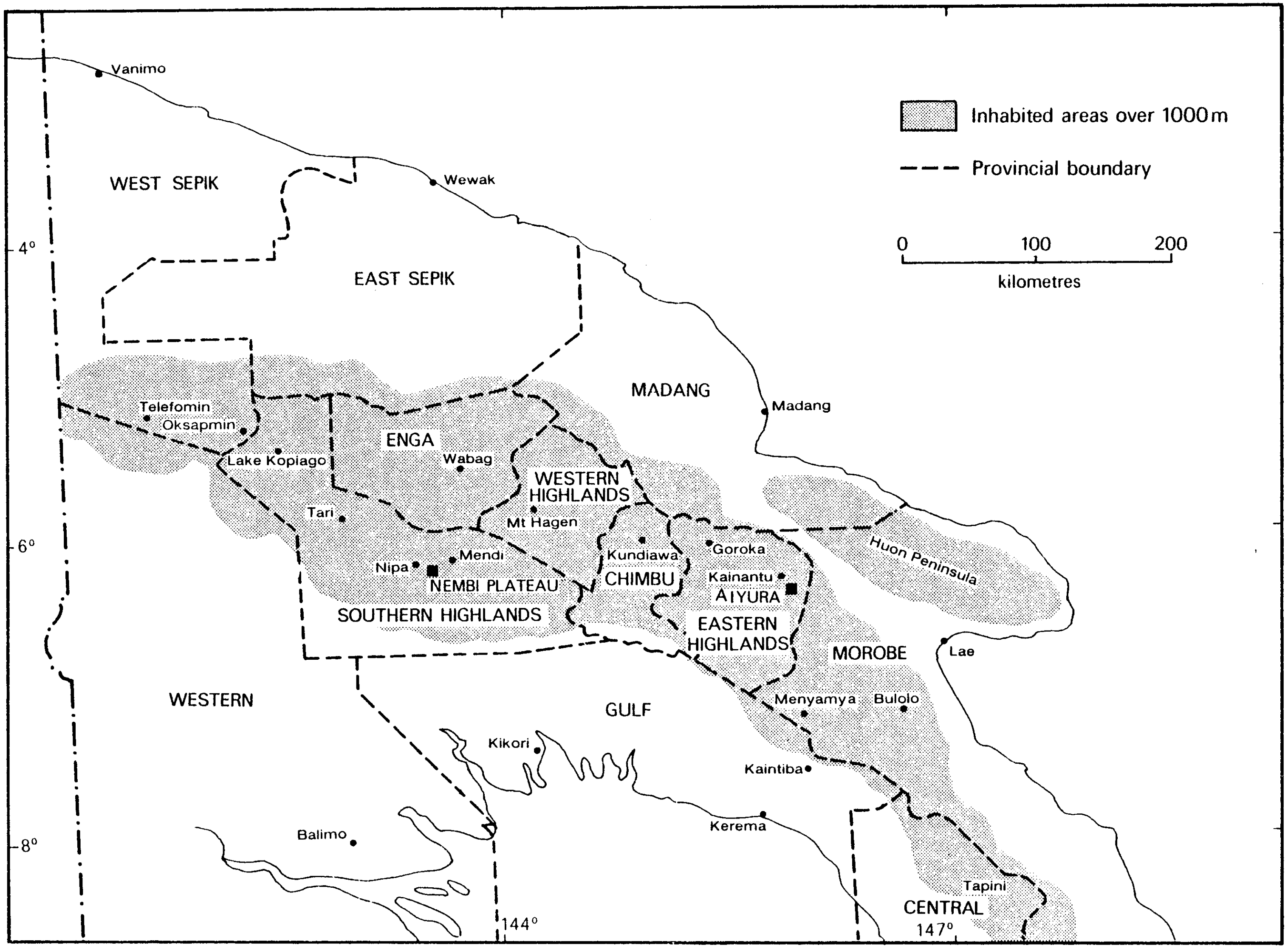

Figure 2.1 Highland region of Papua New Guinea

hearth. However where polygynous marriage is the norm, as on the Nembi Plateau, a household often contains more than one cooking hearth. Data collection is influenced by the sex which is principally responsible for a particular element of the village economy. Thus pig ownership and ceremonial exchanges are controlled by men, particularly heads of households, whereas women are regarded as being responsible for sweet potato production.

The Highlands Environment

The region as defined extends from 1000 m above sea level to the upper limit of agriculture, which is 2850 m in parts of Enga and Chimbu (unpublished field observations). The population in this region was about 1.3 million in 1984, and about 90 per cent of these were rural village dwellers. The greatest concentration of population is between 1500 m and 2000 m, although large numbers of people live and practise agriculture in basins and valleys above 2200 m. Within the highlands there is a regular and linear decrease in air temperature with increasing altitude (McAlpine *et al.*, 1983). Seasonal changes in air temperature between summer and winter are slight (1-2 ^{o}C). Mean monthly minimum temperatures at Aiyura (1640 m), for example, range from 12.0 ^{o}C in August to 14.1 ^{o}C in March. Corresponding mean monthly maximums range from 22.8 ^{o}C to 24.7 ^{o}C (McAlpine *et al.*, 1975:124). Irregular frosts occur, particularly at altitudes above 2200 m, but as low as 1600 m, and these are associated with basin topography and low cloud incidence. Published (for example, Brown and Powell, 1974) and unpublished records between 1953 and 1984 indicate that frosts have occurred in most months of the year but mainly in the period July to November.

The region extends over only three degrees range of latitude (approximately 4^{o}30" to 7^{o}30"S) and most of the central highlands lies within a narrower latitudinal range (Figure 2.1). Thus the effects of latitude on daylength variation are small (45 minutes maximum difference) and differences between locations are slight (McAlpine *et al.*, 1983:119). The number of sunshine hours varies somewhat during the year; the mean monthly number of sunshine hours at Goroka ranges from 4.0 hours in February to 5.7 hours in May, with an annual mean of 4.8 hours (McAlpine *et al.*, 1983:124).

The annual rainfall is high everywhere within the highlands and ranges from about 1800 mm to 5000 mm per year. Rainfall is lower in the Eastern Highlands and tends to increase in a westerly direction. Variability of annual rainfall is very low, with a coefficient of variation of annual rainfall of less than 15 per cent (Brookfield and Hart, 1966; McAlpine *et al.*, 1983:65, 71). Because variation in temperature and daylength between seasons is small to negligible, rainfall provides most seasonal variation in equatorial regions, such as the PNG highlands.

The climatic types in the highlands have been mapped on the basis of rainfall seasonality (Figure 2.2). Rainfall seasonality was derived from 40 rainfall stations using Walsh's (1981) classification and mean monthly rainfall data (McAlpine *et al.*, 1975). Walsh's (1981) classification of tropical climates is based on the absolute seasonality and relative seasonality of rainfall. The former depends on the length of the dry season and the latter on the degree of contrast between the amounts of rain at different times of the year (Table 2.1).

The Southern Highlands Province, western parts of Enga Province and the highlands region west to the Irian Jaya border are perennially wet (no month with an average rainfall of less than 100 mm) with a very even distribution of rainfall among months (A0 type climate) (Figure 2.2). Most of the Western Highlands and Enga are also perennially wet but with a definite drier season (A1 climate). The northern part of Chimbu Province and much of the Eastern Highlands have a short but definite dry season (1-2 months) (B1 climate); the northern part of the Eastern Highlands Province is wet but seasonally dry with a seasonality index of 0.2 to just over 0.40 (C1 or C2 climate). A smaller part of this province, centred on Henganofi, has a five month dry season with a rather seasonal distribution of rainfall (D2 climate)(2).

It is important to understand that rainfall seasonality in the PNG highlands is much less pronounced than that in Africa or South Asia where many recent papers stress the importance of climatic seasonality (for example, Chambers *et al.*, 1981). The A and B type climates (0-2 dry months per year) that cover much of the PNG highlands do not occur in South Asia and are very restricted in Africa (Walsh, 1981). Where A and B type climates prevail in the PNG highlands, the dry season is neither sufficiently long nor sufficiently acute for the growth of plants to be seriously affected, and seasonal peaks in either workload or production can be avoided (Bayliss-Smith, 1981). Thus it seems that villagers are not obliged to plant and harvest staple crops in a clear seasonal pattern as suggested, for example, by Meggitt (1958) or Crittenden (1982; 1984), especially in that part of the region that experiences A type climate (Figure 2.2).

Soil types in the highlands display great complexity and variation. Soils developed on volcanic ash are commonly used for sweet potato cultivation, particularly Hydrandepts, but other soil types, such as Tropaquents and Humitropepts, are also used (Bleeker, 1983; Wood, 1987). Soil types are discussed in more detail in sections on agriculture in the two

(2) Abeyasekera (1987) has produced a new classification of rainfall seasonality for PNG. There is strong agreement between his classification and that based on Walsh's method. Locations classed as having A0 and A1 type seasonality here (Figure 2.2) are mostly classed as B2 by Abeyasekera, that is, those with an even distribution of rainfall throughout the year and a very slightly drier period in June and July. Locations classed as B1 and C1/C2, using Walsh's categories (Figure 2.2), are classed C4 by Abeyasekera, that is, those with a wetter period between December and March.

Table 2.1 Classification scheme of tropical climates based on rainfall seasonality(1)

Absolute seasonality(2) Symbol	Type	No of dry months (months <100 mm)	Relative seasonality(3) Symbol	Type	$\overline{SI}$
A	Perennially wet	0	0	Very equable	<0.20
B	Wet with short dry season	1-2	1	Equable but definite drier season	0.20-0.39
C	Wet seasonally dry	3-4	2	Rather seasonal	0.40-0.59
D	Wet and dry	5-7	3	Seasonal	0.60-0.79
E	Dry seasonally wet	8-9	4	Markedly seasonal; long drier season	0.80-0.99
F	Dry with short wet	10-11	5	Most rain in ≤3 months	1.00-1.19
G	Arid	12	6	Extreme	≥1.20

Notes

(1) This classification follows Walsh (1981).

(2) Absolute seasonality is based on the number of months with a mean monthly rainfall of less than 100 mm (Walsh uses 4" or 102 mm).

(3) Relative seasonality is based on the mean seasonality index ($\overline{SI}$):

$$\text{Mean SI} = \frac{\sum_{n=12}^{n=1} \left| \bar{x}_n - \frac{\bar{R}}{12} \right|}{\bar{R}}$$

where $\bar{R}$ = mean annual rainfall

$\bar{x}_n$ = mean rainfall of month n

n = month from 1 (January) to 12 (December)

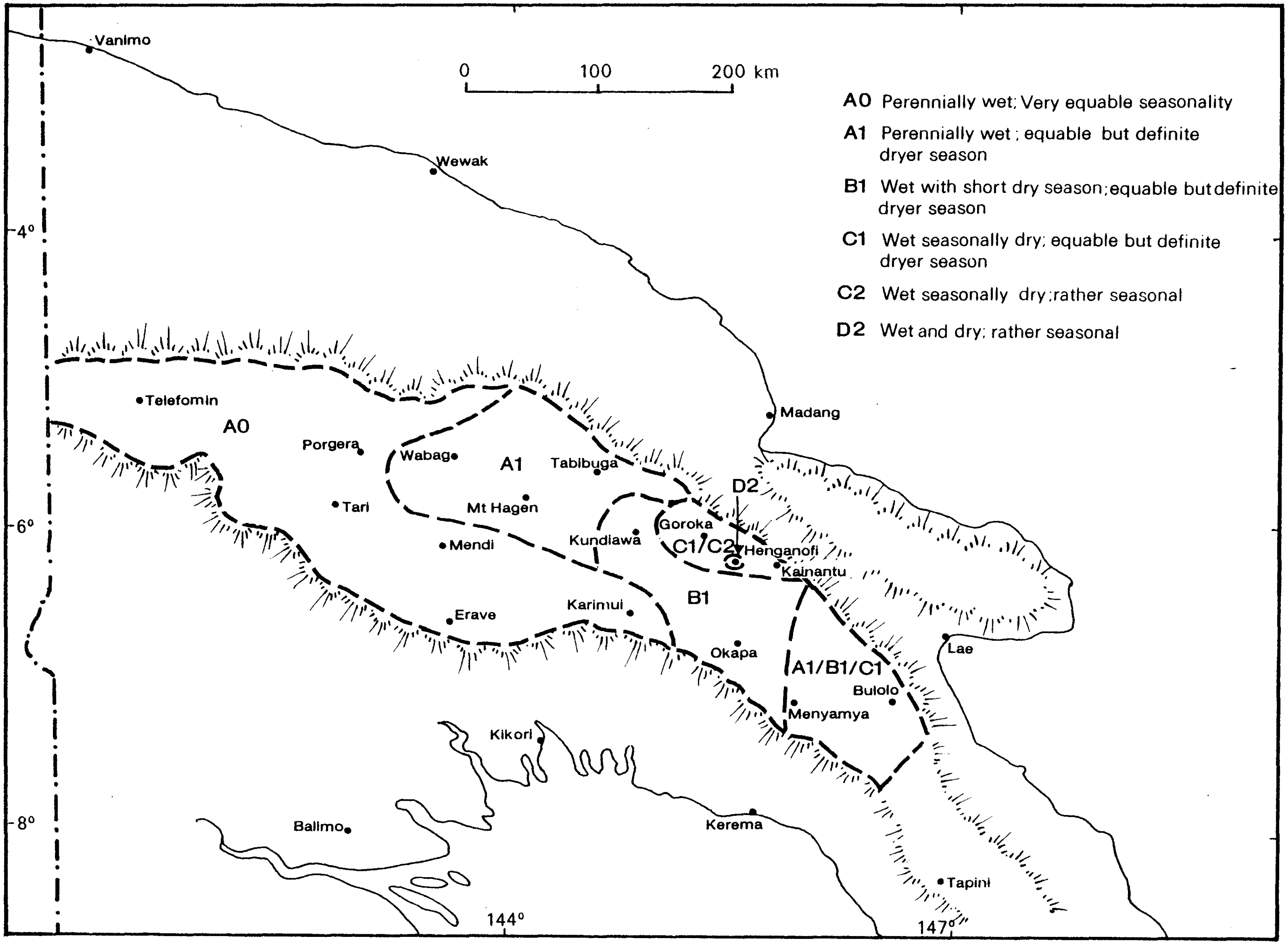

Figure 2.2 Climatic types in the Papua New Guinea highlands based on rainfall seasonality

study villages later in this chapter; and in the section on sweet potato time-of-planting trials (Chapter 6).

Food Production Systems

The major source of food for highlands villagers is their own subsistence food gardens but they also obtain sustenance from their pigs, imported foods (mainly rice, flour, tinned fish, tinned meat and animal fat), hunted and gathered food, food purchased in local food markets and that received as gifts or at feasts (Figure 2.3). Villagers purchase some food in local food markets, as well as selling it. The market economy is poorly developed compared with that of other tropical countries, although it is expanding (Bourke, 1986). There are very few villagers in the region who do not have access to land for food production.

One of the most striking features of highlands agriculture is the dependence on a single staple, sweet potato. Twenty five studies summarised in Table 2.2 indicate that, in the central highlands, sweet potato provides between 47 per cent and 94 per cent of people's energy intake; between 19 per cent and 73 per cent of their protein intake; and occupies 37 per cent to 91 per cent of land planted to food crops. Numerous other crops are grown and collected for food. With some minor exceptions, villagers do not store food after harvest but significant pre-harvest storage occurs as the harvesting period of sweet potato is rather flexible. This is examined in greater detail below.

The marked dependence on a single staple crop which is not stored after harvest renders people more vulnerable to fluctuations in subsistence food supplies. Unlike the PNG lowlands, alternative staples such as yams, bananas or sago are not available in sufficient quantities to replace the main staple when supply is reduced(3).

Sweet potato is generally grown in cropping systems of moderate to high intensity as defined by the ratio of periods of cropping to fallow. Some low intensity systems based on long forest fallows are used on the highlands fringe. In parts of the highlands, including the two study villages, supplementary crops are grown in specially planted gardens, termed "mixed gardens". The intensity of cultivation of these is low. In other parts of the region, especially where total agricultural intensity is generally low, supplementary crops are planted in sweet potato gardens.

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(3) In the PNG lowlands food shortages are often defined by villagers as lack of availability of a favorite food, such as taro in the Goodenough Bay area of Milne Bay (Kahn, 1986:34) or yams in the inland Sepik (Lea, 1965) rather than absolute shortage of energy foods. In the highlands a subsistence food shortage is synonymous with a sweet potato shortage.

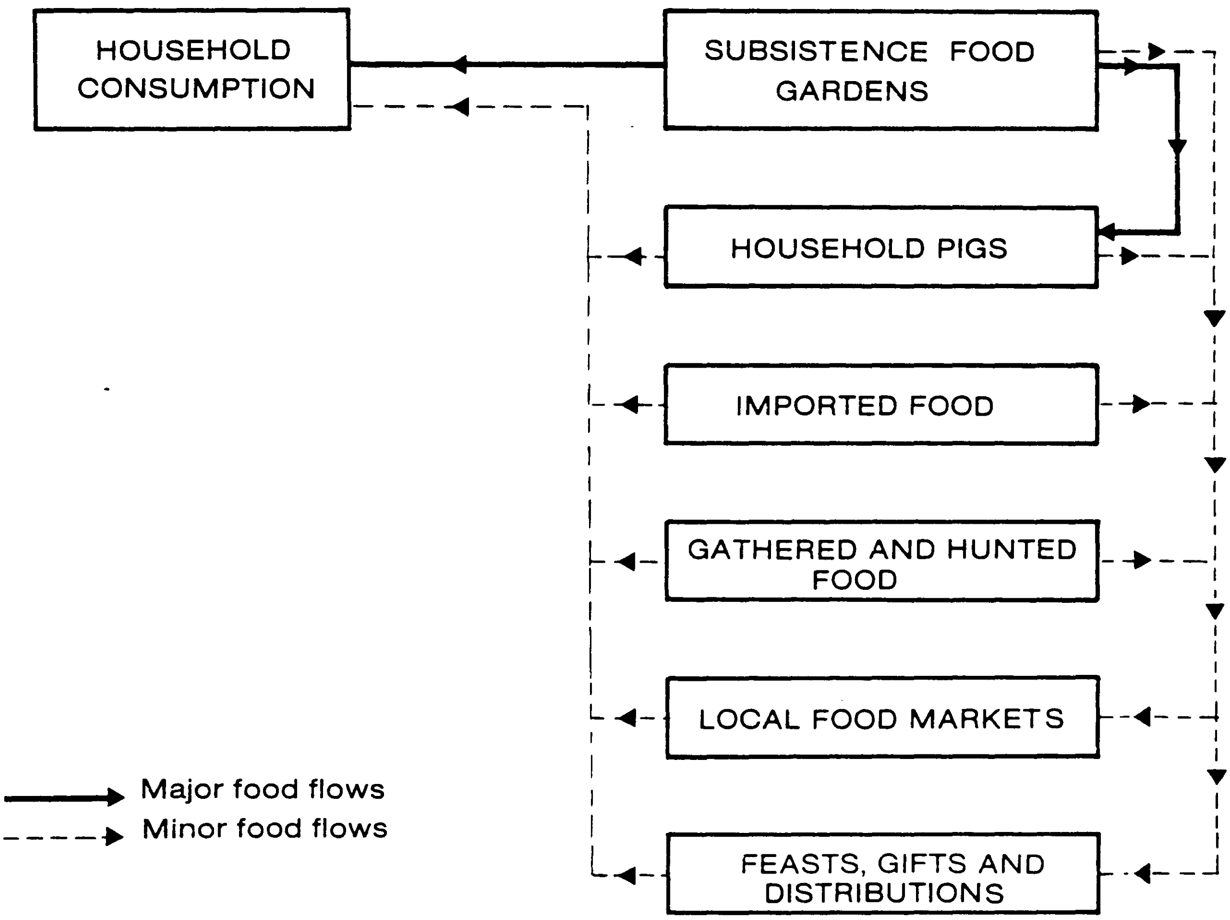

Figure 2.3 Highland villagers' food supply systems

Table 2.2 Importance of sweet potato in the diet of various groups of people in the highlands and highlands fringe

Location	Contributions of sweet potato (%) Energy intake	Protein intake	Total food intake (by wt)	Area of food crops planted	Source
Gumine, Chimbu(1)	94	53	83	-	Bailey & Whiteman (1963)
Sinasina, Chimbu	92	-	89	-	Oomen & Malcolm (1958)
Baiyer R, WHP	89	73	86	-	Oomen & Corden (1970)
Wage V, SHP	88	53	77	-	Sillitoe (1983)
Kundiawa area, Chimbu(1)	87	48	80	-	Bailey & Whiteman (1963)
Sinasina, Chimbu	84	69	-	-	Lambert (1975)
Okapa, EHP	80	60	-	-	Jeffries (1978)
Okapa, EHP	78	41	-	-	Reid & Gajdusek (1969)
Upper Chimbu V	77	41	70	-	Hipsley & Kirk (1965)
Sinasina, Chimbu(2)	76	56	77	-	Venkatachalam (1962)
Lai V, Enga	73	33	63	63-67	Waddell (1972)
Siane, Chimbu	65	-	56	-	Salisbury (1962)
Lufa, EHP	64	37	-	-	Norgan *et al.* (1974)
Sinasina, Chimbu	53	34	61	-	Harvey & Heywood (1983)
Nembi Plateau, SHP(3)	47	19	-	-	Baines (1983)
Simbai V, Madang Prov(4)	30	10-17	19	-	Rappaport (1968)
Simbai V, Madang Prov(4)	25	-	16	-	Clarke (1971)
Simbai V, Madang Prov(4)	-	-	14	-	Buchbinder (1973)
Upper Kaugel V, WHP	-	-	>90	-	Bowers (1968)
Sirunki Plateau, Enga	-	-	90	-	Sinnett (1975)
Sirunki Plateau, Enga	-	-	-	91	Allen (1982)
Nembi Plateau, SHP	-	-	-	95	Crittenden (1982)
Nembi Plateau, SHP	-	-	-	89	Bourke (1984b)
Lai V, Enga	-	-	-	87	Allen (1982)
Tsak V, Enga	-	-	-	83	Allen (1982)
Upper Lamari V, EHP	-	-	-	78	Grossman (1984)
Aiyura V, EHP	-	-	-	57	Bourke (in press)
Lamari V, EHP	-	-	-	37	Boyd (1975)

Notes

(1) Adult men only. Figures for other groups in the population are similar.

(2) Venkatachalam's data were recalculated by Lambert (1975).

(3) Pregnant women only

(4) Highland fringe location. All others are central highlands.

Pigs are an important component of the food production system in the highlands. A number of authors have recorded the number of pigs and people at different locations in the region and these data are summarised in Table 2.3. These studies indicate that there is on average slightly more than one pig per person (mean ratio is 1.2; n = 50; SD = 0.78). The ratios for locations on the highlands fringe are lower and the mean of the ratios for locations within the central highlands is slightly above the regional mean (1.3; n = 44; SD = 0.77)(4).

A number of studies suggest that pigs consume a high proportion of the sweet potato harvest. The eight published recordings of the proportion of sweet potato fed to pigs in the highlands indicate a range of 38 per cent to 64 per cent with a mean of 52 per cent (SD = 9.0 per cent) (Table 2.4). Pigs are managed and used differently in different parts of the region. In much of the western part, pig numbers, and more importantly animal live-weight (Hide, 1981), are increased over a long time period in preparation for large scale slaughters of animals. Animals are killed over a few hours and the pork is distributed and redistributed to many people over large distances. As well, live pigs are exchanged between people as part of the exchange networks. In most of the Eastern Highlands, including the Kainantu area, and in parts of the highlands fringe, these periodic slaughters and exchanges of live animals do not occur. Pigs are killed in small numbers and total live-weight of animals does not fluctuate so greatly. It has been suggested that a series of events associated with pig killing ceremonies are responsible for food shortages (for example, Criper, 1967; Hide, 1980). This possibility is examined in Chapter 5.

Cash crops grown in villages include Arabica coffee, food crops, pyrethrum (above 2400 m), cardamom (below 1600 m), and chilli. Coffee is the most important of these. My field observations are that there is little competition between coffee and sweet potato for garden land, except possibly in parts of the Asaro and Wahgi Valleys, as most village coffee is planted on moister sites and sweet potato prefers well drained land. There is some competition between coffee and the mixed gardens as both are planted on less well drained sites (Brookfield, 1973a; Bourke, 1985b). It is a view widely held by agricultural officers and others that neglect of food gardens during the annual coffee harvesting season is responsible for food shortages (for example, Lambert, 1976; Grossman, 1984). This possibility is examined in Chapter 5.

There is considerable flexibility in highlands food supply systems. This means that short term changes in planting rate do not necessarily result in a major change in food supply some months later. This flexibility occurs firstly because people grow a mixture of cultivars of most crops, including sweet potato (Bourke, 1985c). These cultivars have a

(4) The recorded ratios of pigs to people include only domesticated animals. Wild pigs are numerous and are hunted by villagers on the highlands fringe, but they do not occur in the central highlands (above an altitude of about 1500 m).

Table 2.3 Ratio of pigs to people recorded at various locations in the highlands and highlands fringe

Location	Pigs:people ratio	Source
Kompiam area, Enga	3.8(1)	Feil (1984:243)
Bena V, EHP	3.0(2)	Howlett (1962:171,208)
Asaro V, EHP	2.8(3)	Howlett (1962:185,202)
Bena V, EHP	2.4	Moulik (1973:53-57)
Kainantu area, EHP	2.4	Watson (1983:52,89)
Lai V, Enga	2.3	Waddell (1972:61-62)
Okapa area, EHP	2.2	Robbins (1982:62,248)
Kaip V, WHP	2.1	Malynicz (1977:202)
Lower Lai V, Enga	2.1	Bulmer (1960:95,128)
Tsak V, Enga	2.0(4)	Feachem (1973:30)
Tari area, SHP	1.7(5)	Wood (1984a:198)
Upper Chimbu V, Chimbu	1.6	Wohlt & Goie (1986:44)
Bena V, EHP	1.5	Moulik (1973:53-57)
Mingende area, Chimbu	1.5(6)	Brookfield and Brown (1963:59)
Mendi V, SHP	1.4	Lederman (1986:242)
Upper Chimbu V, Chimbu	1.3	Montgomery (1960:8-9)
Sinasina, Chimbu	1.2	Hatanaka (1972:96)
Sinasina, Chimbu	1.2(7)	Hughes (1966:96)
Asaro V, EHP	1.2	Moulik (1973:53-57)
Koronigl V, Kerowagi, Chimbu	1.1	Malynicz (1977:202)
Asaro V, EHP	1.0	Howlett (1962:208)
Chimbu Prov (North)	1.0(8)	Wohlt & Goie (1986:161)
Dom, Chimbu	1.0	Wohlt & Goie (1986:111)
Sinasina, Chimbu	0.9	Wohlt & Goie (1986:79)
Asaro V, EHP	0.9	Malynicz (1977:202)
Bena V, EHP	0.9	Malynicz (1977:202)
Chuave area, Chimbu	0.9	Salisbury (1962:79,92)
Aiyura Basin, EHP	0.8(9)	Bourke (thesis)
Nembi Plateau, SHP	0.8	Bourke (1984b:67)
Okapa area, EHP	0.8	Jeffries (1978:18,29)
Poru Plateau, SHP	0.8(10)	Strathern (1978:90,96,97)
Wage V, SHP	0.8	Sillitoe (1983:229)
Karimui Plateau, Chimbu (16)	0.7	Hide *et al.* (1984:226)
Lamari V, EHP	0.7(11)	Boyd (1985:130)
Sinasina, Chimbu	0.7(12)	Hide (1981:408)
Sinasina, Chimbu	0.7	Venkatachalam (1962:4)
Jimi V, WHP	0.7	Joughin & Thistleton (1987:106)
Upper Lamari V, EHP	0.7(13)	Grossman (1984:160)
Ambum V, Enga	0.6	Meggitt (1974:168)
Kandep area, Enga	0.6(14)	Wohlt (1978:154)
Lake Kopiago, SHP	0.6	Modjeska (1977:41)
Norikori area, Kainantu, EHP	0.6	Watson (1983:52,89)
Simbai V, Madang Prov(16)	0.6(15)	Rappaport (1968:93)
Sirunki Plateau, Enga	0.6	Sinnett (1975:17,28)
Nembi Plateau, SHP	0.5	Crittenden (1982:476)
Simbai V, Madang Prov(16)	0.5	Clarke (1971:19,84)
Upper Lai V, Enga	0.5	Megggitt (1974:168)
Oksapmin, WSP(16)	0.4	Cape (1981:189)
Hindenburg Ra, WP(16)	0.1	Hyndman (1979:11,212)
Upper Sepik area, WSP(16)	0.1	Morren (1977:294)

Notes

(1) Eight subclans recorded with a range of 3.0 to 4.5

(2) Mean of 2 figures (3.0, 3.0) recorded at different periods

(3) Mean of 3 figures (3.2, 2.8, 2.4) recorded at different periods

(4) Mean of 6 figures (range 1.1 to 3.1) from 6 clans

(5) Mean of 7 figures (range 1.1 to 2.1) for 7 environmental zones in the Tari area

(6) An estimate of the maximum ratio over the pig cycle

(7) Mean of 2 figures (1.5, 0.8) from 2 clans

(8) Mean for all North Chimbu. Wohlt and Goie (1986:160-163) give mean ratios for 12 zones in North Chimbu (0.6 to 1.4).

(9) The ratio of 0.8 is for all households in Asiranka Village (Table 2.9). For the 10 households studied more intensively, the recorded ratio was 1.2 to 1.5 at four samplings (Table 2.8).

(10) Mean of 2 figures (1.0, 0.7) recorded at 2 different periods.

(11) Mean of 2 figures (0.6, 0.8) recorded at different periods for 5 clans (range 0.5 to 0.9)

(12) Mean of 6 figures for 2 clans recorded at 3 different periods (range 0.3 to 0.9)

(13) Mean of 3 figures (0.9, 0.5, 0.7) recorded at different periods

(14) Mean of 34 figures recorded at monthly intervals (range 0.5 to 0.7)

(15) Mean of 2 figures (0.3, 0.8) recorded at different periods

(16) Location is on the fringe of the Central Highlands

Table 2.4 Proportion of sweet potato fed to pigs at various locations in the highlands

Location	Proportion of sweet potato fed to pigs (%)	Source
Lai Valley, Enga Prov	64(1)	Waddell (1972:118)
Dom, Chimbu Prov	62	Harvey & Heywood (1983:198)
Simbai V, Madang Prov	56(2)	Rappaport (1968:60,280)
Sinasina, Chimbu Prov	53	Hide (1981:368)
Dom, Chimbu Prov	50	Harvey & Heywood (1983:198)
Wage V, SHP	49	Sillitoe (1983:228)
Sinasina, Chimbu Prov	42	Harvey & Heywood (1983:104)
Nembi Plateau, SHP	38	Crittenden (1982:474)

Notes

(1) Waddell estimated that 49 per cent of all garden produce was fed to pigs.

(2) Rappaport estimated that pigs consumed 41 per cent of total root crops carried to dwellings.

range of growth rates so that tubers are available over several months, even from plantings made at about the same time. Secondly, these can be stored in the soil for up to several months without deterioration after they attain their maximum size if they are not required for immediate consumption. Thirdly, pigs increase the flexibility of the food supply system. Pigs act as a repository for surpluses which are otherwise impossible to store and their rations are withheld when food is scarce, thus acting as a buffer between the food garden and the human consumers (Vayda *et al.*, 1961). The fourth factor which lends flexibility is the adoption in recent decades of the newly introduced cassava and *Xanthosoma* taro. Tubers of both species can be successfully stored on the plant for many months after they attain maximum size. They are thus available for human or pig consumption when sweet potato is in reduced supply. Both species are commonly planted at lower altitudes, although only small areas are planted above 1600 m.

Despite the dependence on a single major staple crop which cannot be stored after harvest, highlands food supply systems are reasonably stable and are able to absorb some short term supply variation. This property of stability (Conway, 1985) is important in understanding the impact of short term changes in crop yield or planting rates on food supply.

The focus now moves from the highlands region as a whole to the two communities (Asiranka and Upa) in which the most intensive observations were made.

ASIRANKA VILLAGE

Asiranka Village is located in the Aiyura Basin near Kainantu in the Eastern Highlands (Figure 2.4). It was chosen as a study site firstly because of the excellent long term rainfall records from the adjacent Highlands Agricultural Experiment Station and secondly because of an earlier study of its agriculture by Schindler (1952).

The EHP was the first part of the highlands to be visited by Europeans(5) and the people have been more affected by the outside world than those in other parts of the region, especially the Southern Highlands where change is more recent. The cash economy is more developed, particularly in the northern part of the province, than in much of the rest of the region, but subsistence production still provides most of the food consumed by villagers. Road access is good. Most of the northern part of the province has 3 to 4 dry months on average (C1 or C2 climate). In the southern part, including the

(5) During the 1920s, Lutheran evangelists established mission stations in Kainantu District and missionaries made major exploratory patrols from 1926 to 1928. Government patrols (1924) and gold miners (1927) also entered the area during this decade. The Upper Ramu Patrol Post (now Kainantu town) was established in 1932 (Radford, 1987). Several other patrol posts were established elsewhere in the Eastern Highlands from 1933 onwards.

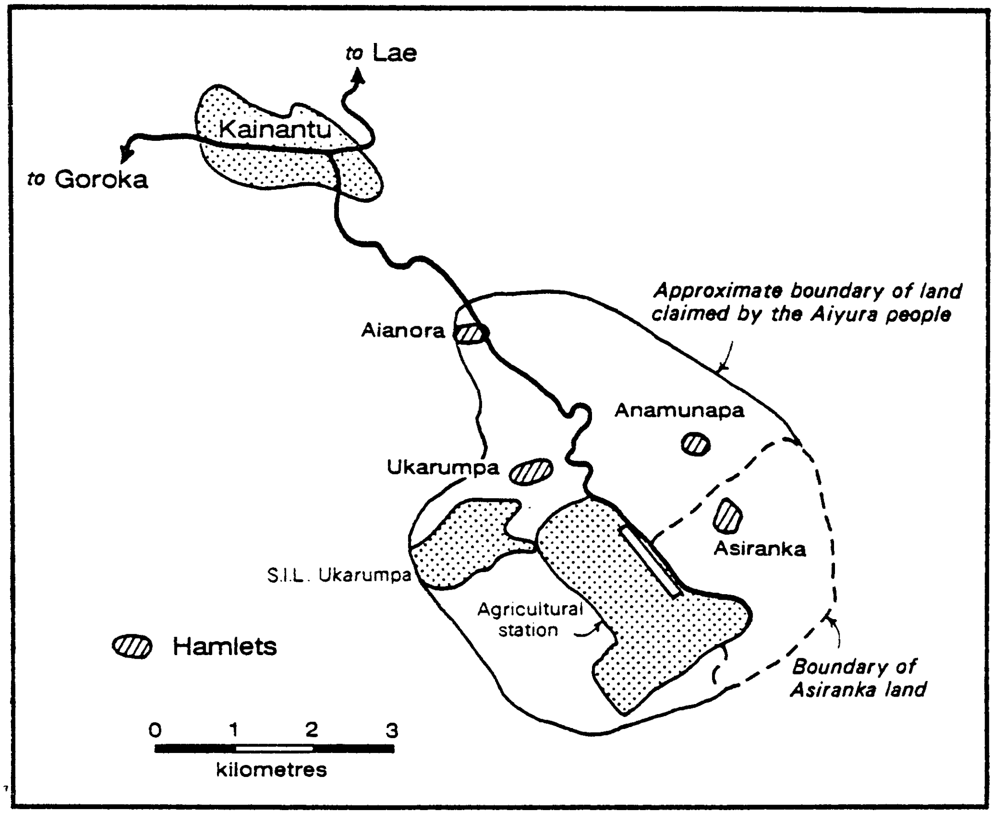

Figure 2.4 Location of Asiranka Village and Aiyura Basin

Aiyura Basin, there are only one or two dry months each year (B1 type climate) (Figure 2.2).

Changes in land use and agricultural practices at Asiranka are documented more fully in a separate paper (Bourke, in press) (Appendix 2). The following description is based on a study over a six year period (early 1978 to late 1984) of land use and agriculture in the village, in particular monthly surveys of food gardens planted by ten women over a three and a half year period.

Since the mid-1940s, the hamlets have been located at the junction of the steep sides and the poorly drained bottom of the Aiyura Basin at about 1630 m (Figures 2.5, 2.6). Mean annual rainfall measured at the adjacent agricultural station is 2100 mm (38 years of records) with only one month receiving less than 100 mm average rainfall each year. The seasonality index is 0.31 (B1 type climate). The major soil type used for sweet potato production between the mid-1940s and mid-1982 is a Hydrandept. These soils are located on the colluvial fans. Drainage depressions are used for mixed gardens and coffee. Here the soils are deep clays, poorly drained and high in organic matter.

The Villagers

The people are Gadsup language speakers and identify themselves as part of the Aiyura group of villagers (population 930 in the 1980 census). People today cannot unambiguously identify clans within the village. The resident population of Asiranka was 420 in 1984 and people lived in 92 households in eight named hamlets(6). The male to female ratio was 109:100 and 54 per cent of the resident population was younger than 20 years. In 1980, 101 people were absent from the village because of outmigration for marriage or wage labour (Table A2.2). Just over half of the absentees (61 per cent) were male. The mean annual population growth rate between 1950 and 1980 was 3.1 per cent. This high growth rate occurred, despite outmigration of wage earners, because of a net influx of people from other parts of the province. The gross population density is 94 persons/km^2, although the density on the grassland flats which provided most land for agriculture between 1979 and mid-1982, was much greater (546 persons/km^2) (Table A2.4).

The villagers' first direct contact with outsiders (probably Lutheran missionaries) occurred in 1928 or soon thereafter. Some changes actually pre-dated first contact with outsiders, such as the arrival of corn sometime between 1922 and 1927, but the rate of

(6) Members of the same household usually sleep in the same dwelling. A typical household consists of a married couple, their children and elderly relatives. Some households consist of women and children from polygynous marriages or several single young men or women.

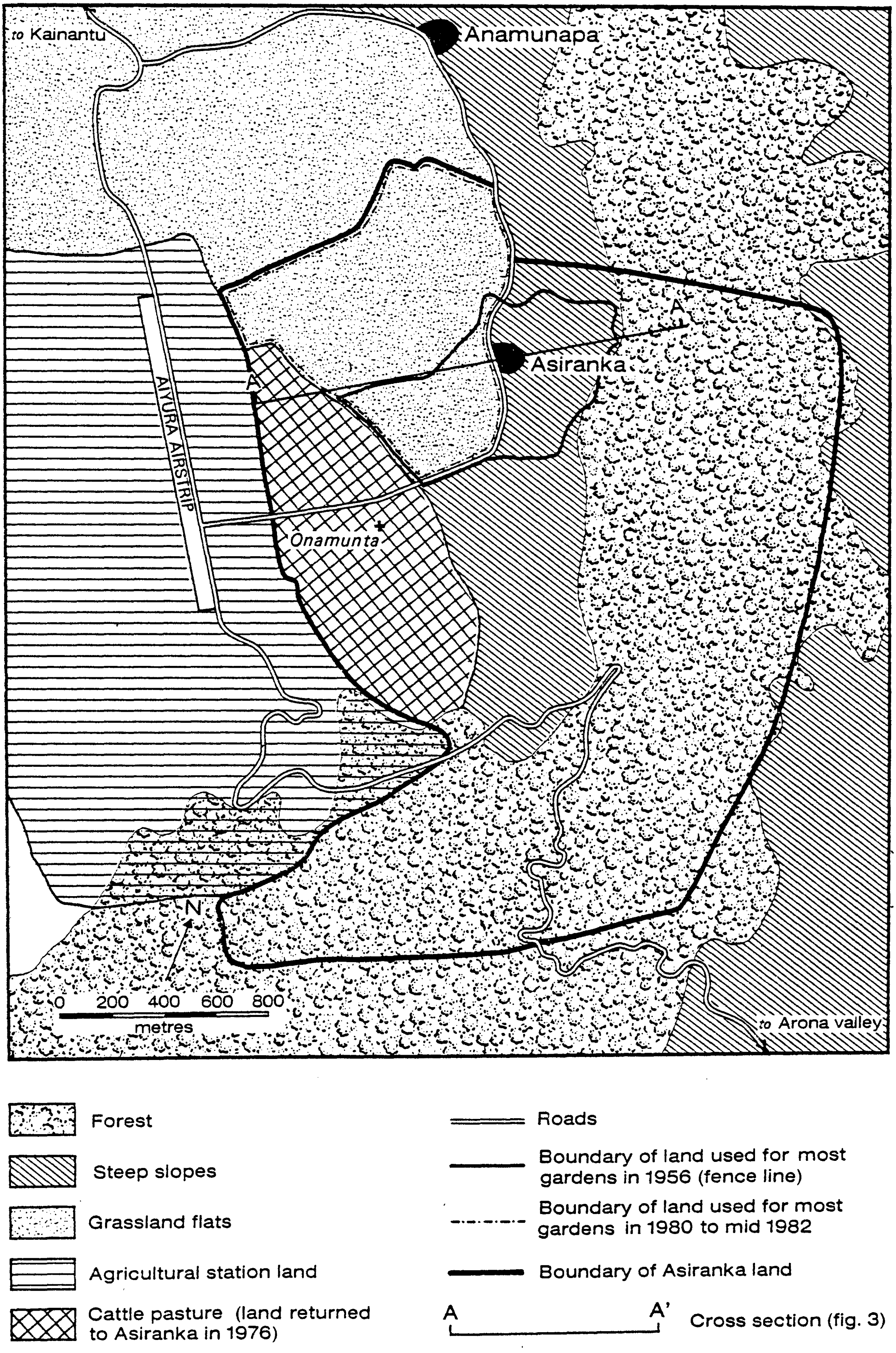

Figure 2.5 Land types and use, Asiranka Village

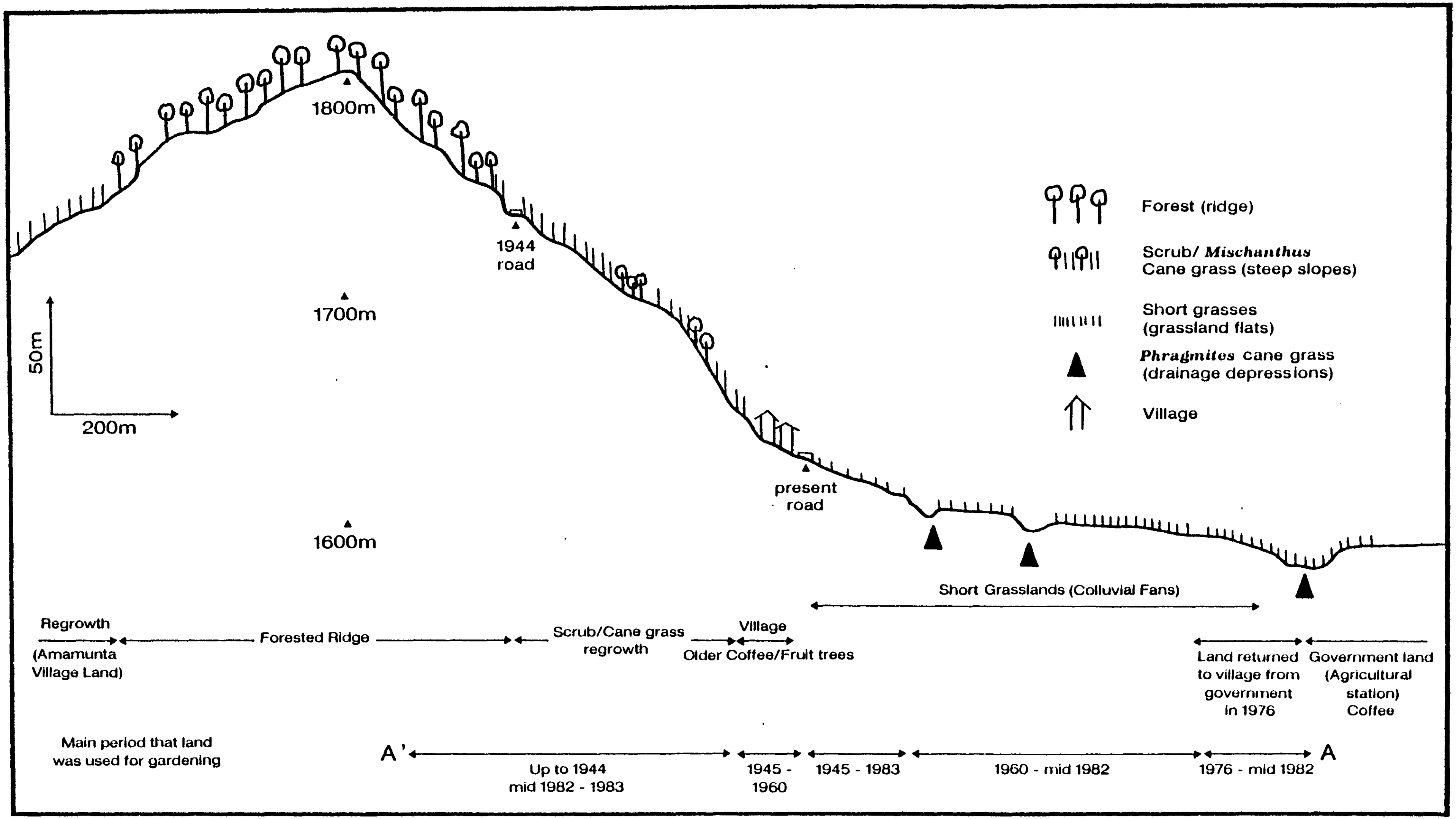

Figure 2.6 Cross section through Asiranka Village (50/230° mag) showing land types and land use

change increased during the 1930s with the establishment of the Upper Ramu Patrol Post, the arrival of Lutheran evangelists in nearby villages and particularly the establishment of the agricultural station in 1937 (Table A2.1).

The Pacific War years were particularly traumatic. Nine Aiyura villagers were shot and killed by police in 1942 and 1943; the Aiyura Basin was bombed and strafed by Japanese aircraft; and large numbers of outsiders worked on the agricultural station. The villagers fled their land and in 1944 and 1945 returned, moving to the present site of Asiranka. Between 1945 and 1980, wage labour increased, coffee cultivation commenced (in 1949) and expanded, and agriculture intensified. Aiyura people are consistently described in patrol reports during the 1950s and 1960s as economically progressive.

Tribal fighting ceased soon after contact with outsiders, but there have been some very minor fights during the 1980s. Elaborate exchange networks and pig killing cycles, such as those that exist in much of the western part of the highlands, are not practised. Minor exchange payments of cash and food are made at funerals and on other occasions (Table 2.5).

The external cash income for village residents is high by highlands standards, with a mean income of about K220 per resident per year (Table 2.6). A third (34 per cent) of the resident males and 14 per cent of the resident females are engaged in wage or salary employment (Table A2.3); and in half of the households in the village, at least one person receives a wage or salary. About 60 per cent of the village cash income is derived from wage labour, mostly within the Aiyura Basin. Because a high proportion of the cash income is derived from wages or salaries, year to year income is relatively stable and does not fluctuate as greatly as in communities which are more dependent on sale of coffee and casual labour picking coffee (Table 2.6).

The child malnutrition rate is relatively low although it is not insignificant. Maternal and child health clinic records for Asiranka children between April 1980 and November 1984 indicate that 13 per cent of children aged 0-12 months are malnourished (below 80 per cent weight for age on the Harvard standard) and 25 per cent of children aged 1-5 years are malnourished. No children were recorded as seriously malnourished (below 60 per cent weight for age). The impression gained is that the level of illness, including scabies and pneumonia, is surprisingly high for a community with access to reasonably good medical services and a relatively high level of cash income. The level of alcohol consumption and abuse is moderately high. A high proportion of adult males in the village are intoxicated at least once between the Thursday and the Saturday of the government/private sector pay week.

Table 2.5 Exchange payments for a sample of 10 male-headed households, Asiranka Village, EHP and Upa Village, SHP(1)

Class of wealth		Asiranka Village 1983	Asiranka Village 1984	Upa Village 1983	Upa Village 1984
CASH (kina)	Received	320	40	1280	1460
	Paid out	64	517	2960	2060
	Net	256	- 477	- 1680	- 600
SHELLS (number)	Received	- (2)	-	405	257
	Paid out	-	-	287	353
	Net	-	-	118	- 96
PIGS (number)	Received	0	0	43	30
	Paid out	0	1	34	29
	Net	0	- 1	9	1

Notes

(1) To obtain mean payments per household, divide by 10. Data are based on interviews with the male heads-of-household of 10 households in each study village in late November 1984. The 1984 data is for 11 months only, but at Upa there were likely to be few exchanges in December of that year because of depressed conditions associated with lack of available cash and the food shortage. I believe the Upa figures are fairly reliable as my experience is that Upa villagers are able to remember receipts and payments over long periods. The Asiranka figures are less reliable as people do not remember these transactions so well. The smaller magnitude of exchange payments at Asiranka makes this unreliability less critical.

(2) Mother-of-pearl shells are not used as valuables in Asiranka Village.

Table 2.6 Estimated external cash income (kina) for residents of Asiranka Village, EHP, and Puit Clan, Upa Village, SHP, in 1983 and 1984(1)

Source of income(2)	Asiranka Village 1983	Asiranka Village 1984	Puit Clan, Upa Village 1983	Puit Clan, Upa Village 1984
Wages	55,000	59,000	100	200
Sale of coffee	29,000	19,000	3,500	2,100
Sale of fresh food and pig meat	6,000	6,000	800	700
Casual labour picking coffee	1,000	0	7,100	200
Gifts/remittances from non-residents	6,000	7,000	500	500
Other(3)	1,000	1,000	300	600
Total(4)	98,000	92,000	12,300	4,300
Income per household/year	1,065	1,000	384	134
Income per resident/year	233	219	55	19

Notes

(1) The source is fieldwork conducted by author in September-November, 1984. Detail of calculations and assumptions used to derive estimates are given in Appendix 5.

(2) Income derived from outside the village only is considered. That derived from internal sources such as gambling, black-market beer sales and trade store profits (K1000 trade store profits for the Puit clan in 1984) is excluded. Receipts for bride price and compensation payments are excluded because there was a net cash outflow from the 10 sample huseholds in both villages over the two year period (Table 2.5).

(3) For Asiranka, other sources include profit from sale of firewood and cattle, gambling and social nights. For the Puit clan it covers sale of woven baskets only.

(4) The population of Asiranka Village was 420 persons in 1984; for the Puit clan it was 225 persons.

The following land types are available for agriculture (Figure 2.6):

(1) Grassland flats (colluvial fans)
(2) Drainage depressions in the grassland flats
(3) Scrub regrowth (steep slopes)
(4) Forest area (forest fallow and grassland fallows)

The proportion of food gardens situated on the various land types is given in Table A2.5. Between 1950 and mid-1982, most food gardens (ca 85 per cent) were situated on the grassland flats (sweet potato gardens) and in the drainage depressions (mixed gardens). Most of the remainder of the food gardens were planted in the forest area. In mid-1982, following damage to food gardens by domesticated pigs and a minor frost, there was a dramatic shift of gardens away from the grassland flats to the forest area and later to the scrub regrowth on the steep slopes (Table A2.5). This situation continued at least until late 1984. Between 1978 and mid-1982, subsistence gardening was intensive but appeared to provide an adequate supply of food.

The garden types planted are dependent on the land types. The colluvial fans are used for sweet potato, peanut and winged bean gardens. The leguminous species are grown in rotation with sweet potato as a conscious attempt to maintain sweet potato yields. The mixed gardens, which contain numerous supplementary crops but rarely sweet potato, are planted in the drainage depressions. Most new coffee plantings since about 1970 have been made in the mixed gardens in the drainage depressions. Gardens made in scrubby regrowth, forest or grasslands in the forest area contain sweet potato mixed with supplementary crops. Some minor areas of "household" gardens were also planted. I recorded 87 crop species grown or collected as food or narcotics between 1979 and 1982 (Table A2.7). Of these, 71 crops were eaten by the villagers themselves and three crops used as narcotics (tobacco, highland betel nut, highland betel pepper). The remainder are grown for sale to expatriates. Despite this impressive number of crop species, a limited number of food crops dominates agriculture. Measurements of garden areas actually planted over a three year period by 10 women indicate that 57 per cent of all garden area was planted to sweet potato and 16 per cent to peanuts. The numerous species grown in mixed gardens accounted for a further 18 per cent of garden area planted and winged beans for 4 per cent (Table A2.6).

Coffee is the most common tree crop (Table 2.7). The mean number of coffee trees per household was 464 in 1984 (range: 282 to 598 trees), most of which were mature. Karuka nut pandanus (176 trees per household, mostly immature) and highland betel nut

Table 2.7 Number of tree crops per household in Asiranka Village, EHP, and Upa Village, SHP(1,2)

Tree crop	Asiranka Village Number	Asiranka Village % bearing	Upa Village Number	Upa Village % bearing
Coffee (*Coffea arabica*)	464	95	478 (3)	95
Karuka nut pandanus (*P. julianettii*)	176 (4)	28	12	60
Highland betel nut (*Areca macrocalyx*)	137	23	0	-
Marita pandanus (*P. conoideus*)	19	32	29 (5)	82
Ficus copiosa	- (6)	-	8	86
Avocado (*Persea americana*)	5	35	1	0

Notes

(1) The source is field counts of trees by the author in 10 male-headed households in each community in September-November, 1984. Household size in Upa (14.5 persons) is much larger than in Asiranka (3.9 persons); hence number of trees *per person* is generally greater in Asiranka.

(2) *Casuarina oligodon* is an important planted species in both villages, but trees of this species were not counted.

(3) Coffee numbers at Upa exclude the very large holdings of a single household head. There are 11.8 persons per household for coffee holdings at Upa.

(4) Probably underenumerated, as the people spoke of trees that I did not see.

(5) Marita pandanus trees were not counted in the Wage Valley, and this figure is an underestimate.

(6) Not recorded, but numbers are small at Asiranka.

(137 trees, mostly immature) were the other significant tree crops. The number of coffee trees per household is similar to that of other coffee producing areas. Anderson (1977:38), for example, recorded a mean of 420 coffee trees per "grower" (which is likely to approximate to male heads of households) in the Eastern Highlands in 1976; Grossman (1984:185) recorded 0.045 ha of coffee per capita which approximates to 525 trees per household. The number of mature karuka nut pandanus trees (49 per household) is a fraction of numbers planted in high altitude locations elsewhere in the highlands (B.Carrad, pers.comm., August 1984).

Coffee is the major source of non-wage income (Table 2.6). The first coffee was planted in the village in 1949 (Graham, 1949) and a coffee processing factory operated there between about 1961 and 1969. Between 1980 and 1984, members of the 10 households that I surveyed planted 60 m^2 (17 trees) of coffee per household per year. Whilst the trees are nominally owned by individuals (usually adult males), in practice coffee is picked, processed and sold by adults and young adults of the owner's household. Arrangements for distributing proceeds of sale vary among households. Up until late 1984, at least, all coffee was sold as parchment, that is, it was processed in the village before sale.

Pigs are maintained and are killed singly or in small numbers for feasts given on traditional (for example, funerals) or modern (for example, return of an individual from jail) occasions. I recorded the pig herds of the 10 women I worked with on four occasions (Table 2.8). Despite some problems with the data, they do suggest that total pig numbers are relatively stable. The mean ratio of pigs to people for the sample households for the four counts is 1.3. This is the same as the mean of the published data for the central highlands as a whole (1.3) and somewhat greater than the ratio for the entire village in late 1984 (0.8).

The villagers acquired three cattle from the agricultural station as a gift in 1951 (Morgan, 1951). In 1976 some of the agricultural station land was returned to the village and this was used in part for two cattle enclosures. In 1984, 30 cattle owned by nine individuals were pastured in these two enclosures (Figure 2.5). The grazed area was not used for food gardens. Beasts were sold to people from Asiranka and other communities and were a minor source of cash income. The contribution of these animals to village food supplies was negligible.

Data on certain important parameters are presented for the 10 households and for the village as a whole (Table 2.9). These data indicate that the sample households are representative of the village for the number of people per household; the number of people per adult female (that is, the dependency ratio on the gardeners); the proportion of

Table 2.8 Number of pigs owned by 10 women of Asiranka Village at four times(1)

Animal size(2)	May 1980	March 1982	November 1983	September 1984
Piglet	- (3)	6	25	28
Small/medium	-	3	7	20
Large	-	49 (4)	18	12
Total	53	58	50	60
Ratio of pigs:people	1.2	1.3	1.2	1.5

Notes

(1) The source is pig censuses conducted by author. Pigs were not sighted. The arbitrary size classification and inconsistencies in counts of piglets at different census times are not satisfactory; but I believe the numbers provided by the women are accurate. All animals are in the control of owners, not agisted out.

(2) Animal size is an arbitrary classification as used by the villagers. No measurement of animals was made.

(3) In May 1980 only the total number of pigs was recorded for each woman. Piglets (animals younger than about 2 months) were not included.

(4) The large category for this census was not consistent with the two later censuses. "Large" pigs in 1982 are likely to include those classed as "medium" sized animals in 1983 and 1984.

Table 2.9 Some characteristics of 10 sample households and entire social group, Asiranka Village and Upa Village(1)

Index	Asiranka Village, EHP 10 households	Asiranka Village, EHP Village	Upa Village, SHP 10 households	Upa Village, SHP Puit Clan
Population	39	420	145	225
Number of households	10	92	10	32
People/household	3.9	4.6	14.5	7.0
People/adult female	3.0	3.9	3.9	4.2
Percentage of households receiving wage income	50	51	10	3
Average wage income/ household/fortnight (kina)	22	24	0.90	0.30
Pigs/person	1.5	0.8	0.5	0.5
Pigs/adult women	4.8	1.7	1.8	2.0
Percentage of households with non-resident wage earners	30	16	20	25
Percentage of adult males absent	14	14	21	22

Notes

(1) The source is surveys of the sample households and all households in Asiranka Village and the Puit clan conducted by author in September-November, 1984. The 10 households in Upa belong to three clans (Puit, Murupa and Palam); whereas the broader survey was of all members of the Puit clan only. These are male-headed households in Upa, not female cooking hearths. There may be more than one cooking hearth per household. In Asiranka male-headed households generally correspond with female cooking hearths.

households receiving wage income; the average wage income per fortnight; the number of adult males absent from the village; and the proportion of households with non-resident wage earners. However the number of pigs per person or per woman is 2 to 3 times greater in the 10 sample households than in the entire village. This suggests that the females in these households had a greater commitment to producing food for pigs than did women in the village as a whole. The garden area planted was 834 m^2 per person per year over a 36 month survey period (1980-82) for the 10 households (Table A2.6). This is towards the lower end of the range of garden area under subsistence crops in the highlands (Allen, 1984a:77), but the figure is not especially low.

My interpretation of the above is that the adult females in the 10 sample households remained committed to subsistence food production and pig raising, despite the relatively high level of wage income (K24 per fortnight per household). The gardening practices of these households are likely to be representative of many rural villages in the northern part of the Eastern Highlands.

UPA VILLAGE

The other community where intensive studies were made was Upa, which is on the Nembi Plateau in the Southern Highlands (Figures 2.1, 2.7). Upa was chosen as the site for a rapid rural appraisal in 1978 because of good records on child malnutrition held at the nearby health centre (Allen, 1984b). The Nembi Plateau was selected in 1979 as the second site for the present study because of a number of contrasts between there and the Eastern Highlands site, particularly climatic seasonality, involvement with cash cropping and other non-traditional activities, access to cash and levels of child malnutrition. The research was continued at Upa because of the base line data collected in 1978 (Allen *et al.*, 1980; Spenseley, 1980; Allen, 1984a; Bourke, 1984b; Cogill and Clarke, 1984; Pain, 1984; and Wood, 1984b). Further research was conducted in 1980-81 by Crittenden (1982) and Baines (1983) who worked in an adjacent clan at Kongip.

The highlands part of the Southern Highlands Province was partially explored by Europeans during the 1930s. However, sustained contact with outsiders for most Southern Highlanders dates from the early 1950s; and for some people, including the Nembi Plateau villagers, it dates only from about 1960 onwards. Thus the process of social and economic change commenced more recently than elsewhere in the highlands. The cash economy is poorly developed. The period of this study on the Nembi Plateau (mid-1978 to late 1984) is one of relatively fast economic change, including the opening up of a good road network throughout much of the province.

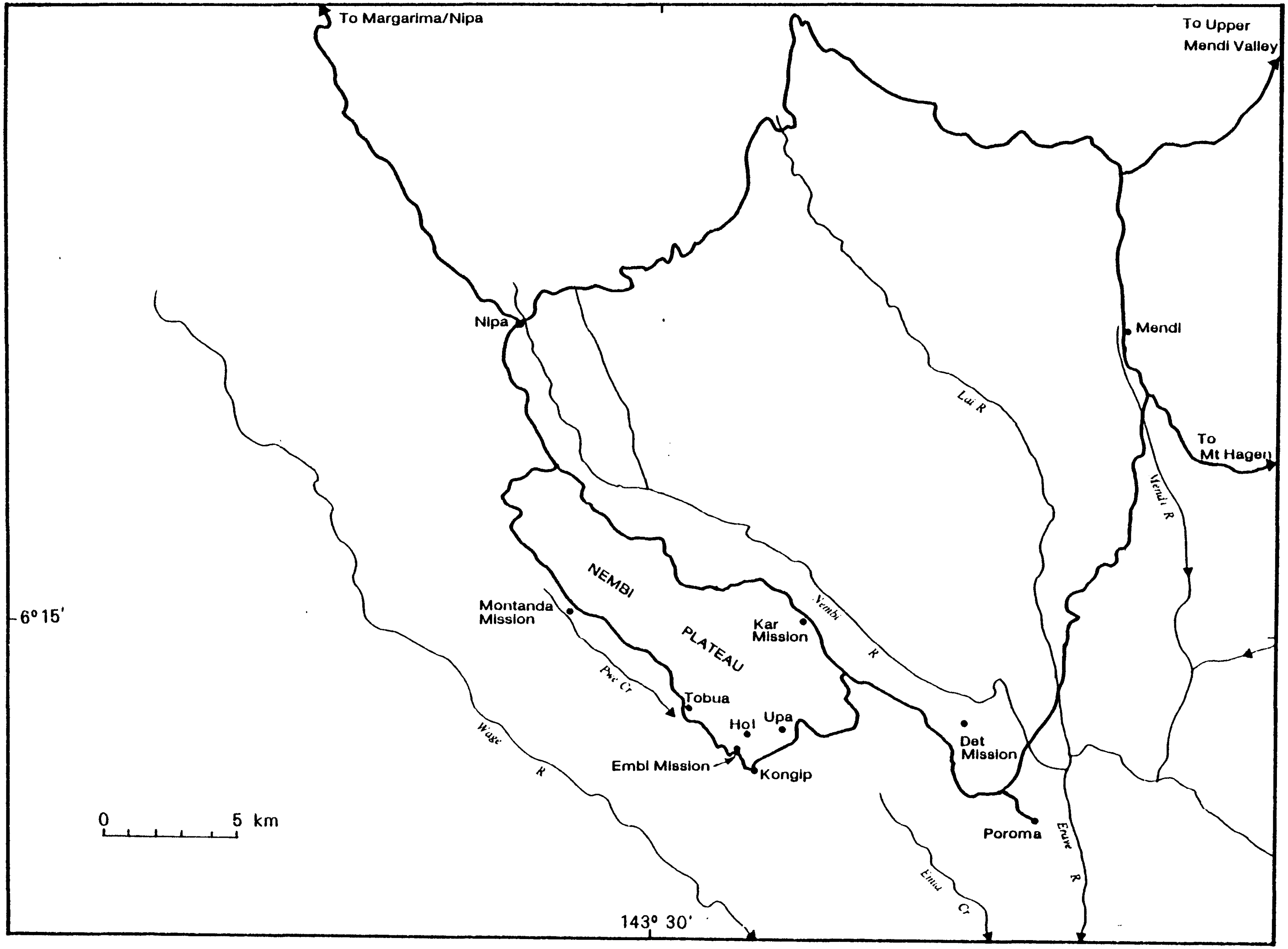

Figure 2.7 Location of Upa Village and Nembi Plateau

All of the Southern Highlands, including the Nembi Plateau, has an A0 type climate, that is, it is perenially wet with very little rainfall seasonality (Figure 2.2). The long term mean rainfall on the Nembi is probably about 2900 mm per year, which is the mean of the nearby recording station at Poroma (2600 mm), Mendi (2800 mm) and Nipa (3200 mm)(7). Mean rainfall exceeds 100 mm in all months and exceeds 200 mm in most months(8).

The Nembi Plateau has a karst landscape with limestone ridges separated by dolines, landslides and some valleys (Pain, 1984). The clan lands of the Upa people are located near the bottom and lower sides of an enclosed basin (1670 m at the bottom) and range up to 2000 m. Almost all food gardens are located on volcanic ash soils, termed Typic Hydrandepts. Soil depth and organic content are greater on the lower slopes and doline floors (Wood, 1984b; 1987). The ash soils have a good structure, although they are deficient in potassium and boron (D'Souza and Bourke, 1986).

The Villagers

The Nembi people speak the Mendi language. The Upa villagers belong to three clans - Puit, Palam and Murupa(9). The 1978 study team collected most information from members of the Puit clan but demographic and land use data were gathered from the Puit, Murupa and Pubi clans. The long term garden monitoring of the present study was done with households belonging to all three clans of Upa. Other data were collected for the Puit clan only.

The 1983 census gives the resident population of the Nembi Plateau census division as 7732 and the population of the Upa census unit as 771 (Crittenden and Puruno, 1984). My October 1984 census indicated a resident population of 225 people in the Puit clan. The male to female ratio was 91:100 and 57 per cent of the resident population were younger than 20 years. In 1983, 85 people (10 per cent of the total) were absent from Upa. The absentee rate for adult males increased over the period of this study. In 1978, 8 per

(7) This was also the mean rainfall recorded by D'Souza at Hol in 1979-1981.
(8) Crittenden (1982; 1984) and Crittenden and Baines (1986) classify the Nembi rainfall regime into four seasons as follows: long wet, long dry, short wet and short dry. Three types of analyses show this classification to be unfounded. These are examination of available monthly rainfall records for nearby stations, the seasonality index, and long term water balances. Monthly rainfall records for nearby locations include Hol, Nembi Plateau (1979-1981), Poroma (1967-1976), Nipa (1961-1972), Mendi (1951-1984), Tari (1952-1982), and Kagua (1958-1971). The seasonality indices for some nearby locations are: Mendi 0.11, Nipa 0.14, Lake Kutubu 0.10, that is, all locations are perennially wet with very little rainfall seasonality (Table 2.1). Long term water balances (1956-1984) for Mendi also indicate that the soil is almost completely saturated in all months, and that water surpluses are fairly evenly distributed throughout the year (Figures 7.1, 7.2, 7.5).
(9) A fourth clan at Upa, named Pilan, migrated from the Nembi Valley, probably in the early 1960s. They are considered part of the Puit clan for purposes of pig kills and traditional dancing, but are not included with other Puit clan data here.

cent of the adult males of Upa aged between 20 and 59 years were absent (Allen, 1984a:71) and this had increased to 24 per cent of adult males by March 1983. In 1984, 22 per cent of adult men from Puit clan were long term absentees. Gross population densities are high by PNG standards. In 1978/1980 they were 119 persons/km^2 (Pubi), 89 (Murupa), 65 (Puit) and 47 (Nembi Plateau) (Allen, 1984a:76).

Crittenden (1982; 1984:123) has argued that the high population densities are a result of movements on to the Plateau during the past 20 years as a result of pacification, vehicle roads, missions on the Plateau and malaria in the Wage Valley. I dispute this conclusion. Most of the patrol reports prior to the early 1960s comment on large populations of people and many comment on the extensive areas of food gardens and shortage of timber; for example, Hides (1935:75-91); Champion (1938); Timperley (1950); Terrell (1955); Jensen-Muir (1961); and Butler (1961). One example will suffice. C. E. Terrell (1955) passed through the Plateau in November 1954. He refers to "the dense and close packed villages" in the south-east region of the Plateau and further writes:

> The population density increased considerably as we got into the Pou'e Valley, and at times we were passing through villages with ceremonial grounds every five minutes. The population for part of the area would be more dense than it is round Nipa.

Reports of the more numerous patrols during the 1960s continued to comment on the high populations and intensity of land use. These observations, made over half a century, suggest that there have been no recent major population moves on to the Plateau.

The first direct contact of the Nembi people with outsiders was in 1935 when a Papuan Government Patrol crossed the Plateau (Hides, 1935)(10). Between 1935 and 1960 the Nembi villagers were contacted by outsiders on about 11 occasions (Appendix 3). However all encounters were transitory and most patrols only visited a part of the Plateau. It was not until after Nipa Patrol Post was established in late 1959 that contact intensified. Tribal fighting continued until late 1964 (Read, 1964).

Contact increased during the 1960s and 1970s. By late 1968, Pei of Upa Village was operating a trade store and work had commenced on the first cattle project at Upa (Hicks, 1968); the vehicular road from the Nembi Valley that crossed the Plateau was completed as far as Upa (Dangerfield, 1968); and the Christian Union Mission (CUM) had established a mission station at Montanda (McNeill, 1969). A Catholic mission station was opened at Pumberel in 1969; in the following year the CUM established a second station at Embi and the Administration opened a primary school at Pumberel.

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(10) Indirect effects were felt slightly before direct contact. For example, the first steel axe and the leafy green *Amaranthus cruentus* are said to have arrived in the early 1930s.

When I first visited the Plateau in May 1978, a usually passable four-wheel drive road connected the Plateau with the Nembi Valley and thence to Nipa and Mendi; the villagers were served by three primary schools and there was a health service at Embi (later transferred to Hol) operated by the CUM. A cattle project at Upa had failed and cash cropping was very limited. Some men were away as long term migrants but their numbers were small. Very few women had been as far as Mendi and only a limited number of men had gone beyond Mt Hagen. A few young men had gone to the Wahgi Valley in the Western Highlands as seasonal workers on coffee plantations.

Between 1978 and 1984 the people became more involved in the wider economy. There was an increase in the number of men leaving the area for long term employment in the Western Highlands and in the lowlands; and there was an increase in the number of men, and later married women, who moved to the Wahgi Valley during the coffee harvesting season to provide short term casual labour on plantations. The number of people migrating reached the maximum in 1983 when one-third of the resident adults were absent for at least a part of the coffee harvesting season. The number dropped dramatically in 1984 following a series of fights in the Wahgi Valley in 1983 between Nembi people and others, and a poor coffee harvest in 1984 (Figure 2.8; Table A5.2).

Tribal fighting among people on the Nembi Plateau and in the Valley was the subject of many comments by patrol officers until 1964 when fighting more or less ceased. However in 1981 fighting began again (Crittenden, 1987) and continued until late 1983. Puit and Murupa clan members joined the fighting, the Puit clan to a lesser degree. The different rates of participation of various clans in tribal fighting between 1981 and 1983 allows testing of the hypothesis that tribal fighting causes food shortages (Chapter 5).

The Nembi villagers participate in elaborate exchange networks involving mother-of-pearl shells, live pigs, pig meat, other valuables and now cash, as do other people in the Southern Highlands (Sillitoe, 1979; Lederman, 1986). The exchanges take several forms. They occur as "bride price" payments, mortuary and compensation payments. There is a constant circulation of valuables and cash in exchange transactions. Pig slaughters are held irregularly; when they occur, large numbers of pigs are killed and pork is distributed and redistributed widely. It is the men who are mainly involved in these transactions. They absorb a significant proportion of men's energy, although the women are responsible for the feeding and care of the pigs. Data collected for 1983 and 1984 on exchange transactions for the ten male-headed households indicate large scale movement of cash, mother-of-pearl shells and live pigs (Table 2.5).

Estimates of cash income in 1983 and 1984 for the Puit clan show that income levels are low and sometimes fluctuate markedly from year to year (K55 per resident in

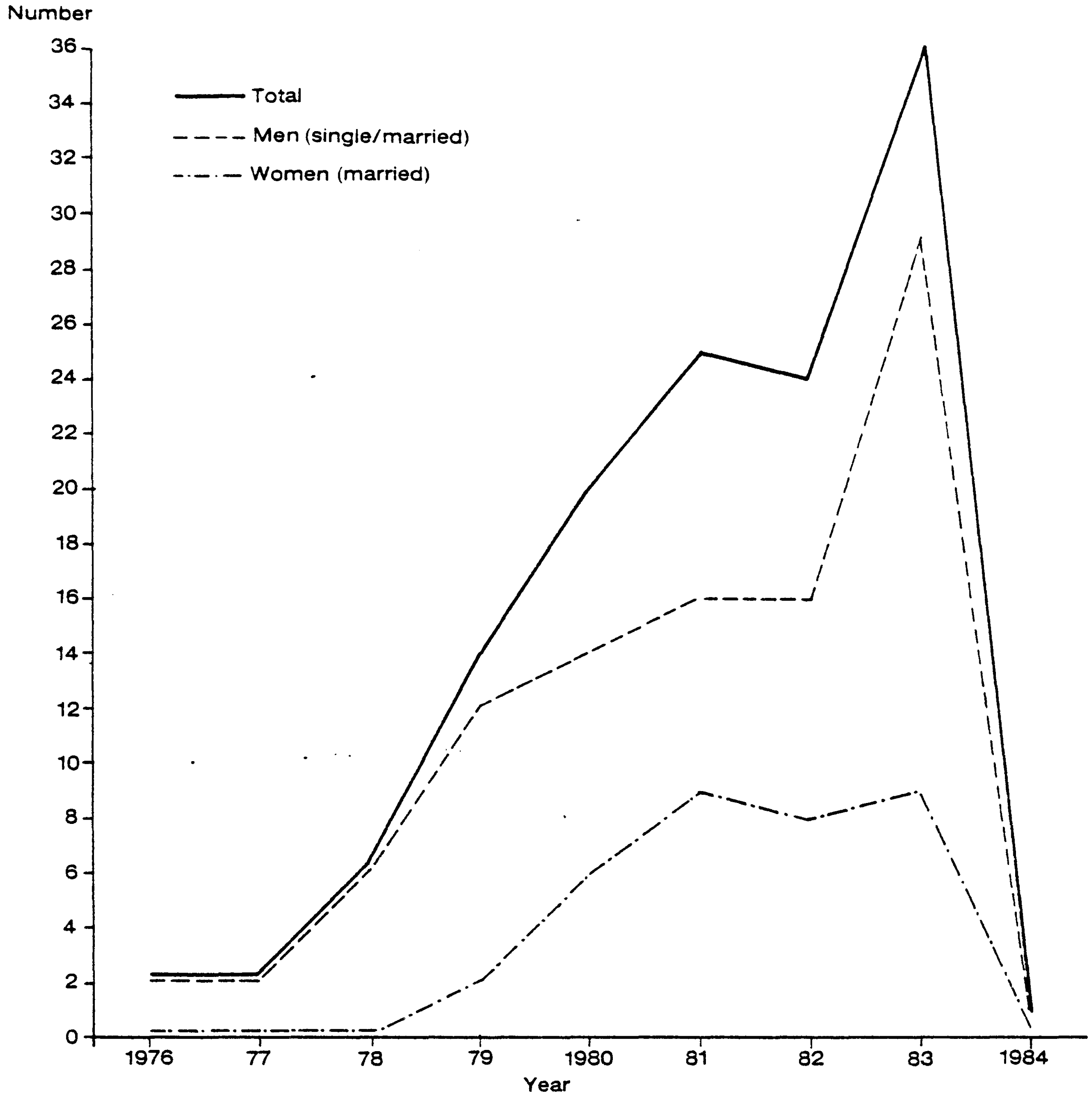

Figure 2.8 Number of Puit Clan members (Nembi Plateau) engaged in seasonal wage labour on coffee plantations, 1976 to 1984

1983 and K19 in 1984) (Table 2.6). In 1983 wages earned as casual labour in the Western Highlands were the largest single component. This income was negligible in 1984 and sale of locally grown coffee, whilst down on previous years, became the largest component. Only one clan member (a magistrate) received a wage income. Coffee growing had expanded from a very small base in the mid-1970s as had seasonal wage labour (Figure 2.8). Consequently the village cash income has increased from a negligible level in the mid-1970s to still modest levels in the mid-1980s.

Child malnutrition rates are high. Between September 1978 and December 1984, 44 per cent of children aged 1-5 years attending Maternal and Child Health clinics on the Plateau were malnourished (60 to 80 per cent weight for age on the Harvard standard) and 2.3 per cent were severely malnourished (less than 60 per cent weight for age) (58,400 observations). Of the children aged 0-12 months attending clinics (16,600 observations), 17 per cent were malnourished and 3.1 per cent were severely malnourished. Results of the 1983 national nutrition survey indicate that the malnutrition rate in Nipa District is only exceeded in the highlands region by Okapa and Wonenara Districts in the Eastern Highlands (Heywood, 1985).

When money is available, as in 1983, some alcohol is consumed on the Plateau, but the consumption rates are low. In years when cash is in short supply and especially when available cash is spent on food, as in 1984, alcohol consumption is negligible. Some imported food is consumed by villagers, particularly when food supply from subsistence gardens is reduced, but levels of consumption are still low. A food intake study of pregnant women at Kongip Village between April 1980 and February 1981 indicated that purchased food provided between 8 and 17 per cent of the women's energy intake and between 18 and 24 per cent of their protein intake (Baines, 1983:57).

Agriculture and Land Use

Agriculture is mostly confined to slopes of limestone ridges and dolines(11). Sweet potato gardens and mixed gardens are the main garden types. Measurements made of garden area planted by 10 women between July 1980 and June 1982 indicate that 81 per cent of plantings were in sweet potato gardens, 18 per cent were in mixed gardens and less than 1 per cent in other garden types, such as household gardens or plots of peanuts (Table A13.5). Sweet potato gardens are planted on the slopes with a limited number of other food crops interplanted. Land use is very intensive, with some land planted with sweet potato crops separated by only short fallows, for up to 40 years. Over the 24 month monitoring period, 86 per cent of all sweet potato planted followed another sweet potato crop. The remaining 14 per cent followed a grass fallow (Table A13.5).

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(11) A fuller description of agriculture is given in Appendix 4.

Sweet potato yields are some of the lowest ever recorded in PNG for subsistence gardens (Bourke, 1985c). In early 1979, a sample of subsistence yields was measured as 6.3 t/ha (Bourke, 1984b); the mean control yield in 11 agronomic trials was 7.2 t/ha (D'Souza and Bourke, 1986); and subsistence yields recorded at Kongip were 7.1 t/ha (Crittenden, 1982:474). Some compost made from old sweet potato vines, grass and weeds is formed inside the beds. In November 1984 I recorded fresh weight of organic matter used as compost in nine gardens. The mean quantity applied was 4.8 t/ha, which is much lower than the rates of 17 and 29 t/ha recorded in the Lai Valley and the Kandep area of Enga by Waddell (1972) and Wohlt (pers.comm., 1982) respectively; or the rate of 20-30 t/ha in the Tari area (Wood, 1984a:104). New land is occasionally opened up for sweet potato gardens after secondary forest and scrub fallows. This was done in late 1984 as a response to a major food shortage (Chapter 8). Over the 24 month recording period (1980-1982), area of sweet potato planted by 10 women averaged 440 m^2 of sweet potato per person and 100 m^2 of mixed garden per person(12).

Mixed gardens are sometimes planted in fertile locations on the slopes, but are mostly located in the bottom of dolines or adjacent to a stream. A large number of crop species is planted in a mixed pattern. These gardens are not replanted after harvesting, unless they are converted into sweet potato gardens. They follow a long (over 10 years) grass fallow. The main crops grown in the mixed gardens and a list of 57 food plants used are given in Table A4.1.

Surveys of pig numbers at Upa at three periods between 1978 and 1984 suggest that the ratio of pigs to people is relatively constant, although animal live-weight is likely to vary greatly before and after the major pig killing ceremonies (Table 2.10). In April 1984, members of the Puit and Palam clans, but not the Murupa clan, took part in a large pig kill at Upa. The seven household heads, who were members of the survey households, claimed to have killed 65 animals in total, with a mean market value of K360. Prior major kills for these two clans were in 1972 (according to the villagers) and in 1961 (Butler, 1961), A large pig kill in 1981 involved clans from Pumberel to Enip on the Plateau, but not the Upa people (E. D'Souza, pers.comm., November 1984). The different rates of participation by various clans in these ceremonies will be used to examine the possibility that they are a contributing factor to food shortages (Chapter 5).

(12) The area of sweet potato is somewhat lower than the cross sectional measurements of 720 m^2 of sweet potato made in the 1978 survey of Puit clan (Table A4.3); and the cross sectional recordings of 880 m^2 of sweet potato recorded by Crittenden (1982:474) at Kongip. The 1980-1982 longitudinal survey is likely to reflect more accurately actual garden areas planted, as it is difficult in a cross-sectional survey to differentiate between producing and old sweet potato gardens.

Table 2.10 Ratio of pigs to resident population recorded at various times, Nembi Plateau(1)

Time	Sample	Ratio of pigs:people	Source
Sep78	Puit clan, Upa	0.77	Bourke (1984b)
Mar81	10 households, Upa	0.57	E. D'Souza, pers. comm. (Dec, 1981)
Nov84	Puit clan, Upa(2)	0.46	R. M. Bourke, (unpubl. data)
1981	Pubi clan, Kongip	0.5	Crittenden (1982:474)

Notes

(1) Pigs were not sighted and figures are based on owner's recollection of animals for the three censuses at Upa. I have no indication that these figures do not provide a reasonable estimate of herd size in this community.

(2) Members of the Puit clan took part in a large pig killing ceremony in April 1984.

Table 2.11 Number of coffee trees recorded at various times, Upa Village, Nembi Plateau(1)

Time	Sample	Number of coffee trees per person	Percentage bearing	Source
Jan70	Upa Village	0	-	Bullock (1970)
Sep71	Upa Village	9	0	Smedley (1971)
Sep78	Puit clan, Upa	10	34	Bourke (1984b)
Sep78	Puit, Muruba, Pubi clans	8	-	Allen (1984b)
Nov84	10 households, Upa	40 (2)	95	R. M. Bourke (unpubl. data)

Notes

(1) The 1978 survey of Puit clan and the 1984 survey of 10 households in Upa are based on counts of actual trees. The figure for the 3 clans in 1978 is based on measurements from aerial photographs. Trees bear from 2-3 years after field planting.

(2) One of the 10 sample households contained a man who owns a very large number of coffee trees. His holdings have been excluded from the 1984 census. If they are included this figure becomes 56 trees per person (94 per cent bearing).

Table 2.12 Some physical, social and land use/agriculture characteristics of the two study villages in 1984

Characteristic	Asiranka Village, Aiyura Basin, EHP	Upa Village, Nembi Plateau, SHP
Physical		
Altitude of hamlets (m)	1640-1650	1670-2000
Altitude of food and cash crops (m)	1580-1830	1670-2000
Mean annual rainfall (mm)	2100	ca 2900
Climatic type (rainfall seasonality)	B1	A0
Major agricultural soils	Hydrandept	Hydrandept
Social		
Population	420	225 (1)
Gross population density (persons/km^2)	94	65 (1)
Child malnutrition rate (%)(2)	25	46
Cash income (kina/resident/year)	219	19 (1)
Tribal fighting (1980-1984)	None	Some
Elaborate exchange system	No	Yes
Pig kill cycles	No	Yes
Effective period of contact (years)	Over 50	Over 20
Level of alcohol abuse	Moderately high	Very low
Land use/agriculture		
Staple food	Sweet potato	Sweet potato
Sweet potato yields (t/ha/crop)(3)	14.0	6.3
Mixed gardens present	Yes	Yes
Pig:people ratio	0.8	0.5(1)
Importance of coffee growing	Moderate	Minor
Importance of nut pandanus	Minor	Very minor
Cattle grazing	Some	None

Notes

(1) Puit clan only

(2) Percentage of children below 80 per cent weight for age. The Asiranka mean is for children aged 1-5 years attending MCH clinics for the period April 1980 to November 1984. The Nembi Plateau mean is for all Nembi children aged 1-5 years attending MCH clinics for the period September 1978 to December 1984.

(3) Asiranka sweet potato yields recorded over 12 months in 1981-1982; Upa yields were recorded in March-April 1979. The bases of the yield calculations are given in Table 6.2 and in Chapter 6 for Asiranka, and in Appendix 4 for Upa.

Coffee is the only tree crop of any significance (Table 2.7). Planting increased rapidly from 1978 to 1984, but the number of trees per person is still low (Table 2.11). A cattle project was established in the early 1970s on land at the bottom of the Basin which is only very occasionally used for food gardens. By mid-1978 the beasts had all been consumed or had perished and only the barbed wire remained.

The 10 sample households are compared with the Puit clan as a whole in Table 2.9. The sample households are larger than the average for the clan as a whole because of the presence of three large households in the sample. However for every other parameter examined, including the key ones of ratio of people to adult women and number of pigs per person, the sample households are representative of the clan (Table 2.9)(13).

THE TWO COMMUNITIES COMPARED

The two communities described above are fairly representative of their respective locations. At Asiranka the climate is slightly less seasonal and wetter than the region immediately to the north and to the west, and cash income from wage employment is higher than that in many other rural villages. In other aspects, including the physical environment, agricultural practices, commitment to coffee production and the social systems, Asiranka Village is representative of communities in the northern parts of the Eastern Highlands Province. In all respects, Upa is representative of communities on the Nembi Plateau, and to a lesser degree, of those elsewhere in Nipa District.

Certain characteristics of Asiranka and Upa that are relevant to variation in food supply are summarised in Table 2.12. A number of aspects of the two villages are similar, including the altitude, volcanic ash soils, relatively high population density, main food crops grown, garden types and the ratio of pigs to people. However other important characteristics differ. Upa is wetter than Asiranka and the rainfall distribution at Upa is not seasonal as it is at Asiranka; cash incomes are considerably higher at Asiranka; the elaborate exchange systems and pig killing cycles at Upa are absent at Asiranka; the Asiranka people have been incorporated into the wider cash economy for longer and to a greater extent than Upa people; and tribal fighting still persists at Upa. Later it is argued that the causes of variation in food supply in both communities and in both provinces are the same. These similar findings from these contrasting parts of the highlands increase confidence in the general applicability of the findings to the region as a whole.

(13) The fact that the 10 households studied most intensively at Asiranka and Upa are representative of the villages as a whole is fortuitous. In both communities, the group of ten women that we worked with was selected by important men. With hindsight, we could have been more demanding in selecting a sample, but our garden survey techniques had not been previously used before in village studies in PNG and we were not certain how many demands we could make on the community.

CHAPTER THREE

VARIATION IN THE SUPPLY OF SWEET POTATO AND OTHER FOODS

The purpose of this chapter is firstly to present information on variation over time in the supply of sweet potato and other food crops, with particular emphasis on episodes of food scarcity. These data are analysed in later chapters where explanations are sought for causes of *taim hangre*. The second purpose is to examine the hypotheses that the frequency of food shortages has altered since contact between highlanders and outsiders and that food shortages are regular occurrences.

Two common assertions about food shortages in the PNG highlands are that they have increased in frequency since contact between highlanders and outsiders (for example, Grossman, 1984; Clark, 1985) and that they occur annually (for example, Lambert, 1976; Crittenden, 1982; 1984). If the first assertion is true, strong support is lent to the argument that "modernisation" and the incorporation of previously isolated subsistence economies into the world economy has increased the risk of food shortages. If food shortages happen on a regular annual basis, then a link between regular annual climatic cycles or other seasonal activities such as the coffee harvest and food shortages is indicated. It is necessary, therefore, to look carefully at the pattern of variation over time in the supply of sweet potato and other foods in order to test these two hypotheses.

DATA SOURCES

The ideal data for this analysis would be long term quantitative recordings on subsistence food production from a number of locations. Collection of reliable long term subsistence production data from even one location would present massive logistic and cost problems, and such data are not available. It is therefore necessary to use surrogate measures of food production, a technique well established elsewhere (for example, Dando, 1976; Bryson and Murray, 1977). Several surrogate sources are available. These are: surveys of periodic food markets; written reports on food supply by outsiders, including patrol officers and agricultural officers; and my observations from the two study communities. Comments by outsiders, including myself, are based on statements made by villagers about food supplies, and people's observed behaviour. The utility and limitations of these sources are discussed prior to presentation of the data.

Market Surveys

Some long term recordings of both price and quantity of food in periodic markets in the highlands are available. To use these sources as an index of village food supply, it is necessary to establish firstly that price and supply are related in these markets and secondly that supply of food in these markets is a reasonable reflection of food produced in village gardens.

Only a small proportion of total sweet potato production is offered for sale in food markets. Most of this is surplus from subsistence needs rather than purposive commercial production. Both villagers and non-villagers buy in the market, and the mix of buyers varies among markets. When subsistence food is in scarce supply, the demand for sweet potato by villagers increases and the quantity offered for sale decreases. It is this tendency for the supply and demand to move in opposite directions, as well as the small proportion of total production that moves through the market place, that gives rise to the large variations in asking price.

Two studies indicate that there is an inverse relationship between the supply and asking price of food items in highlands markets. In 1972-73, von Fleckenstein (1976) examined this relationship for sweet potato in Goroka market. He concluded that, in both the short and long term, the asking price for sweet potato reflected the supply in the market. Hide *et al.* (1984:240-242) recorded sweet potato price and tuber weight in Karimui market in 1981-82. They found that the mean monthly tuber weight was negatively correlated with price.

The relationship between supply and price is further examined using results from surveys conducted by the author and colleagues in four highlands markets and purchase records of the Food Marketing Corporation (FMC)(1). Correlation coefficients between the number of bundles of sweet potato and corn on display and the mean monthly prices were derived (Table 3.1). There is a negative relationship between the number of bundles of produce on display and mean price for all comparisons, and this attains statistical significance for six of the eight comparisons. Monthly purchases of sweet potato and corn by the FMC between 1976 and 1981 in Goroka are negatively correlated with the prices of these commodities in Goroka market. FMC purchases of corn are positively correlated with the number of bundles on display in the market (Table 3.1). This analysis adds support to the findings of von Fleckenstein (1976) and Hide *et al.* (1984) that there is a negative relationship between the supply and asking price of sweet potato in highlands markets.

It is more difficult to establish that the supply of food in markets is directly related to village food supplies. The characteristics of food supply systems in the highlands (Figure 2.3) suggest that this should be the case, given that most market supplies originate

(1) Market survey techniques for the four markets are described in Appendix 6 and Table A6.1. The Food Marketing Corporation was a government-run organisation that purchased produce from villagers and resold it to retailers or to consumers between 1974 and 1981.

Table 3.1 Correlation coefficients between certain monthly price and quantity data for sweet potato and corn, Goroka, Kainantu, Aiyura and Hol markets

Comparison(1)	Number of data points	Correlation coefficient(2)
Sweet Potato		
Number of bundles on display, Goroka market vs constant price, Goroka market (Oct79 to Sep82)	31	- 0.421*
Number of bundles on display, Kainantu market vs constant price, Kainantu market (Mar79 to May83)	51	- 0.249
Number of bundles on display, Aiyura market vs constant price, Aiyura market (Mar79 to May83)	50	- 0.506***
Number of bundles on display, Asiranka sellers only, Aiyura market vs constant price, Asiranka sellers only, Aiyura market (Mar79 to May83)	47	- 0.395**
Number of bundles on display, Hol market vs constant price, Hol market (Oct79 to Sep81)	24	- 0.385*
FMC purchases, Goroka vs constant price, Goroka market (Jan76 to Aug81)	60	- 0.312*
FMC purchases, Goroka vs number of bundles on display, Goroka market (Oct79 to Aug84)	23	0.033
Corn		
Number of bundles on display, Goroka market vs constant price, Goroka market (Jul79 to Sep82)	28	- 0.492**
FMC purchases, Goroka vs constant prices, Goroka market (Dec76 to Aug81)	45	- 0.383**
FMC purchases, Goroka vs number of bundles on display, Goroka market (Jul79 to Aug81)	26	0.642***

Notes

(1) Sources and survey techniques for Goroka, Kainantu, Aiyura and Hol (Nembi Plateau) markets are described in Appendix 6.

(2) *, **, *** indicate significance at $P < 0.05$, < 0.01, < 0.001 respectively.

from subsistence surpluses rather than commercial production. Some evidence is available which suggests that the supply of food in markets is closely related to food supply within the market catchment area.

The first type of evidence for this is the relationship between market prices and reports of *taim hangre*. Very high market prices of sweet potato often occur at the same time that villagers report that subsistence food is scarce. This occurred, for example, in Enga markets following frost damage to food gardens in 1972 (Scoullar, 1973:3); in various markets in Chimbu in 1972 during reported food shortages in parts of the province (Harvey and Heywood, 1983:124; Hide, 1981:38); and in mid- to late 1984 when very high prices for sweet potato in Kainantu, Kundiawa, Mendi, Tari and Hol (Nembi Plateau) markets coincided with widespread reports of food shortages in surrounding areas.

Further evidence for the relationship between supply in the market and in the village comes from a food intake study done on the Nembi Plateau (Baines, 1983:45-66). This indicated that consumption of foods other than sweet potato reflected the quantity of these foods offered for sale in Hol market. Baines conducted a food intake study of pregnant women attending the Pumberel Health Centre between April 1980 and February 1981, using the 24 hour recall method. She recorded large differences in the intake of garden foods other than sweet potato(2). The contribution of this group of foods to the women's energy and protein intake was considerably less between August 1980 and January 1981. This corresponds with the recorded quantity of these foods offered for sale in the weekly Hol market over this period (Figure 3.13).

Thus it is possible to argue on good grounds that there is a negative relationship between supply and price within highlands markets, and that the supply of food in these markets reflects supplies available to villagers in the surrounding areas from their subsistence gardens. Thus market survey recordings can be used with some confidence as a surrogate measure of village food supplies.

Documentary Sources

The second major indicator of the quantity of subsistence food supplies is documentary sources. Two major types are used. These are firstly comments by patrol officers prior to independence and secondly observations by agricultural officers and others for the period after independence, especially between 1979 and 1984.

(2) There was little variation in the contribution of sweet potato to energy and protein intakes over the 11 months. There was a minor *taim hangre* in this part of the Nembi Plateau between about September 1980 and March/April 1981. It is not surprising that this was not apparent in Baines' intake study, given that it was based on different women each month using estimated rather than recorded portion sizes.

Australian administration of the PNG villagers depended on patrol officers. These men walked, and later drove, from village to village and provided the link between the villagers and the central administration. Patrols lasted from several days to many months, but a typical patrol lasted from four to six weeks in the 1950s and from two to four weeks as the network of government stations became denser and vehicular roads were built. At the completion of each patrol, the patrol officer wrote a report. These are now lodged in the PNG National Archives, as well as in provincial and district archives. I read the available patrol reports from the Eastern and Southern Highlands in archives in PNG and Canberra(3).

Patrol officers were interested in subsistence food supplies for two reasons. Firstly, patrol officers represented the colonial administration which assumed responsibility for villagers' welfare. One of the tasks of the patrol officers at each village was to ask the village representative about complaints or problems. Responses sometimes included comments on food supply. Secondly, extended patrols depended on villagers to sell some staple foods for consumption by carriers and police. This was more the case in earlier periods when patrols were typically large and of extended duration. Three examples of the types of comments on food supply in patrol reports are now given. They are interpreted as indicating an adequate, an inadequate and a particularly good supply of food respectively.

> Throughout all the Gadsup area there is an ample, if not abundant, supply of foodstuffs. New gardens are in the process of being cleared and planted ... (Kelly, 1949)

> Throughout the period of the patrol food was in short supply, and in a few villages the position was quite serious. A number of new gardens are now being harvested, but for some two months the people's diet was mainly sugar-cane and pitpit. [A section on possible reasons for the food shortage followed] (Jinks, 1958)

> Staples of sweet potato, pitpit and banana are readily available. There is no evidence of any shortage and in fact the patrol was swamped in vegetables brought in for sale. (Staples, 1966)

Until about 1947, reports were made in a narrative style; thereafter they were presented in a more standard format. Between the late 1940s and the late 1960s references to village food supplies were made in a section on agriculture and stock. After about 1968, food shortages were still reported but there were fewer comments on subsistence agriculture as the emphasis changed to cash crops. After 1971 there are few complete

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(3) Sources used were the PNG National Archives in Port Moresby; Australian Archives, Pacific Manuscripts Bureau, Australian War Memorial and the National Library in Canberra; provincial archives in Goroka and Kainantu; DPI files at Aiyura; and private papers of Mr I. Champion, Canberra. Sources for the period 1979 to 1985 are given in Appendix 6.

patrol reports in archives and the frequency of patrolling declined. Hence patrol reports are a less useful source after 1971.

My confidence in reports by patrol officers on village food supply rests on the following bases:

1. Comments on food supply were provided consistently in patrol reports once regular patrols were established in a region. A section of the report was devoted to village agriculture, particularly between about 1947 and 1968.

2. My assessment of food supplies depends on an accumulation of reports. Many food shortages, but not all, were reported on separate occasions by the same or another patrol officer. This is especially the case during the 1960s when patrolling was more regular and frequent.

3. There is considerable evidence that discussion on food supply was independent of earlier reports and those from other locations. For example, in the reports of Southern Highlands patrols, there were numerous references to a drought in mid-1965, followed by a widespread, but not very serious, food shortage later in the year; there were a number of reports of very abundant food supply in 1966; and numerous reports from widely scattered parts of the Province during 1967 that food was scarce (Figure 3.11, Table A7.2). The few available comments on food supply for specific periods by other outsiders, such as agricultural officers and anthropologists (for example, Loh, 1967; Hide, 1981:37-38), tend to confirm the statements made by patrol officers.

Certain shortcomings of patrol reports must be recognised, however. They were written by many different officers over an extended period. The patrol officers' varying emphases on village food supplies were affected by such factors as their attitudes to the welfare of villagers, the frequency of patrols to different areas, and even the style of reporting used. The frequency of patrolling varied considerably within the highlands from the 1930s onwards. This can be seen from Figures 3.1 to 3.4 where the number of "patrol-months" and comments on food supply are plotted by year for all districts in the Eastern and Southern Highlands(4). Even in adjacent locations, such as Kainantu and Wonenara Districts, the frequency of patrols and comments on food supply were very different (Figure 3.1). My judgment is, however, that patrol reports before 1972 are a systematic source of information on variation in village food supply, especially at the district level, provided certain limitations in the data are recognised.

(4) A "patrol-month", as used here, is a month in which a patrol occurred, rather than 30 or 31 days of patrolling.

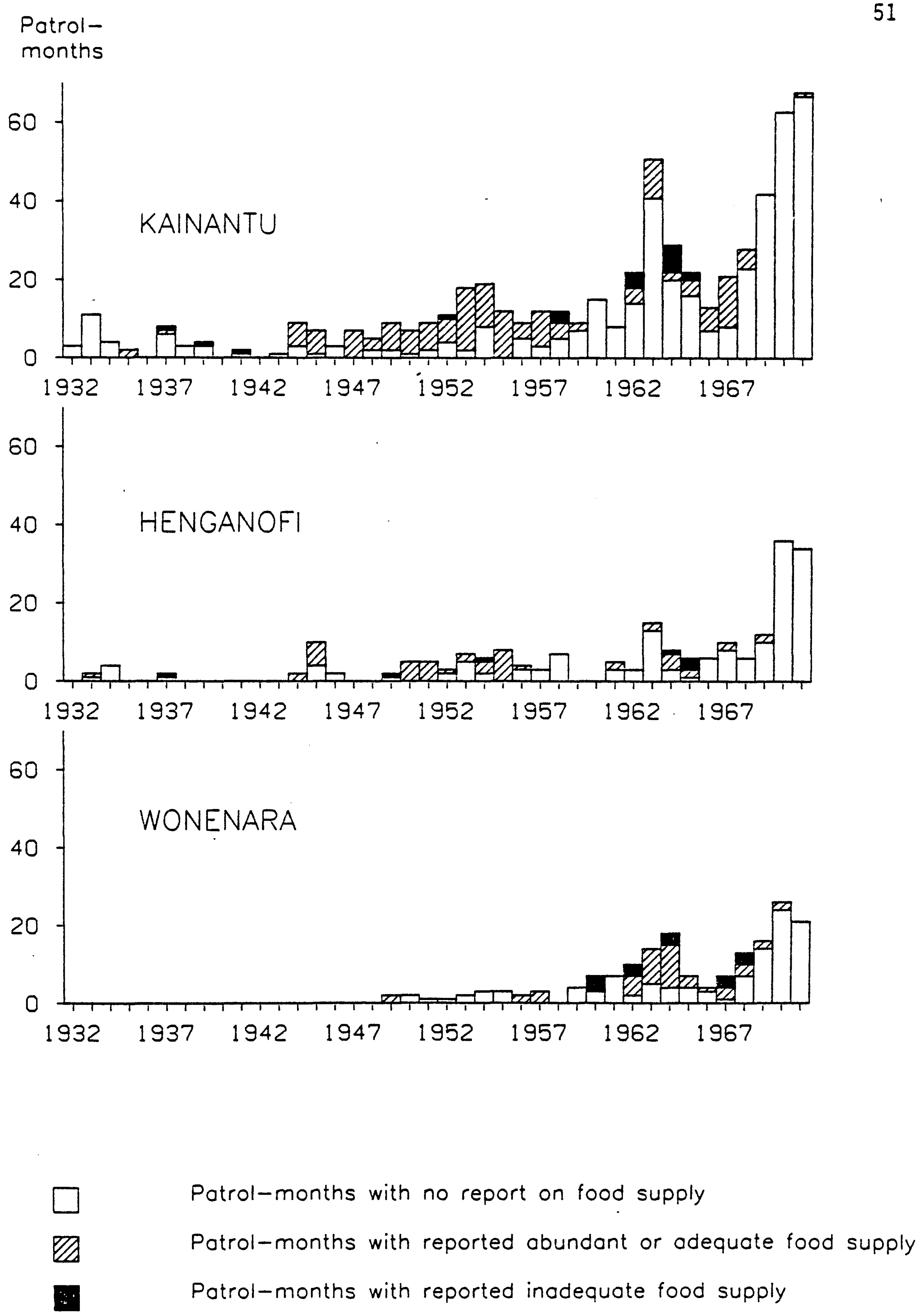

Figure 3.1 Reported food supply: Kainantu, Henganofi, Wonenara Districts, Eastern Highlands, 1932 to 1971 (Source: patrol reports)

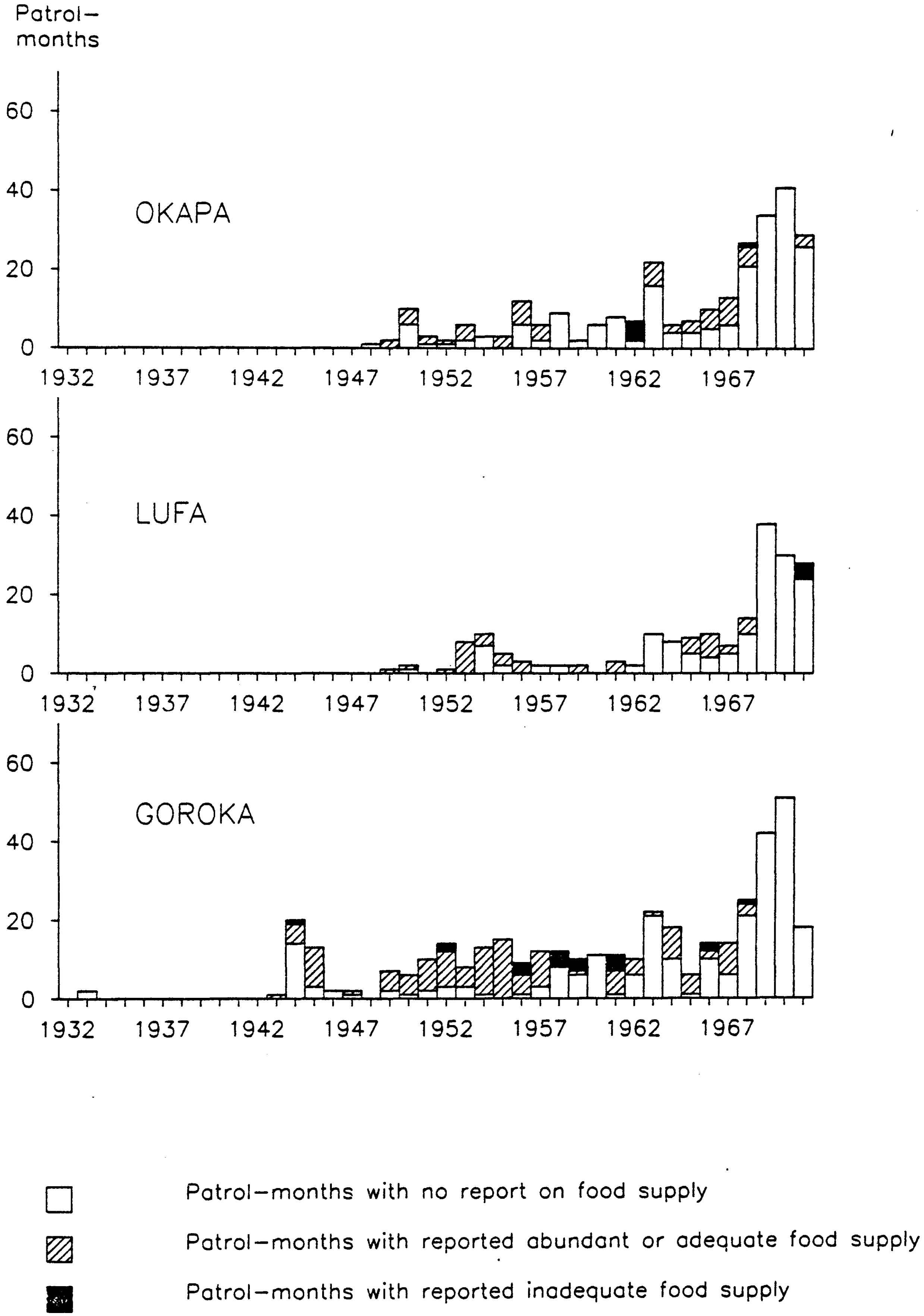

Figure 3.2 Reported food supply: Okapa, Lufa and Goroka Districts, Eastern Highlands, 1932 to 1971 (Source: patrol reports)

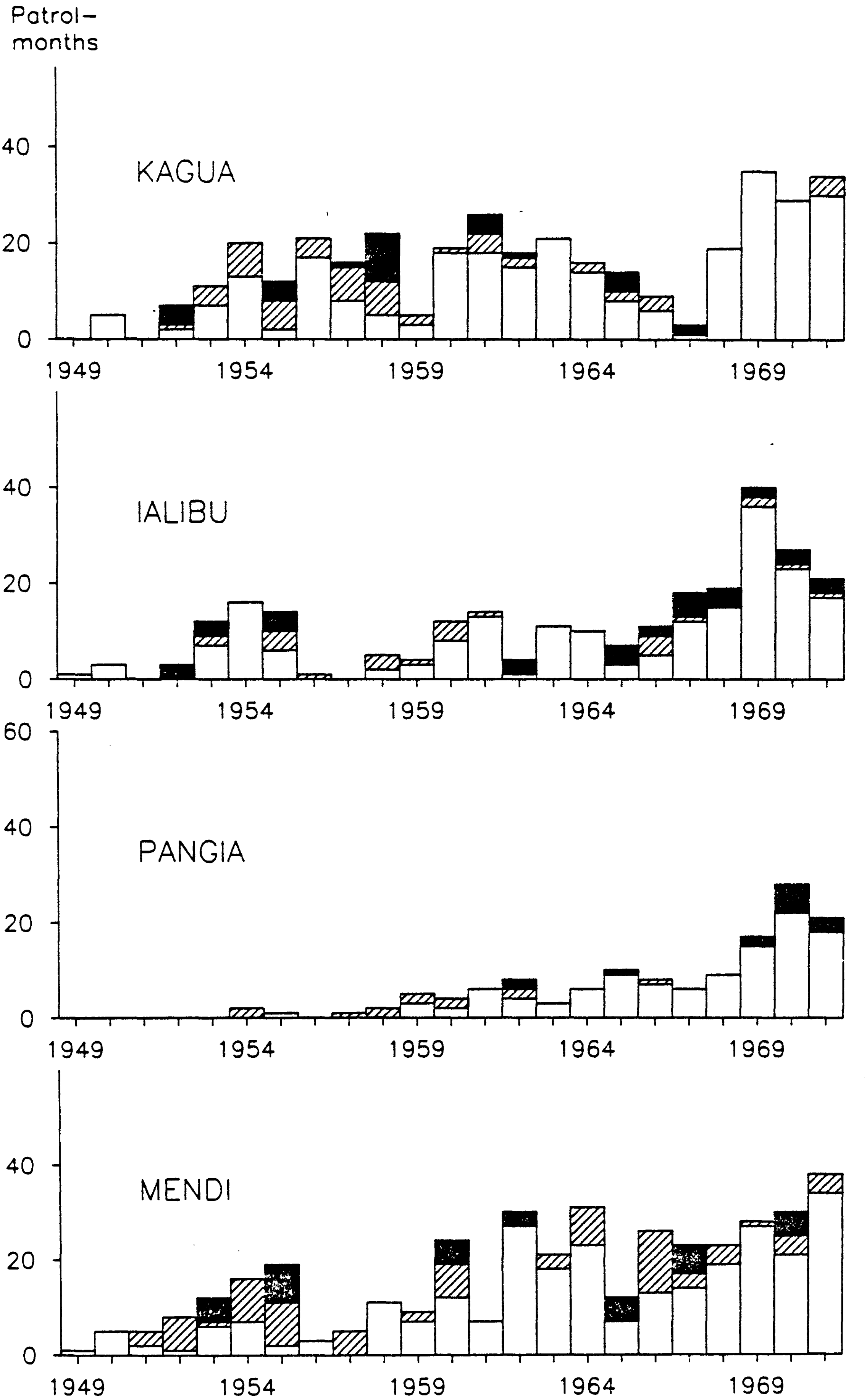

Figure 3.3 Reported food supply: Kagua, Ialibu, Pangia and Mendi Districts, Southern Highlands, 1949 to 1971 (Source: patrol reports)

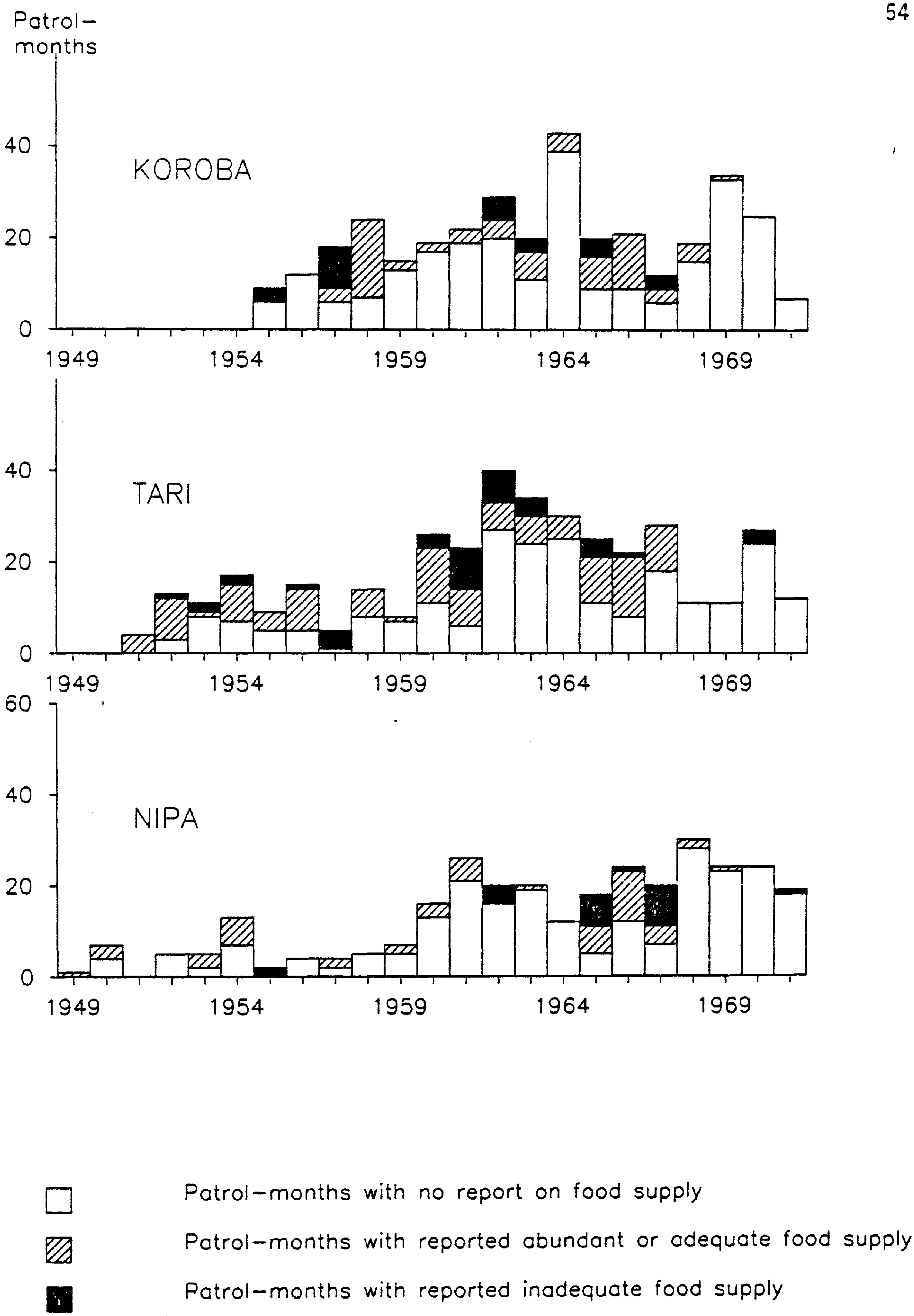

Figure 3.4 Reported food supply, Koroba, Tari and Nipa Districts, Southern Highlands, 1949 to 1971 (Source: patrol reports)

The other major documentary source used is reports in government correspondence files, especially those by provincial divisions of primary industry. These were used to derive a data base for all districts in the five highlands provinces for the period 1979 to mid-1985. The basis for these comments is again statements by villagers that food was scarce during a particular period. Unlike most patrol reports, these comments generally arise from investigations of reported food supply problems, rather than comments following multi-purpose patrols. Details on sources, and discussion on some limitations of these, are given in Appendix 6 and Table A6.3.

VARIATION IN THE SUPPLY OF SWEET POTATO

Ten data sets are now presented on variation in the supply of sweet potato over time. The first three are based on surveys of periodic food markets, the next five on documentary sources, and the final two on observations by the author and others in the two case study villages.

Goroka Area, 1970 to 1985

The first data set is the price of sweet potato in Goroka market between October 1970 and December 1985. The data source is prices collected weekly by agricultural officers for use in computing a consumer price index. Unadjusted monthly mean prices are given in Table A6.4 and prices in constant currency in Figure 3.5.

Peaks in sweet potato price indicate relatively short supply, but not necessarily that subsistence food supplies are so low that villagers complain of *taim hangre* or even that their food intake is restricted. Seven episodes of exceptionally high prices occurred in 1970-71, 1972-73, 1974-75, 1978-79, 1979-80, 1980-81 and 1982-83. All seven episodes happened between about October and February.

There is an apparent indication from Figure 3.5 that fluctuations in price have become less marked since the early 1980s. This is unlikely to reflect a real reduction in variation in village food supplies. Firstly, price rises in late 1982 were probably much greater than is apparent from these figures(5). Secondly, the dampening of price fluctuations is likely to reflect improving road networks and a consequent expanding market catchment and the more widespread use of imported food when subsistence food is scarce(6).

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(5) When sweet potato is scarce in markets and prices are high, competition amongst buyers intensifies and the surveyors cannot weigh sufficient tubers to obtain a price. This almost certainly occurred in Goroka market in late 1982.

(6) There are two other trends in this data set. The first reflects price inflation, which has been removed by conversion of prices into constant currency (Table A6.2). The other is the downward movement in prices between 1971 to 1975, an upward movement between

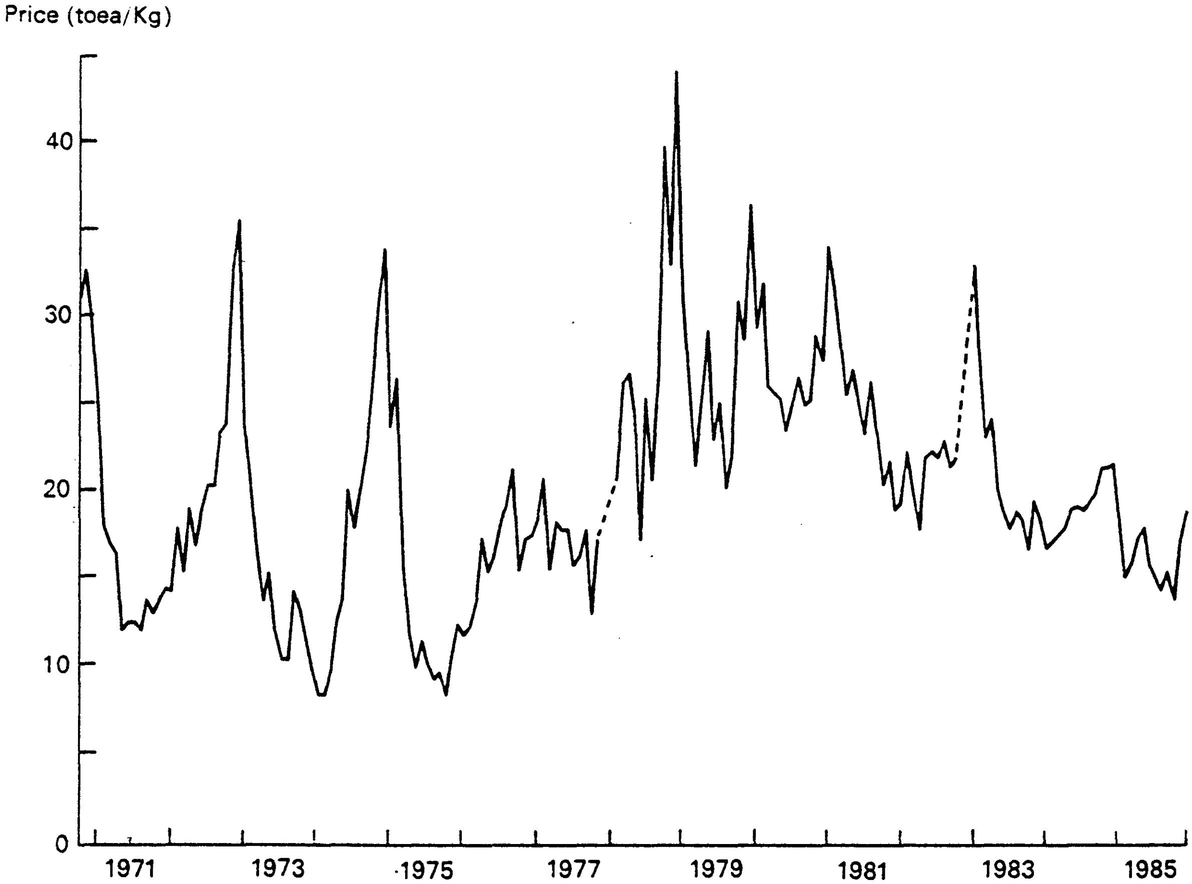

Figure 3.5 Price of sweet potato, Goroka market, October 1970 to December 1985 (constant 1984 currency) (Source: National Statistics Office)

There is no annual pattern in these price movements. There is a suggestion of a biennial cycle between 1970 and 1976, but this was not maintained after 1976.

Kainantu Area, 1979 to 1984

The second data set is also based on sweet potato prices in periodic food markets, at Kainantu town market and a nearby small rural market at Aiyura. The data cover the period March 1979 to May 1983, with several recordings extending it to late 1984. The market survey techniques used are described in Appendix 6 and Table A6.1 and prices are presented in Figure 3.6 and Table A6.5. There is a close and positive relationship between the prices in these nearby markets ($n = 50$; $r = 0.740$***).

Sweet potato prices rose steadily during 1979, peaking at the end of the year. After a long steady decline between early 1980 and mid-1982, they rose rapidly and peaked in late 1982. Another cycle followed with price peaks occurring in late 1984. Again this data set shows that sweet potato price, and hence supply, do not follow an annual cycle.

Nembi Plateau, 1979 to 1982

The final data set which relies on market prices is for Hol market on the Nembi Plateau. It covers a three year period (1979 to 1982) with further recordings in late 1984 (Figure 3.7, Table A6.5).

Between late 1979 and mid-1982, price movements occurred without there being any sharp peaks. The highest prices occurred in late 1979 and in late 1980-early 1981. There was no annual cycle in price movement. In October/November 1984, sweet potato prices were recorded as 21.3 toea/kg, which is more than twice the maximum price recorded between 1979 and 1982.

High prices for sweet potato also prevailed in other markets in the Southern Highlands in mid- to late 1984. In October 1984, sweet potato prices in Mendi market were recorded by myself on one day only. The mean price on that day of 20 toea/kg was about twice that which generally prevailed in this market (C. Floyd, pers.comm., October 1984). In mid-1984, prices in Tari market peaked at 60 toea/kg (E. D'Souza, pers.comm., November 1984). This compares with a usual price of about 8 toea/kg in that market.

The five data sets derived from documentary sources are now considered.

1975 and 1980, and a downward one to 1985. This reflects the price movement of coffee, one of the major external sources of cash income within the region (Figure 5.5).

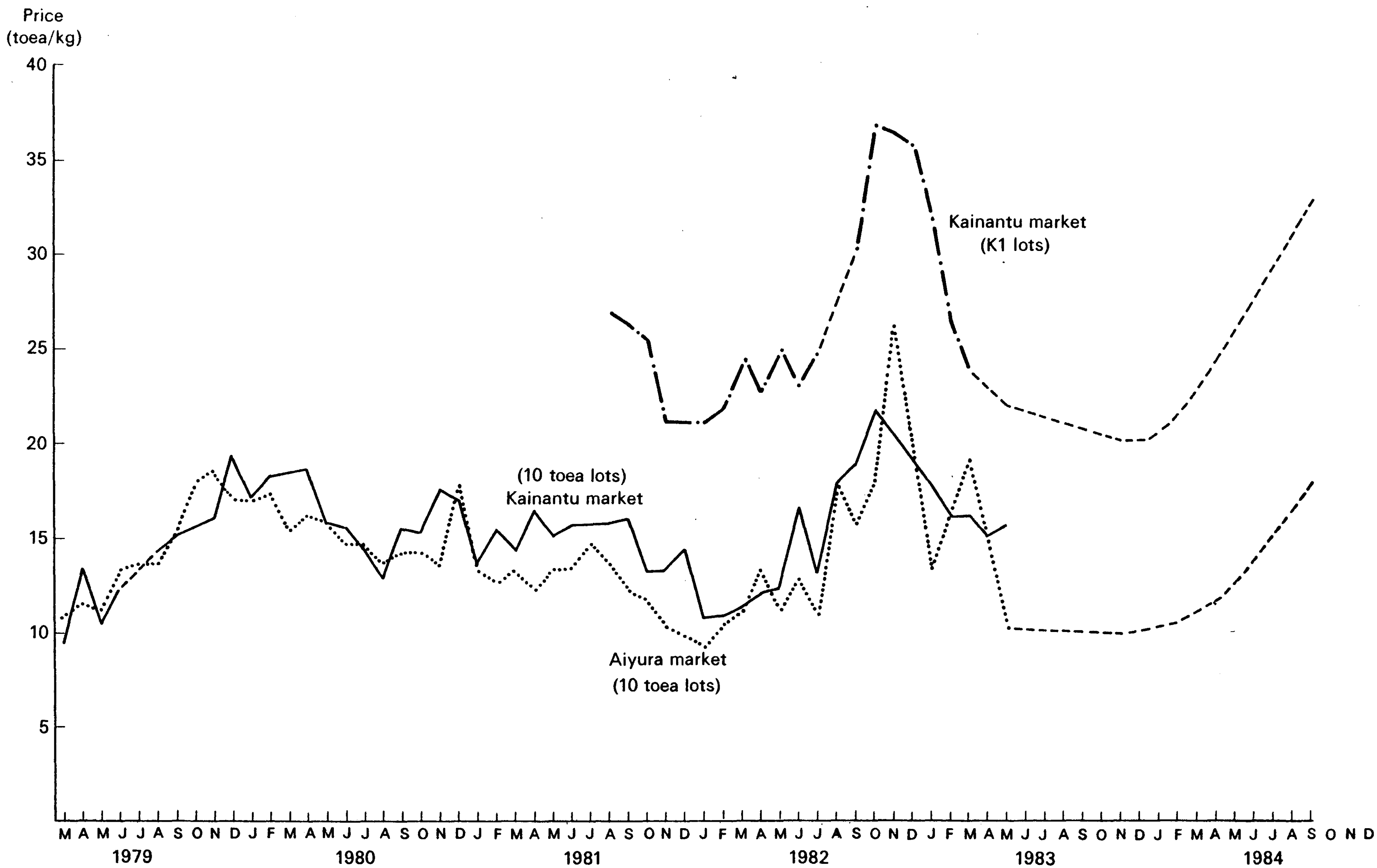

Figure 3.6 Price of sweet potato, Kainantu and Aiyura markets, March 1979 to September 1984 (constant 1984 currency) (Source: author's surveys)

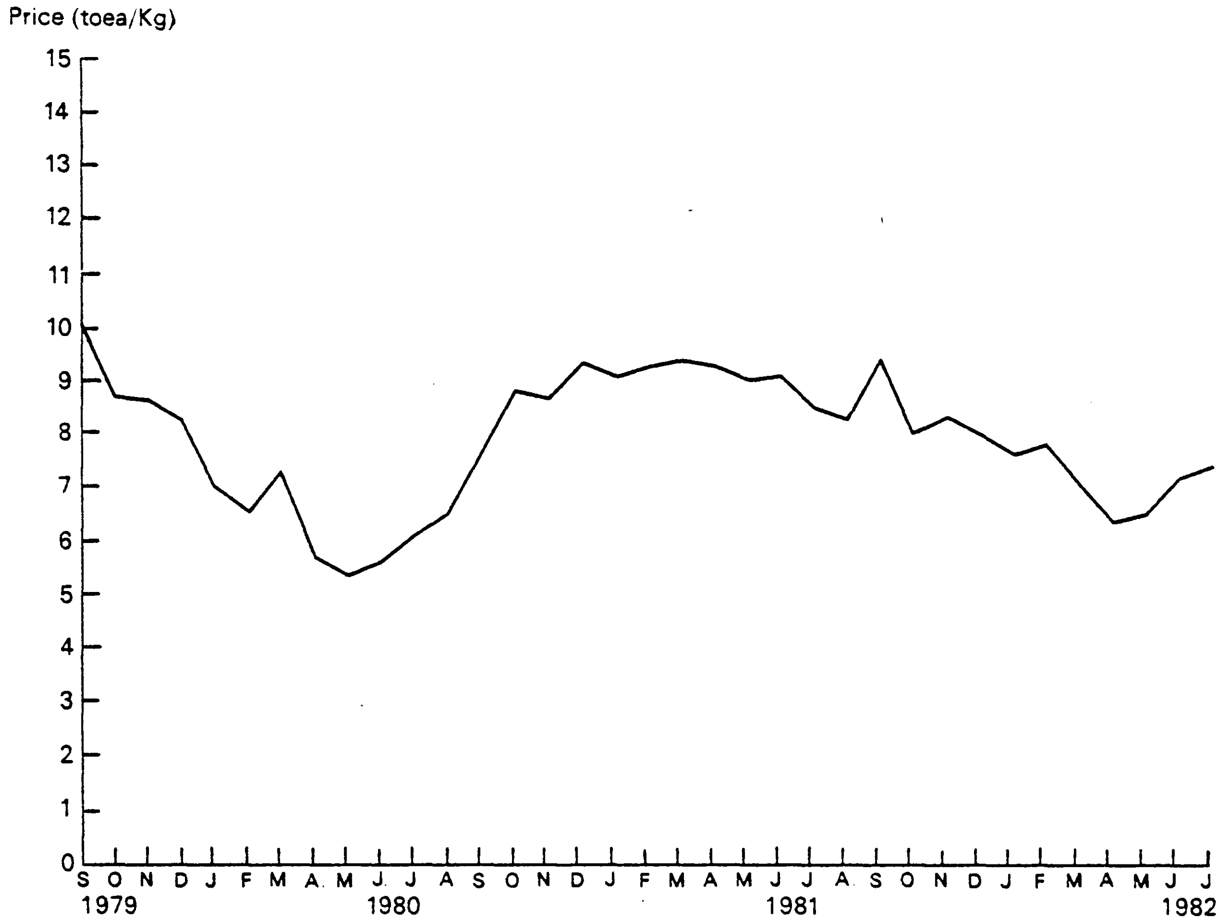

Figure 3.7 Price of sweet potato, Hol market, Nembi Plateau, September 1981 to July 1982 (constant 1984 currency) (Source: surveys by E. D'Souza)

The Five Highlands Provinces, 1979 to 1984

This data set covers the 28 districts of the five provinces of the central highlands for the six year period 1979 to 1984. The basis is comments by outsiders, particularly reports by agricultural officers. The data are presented in Figure 3.8 and Table A6.3, together with explanations offered by non-villagers for the cause of food supply problems(7).

The data are firstly considered by province. The Eastern Highlands and Chimbu Provinces exhibit similar patterns, as do the Western Highlands and Enga. The pattern in the Southern Highlands differs from those in the other provinces. Reports of food shortages are most common in the Southern Highlands and least common in the Western Highlands and Enga. There was an average of four reported food shortages per district in the Southern Highlands over the six year period compared with one per district in the Western Highlands and Enga and two to three per district in the Eastern Highlands and Chimbu.

In the Eastern Highlands and Chimbu, widespread shortages of sweet potato occurred in the latter half of 1982 and 1984. Otherwise, reported food shortages were restricted to Lufa, Sinasina and Gumine Districts in 1980-81 and four districts in Chimbu in early 1979. In the Western Highlands and Enga Provinces, food shortages associated with frosts were reported from high altitude locations in Tambul, Kandep and Lagaip Districts in 1980-1981 and 1982-83. The only other reports in these two provinces were for localised parts of the Jimi, Wahgi, Hagen North and Lagaip Districts. In the three populous districts of Hagen Central, Wabag and Wapenamanda, no food shortages were reported between 1979 and 1984. In contrast, food shortages were common in the Southern Highlands, with frequent shortages between 1981 and 1984 (Figure 3.8).

The data set is now considered on an annual basis. Food shortages said to be caused by frost were reported in 1980-81 in many high altitude locations. Reports of shortage, often accompanied by comments that plants failed to tuberise normally, were made in parts of the Southern, Eastern and Western Highlands and in Enga in early to late 1981. In late 1982-early 1983, food was in short supply in much of the Eastern and Southern Highlands and Chimbu, reportedly because of drought or a combination of drought and frost. This pattern was repeated in mid- to late 1984 when food shortages were reported from the same locations, as well as from some locations on the fringe of the central highlands (Telefomin, Oksapmin, Menyamya and Kaintiba areas).

(7) These explanations are not necessarily accepted. Numerous explanations were advanced for the 1984 food shortages but these are not noted in Figure 3.8.

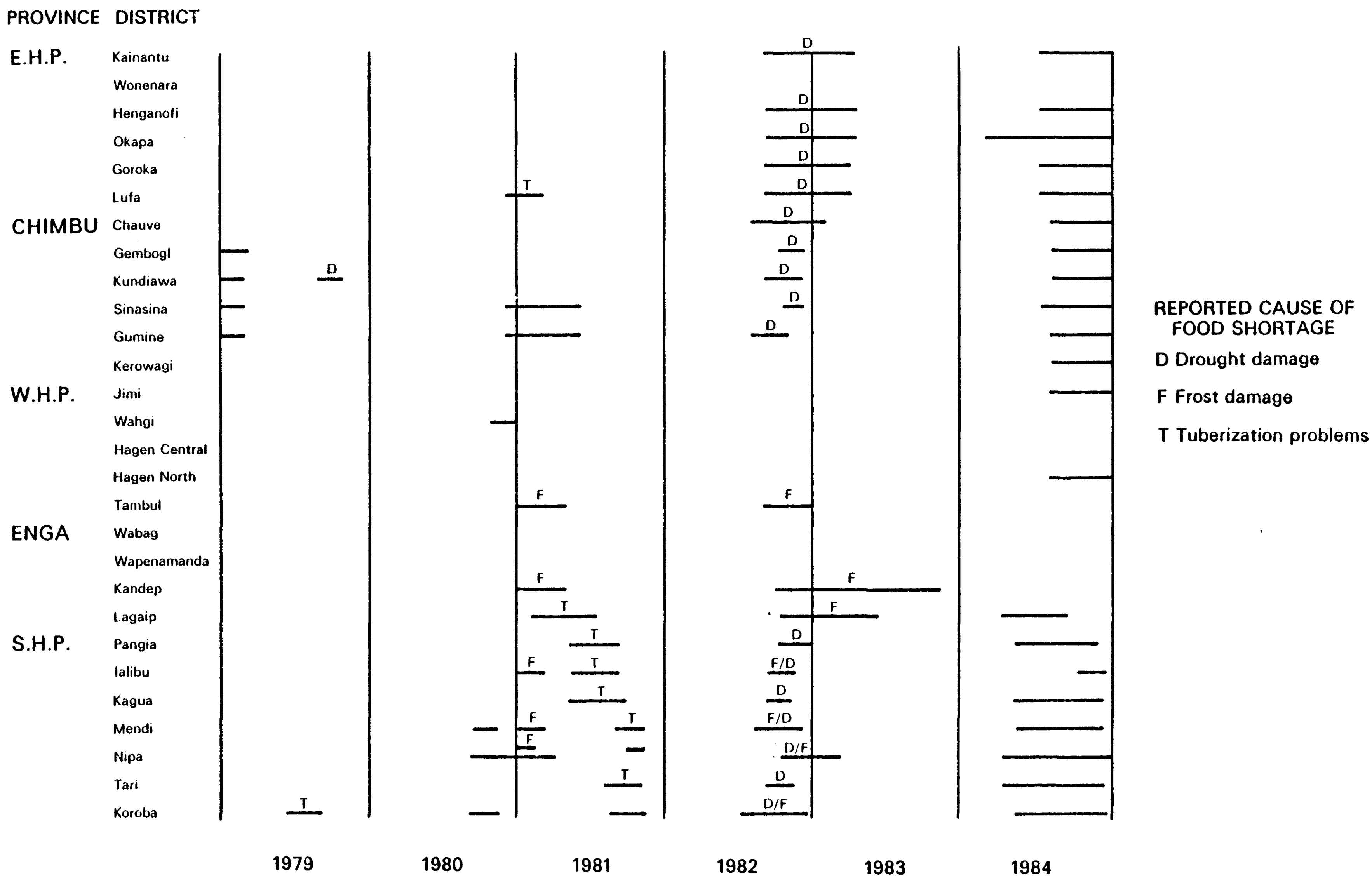

Figure 3.8 Reported periods of food shortages in the Papua New Guinea highlands, by district, January 1979 to December 1984 (Source: Table A6.3)

Whilst isolated reports of food shortages did occur from some districts, the overall pattern is clearly not random, suggesting that the causes were not local. There were, for example, no reports of subsistence food shortages in 1983, apart from the continuing effects of the 1982 frosts at high altitude locations. In contrast food was scarce in many parts of the highlands from mid- to late 1984. The duration and intensity of reported food shortages apparently varied among districts, although the nature of the data sources makes this difficult to evaluate. There is however an indication that, at high altitude locations, periods of food shortages commence and finish some months later than at nearby lower altitude locations. For example, in the Southern Highlands in 1984, villagers in the high altitude Margarima area reported food shortages from August onwards, whereas they occurred in the lower altitude areas of Nipa, Tari, Koroba, Mendi and Kagua areas from May or April.

These food shortages did not follow any annual pattern for any district between 1979 and 1984. Nevertheless, food is more likely or less likely to be scarce at specific times of the year. In the Eastern and Western Highlands and Chimbu, food is more likely to be scarce between September and December and less likely between March and July. In the Southern Highlands, food is more likely to be scarce between June and November and less likely between December and April.

Eastern Highlands Province, 1944 to 1971

The next data set covers the six districts of the Eastern Highlands and is mostly based on comments in patrol reports. The period extends from 1944 to 1971, although systematic records commenced later in Okapa, Lufa and Wonenara Districts. The data are presented in Figure 3.9 with further detail and sources given in Figures 3.1, 3.2 and Table A7.1. Periods of food shortages and abundant food supply are classified as occurring in a limited part of a district or as widespread in a district. "Limited" refers to a restricted area (for example, one census division only) and "widespread" indicates that the event occurred in many parts of a district.

Reports of food shortages or especially abundant food supply are not common in the Eastern Highlands (Figure 3.9). There were only 11 periods between 1944 and 1971 when food shortages were widespread and only 10 periods when food was reported as especially abundant at a district level. There is considerable variation in the patterns among districts. The only common pattern between the districts is the widespread food shortages in Kainantu, Wonenara and Okapa Districts in mid- to late 1962, and the abundant supply in Kainantu and Henganofi Districts in mid-1945.

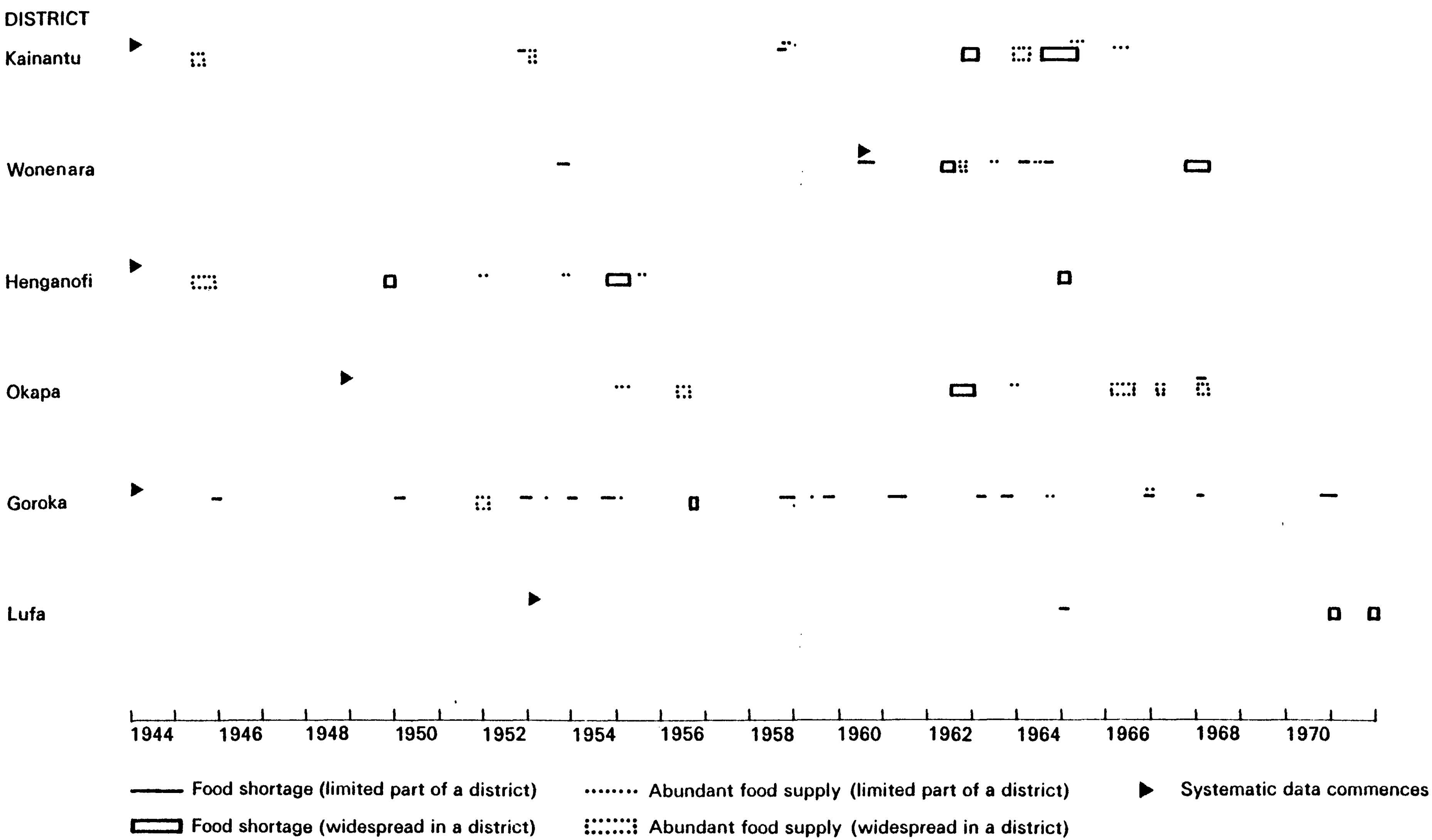

Figure 3.9 Reported periods of food shortages and abundant food supply, by district, Eastern Highlands, 1944 to 1971 (Source: patrol reports)

There is no evidence of any regular annual food shortages or abundances from this data set, although episodes of food shortages are more likely between October and January and less likely between April and July. Episodes of abundant food supply exhibit less clear trends, but they are more common between June and August.

The data run is sufficiently long and of uniform quality to examine the possibility that the frequency of food shortages has changed over time. Despite the increasing frequency of observations over time, there is no indication from this data set that episodes of food shortages became more common or less common over this period (Figures 3.1, 3.2). For example, in the three districts of Kainantu, Henganofi and Goroka where systematic recording occurred for the entire period, there were seven, eight and seven reported food shortages for each of the nine year periods 1945-1953, 1954-1962 and 1963-1971 respectively. There were seven, four and five periods of abundant food supply over the same nine year periods (Figure 3.9).

Kainantu District, 1935 to 1984

The focus now narrows again, this time to a single district in the Eastern Highlands where the data set is based on observations by agricultural officers as well as patrol officers. Comments by these people on village food supply in the Kainantu District commenced in 1935. Continuous observations by agricultural officers based at the Highlands Agricultural Experiment Station at Aiyura are available for the period 1972 to 1985. Thus it is possible to extend the data set for Kainantu District to a 50 year period, although the associated limitations of using a mixture of sources must be recognised. The data run extends over almost the entire period since contact (Figure 3.10).

As for the province as a whole, periods of food scarcity or particularly abundant supply are relatively infrequent in the Kainantu District. There were seven episodes of food shortages and four of abundant supply over this 50 year period. Three of these events occurred in the first third of the period, two in the middle third and two in the last third(8). Again there is no indication of any annual occurrence of events nor that the frequency of food shortages is changing over time. One feature is particularly interesting. This is the apparent occurrence of six of the seven episodes of food shortages as paired events, that is, 1936-37 and 1938-39; 1962 and 1964-65; and 1982-83 and 1984-85. Furthermore, a period of especially abundant supply was reported in 1963 between one pair of shortages.

(8) Systematic evidence for shortages prior to 1944 are very limited in the highlands. However there are several independent reports of shortages elsewhere between 1937 and 1939. Local shortages were reported in the Kundiawa area in Chimbu between April and June 1937 (Hide, 1978:3); there were acute shortages in the Goilala area of the Papuan highlands in 1938-39 (Murray, 1940:24-25); and shortages occurred in the vicinity of Mt Hagen in 1939 (Gitlow, 1947:66).

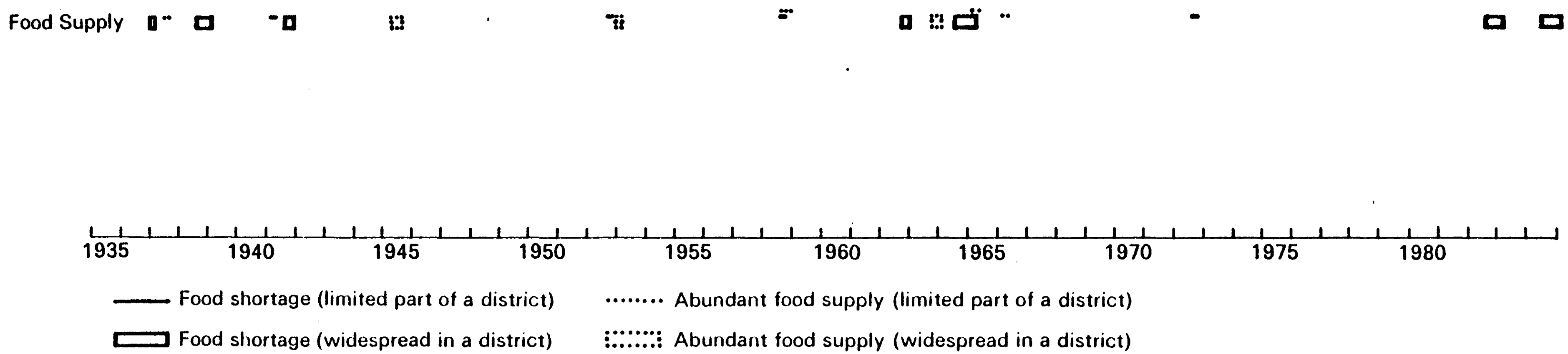

Figure 3.10 Reported periods of food shortages and abundant food supply, Kainantu District, 1935 to 1984 (Source: Table A7.1)

These paired shortages, which also occur in other data sets, are considered further in Chapter 8.

Southern Highlands Province, 1952 to 1971

Patrol reports also form the basis of the next data set which covers all districts in the Southern Highlands over a 20 year period. The data are presented in Figure 3.11 with further detail in Figures 3.3, 3.4 and Table A7.2.

Reports of shortages were frequent in the Southern Highlands during this period. There were 34 episodes when shortages were reported as widespread at a district level and six periods when food was reported to be in particularly abundant supply in much of a district (Figure 3.11). Widespread shortages occurred in three or more districts in 1955, 1962, 1965-66, 1967-68 and 1970-71. There were reports of abundant food supply in most districts in 1966. Adjacent districts tend to exhibit similar patterns, for example, Pangia and Ialibu Districts, or Kagua and Mendi Districts. The pattern of variation in Tari District is unlike that in other districts.

Episodes of shortages and abundant food supply did not occur annually in the Southern Highlands over this period, although they were more likely to occur in certain months. Shortages were more common between July and December (and especially between August and November), and less common between February and May. Periods of abundant supply occurred more frequently between June and October and less frequently between March and May.

There is no indication in this data set that the frequency of food shortages increased or decreased over this period. The 20 years were split into four periods of five years each and data for Pangia excluded, because of the brevity of recordings. There were 13, 9, 15 and 10 shortages for each of the five year periods; and 6, 4, 7 and 1 periods of abundant supply for the four periods respectively.

Southern Highlands Province, 1972 to 1974

Because of a loss of quality in the available data sources after 1971, it is necessary to split the Southern Highlands data run after this date. Data sources for this three year period are given in Table A7.3. Widespread shortages were reported in all districts of the Southern Highlands in late 1972 and early 1973 except for Pangia District. These shortages were most severe at high altitude locations in the Ialibu Basin, Mendi and Lai Valleys, and Margarima area; but they were also severe in some lower altitude parts of Nipa and Koroba Districts.

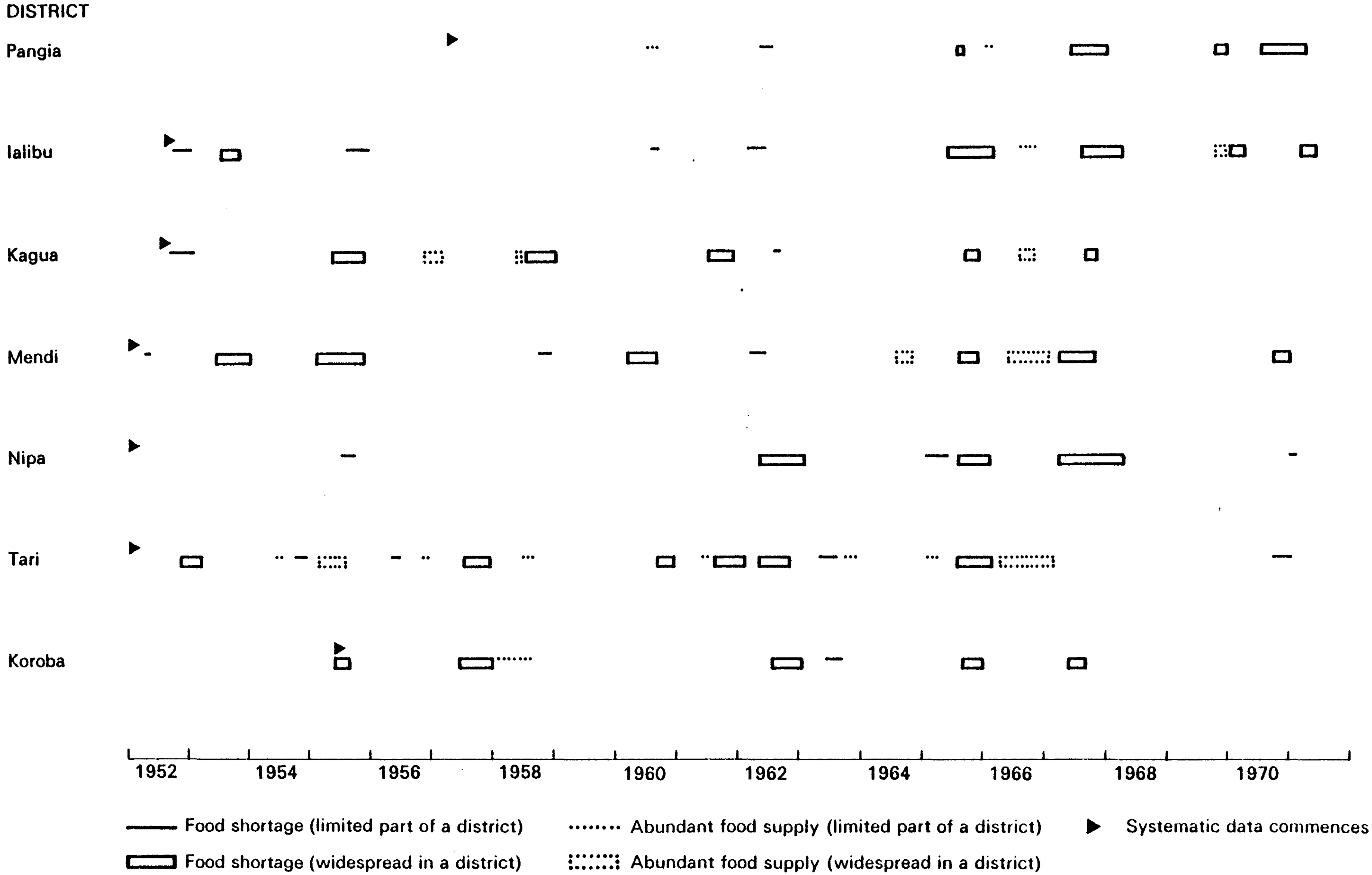

Figure 3.11 Reported periods of food shortages and abundant food supply, by district, Southern Highlands, 1952 to 1971 (Source: patrol reports)

Some indication of the relative severity and extent of the food shortages can be gauged from the numbers of people who were provided with food by the Administration in different parts of the province (Table 8.3). The shortages appear to have commenced earlier (in about August/September) in the high altitude locations and in about October/November at lower altitudes. Food aid was provided in the highlands until May 1973, but details are not available to the author regarding its cessation at different locations.

In mid- to late 1974, food was reportedly scarce in Pangia District, in one village at least in the Wage Valley in Nipa District, and in the Koroba area (Table A7.3). Food shortages may have occurred elsewhere in 1974, but by that time systematic information was not available.

Asiranka Village, Eastern Highlands, 1978 to mid-1985

The final two data sets on sweet potato supply are from the study communities, although most of the food shortages discussed here affected other villages in the Kainantu District and on the Nembi Plateau respectively.

Between 1978 and 1984, there were three episodes of food scarcity at Asiranka. The first was a minor event and was not widespread throughout the area. It lasted about a month in December 1980. Indications of the shortage, other than people's complaints, were their unusual enthusiasm to buy sweet potato from the Highlands Agricultural Experiment Station at Aiyura and the price that Asiranka sellers were asking in Aiyura market in that month. Asiranka people who had surplus sweet potato for sale were asking 14 toea/kg in December. This compares with a price of 10 toea/kg during the four months before and the four months after December.

The second shortage commenced in August 1982 and continued until about March 1983, although garden food supplies were not adequate for all households until about June 1983. People responded in a number of ways. These included increasing purchases of imported food; obtaining rice on credit from a Kainantu-based businessman in exchange for coffee in the following harvesting season; increasing the garden planting rate; seeking food aid from the provincial government; and obtaining gifts of food from expatriates living in the Aiyura Basin. The asking price of sweet potato offered by Asiranka people in Aiyura market increased to 20-21 toea/kg. This was about twice the price that prevailed during the year prior to the food scarcity.

The third and most serious shortage over this seven year period occurred between June 1984 and February 1985. The worst of the shortage (about July-October 1984) coincided with the coffee harvesting season and because of the greater availability of cash during this period, the impact was more muted. Nevertheless people found it necessary to make adjustments. These included using a higher proportion of cash income to buy imported food and increasing the rate of garden planting (Chapter 8). People living in households where cash income was not high had to make other adjustments, including drastic reductions in pig rations and selling large quantities of other garden produce to generate cash in order to buy rice and tinned fish. These adjustments appeared to be a sufficient buffer and there was no indication that people's food intake was seriously affected by the shortage, other than through increased consumption of imported food. The food supply returned to normal by March 1985(9).

It is difficult to judge the frequency of episodes of food scarcity prior to 1978, using oral sources, because villagers do not appear to remember smaller fluctuations in food supply. Nevertheless food supply problems of any significance appeared to be very infrequent at Asiranka. The major shortage that affected the western part of the highlands in 1972 did not occur in Asiranka and, in fact, some people donated sweet potato to those "Mt Hagen" people affected.

Neither Aub Schindler, who was at Aiyura between 1944 and 1962, nor Alan Kimber (1966 to 1980) recall any major food shortages in the Aiyura Basin during their periods of residence (pers.comm., 1984). This suggests that the 1984 event had a larger impact on the villagers than any other between 1944 and 1984 (with a gap in the information between 1962 and 1966). This is consistent with the district level data for Kainantu where the only widespread shortages between 1944 and 1980 occurred in 1962 and 1964 (Figure 3.10).

In separate interviews, four village informants who were born between about 1912 and 1935, said that no major food shortages had occurred during their lifetime, prior to the 1982-83 and 1984-85 events. Two of these people spoke of food shortages they had heard of during their parents' lifetimes that were severe enough to force people to eat tubers of two selfsown species (pueraria and wild yam). Another informant, a man born between 1900 and 1910, spoke of a major shortage that had occurred when he was a child, when people ate wild pueraria and wild yams. He provided a graphic description of the effects on the villagers: very thin arms and legs and very large bellies. My cautious interpretation based on this information and other interviews is as follows: a major food shortage occurred in Asiranka some time between 1910 and 1916. Other episodes of food scarcity,

(9) The source of information for 1985 is telephone conversations with informants in the highlands. This was facilitated at Asiranka because the switchboard operator at HAES Aiyura was an Asiranka woman.

possibly as severe as the 1982-83 event, have occurred from time to time, but they have not been serious enough to make an indelible impact on the memories of villagers. The 1983-84 food shortage was the most serious one since Schindler's arrival in the area in 1944.

Upa Village, Southern Highlands, 1978 to 1984

Over this seven year period, there were four food shortages in Upa Village, as follows: July 1978 to about February 1979; September 1980 to about March/April 1981; about October 1982 to about February 1983; April 1984 to March 1985. The 1978-79 shortage coincided with fieldwork by the author and others during the agriculture and nutrition survey on the Nembi Plateau (Allen, 1984b)(10). A number of responses by the villagers were particularly striking during the 1978-79 shortage. Women spent very long periods digging through old sweet potato plots searching for very small tubers. Random inspection and weighing of women's garden bags showed that they contained numerous tiny tubers, all of which would have been considered inedible elsewhere in the highlands (virtually all were less than 100 grams and many were less than 50 grams). People were very enthusiastic about selling non-staple foods to obtain cash, a situation that subsequent observations showed was not the norm.

The second shortage in 1980-81 was observed by D'Souza as he was residing on the Plateau then and I made several brief visits during this period. It was not particularly severe, although it did coincide with somewhat higher than usual prices for sweet potato (Figure 3.7) and reduced quantities offered for sale in Hol Market (Table A6.7). The third shortage occurred between about October 1982 and February 1983. D'Souza heard of the shortage during visits there but no other observations were made. Later people claimed that they unsuccessfully sought food aid from the government.

The fourth shortage at Upa extended from April 1984 to March 1985, with food especially scarce between about June and November 1984. It was the most prolonged and serious of the four events and generated considerable comment among the villagers. Some people lost weight, including young children. This shortage caused people to increase dramatically their garden planting rate, particularly from fallow land; they consumed selfsown "bush" foods; and diverted limited cash income from other uses to buy imported food. Some stealing occurred and women searched their gardens carefully for small tubers (Chapter 8). At the nearby government-run primary school, teachers sent children home at mid-day during this period because they thought the children's concentration was impaired during the afternoon due to lack of food.

(10) Various surveys were conducted between May 1978 and April 1979.

Long term data from the Nembi Plateau indicate that the child malnutrition rate increased in late 1984 (Chapter 4), thus reinforcing the Upa observations. Apart from the young children, other people at Upa were also clearly affected. Some older children, women and elderly adults were severely underweight and they attributed this to the food problems being experienced.

Surveys were conducted in Asiranka and Upa on the main foods eaten at the evening meals in September and November 1984. There are considerable problems in conducting food intake studies in PNG (McArthur, 1977; Harvey and Heywood, 1983:195-200), and a one off survey such as this is of limited value. Nevertheless the survey does indicate differences in the impact of food shortages in the two communities in 1984. At Asiranka I observed the meals being prepared or eaten during visits for other purposes, such as checking an anomaly in household census details. Information was obtained from 27 households out of a total of 92. Each household was surveyed once only and meals that were provided especially for me have been excluded. The survey at Upa was more systematic. Most cooking hearths were visited once, covering the three clans that constitute the village. This involved brief visits to 117 cooking hearths during two evenings. The visits were unexpected and there was no indication that eating patterns were altered because of the survey.

The results are presented in Table 3.2. In both communities sweet potato constituted the main food eaten on the survey evening in about two-thirds (67-71 per cent) of the households. At Asiranka rice was the main food for the remainder of the households, except for two of them, where people ate greens and sugarcane only. Rice was much less important in Upa where it was the main food eaten in only 9 per cent of cooking hearths on the survey evening.

Of particular interest is the finding that members of 8 per cent (9 cooking hearths) of the households at Upa ate no evening meal at all and members of another 8 per cent of cooking hearths ate only foods of very low calorie value, such as pumpkin fruit, leaves, and other vegetables. This unexpected finding was checked by repeated questioning. On the Nembi Plateau, people may eat a light meal in the morning and snacks of sugarcane, sweet potato and other foods during the day, but the main meal is in the evening. Such a survey is inadequate as an indicator of daily food intake, but it does reinforce the observation that for some people food intake was very low during this shortage.

Villagers spoke of a number of major food shortages prior to 1978 at Upa. The 1972 frosts, which were the only ones in any informant's lifetime, the associated food shortage and the Government relief effort of late 1972-early 1973 are well remembered. One informant, a man who was born about 1923, recalled two major shortages that

Table 3.2 Survey of evening meals, Asiranka and Upa Villages, September/November 1984(1)

Main food eaten on evening of survey	Per cent of households Asiranka	Upa
Sweet potato(2)	67	71
Rice(2)	26	9
No food at all	0	8
Pumpkin fruit	0	4
Leaves and other vegetables(3)	7	4
Bananas	0	3
Scones(4)	0	1

Notes

(1) At Asiranka 27 out of 92 households were surveyed in September 1984. At Upa 117 cooking hearths, which is most of the village, of the Puit, Murupa and Palam clans, were surveyed in November 1984.

(2) Various green leafy vegetables were also eaten with some meals of sweet potato and rice.

(3) At Asiranka this consisted of rungia and sugarcane. At Upa leaves and other vegetables included oenanthe, rungia, pumpkin tips, highland pitpit, and fruit of *Ficus copiosa*.

(4) Scones consist of deep fried flour.

occurred in the early 1930s and early 1940s. He told of people fighting over selfsown plots of a leafy green (oenanthe) and people dying from hunger. All older informants insisted that the effects of food shortages are now much less severe than in their youth or their parents' lifetimes because of the possibility of using cash to buy imported food.

VARIATION IN THE SUPPLY OF OTHER FOOD CROPS

Whilst sweet potato is the main food crop grown and eaten by highlanders, many other crop species are also utilised. At Asiranka, for example, people cultivate and eat over 70 crop species, and at Upa over 50 species. Most of these crops, taken individually, have a very small effect nutritionally. Nevertheless their combined contribution to people's diets is important. An understanding of the pattern of variation in supply of these foods is therefore necessary to an understanding of variation in the total food supply of highlanders.

The dietary intake studies cited in Table 2.2 indicate that the following crops or crop groups, other than sweet potato, make modest contributions to highlands diets: green leafy vegetables, sugarcane, corn, bananas, highland pitpit, beans/pulses, taro, pumpkin, yam and karuka nut pandanus. On the highlands fringe, root crops other than sweet potato make a greater contribution and marita pandanus is more significant (Rappaport, 1968:73; Clarke, 1971:179). Karuka nut pandanus is a more important food source for people living at altitudes above 2000 m.

The production and consumption pattern of any individual crop species is not particularly important for this study, unless it constitutes a significant part of people's diets, at least for part of the year. The production patterns of foods that readily substitute for each other and can be considered as a food group are of greater interest. The following food groups are important in the highlands:

1) Sweet potato
2) Staples other than sweet potato
3) Green leaf and other vegetables
4) Beans

The only long term data on supply of all food crops in the highlands come from our surveys of six highlands markets (Table A6.1)(11). The relative importance of different food crops in Kainantu and Hol markets is indicated by the mean number of bundles

(11) For simplicity, only data from Kainantu and Hol markets are presented. The pattern in the other markets surveyed in the Eastern Highlands is fairly similar to the pattern at Kainantu. Price data from Goroka, collected for use in the CPI, are available for a number of food crops and conclusions based on these prices are also similar.

offered for sale at the time of our fortnightly/weekly surveys over a 3 or 2 year period (Table 3.3). A number of crops are important in both markets, including sweet potato, bananas, peanuts and sugarcane. There are some minor differences, for example, cabbage and oenanthe are important at Kainantu but not at Hol.

The number of bundles on display in Kainantu market of all foods (except sweet potato), vegetables, staples (except sweet potato) and beans are presented in Figure 3.12 for a 37 month period, with the monthly means in Table A6.6. The supply of all foods fluctuates over time, in part because of the pattern of supply of certain species such as mango, but there is no recurring pattern. The supply of vegetables, staples other than sweet potato, and beans likewise exhibits no recurring patterns. In particular there is no evidence of annual seasonal variation in supply of any of these food groups.

The numbers of bundles on display in Hol market over a 25 month period for the same food groups are presented in Figure 3.13 with monthly means in Table A6.7. The pattern in Hol market contrasts markedly with that in Kainantu market. At Hol, the supply of all food groups fluctuates on a regular annual basis as does total food supply in the market (Figure 3.13). The best supply for all commodity groups was between December and June and the poorest supply between July and November. The pattern varied somewhat between the two years. The best supply of all food crops (other than sweet potato) occurred between February and May 1980 and between January and April in 1981.

The major reason for the marked contrast between these two locations lies in the pattern of variation in supply for individual crop species. In the Kainantu area, the supply of some food crops varies in a regular annual pattern but the supply of most foods varies irregularly. In contrast, the supply of most food crops other than sweet potato varies regularly on the Nembi Plateau and the period of peak supply for many species tends to be during the early months of the calendar year.

These contrasting patterns for individual species at the two locations are illustrated using data on corn, cooking bananas and common bean (Figures 3.14, 3.15, 3.16, Tables A6.8, A6.9). In both locations, the supply of corn is markedly seasonal, with peak production between January and April (Figure 3.14). There is a contrasting pattern in the supply of cooking bananas and common beans in the two markets. In Hol market, the supply of cooking bananas and common bean varies seasonally whereas in Kainantu market there is no regularity in the supply pattern (Figures 3.15, 3.16). It is the combined effect of the patterns for these individual crop species that produces the seasonal supply for all plant foods other than sweet potato on the Nembi Plateau. In the Kainantu area the supply of most food crops does not vary in a regular manner and there is no additive effect from the individual foods as there is on the Nembi Plateau.

Table 3.3 Mean number of bundles of certain food crops offered for sale on Friday/Saturday morning at Kainantu and Hol markets(1)

Crop	Kainantu market	Hol market
Sweet potato	616	162
Cabbage	536	41
Peanuts	303	108
Oenanthe	265	3
Coconuts	162	0
Eating banana	159	214
Cooking banana	150	78
Mandarin	130	0
Xanthosoma taro	120	7
Sugarcane	98	145
Cucumber	93	46
Chinese cabbage	93	0
Marita pandanus	87	103
Corn	84	103
Spring onion	77	3
Mango	65	0
Pumpkin tips	57	7
Taro	55	7
Rungia	55	44
Choko tips	54	0
Pak choi	54	3
Potato	52	3
Ferns	52	0
Aibika	51	4
Karuka nut pandanus	50	12
Pineapple	50	6
Ginger	42	12
Pumpkin fruit	38	113
Nasturtium schlechteri	33	39
Common bean	29	19
Winged bean tubers	22	18
Amaranthus spp	11	28
Winged beans	3	13
Highland pitpit	3	54
Hyacinth beans	0	14
Other food crops	172	20
ALL FOOD CROPS	3921	1429

Note

(1) Commodities listed are those for which a mean minimum of 20 bundles per market was on display in Kainantu market or 10 bundles in Hol market. Recordings were made of produce on display only on the Friday (Kainantu) and Saturday (Hol) morning. Values are the mean for a 3 year period for Kainantu (June 1979 to May 1982) and the mean for a two year period for Hol (October 1979 to September 1981).

The units used are bundles of 10 toea value. Commodities which are sold in lots for a higher price (for example, sweet potato, cabbage, pineapple) have been converted into 10 toea equivalents. This is a crude index of weight of produce as the size of bundle (that is, price per unit weight) is dependent on overall supply.

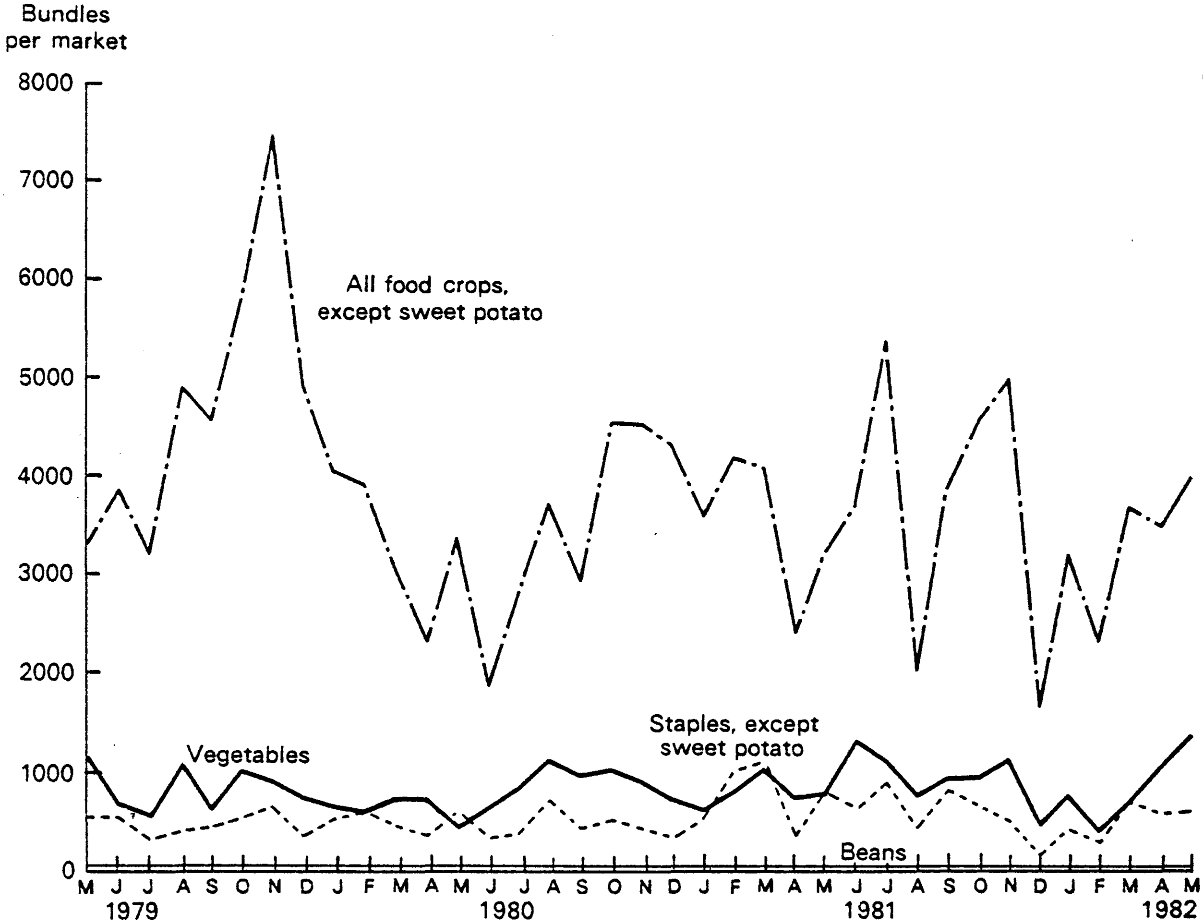

Figure 3.12 Number of bundles of various food groups on display per market, Friday mornings, Kainantu market, May 1979 to May 1982 (Source: author's surveys)

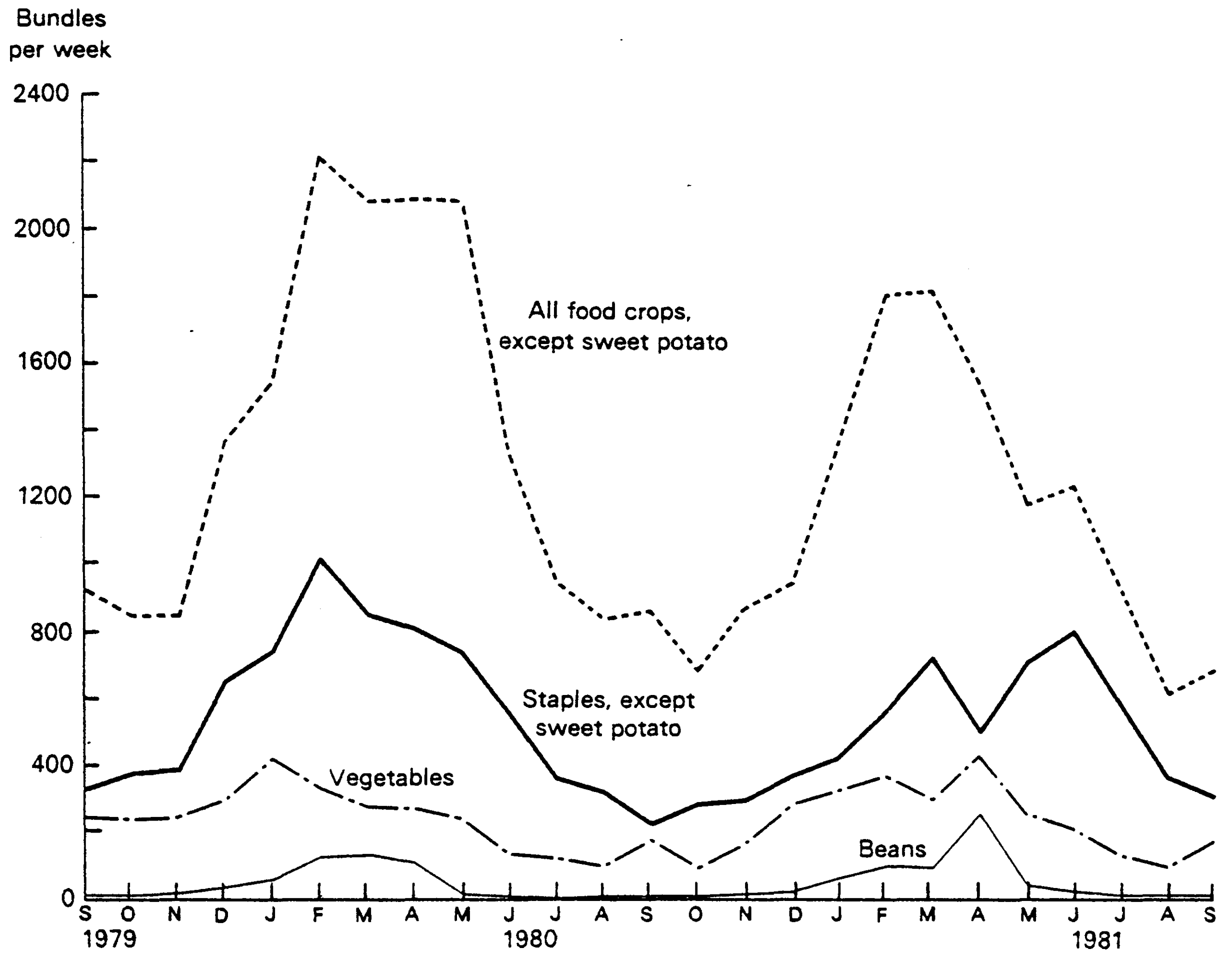

Figure 3.13 Number of bundles of various food groups on display per market, Saturday mornings, Hol market, September 1979 to September 1981 (Source: surveys by E. D'Souza)

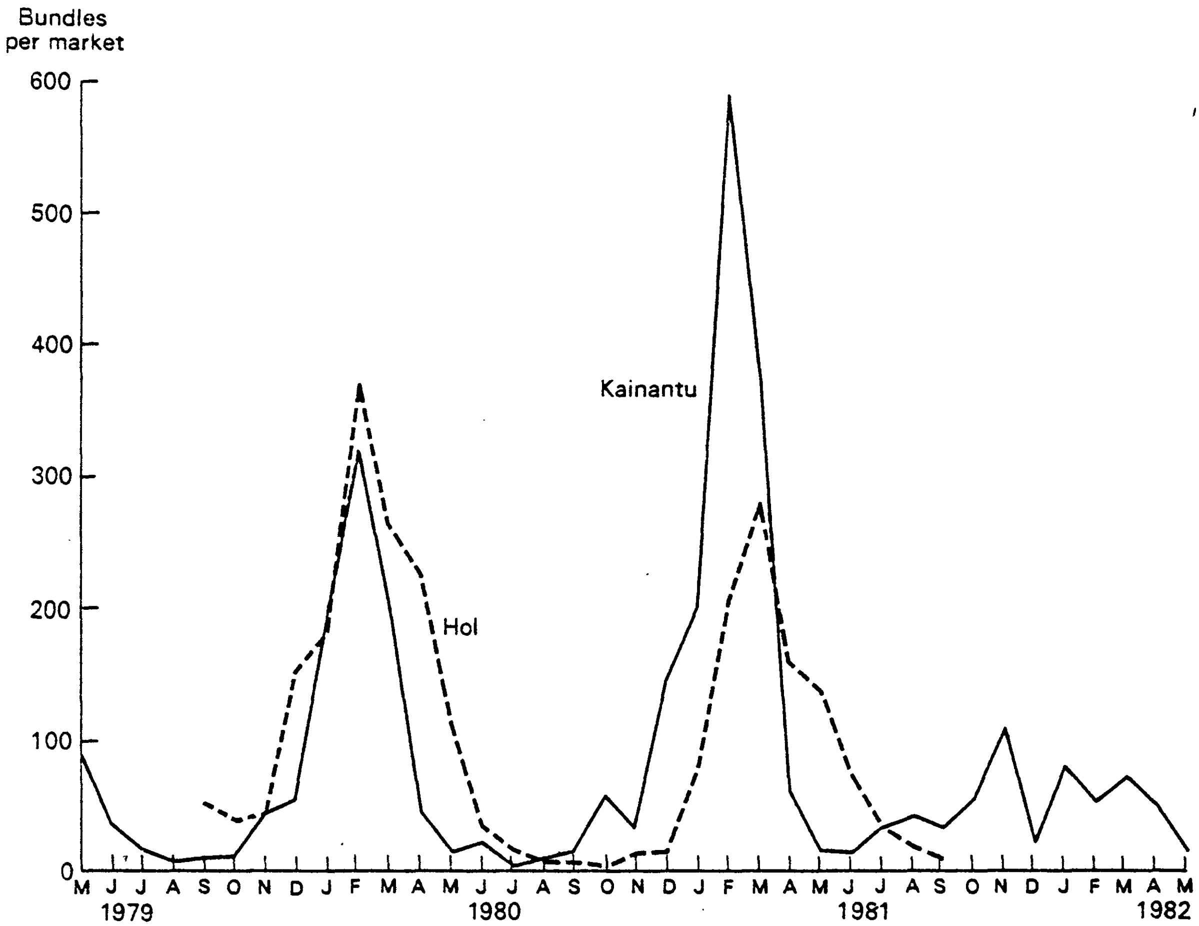

Figure 3.14 Number of bundles of corn on display per market, Friday/Saturday morning, Kainantu and Hol markets, May 1979 to May 1982 (Source: surveys by R. M. Bourke and E. D'Souza)

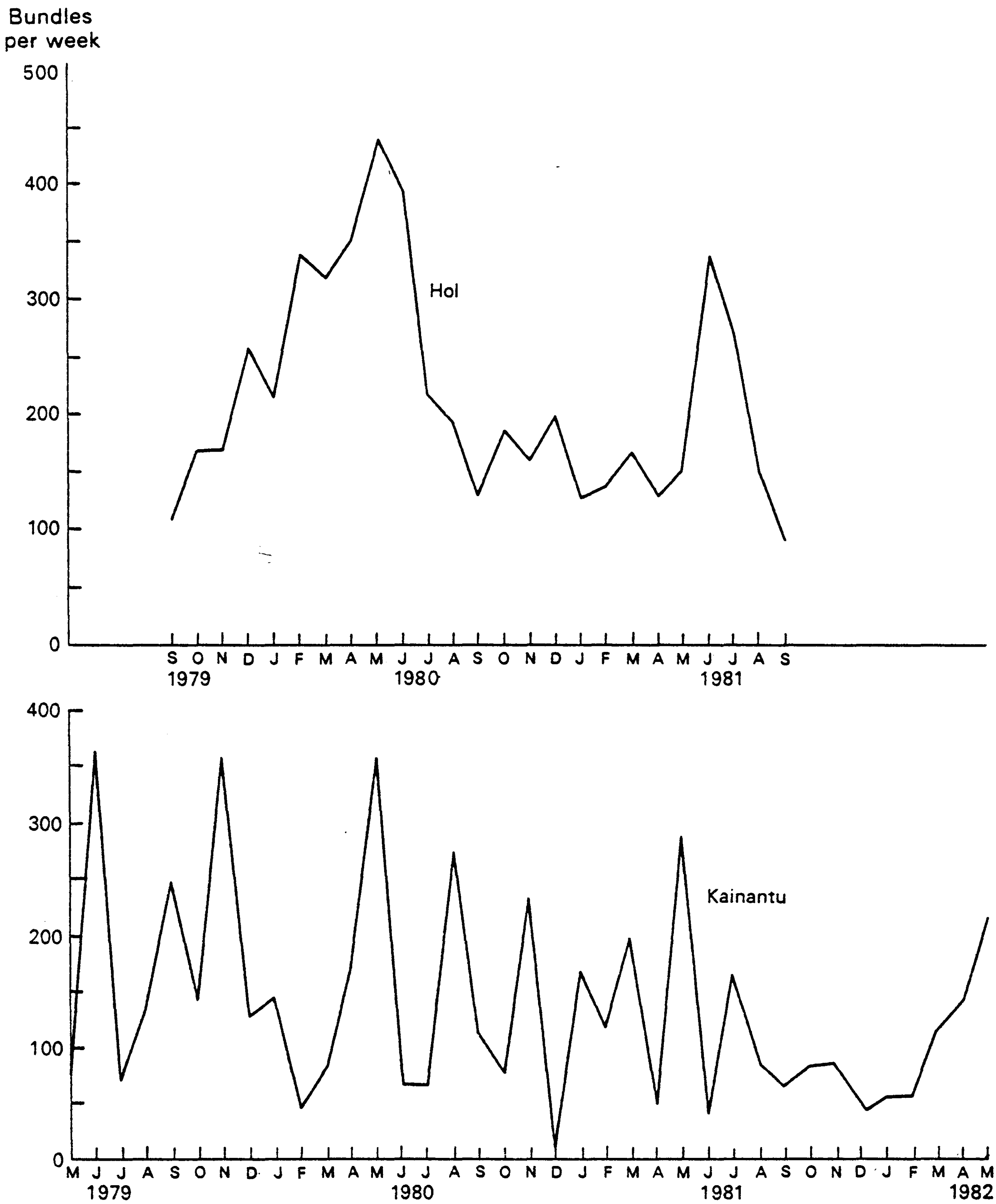

Figure 3.15 Number of bundles of cooking bananas on display per market, Friday/Saturday mornings, Kainantu and Hol markets, May 1979 to May 1982 (Source: surveys by R. M. Bourke and E. D'Souza)

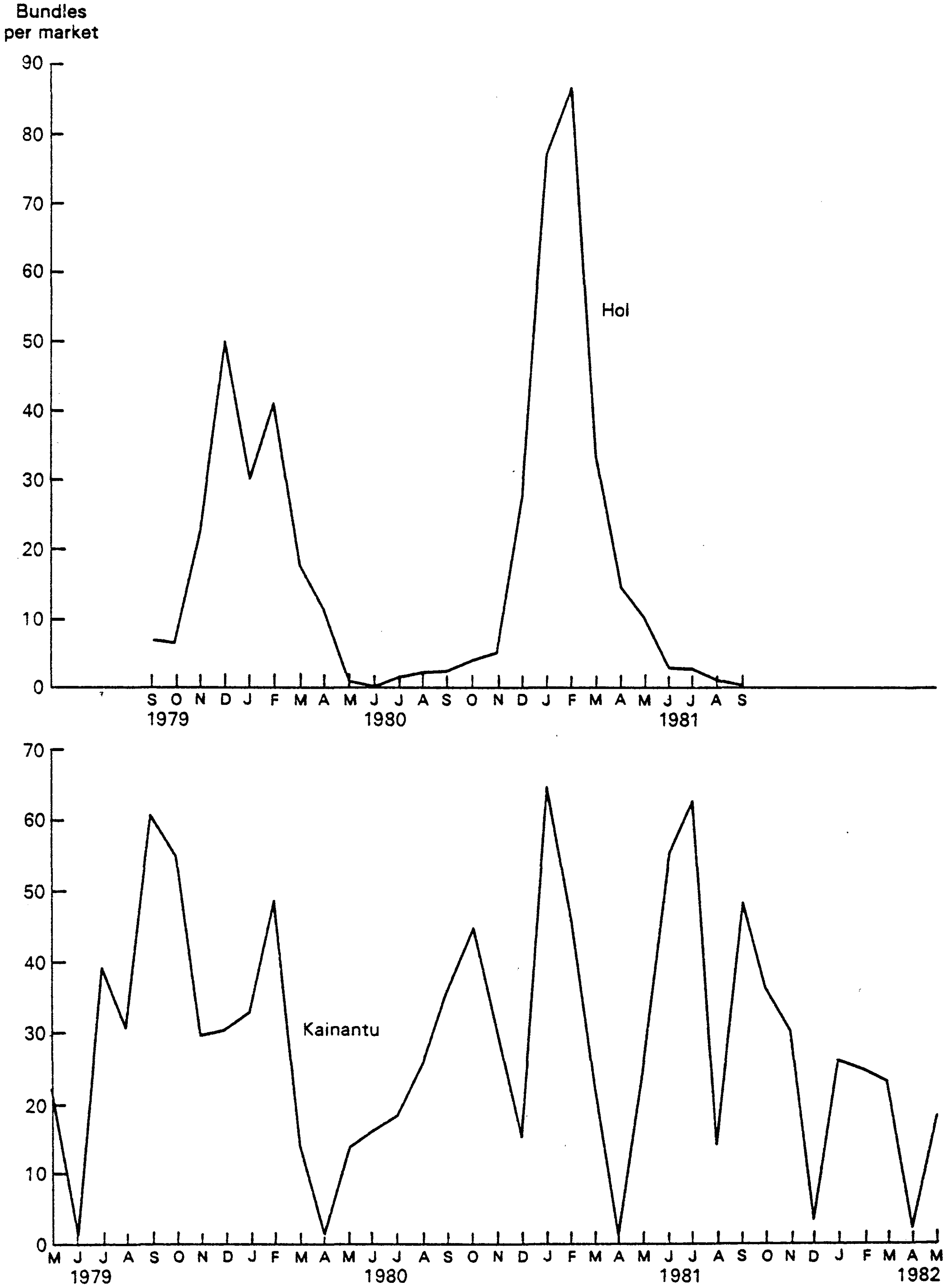

Figure 3.16 Number of bundles of common bean on display per market, Friday/Saturday morning, Kainantu and Hol markets, May 1979 to May 1982 (Source: surveys by R. M. Bourke and E. D'Souza)

Explanations for these patterns lie in the planting rates for mixed gardens, the proportion of various foods planted in different garden types and ultimately in the intensity of subsistence agriculture. This is considered in Chapter 8.

CONCLUSIONS

Because direct recordings of food supply are unavailable, surrogate measures are necessary. Market surveys and documentary sources provide adequate information on food supply variation, although both sources suffer from some limitations. Given the nature of the data sources, it is not possible to quantify variation in food supply. One cannot, for example, translate a 100 per cent rise in sweet potato prices in a certain market into a deficiency of so many tens of thousands of tonnes of sweet potato in the market catchment area. Many of the reported food supply problems affect part of the highlands region only, for example, those in 1981 (Figure 3.8). Others affect most of the region. This was the case in 1982 and 1984 when people in most parts of the Eastern and Southern Highlands and Chimbu were affected. The shortage in 1984 probably affected 800,000 villagers in the region and the impact ranged from minor inconvenience to a major effect on people's wellbeing.

The data set for the period 1979 to 1984 indicates that food shortages are more common in the Southern Highlands than elsewhere in the region, and less common in those parts of Enga and the Western Highlands which are not susceptible to frost damage. Both patrol reports and observations from the two study communities show that food supply problems have been and continue to be more common and more severe in the Southern Highlands than in the Eastern Highlands.

In all ten data sets examined, there was no evidence for annual cycles of scarcity or abundance of staple foods in the highlands. Thus the frequent claims for an "annual *taim hangre*" made in the literature are unfounded. In a number of the data sets, shortages sometimes occurred as paired events, with an interval of 14 to 22 months between the end of the first food shortage and the start of the second. This pattern occurred between 1970 and 1976 for sweet potato prices in Goroka market (Figure 3.5); in 1982 and 1984 in much of the region (Figure 3.8); for six of the seven food shortages in the Kainantu District over a 50 year period (Figure 3.10); between 1953 and 1972 in Mendi District (Figure 3.3); and for the four shortages in Upa Village between 1978 and 1984. These paired food shortages point to cycles in planting rates and provide a key to an overall explanation of the occurrence of some food shortages (Chapter 8).

All long term data sets indicate that the frequency of shortages has not altered since contact between highlanders and outsiders (Figures 3.1 to 3.4, 3.9 to 3.11). In certain

Table 3.4 Months when food shortages are more likely or less likely to occur in the Eastern and Southern Highlands(1)

Province	Period	More likely	Less likely	Source
Eastern Highlands	1944-1971	Oct-Jan	Apr-Jul	Patrol reports
	1970-1984	Oct-Feb	Mar-Jul	Sweet potato price, Goroka market
	1979-1984	Sep-Dec	Mar-Jul	All sources
Southern Highlands	1952-1971	Jul-Dec	Feb-May	Patrol reports
	1979-1984	Jun-Nov	Dec-Apr	All sources

Notes

(1) Food shortages are reported from all months of the year in both provinces, but they are more common during certain months. There is no evidence for annual cycles of food availability in any of the data.

locations, apparent trends appear. For example, there was an apparent increase in frequency of food shortages in Pangia District in the late 1960s and early 1970s (Figure 3.3) and this has been used as evidence for increasing frequency of food shortages since contact by Strathern (1984:75-77,81-82) and Clark (1985:147-149). The apparent increase in shortages almost certainly is the result of the short duration of observations and random variation rather than a real change in frequency. This can be illustrated using the observations from Kainantu. If the period 1944 to 1971 is used, the only widespread food shortages occurred towards the end of the period (Figure 3.9). However, if observations from the longer period 1935 to 1984 are used, food supply problems are evenly distributed over the whole period (Figure 3.10).

Whilst the supply of sweet potato does not vary in an annual cycle in the highlands, food supply problems are more likely to occur at certain times of the year. Information on the periods when food is more likely or less likely to be scarce is summarised in Table 3.4. The Eastern Highlands and the Southern Highlands display different patterns. However in both provinces, the periods when food shortages are more likely or less likely to occur have remained constant. These unchanged patterns of shortages over the period since contact reinforce the conclusion that the nature of food supply problems, and by implication their causes, have not altered substantially over the past 50 years. What has altered is the way people respond to food supply problems (Chapter 8).

In the Eastern Highlands, the supply of all garden foods other than sweet potato does not vary in any regular manner, despite the seasonal climate. This contrasts with the pattern on the Nembi Plateau where the supply of these foods as a whole and the various food groups (apart from sweet potato) varies in a regular annual cycle even though the seasonal climatic variation is extremely weak (Figures 3.12, 3.13). The immediate reason for this contrast is the pattern of supply of individual crop species, but this, in turn, is determined by the pattern of seasonal planting of mixed gardens and the proportion of the various foods planted in mixed or sweet potato gardens. It will be argued later that this depends on the intensity of subsistence agriculture.

The lack of annual cycles in supply of staple foods in the highlands suggests that annual climatic variation or seasonal coffee harvests are not responsible for food shortages. The unchanging frequency of food shortages since contact does not lend support to the hypothesis that modernisation has increased the risk of food shortages. These relationships are examined more fully in Chapter 5, but the conclusion indicates that detailed examination of the behaviour of plants and people is required. Before this is addressed, I show in the next chapter that food shortages have significant effects on people's wellbeing.

CHAPTER FOUR

EFFECTS OF FOOD SHORTAGES ON PEOPLE

The broad spatial and temporal patterns of food shortages in the highlands of PNG have been established. Before proceeding to an examination of the determinants of these patterns, it is worth enquiring into the effects of such food shortages on the wellbeing of highlands people. Papua New Guinea is not known as an area of recurring famine on even a small scale by world standards. So does it matter if food is sometimes scarce? What are the effects on people's wellbeing; in particular, how do food shortages affect the population's death rate, adults' and children's body weight, and infants' birthweight?

Severe reduction in food intake produces a number of changes in human physiology and behaviour (Sorokin, 1975). One physiological effect is weight loss, initially loss of fatty tissue, then muscle tissue. This may eventually result in death from infectious diseases such as pneumonia and diarrhoea. The significance of weight loss for adults is unknown for the PNG highlands. For highlands children, it has been shown that the prospective risk of mortality is higher for children who are classed as less than 80 per cent of weight for age on the Harvard standard. The risk is very much higher for children who are less than 60 per cent weight for age (over 200 deaths per 1000 children per 18 months) (Heywood, 1982).

Maternal diet is important in determining birthweight, and women subject to severe food deprivation during pregnancy bear small children (Hytten and Leitch, 1964:373; Prentice, 1980; Rosso and Cramoy, 1979:176-177). Birthweight is important as it influences a child's subsequent growth pattern and body weight (Jelliffe, 1966). A study in France in 1977 and 1978 (Frydman *et al.*, 1980) and another on the effects of the 1944-45 winter famine in the Netherlands (Stein *et al.*, 1975:92-96) show that diet during the third trimester of pregnancy is especially important in determining birthweight. However, Hytten (1980), whilst accepting that birthweight will be reduced following extreme conditions such as famine during the mother's pregnancy, cautions that the foetus is remarkably safe and well protected from the vagaries of maternal food intake. Other factors which may influence birthweight are the mother's body weight, parity, socio-economic class and health, as well as the child's sex (Aebi and Whitehead, 1980; Hytten and Leitch, 1964).

DEATHS

Following frosts and drought in 1941, food was extremely scarce in high altitude locations of Enga. This occurred before colonial contact had been established in this part of the highlands, but many oral accounts suggest that numerous deaths occurred as a direct result of the shortages (Dwyer, 1952; Meggitt, 1956:125; Meggitt, 1958:255; Powell and Powell, 1974; Waddell, 1973a:22; Waddell, 1974:42; Wohlt, 1978; Goie, 1986:3). For example, in a high altitude village in Kandep District, the villagers in 1972-75 claimed that 46 deaths resulted from the 1941 famine (Wohlt, 1978:31, 111). Powell and Powell (1974:28) even suggest that thousands of people died as a result of this food shortage, and they quote an expatriate labour recruiter who passed through the Kandep area in 1943 who attributed the small populations to the extended famine. Following a patrol through the Kandep area in 1952, a patrol officer recorded comments made by people about the famine which had occurred ten years earlier. He reported that there had been "mass migration" and that "many people died on the road as they sought food and warmer regions" (Dwyer, 1952). Despite the absence of direct observation by these outsiders and any quantitative data, it is clear from the numerous oral accounts that many people died following the 1941 food shortage in Enga.

Deaths associated with food shortages are also reported from the Southern Highlands. Sillitoe (1983:24fn), writing on a village in the Wage Valley west of Nipa, states:

> The last such famine (in which many people starved to death) occurred in the Wola area within living memory sometime in the mid-1920s.

In the Tari Basin in 1986, older informants recalled a food shortage in which many people became emaciated, some died and families were split up (B. J. Allen, pers.comm., 1986). It is said that some people wandered aimlessly through the region and bodies were left beside walking tracks. At the time an aeroplane first flew over the area (1 February, 1936), the people were recovering from the shortage, which suggests that it occurred in 1935. Allen's informants indicated that this food shortage was much more severe in this area than the 1941 or 1972 events. In a community in the Upper Mendi Valley in the Southern Highlands, older people claimed in 1976 that people had died following frosts and subsequent food shortages in the late 1930s(1). They attributed the deaths to hunger and to fighting following stealing from food gardens (Simpson, 1978:105-106).

Deaths during previous food shortages were also recalled by people at Upa on the Nembi Plateau. In separate interviews in 1984, many older male informants observed that, in contrast with earlier times, people do not now die when subsistence food is scarce. One man spoke of deaths during food shortages when he was a child (early 1930s) and again when he was a young adult (early 1940s).

(1) The frosts reported in the Upper Mendi Valley by Simpson probably occurred in 1941.

In contrast to the Southern Highlands and Enga Provinces, there are no reports of deaths associated with food shortages from the Eastern Highlands and Chimbu Provinces in the recent pre-colonial period. At Asiranka Village in 1984, nobody mentioned death in discussing previous food shortages; and the only informant to have experienced a major food shortage (about the second decade of this century) did not volunteer any information about deaths.

In 1972-73, there were widespread and severe food shortages in much of Enga, Southern Highlands and Western Highlands Provinces, and the Australian Administration conducted a large scale food relief operation (Chapter 8). No one died as a result of the shortage (Waddell, 1974; Powell and Powell, 1974), although it has been suggested that many highlanders would have died but for the relief programme (Powell and Powell, 1974:32).

People in some areas of the highlands have occasionally reported deaths during more recent food shortages. For example, some 60 deaths were attributed by villagers to food shortages in 1980 and reported to a government team (Wohlt *et al.*, 1982:31-32). Investigations of such claims have not been easy, partly because villagers' perceptions of the cause of death may be very different from those of a European or educated Papua New Guinean, and after certain events, such as severe frosts, all deaths tend to be attributed to the event. However, most investigations by government officials in recent years have concluded that other factors, particularly disease, have caused these deaths (various provincial government files; Wohlt *et al.*, 1982). Nevertheless, some official investigations have concluded that deaths were caused by lack of food. Very little evidence is tendered in their reports and it is impossible to accept their conclusions unreservedly. A higher than usual death rate may have resulted from food shortages in recent decades, but clear evidence for this is lacking. For example, a provincial government team investigated reported hunger-related deaths in the Okapa area of the Eastern Highlands in early 1983. After visiting four villages in the Auyana Census Division, they concluded that seven people had died from hunger-related causes (Saropo, 1983).

Statements made by village informants to outsiders about deaths associated with food shortages that have occurred during the last 70 years must be regarded with some suspicion. It is likely that the severity of these events has lost nothing in the retelling. Nevertheless, the concurrence of much of the oral evidence would indicate that it can be cautiously accepted. Reports of deaths caused by shortages come from high altitude locations in Enga (especially in 1941) and from various locations in the Southern Highlands in the 1920s, 1930s and 1940s. This latter pattern is consistent with the conclusion in Chapter 3 that shortages occur more frequently in the Southern Highlands than elsewhere in the highlands. There is no clear indication that food shortages have resulted in higher than normal death rates since the early 1940s.

ADULT BODY WEIGHT CHANGES

Body weight is the anthropometric measurement most used to assess people's nutritional status (Jelliffe, 1966:64). Adult body weight may alter over time because of changes in food intake, changes in energy expenditure, disease and parasitic infections and pregnancy. For populations of men and non-pregnant women, changes in body weight over time are the net outcome of changes in energy intake and energy expenditure, unless major changes in disease incidence occur.

A number of studies have been made in the PNG highlands which relate change in adult body weight over time to change in food supply and energy expenditure. Some of these studies indicate that change in food supply is responsible for change in adult body weight; others attribute body weight change to change in energy expenditure. These are now reviewed.

On the Nembi Plateau, Crittenden recorded the weights of non-pregnant females over an 11 month period. The mean weight of 12 women increased between March and August 1980 and then declined between August 1980 and February 1981. The maximum mean difference in weight was 3.0 kg (Crittenden and Baines, 1986). Crittenden and Baines attribute this weight variation to seasonal patterns in labour expenditure.

Further analysis here confirms Crittenden and Baines' (1986) suggestion that changes in labour expenditure were responsible for the recorded weight changes rather than change in food availability. Correlations were sought between the mean body weight of these women and certain parameters of food availability and garden area planted during the previous month(2). There was no correlation between the women's body weight and the quantity of food on display in Hol market, nor between body weight and the price of sweet potato (Table 4.1). There were, however, highly significant negative correlations between their weight and the garden area planted during the previous month. The weight recordings extended over 11 months only and the sample was small. Nevertheless there is

(2) The body weight and garden area measurements were made on samples from adjacent communities. It will be argued that variation in garden planting rate occurred in response to food supply conditions and this occurred across much, if not all, of the Nembi Plateau. Cultivation of food gardens is not the only activity on which the women expend energy. However, work in food gardens demands much of their energies, and labour inputs into gardening are likely to vary more than inputs into domestic duties. Hence variation in energy expended in preparing and planting food gardens would account for a high proportion of the variation in total energy expenditure between months. Correlations were made with a one month lag as body weight is an outcome of recent past consumption and activity rather than present consumption and activity.

Table 4.1 Correlation coefficients between mean monthly body weight of Pubi women and certain other parameters recorded in the previous month(1)

Parameter	Correlation coefficient(2)
Number of bundles of sweet potato on display at Hol market(3)	0.370
Number of bundles of all food crops (except sweet potato) on display at Hol market	- 0.087
Price of sweet potato, Hol market	- 0.577
Area of sweet potato planted per month(4)	- 0.741**
Area of mixed vegetable gardens planted per month	- 0.817**
Area of all food crops planted per month	- 0.806**

Notes

(1) Body weight data covers the period March 1980 to February 1981, with October 1980 missing (n = 11). The weights are for 12 women of the Pubi clan, Kongip Village which is adjacent to Upa Village (after Crittenden and Baines, 1986).

(2) ** indicates significance at $P < 0.01$

(3) Price and quantity data from Hol market are presented in Tables A6.5 and Table A6.7 and the methodology described in Chapter 3 and Table A6.1.

(4) The garden areas planted per month were recorded from a sample of 10 women in Upa Village. Methodology is discussed in Chapter 8 and data given in Table A13.4.

a clear indication that over this period these women lost weight following periods of greatest garden activity and hence energy expenditure. The period of comparison is too short to conclude that these changes occur on an annual seasonal basis.

On the other hand, in two other studies conducted in the Southern Highlands, no relationship was found between adult body weight and garden activities. Also working on the Nembi Plateau, Baines (1983:66-67) recorded the body weight of pregnant women attending the Pumberel Health Centre over an 11 month period in 1980-81. She found no difference in mean body weight between four three-month periods. Another study in the Southern Highlands attempted to relate garden activity and adult body weight change at locations in the Upper Mendi Valley, the Tari Basin and in the Pangia area (Crittenden *et al.*, 1985). The authors considered that "serious methodological problems associated with data collection and analysis meant that no firm conclusions could be drawn from the lack of patterns" (p44). No patterns were detected in adult body weight change and it was not possible to relate change in adult body weights to garden areas planted.

Three longitudinal studies of body weight change have also been done in Chimbu. Bailey (1963) recorded adults' body weight for village communities at three locations (Gembogl, Wandi near Kundiawa, and Gumine area) on five occasions between November 1961 and 1962. At Gembogl and Wandi, there were net increases in weight of both men and women over the 12 months. The increases were between about 1.0 and 2.0 kg for these two locations. At the village near Gumine, there were smaller differences between weighings and very little overall weight change over the year. Bailey interpreted the data as indicating an annual seasonal pattern with increases in body weight at all locations in the May-August period and usually a decrease in the preceding period, but his data do not indicate such an annual cycle. There were general food shortages at both the Gumine and Gembogl locations at the start of the study period in late 1961 (Bailey, 1963:399; Bailey and Whiteman, 1963:377) and it is likely that the weight increases represent a recovery from lower body weights when food was scarce, rather than an annual cycle.

Harvey and Heywood (1983:115-122) recorded men's and women's body weights on eight occasions between January and December 1981 in villages in the Upper Chimbu Valley and in Sinasina in Chimbu. At the Sinasina location, weights were considerably higher at the completion of the study, and the maximum difference in mean monthly weight was 2.8 kg (men) and 2.1 kg (women). At the site in the Upper Chimbu Valley the range was smaller (1.3 kg for men and women). There was no indication of an annual cycle at either location. Wohlt and Goie (1986:48-53, 83-88) compare these longitudinal body weight data with those on areas of food garden planted and predicted food availability. At both locations they were able to relate the recorded changes in body weight to predicted food supply. The study in Sinasina commenced just prior to the nadir of a food shortage and the increases in body weight for both men and women are interpreted by Wohlt and Goie as a recovery from reduced body weights caused by this food shortage.

The third Chimbu study was done in a village on the Karimui Plateau on the highlands fringe (Hide *et al.*, 1984:240-245). Hide, Goodbody and Gertru recorded the weights of men and women at Yuro Village on seven occasions between March 1981 and December 1982. The greatest change in mean weight was 1.7 kg for women between February and June 1982. There was not a regular annual pattern of weight change and Hide *et al.* obtained a partial fit between some of the weight changes and the changes in sweet potato availability as inferred from prices at Karimui. They concluded that food availability was probably not the only factor determining weight variations during 1981-82, although it may have been the most important one during the first half of 1982.

Of the six studies of adult body weight change reviewed here, the three conducted in Chimbu indicate that body weight is influenced by food supply, one of the Southern Highlands studies suggested that variation in energy expenditure has a greater influence on body weight change, and two did not observe significant fluctuations in body weight(3). There was no evidence for annual cycles of weight variation in any of the studies.

Variation in food supply as well as in energy expenditure can influence people's weight in the highlands and mean changes of 1 to 3 kg are not uncommon. Variation in energy expenditure and intake are unlikely to be independent, however. Data presented in Chapter 8 show that women and men plant larger food gardens, and therefore expend more energy, when food is relatively scarce. Thus when food is very scarce, the energy expenditure of all adults is likely to be greatest. However, none of the studies reviewed was conducted during a period when villagers considered food to be in extremely short supply, and it is likely that larger weight changes would occur during such episodes. Although several authors have commented on the small changes in weight that they observed (Hide *et al.*, 1984:244; Spencer and Heywood, 1983), a selection of data on seasonal weight changes in other tropical countries (Table 4.2) suggests that the range of mean weight changes in the PNG highlands (1 to 3 kg) is not a lot smaller than that recorded elsewhere.

The functional significance of adult body weight changes is not clear (Spencer and Heywood, 1983). However, weight changes are likely to be greater for the more vulnerable adults in a community, such as older people and women with dependent

(3) The conclusion from the Nembi Plateau is similar to that drawn by Spencer and Heywood (1983) following their study in the PNG lowlands. These authors related changes in adult body weight over time to garden activity rather than variation in food supply.

Table 4.2 Selected data on seasonal adult body weight changes in other tropical countries(1)

Location	Maximum change in mean body weight (kg) between months		Source
	Men	Women	
North-west Ghana	3.7	3.4	Hunter, 1967
The Gambia	-	3.2	Rowland *et al.*, 1981
Comilla District, Bangladesh	-	2.0	Chen *et al.*, 1979
Lake Tumba, Zaire	2.2	1.4	Pagezy, 1984
Central Malawi	1.9	-	Nurse, 1975
Western Botswana	0.6	0.5	Lee, 1979:299

Notes

(1) Other studies cited by these authors and in Longhurst and Payne's (1981) review extend the range of figures slightly.

children whose husbands are absent, than for the population as a whole. Weight losses of several kilograms could have negative implications for their health or that of their young children. Further research is needed to test this possibility, but such research could only be done during a major food shortage.

CHILDREN'S BODY WEIGHT CHANGES

Children are amongst the most vulnerable groups in any community, particularly those less than five years old. Thus it would be expected that the effects of food deprivation would be most apparent in young children. The only published study in the PNG highlands that links variation in children's food intake with reported food shortages is that by Binns (1976). His short-term study was done near a location where Waddell (1972:123-127) had previously conducted an intake study. Waddell's dietary survey was done in a community in the Lai Valley in May 1966 and in December 1966/January 1967, a year of normal food production. He recorded very similar energy intakes during the two periods, although intake of protein and some other nutrients was greater in December/January than it had been in May(4). Binns' dietary intake survey was done in May 1972, just prior to a major food shortage in that part of the highlands. He repeated the survey in December 1972, and then again in January/February 1973 after government food distribution had commenced. The energy intake of children in all age groups, except the 1-3 years group, was much less in late 1972 and early 1973 than in May 1973 and Binns attributed this to the effects of the food shortage. Binn's study established the expected link between subsistence food shortages and reduced food intake for children. In the absence of other direct evidence for a link between food shortages and food intake, it is useful to examine the relationship between food supply and children's body weight.

Because children's weight normally increases with age, the appropriate weight index of their nutritional status is weight for age (wfa). The standard used in PNG is the Harvard Standard which classifies children who weigh between 60 and 80 per cent of their weight for age as malnourished, and those who weigh less than 60 per cent of their weight for age as severely malnourished. A vast amount of data on children's weights has been collected in PNG at monthly Maternal and Child Health clinics, but most of this is erratic and unreliable as an index of the child malnutrition rates over time because there are numerous errors in the recording and transcription of figures (Maclaren and Lennox, 1981)(5).

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(4) Waddell attributed the higher protein intake in December/January to the greater availability of food from mixed gardens at that time.

(5) Occasionally there are indications that the child malnutrition rate has changed markedly in a location. For example, the Health Extension Officer at Gumine in Chimbu reported an abnormally high rate in early 1983. He noted that three quarters of paediatric admissions to the health centre were malnourished during that period. He attributed the

However, a more reliable set of figures exists for the Nembi Plateau. A 75 month long data set on child malnutrition rates was available from the Pumberel Health Centre records. The clinics over this period (late 1978 to the end of 1984) were supervised by American nurses. These figures are accepted as a reasonably good index of child malnutrition on the Plateau. Some 90 per cent of resident children are enrolled at MCH clinics on the Nembi Plateau (Crittenden and Baines, 1986) and over this period the mean attendance was 74 per cent of enrollments (1340 enrolled). Thus the figures cover on average about two-thirds of all resident children. This data set is now analysed to test the hypothesis that variation in food supply on the Nembi Plateau influences the rate of child malnutrition.

Children's growth patterns have been documented in the PNG highlands in the following locations: Kainantu area, the Asaro Valley, North Chimbu, South Chimbu, Kandep Basin, Lagaip Valley, Nembi Plateau, Tari Basin, and throughout the Southern Highlands (Heywood *et al.*, 1981; Heywood, 1982; Harvey and Heywood, 1983; Crittenden and Baines, 1985; Bogan and Crittenden, 1986). All these studies show a similar pattern of mean weight for age declining rapidly during the first year of life and then remaining at about the same level between one and five years. Hence the mean weight for age of children under one year will vary depending on the mean age of children attending clinic in any month and these data cannot be used unless they are corrected for age. Because this problem does not occur for older children in the age group one to five years, data from this age group are examined.

The child malnutrition rates for the central Nembi Plateau are presented as a three monthly running mean in Figure 4.1 and as monthly means in Table A8.1(6). Over this six year period, 44.3 per cent of children attending the clinic were malnourished (60 to 80 per cent wfa) (SD = 6.2 per cent); and 2 per cent were severely malnourished (< 60 per cent wfa) (SD = 1.2 per cent). Thus just under half of the children were classified as malnourished or severely malnourished (46.3 per cent; SD = 6.4 per cent) using the PNG national standard.

The proportion of children who were malnourished varied over time, but not in any regular cycle (Figure 4.1). Analysis of variance revealed no significant differences between annual means or monthly means. Thus there is no evidence for an increase or a decrease in the proportion of the malnourished children between late 1978 and the end of

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increased malnutrition rate to the food shortages being experienced in late 1982-early 1983 (DPI files, Kundiawa).

(6) These figures are from three clinics: Embi/Enip, Upa/Kum and Pumberel. Trends for the entire Plateau are similar, with minor differences. The central part of the Plateau was selected as this is the location of Upa Village and Hol market, and the malnutrition rate differs between the north-east, central and south-east parts of the Plateau (Crittenden and Baines, 1985).

Figure 4.1 Child malnutrition rate, Central Nembi Plateau, October 1978 to December 1984 (percentage of children aged 1 to 5 years less than 80% and less than 60% weight for age) (three monthly running mean) (Source: Pumberel Health Centre records); and reported food shortages, 1978 to 1984

1984, nor was there any evidence for annual seasonal variation. Crittenden and Baines (1986) suggested that there is a higher risk of child malnutrition between August and January each year and a lower risk between February and July. This conclusion was based on a study of children attending the Embi MCH clinic over a 15 month period with sample sizes of between 10 and 34 children per month. For the larger and longer data set analysed here, the means for these two periods were 46.1 per cent and 47.0 per cent respectively. These means are not significantly different (ANOVA). Thus Crittenden and Baines' conclusions for a long term regular variation in the rate of child malnutrition are unfounded.

Over this period there were four reported episodes of food shortages in this location. All four episodes were associated with a rise in the malnutrition rate to above the long term mean (Figure 4.1). The highest rise occurred in late 1984 following the most severe and prolonged of the four shortages. A striking feature of this data run is the large fluctuations in malnutrition rates that occurred in 1981-82 and again in 1983-84. During the second of these episodes, the proportion of children who were less than 80 per cent weight for age rose from a low of 23 per cent in February 1984 to a high of 59 per cent in September that year. It will be argued that subsistence food supplies were especially good on the Nembi Plateau in 1983, and cash income was also high relative to other years (Table 2.6). The dramatic decline in the proportion of malnourished children almost certainly reflects improved subsistence food supplies and greater access to imported food.

When the mean weight for age of a population is about 80 per cent, as is the case here, small changes in the mean weight of children attending clinic can give rise to larger fluctuations in the proportion of children who are below 80 per cent weight for age. This may account for some of the variability of these data, but this factor is not sufficiently important to have caused the large fluctuations in malnutrition rates in 1981-82 and 1983-84. The number of children who were severely malnourished (less than 60 per cent wfa) was high between February and April 1979 (3 to 6 per cent) and again in July to September 1984 (4 to 5 per cent) (Table A8.1). Both of these periods coincide with reported food shortages. Where food shortages are severe enough to result in a large increase in the proportion of severely malnourished children, as appears to have occurred in 1978-79 and 1984-85, Heywood's (1982) findings suggest that an increased rate of child mortality is likely to result.

To summarise: Two of the food shortages that occurred on the Nembi Plateau between 1978 and 1984 were followed by increases in the rate of severely malnourished children and all four shortages were followed by increases in the malnutrition rate. Two cycles of large decreases and then large increases in the malnutrition rate occurred over this period and the second episode of reduced malnutrition rate was associated with a particularly good supply of subsistence food. Thus subsistence food supplies appear to influence the rate of child malnutrition. This assumes particular importance when the proportion of severely malnourished children increases, as this is likely to be associated with increased morbidity and mortality.

BIRTHWEIGHT

Birthweight data are available from the Nembi Plateau which can be used to test the hypothesis that variation in available food supply influences infants' birthweight. R. Crittenden and J. Baines state that mean birthweights on the Nembi Plateau vary on a predictable basis throughout the year and relate this to the overall food supply situation (Crittenden, 1982:508-510; Baines, 1983:31-40; Crittenden and Baines, 1986).

Mean annual birthweights are available for a 14 year period and monthly data for a 7 year period. The monthly figures cover the period January 1979 to March 1986 (Figure 4.2; Table A8.2)(7). They were extracted from the records of the Pumberel Health Centre and include babies born in the Health Centre or brought to the Centre within 24 hours of birth. Stillborn births and those recorded as premature were excluded. The mean birthweight between 1979 and early 1986 was 2.84 kg (n = 833; SD = 0.38). This is low compared with average birthweights worldwide of about 3.3 kg (Hytten and Leitch, 1964:240-253), or from elsewhere in highlands PNG where mean birthweights range from 2.8 to 3.3 kg (Baines, 1983:41).

The annual data are considered first (Table 4.3)(8). Between 1972 and 1985, the most severe food shortages occurred in 1972 and in 1984. If a decline in maternal food intake during pregnancy influences birthweights, it could be expected that they would have been lower in the following years, that is, in 1973 and 1985. The mean birthweight was less in 1973 but there was no decline in 1985 and for the period 1979 to 1985 differences between the annual means were not significant. Because of variation over a year, annual means provide only a crude test of the hypothesis that variation in food supply influences mean birthweight. Even when this test is used, there is no clear indication that such a relationship exists in this data set. Monthly means are a more sensitive index and these are now examined.

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(7) Through an oversight of mine, information on infants' sex and mother's parity was not recorded. This is unfortunate as all PNG studies (Baines, 1983; Greenfield, 1983; P. Heywood, pers.comm., 1986) confirm the established generalisation from other countries that boys weigh more than girls at birth and that birthweight tends to increase with increasing parity. The influence of the child's sex and mother's parity may distort patterns when the number of births is small, although when the number of births per cell is larger (> 50), this source of variation is likely to be unimportant.

(8) There is an apparent increase in mean birthweight over this period, but the sudden and large increase between 1976 and 1977 suggests that some change in recording method occurred about then and the apparent increase is not accepted as a real effect.

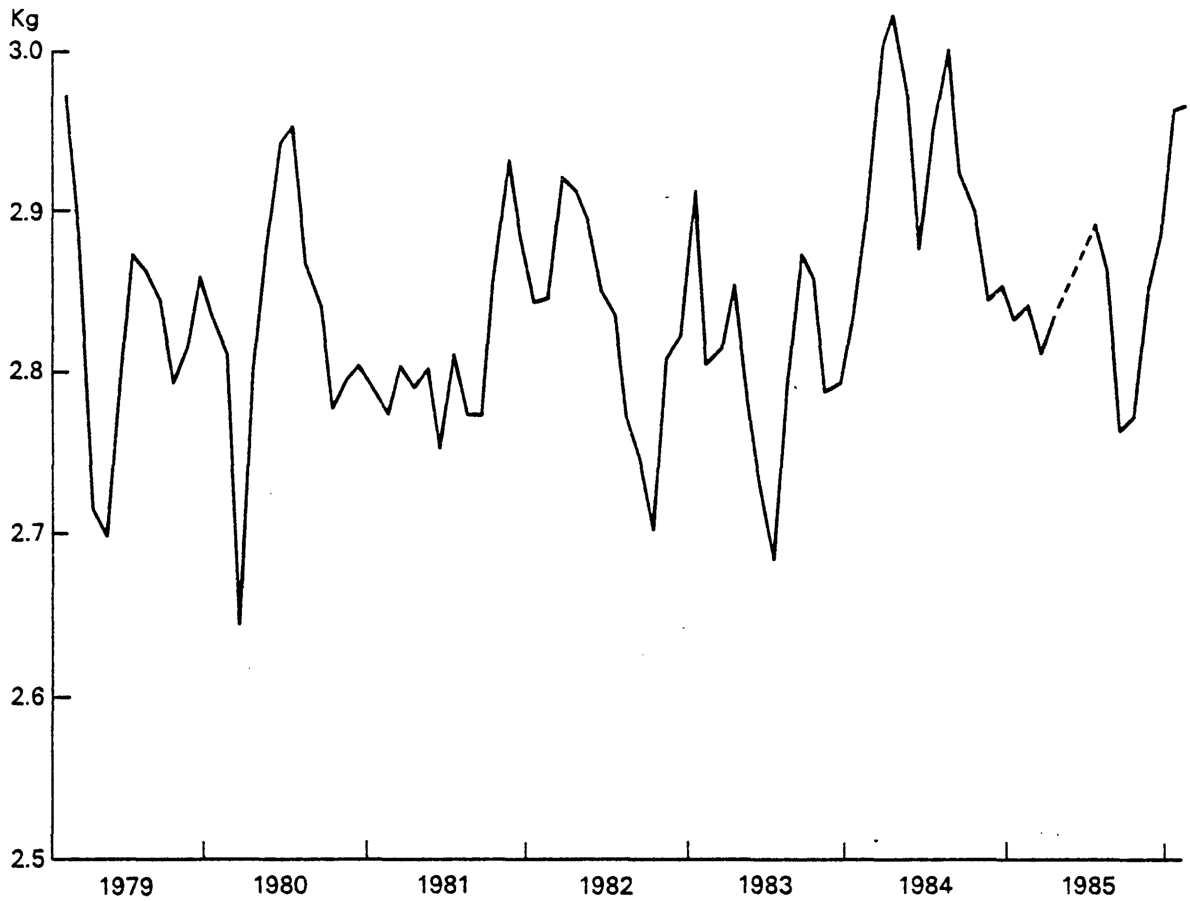

Figure 4.2 Birthweight of children, Pumberel Health Centre, January 1979 to March 1986 (three monthly running mean) (Source: Health Centre records)

Table 4.3 Mean annual birthweight (kg) of children, Pumberel Health Centre, 1972 to 1985(1)

Year(2)	Mean birthweight	SD	n	Per cent <2.0kg	Per cent <2.5kg
1972	2.65	0.37	26	0	31
1973	2.54	0.48	51	12	43
1974	2.66	0.40	65	2	32
1975	2.66	0.31	38	0	26
1976	2.68	0.43	33	9	27
1977	2.85	0.46	48	4	8
1978	2.77	0.38	54	2	15
1979	2.84	0.34	130	0	12
1980	2.84	0.40	180	1	11
1981	2.82	0.35	103	0	11
1982	2.81	0.42	168	0	14
1983	2.79	0.39	82	1	13
1984	2.91	0.37	96	0	8
1985	2.84	0.38	62	0	15

Notes

(1) Source: Birthweights for 1972 to 1978 from Cogill and Clarke (1984:82,85). Data for 1979 to 1985 extracted from Health Centre records by B. J. Allen and J. Baines.

(2) For the period 1979 to 1985, differences between annual mean birthweight are not significant (ANOVA).

It is possible to test the hypothesis that birthweights are lowest following periods of food scarcity, using the assumption that maternal food intake during the final trimester of pregnancy has the greatest influence on birthweight. Periods of food shortage and consequent predicted low birthweight for the Nembi Plateau between 1978 and 1985 are given in Table 4.4. The periods of predicted low birthweight (Table 4.4) do not coincide with the actual periods of low birthweight (Figure 4.2). Food was in particularly good supply in mid- to late 1983 and this could be expected to result in higher than average birthweights in late 1983 to early 1984, but this pattern did not occur (Figure 4.2). Thus there is no evidence that variation in the supply of the staple food influenced mean birthweights on the Nembi Plateau between 1978 and 1985.

Foods other than sweet potato are in best supply between December and June each year and in poorest supply between July and November on the Nembi Plateau (Figure 3.13). If the supply and consumption of foods other than sweet potato influenced children's birthweights, one would expect that birthweight would vary on a seasonal basis every year with the highest birthweights in about April-May-June and the lowest birthweights in about October-November-December. There is no indication from the mean monthly data that such a pattern occurs (Figure 4.2). To test this hypothesis further, the data set for the period 1979 to early 1986 was arranged by monthly means and into the three possible combinations of four by three-monthly periods per year. Differences between mean monthly birthweights are significant ($P < 0.001$, ANOVA) with August significantly greater than October, September and April (Table 4.5). However, this is not a logical pattern and is almost certainly a statistical anomaly. The hypothesis that a predictable change in birthweights occurs between months must be rejected.

Differences between the three-monthly means over the seven years are not statistically significant (Table 4.6). Mean birthweights for April-May-June (2.83 kg) are identical with those for the period October-November-December (2.83 kg). Thus there is no indication that the annual variation in the supply of foods other than sweet potato has any influence on infants' birthweights. Nor is there any evidence that four episodes of relative food scarcity between 1978 and 1985 affected children's birthweights. These conclusions contradict those of Crittenden (1982) and Baines (1983). Their conclusions are now examined in more detail.

Crittenden (1982:508-510) analysed the birthweights (and subsequent body weight) of 60 children in 1980-81. He reported that the mean birthweight of 35 children born between August and January was greater than that of 25 children born between February and July (no adjustment for sex and parity). The birthweight data from Pumberel Health Centre for early 1979 to early 1986 have been split into the same periods of the year used by Crittenden (February to July; August to January) (Table 4.7). For four of the seven

Table 4.4 Periods of relatively scarce food supply and consequent predicted low birthweights, Nembi Plateau, 1978 to 1985

Relatively scarce food supply(1)	Predicted low birthweights(2)
Jul78-Feb79	Oct78-Mar79
Sep80-Mar81	Dec80-Apr81
Oct82-Feb83	Jan83-Apr83
Apr84-Mar85	Jul84-Apr85

Notes

(1) Data on food supply for 1978 to 1985 are given in Chapter 3.

(2) Predicted low birthweights are based on the assumption that reduced food intake during the last 3 months of pregnancy will reduce infants' birthweights.

Table 4.5 Mean birthweight (kg) by month of children, Pumberel Health Centre, January 1979 to March 1986(1)

Month	Mean birthweight(2)	SD	Number
Jan	2.829	0.366	87
Feb	2.882	0.403	78
Mar	2.850	0.322	56
Apr	2.771	0.479	77
May	2.860	0.411	53
Jun	2.890	0.623	48
Jul	2.820	0.350	85
Aug	2.935	0.393	55
Sep	2.772	0.444	64
Oct	2.784	0.353	83
Nov	2.833	0.358	85
Dec	2.877	0.334	62
Mean	2.836	0.384	833

Notes

(1) Source: Birthweights extracted by B. J. Allen and J. Baines.

(2) Differences between mean monthly birthweight are significant ($P < 0.001$, ANOVA), with August being significantly greater than October, September and April.

Table 4.6 Mean birthweight (kg) of children by three-monthly periods, Pumberel Health Centre, January 1979 to February 1986

Year (1)	Mean Jan-Feb-Mar	SD	n	Mean Apr-May-Jun	SD	n	Mean Jul-Aug-Sep	SD	n	Mean Oct-Nov-Dec	SD	n
1979	2.972	.330	29	2.700	.296	25	2.864	.349	33	2.819	.338	43
1980	2.812	.390	41	2.876	.439	37	2.869	.423	45	2.798	.383	57
1981	2.779	.366	29	2.807	.362	30	2.773	.335	22	2.932	.318	22
1982	2.849	.347	39	2.848	.536	36	2.771	.410	52	2.810	.401	41
1983	2.804	.390	23	2.781	.465	21	2.790	.410	21	2.788	.267	17
1984	2.894	.399	16	2.970	.422	23	3.000	.334	18	2.849	.332	39
1985	2.841	.374	32	2.767	.367	6	2.862	.496	13	2.855	.288	11
1979-85	2.846	.368	209	2.831	.431	178	2.836	.397	204	2.828	.350	330
	Feb-Mar-Apr			May-Jun-Jul			Aug-Sep-Oct			Nov-Dec-Jan		
1979-80	2.884	.399	31	2.792	.307	26	2.847	.362	34	2.861	.369	51
1980-81	2.647	.342	32	2.945	.398	44	2.840	.414	43	2.806	.397	51
1981-82	2.809	.355	34	2.755	.342	22	2.774	.331	19	2.883	.313	35
1982-83	2.864	.558	31	2.850	.358	48	2.748	.444	52	2.823	.429	26
1983-84	2.817	.356	23	2.737	.421	24	2.873	.422	15	2.795	.308	19
1984-85	3.004	.434	26	2.879	.261	14	2.925	.367	28	2.853	.347	34
1985-86	2.812	.368	25	3.050	.457	8	2.764	.391	11	2.889	.262	9
1979-86	2.830	.415	202	2.849	.370	186	2.821	.400	202	2.842	.354	225
	Mar-Apr-May			Jun-Jul-Aug			Sep-Oct-Nov			Dec-Jan-Feb		
1979-80	2.717	.308	29	2.874	.361	27	2.795	.306	40	2.836	.410	45
1980-81	2.803	.431	32	2.952	.381	44	2.778	.412	55	2.792	.360	36
1981-82	2.791	.352	32	2.815	.331	20	2.854	.359	24	2.847	.343	40
1982-83	2.859	.552	32	2.833	.364	45	2.702	.451	45	2.913	.354	24
1983-84	2.854	.418	26	2.685	.386	20	2.860	.333	20	2.838	.388	21
1984-85	3.025	.473	16	2.952	.289	21	2.900	.352	34	2.835	.379	31
1985-86	2.733	.311	15	2.982	.429	11	2.771	.360	14	2.963	.421	8
1979-86	2.818	.417	182	2.871	.370	188	2.799	.381	232	2.844	.370	205

Note

(1) Differences between mean three-monthly birthweight over the period 1979 to 1986 are not significant (ANOVA) for each of the three comparisons.

Table 4.7 Mean birthweight (kg) of children during two "seasons", Pumberel Health Centre, February 1979 to January 1986

Year	February to July			August to January		
	Mean(1)	SD	n	Mean	SD	n
1979-80	2.842**	0.360	57	2.855	0.364	85
1980-81	2.820	0.401	76	2.821	0.403	94
1981-82	2.788*	0.347	56	2.844	0.321	54
1982-83	2.856***	0.444	79	2.773	0.438	78
1983-84	2.777	0.389	47	2.829	0.359	34
1984-85	2.960**	0.384	40	2.885	0.355	62
1985-86	2.870	0.397	33	2.820	0.337	20
1979-86	2.839	0.394	388	2.832	0.376	427

Note

(1) *, **, *** indicate significant differences at $P < 0.05$, < 0.01, < 0.001 respectively (t test) for the comparison between the two periods within a year.

years, differences between these periods attained statistical significance, but there is no consistent pattern between years. In two of these years, birthweights were greater for the August to January period, but the opposite pattern occurred in the other two years. For the seven year period, the mean difference between the two periods was only 7 grams and for 170 infants born in 1980-81, the mean difference was 1 gram only.

Baines (1983:31-40) analysed all births at Pumberel Health Centre between January 1979 and January 1981 (322 infants). She combined data from the two years and reported that birthweights in February-March-April were lower than those for the other three-monthly periods of the year, although only the comparison with May-June-July attained statistical significance. The birthweight data for Pumberel Health Centre for the seven year period (1979 to 1986) have been grouped into the same periods (Table 4.6). Mean birthweight was lower in February-March-April 1980-81 than in the other periods for that year, but this pattern was not true for the other year examined by Baines (1979-80), when mean birthweight was highest for this period. There is no consistent pattern between years and differences between means of the four periods over the seven years are small and not significant (Table 4.6).

The conclusions of Crittenden (1982) and Baines (1983) were based on data runs that covered too short a period, and for Crittenden, too few births. My analysis of the longer and larger data set indicates that birthweight does not vary in a regular pattern on the Nembi Plateau.

The present analysis does not demonstrate any relationship between food supply and infants' birthweight on the Nembi Plateau. These findings are consistent with Hytten's (1980) conclusions that the effects of variation in food supply and in maternal food intake are absorbed by the mother and that the foetus is protected from moderate variation. It is possible that during the famines of the pre-colonial period, infants' birthweights may have been influenced by changes in maternal nutrition, but no evidence is available to test this.

CONCLUSIONS

Oral sources indicate that food shortages have been severe enough to cause increased death rates in parts of the highlands, most recently in the early 1940s. All evidence for hunger-related deaths up till the 1940s comes from high altitude locations in Enga and various locations in the Southern Highlands. It is possible that some deaths related to food deprivation have occurred since the early 1940s, but the evidence for this is not convincing. An increased death rate was possibly averted during widespread shortages in parts of the highlands in 1972-73 by food aid provided by the Administration.

The available evidence indicates that changes in adult body weight may occur because of variation in both energy expenditure and food intake. During food shortages as severe as those that have occurred in recent years, both factors are likely to act together so as to depress people's weight, particularly that of women. The significance for people's health of adult weight changes in the highlands is not known. Documented mean weight changes in the PNG highlands are of the same order of magnitude (1 to 3 kg) as those recorded in literature from other tropical countries.

On the Nembi Plateau where cash income is limited, an association exists between the subsistence food supply and the rate of child malnutrition. The malnutrition rate increased during episodes of food scarcity, especially in 1984. It declined in 1983 when subsistence food was in particularly good supply. This is important because other research in the highlands has shown that a decline in the nutritional status of populations of highlands children, as measured by weight for age, is associated with increased mortality.

A seven year data set for birthweight from the Nembi Plateau was analysed. No association was found between mean birthweight and episodes of food shortages, or between mean birthweight and the supply of food other than sweet potato. Nor was there a regular pattern of seasonal variation in birthweight. At least for this period (1979 to early 1986) and this location (Nembi Plateau), it appears that variations in food intake were absorbed by the mothers and not reflected in the weight of their children at birth.

Available evidence all points to the conclusion that food shortages in the highlands of PNG can affect adults and children detrimentally. In the past, people in parts of Enga and the Southern Highlands, at least, exhibited the symptoms of starvation during food shortages and the death rate increased. Since the Pacific war, however, access to imported food and food aid have prevented the recurrence of obvious starvation in highlands populations. Nevertheless, among young children in locations where cash income is limited, the outcome of food shortages is failure to gain body weight or a loss of weight and this is likely to increase the risk of illness and death.

PART TWO

The existence of significant variation in food supply in the Papua New Guinea highlands, the temporal and spatial patterns of food shortages, and their effects on people have been established. The thesis now turns to the problem of explanation.

Production from an agricultural system can only vary for two basic reasons. These are: changes in the yield of a particular crop, that is, the quantity produced per unit area, or change in the area planted over time. Short term changes in yield or area planted are normal in PNG agricultural systems and do not affect food supply significantly because there is sufficient buffering capacity to absorb these. Thus only medium term or long term variation in either yield or area planted, or some combination of both, are of interest here.

Long Term Variation in Yield and Area Planted

It cannot be shown with existing data that sweet potato yields in the PNG highlands have increased or decreased since contact over the past 60 years. However, a number of factors have probably brought about an increase in sweet potato yields. These include the introduction and adoption of high yielding cultivars and the tendency of people to make greater use of lower altitude and more fertile sites since the general cessation of tribal fighting. The widespread adoption of recently introduced and high yielding food crops, such as *Xanthosoma* taro, corn, pumpkin, cassava, potato and peanuts since the 1920s has almost certainly increased overall food production per unit area planted. On the other hand, agricultural production has become more land-intensive in recent decades in much of the region. This is likely to have resulted in a slight decline in sweet potato yields. On balance, a general long term increase in crop yield is more likely than a long term decrease.

Similarly, there is no evidence which suggests that an overall long term decline in area planted per person has occurred during the past 60 years. In a limited number of communities where a high proportion of people devote most of their time to cash cropping or wage labour, a decrease in area cultivated per person is likely. Available evidence suggests that land availability is not yet a constraint on food production, even in the most densely populated areas (Allen, 1982; Bourke and Lea, 1982; Wohlt and Goie, 1986)(1). Thus explanations for variation in food supply must be sought from factors that operate in the medium term of several months to a year.

(1) Some earlier studies did posit land shortages as long as 30 years ago, for example, Brookfield and Brown (1963:105-124). These authors underestimated the flexibility of food production systems, and their predictions of land constraints have not eventuated (H. Brookfield, pers. comm., March 1988).

Medium Term Variation in Yield and Area Planted

The four chapters that follow deal with possible causes of medium term variation in the area of sweet potato planted and sweet potato yield, and relate these to the pattern of food shortages previously described. Chapter 5 deals with a number of factors which have been widely held to cause food shortages through the diversion of villagers' labour away from food production and declines in area planted. Although it is clear that almost none of these factors can be implicated as being a cause of food shortages, they are so commonly presented as being causes, both in the literature and in the everyday received wisdom, that it is necessary to devote a chapter to them.

The yield of crops per unit area may vary over time because of the effect of climatic variation on plant growth, in particular, changes in soil moisture, solar radiation, daylength and temperature. Yields may also vary because of changes in components of agricultural systems such as cultivars, management practices, and soil fertility. However, changes in components of agricultural systems are not likely to account for medium term fluctuation in food supply, except at a very local level. It is the relationship between climatic variation and crop yield that is of interest here and this is examined through international and PNG highlands experimental results (Chapter 6) and by analysis of the pattern of climatic extremes and food supply variation in the highlands (Chapter 7).

Villagers' responses to variable food supply, in particular, variation in the area of crop planted, are considered in Chapter 8. It is a combination of crop yield in response to certain climatic extremes and people's decisions about how much to plant that provides the best explanation for food supply variation.

CHAPTER FIVE

THE DIVERSION OF LABOUR FROM FOOD PRODUCTION

A number of activities have been suggested as causes of diversion of village labour from food production and thus of food shortages. Some of these activities follow contact and the incorporation of the region into a broader economy: cash cropping, wage labour, and establishment of cattle projects. Other suggested causes of diversion pre-date contact with Europeans but still continue to operate: harvests of pandanus nut and a pandanus fruit, the events associated with pig killing ceremonies, and tribal fighting. The relationship between each of these activities and food supply is now analysed.

COFFEE HARVESTING

Arabica coffee is the main cash crop in the highlands and directly or indirectly provides much of the cash income of highlands villagers (Table 2.6; Grossman, 1984:196). Some 70 per cent of national production is grown by smallholders in village plantings, and most of the remainder is produced on plantations. Village coffee production is concentrated in the Western and Eastern Highlands and Chimbu Provinces which produce about 80 per cent of smallholder coffee in PNG (DPI, 1984). Most plantations are located in the Eastern and Western Highlands and these two provinces produce some 85 per cent of plantation coffee. Very little coffee is produced in the Southern Highlands and in 1983 village and plantation producers in that province accounted for only 2 per cent and 4 per cent respectively of PNG's coffee crop (DPI, 1984).

It is widely held in PNG that the cultivation of coffee is responsible for food shortages. It is implicit in this argument that coffee and food compete for villagers' time rather than land. There may be some competition for land use in restricted locations, such as parts of the Asaro and Wahgi Valleys. However, the area of coffee per person is relatively small, and sweet potato and village coffee are generally not planted on the same land types. The only long term published observations on changes in the relative areas of coffee and food crops are Brookfield's data from a community in Chimbu. These indicate that the expansion of coffee area between 1958 and 1970 coincided with a decline in the area planted with mixed gardens, but not sweet potato (Brookfield, 1973a).

The argument is that during the coffee harvesting season, villagers neglect their food gardens, switching their labour to coffee production and associated activities. A brief review of the published evidence follows. Neglect of food gardens during the coffee harvesting season was suggested by Shannon (1973:9, 13) as a possible contributing factor to a food shortage in the Goroka area in 1970. Lambert (1975:37-49; 1976:41), writing on a community in Chimbu and on the highlands in general, speculated whether "... the annual *taim hangri* is a phenomenon that has only appeared since the widespread introduction of coffee." Other authors who discuss a causal relationship between coffee harvesting and food shortages are von Fleckenstein (1976:355-356), Christie (1980:65, 164), Harvey and Heywood (1983:111) and Korugl (1984).

The only authors who present numerical time-series data to support the argument that coffee harvesting is responsible for food supply problems are Crittenden *et al.* (1985) and Grossman (1984). Crittenden *et al.* (1985:35) briefly note that the area of gardens planted per month decreased in the Pangia area of the Southern Highlands during the mid-year coffee flush. Grossman argues that the large amount of time devoted to commodity production (coffee and cattle), coffee-related wage labour outside the village, and card playing and beer drinking as a result of increased cash income in a village in the Kainantu area has increased the seasonality of subsistence production (1984:214). He suggests (p177) that labour expended on harvesting village and plantation coffee contributed to a food shortage in that village in late 1975 to late 1976. He also claims (pp222-224) that a food shortage between about August 1980 and May 1981 was caused in part by intensive labour input into coffee production in May to July 1980. He argues that conflict between coffee and food production was exacerbated by the very high prices received by coffee growers between 1976 and 1980. The Pangia data set covers a 13 month period (Crittenden *et al.*, 1985) and Grossman's data cover 11 months. Both data sets are too short to form the basis of definite conclusions.

On the other hand, several authors have commented on the lack of a relationship between coffee production and food supply. Townsend (1977), who was interested in the very high price received by coffee growers in 1976, noted that food markets in Goroka and Mt Hagen continued to thrive and expand despite the record income levels being received by highlanders. Hide (1980) critically examined some aspects of Lambert's published and unpublished writings on the relationship between coffee production and food intake, and concluded that Lambert's findings were not justified by the available data. The question requires further consideration, especially in the light of the debate in the international literature on the influences of the penetration of cash into subsistence economies.

Coffee Harvesting Season

Coffee is harvested all year round in the highlands, but the harvest is concentrated between May and September, and particularly between June and August. This is illustrated by the production data for processed coffee from the Kainantu District (Figure 5.1, Table A9.1)(1).

Time allocation studies have been done in villages in Enga by Lea (1970) and Waddell (1972:95-107), in Chimbu by Hide (1981:251-263, 622-628) and in the Eastern Highlands by Moulik (1973:112-118), Sexton (1980:102-132) and Grossman (1984:207-218, 268-275). All studies produced data on time allocated to subsistence and cash production. The 23 adults studied by Hide devoted on average 2 hours to coffee production and 18 hours to food production out of a total of 48 activity hours per week. The other studies gave similar results for subsistence food time allocation (15 to 19 hours per week for adults). All studies that were repeated over time showed the greater allocation of time to coffee production during the harvesting season. For Hide's sample, time allocated to coffee was one hour per week during the non-harvesting season and four hours per week during the harvest. For Grossman's sample, corresponding figures for married adults were 4 hours per week and 10 hours per week. Thus the proportion of total activity time devoted to cash crop production is small even during the harvesting period.

Consumption behaviour, and to a lesser degree, other social behaviour, is altered during the coffee harvesting season. Hide's time allocation study in Sinasina in 1972-73 showed a two- to three-fold increase in gambling during the 1972 coffee harvest. Elsewhere in Chimbu, Christie (1980:29, 34-38) documented peaks in sales of beer, petrol, soft drinks and bakery products during the coffee harvesting season; however, her village expenditure survey did not reveal differences in expenditure patterns between the harvesting and non-harvesting season (pp86-107). In the Chuave area of Chimbu, Warry (1982) found that the number of alcohol-related disputes was considerably greater during the coffee harvesting season, although non-alcohol related disputes do not show a seasonal pattern. Grossman (1984:196-214) indicated that the seasonal pattern of beer consumption, card playing, "beer-related activities", trade store operations and sales, and rice and tinned fish consumption all correspond with the seasonal pattern of coffee harvesting.

The influence of the coffee harvesting season is also apparent in wholesale and retail sales in the Eastern Highlands in monthly beer sales, retail sales tax receipts, sales of food and liquor at urban retail stores, and monthly wholesale rice sales (Figures 5.1, 5.2, 8.2, Tables A9.1, A14.3). For all data sets, sales are greatest during the coffee harvesting season, although other influences can be seen(2). Beer sales are the most affected

(1) Processed coffee production in Chimbu and Enga (Howlett *et al.*, 1976:221, 231; Carrad, 1982:152) and unprocessed cherry at Aiyura (1978 to 1984) show a similar pattern.
(2) Other influences include the rise in sales of some commodities during December, probably because of employees spending their holiday pay and pre-Christmas spending. The increases in rice sales in late 1982-early 1983 and again in late 1984 coincided with regional food shortages.

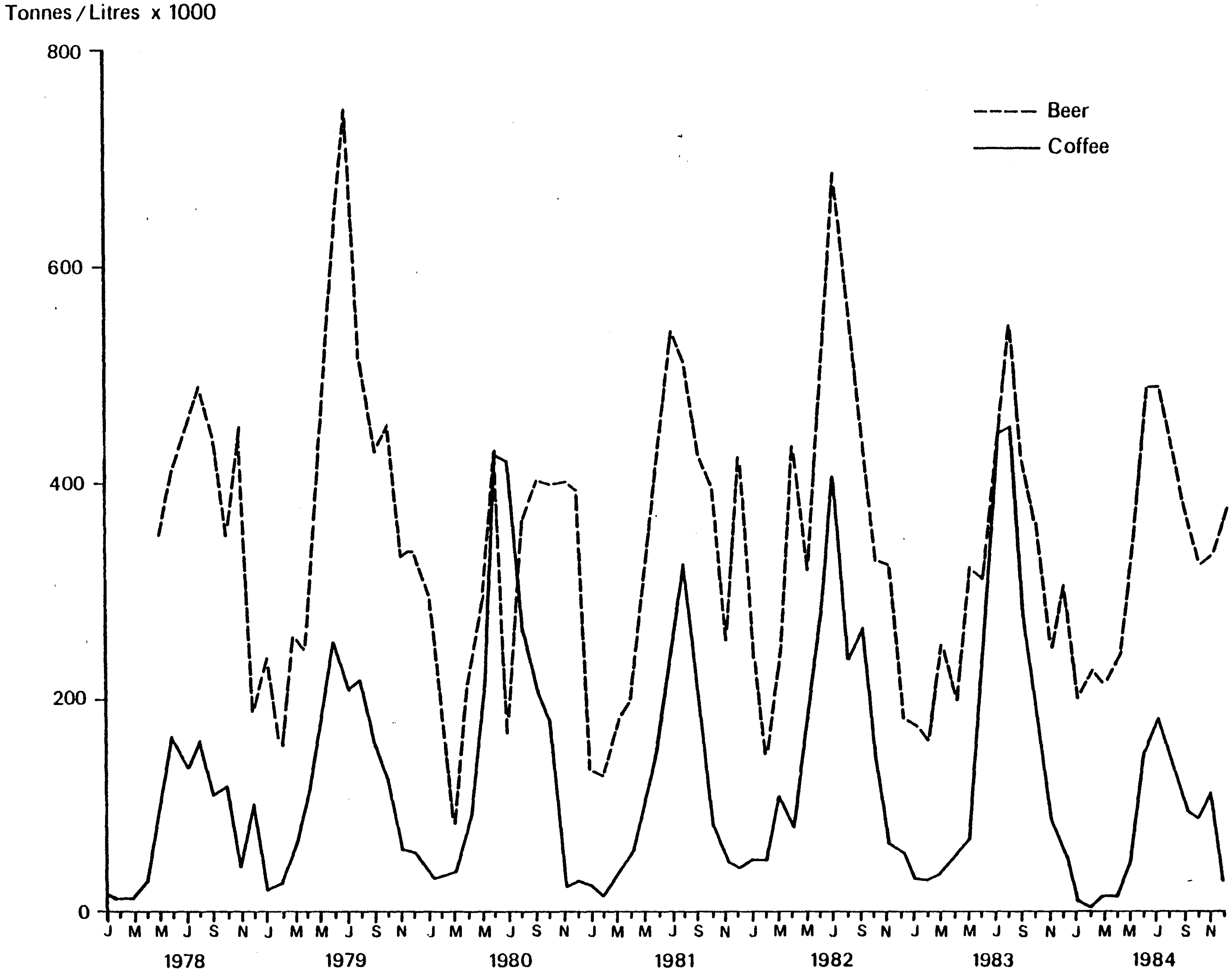

Figure 5.1 Monthly smallholder coffee production, Kainantu factories and beer sales, Eastern Highlands, January 1978 to December 1984 (Source: KKB and Ramu Coffee factories and EHP provincial government)

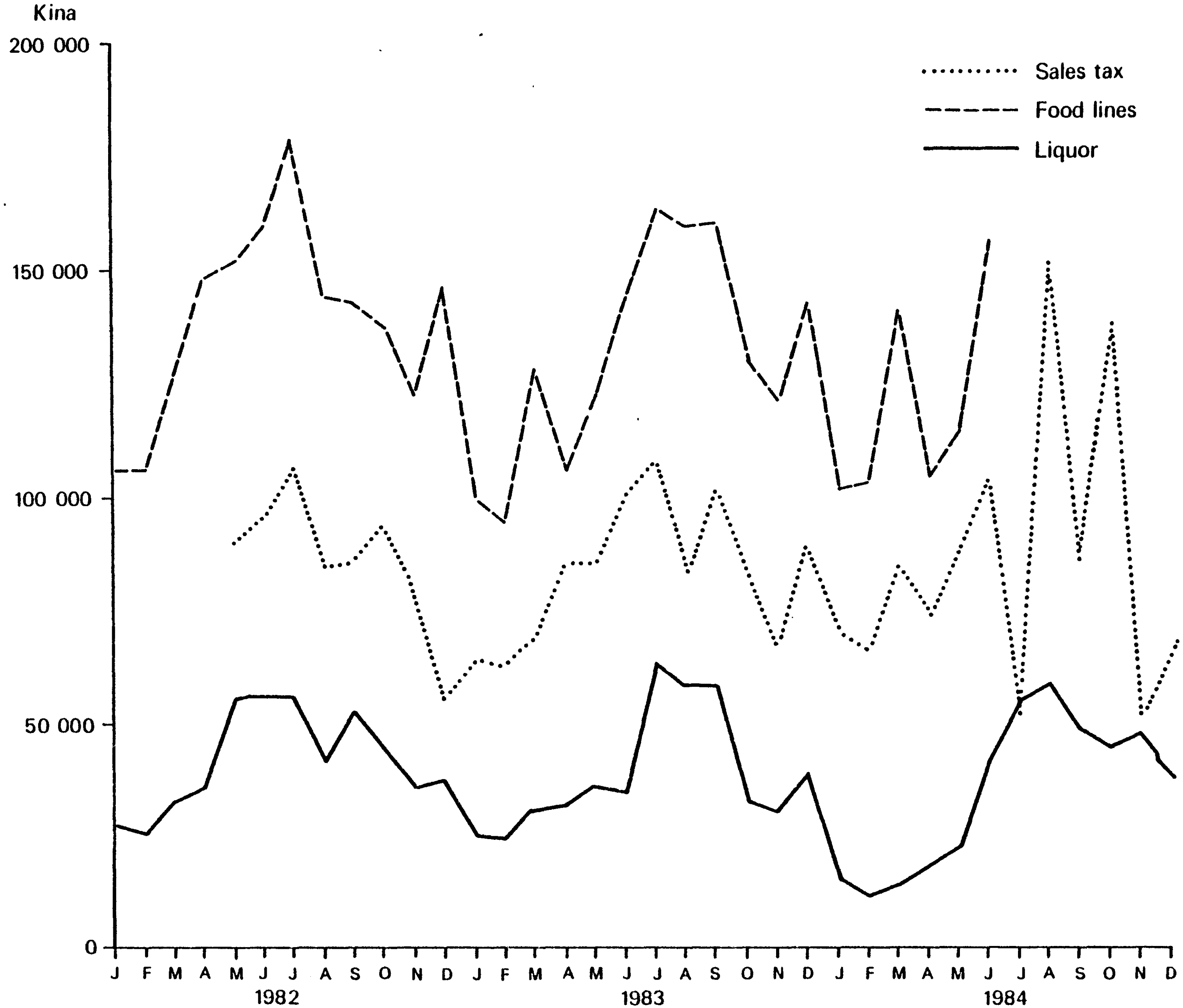

Figure 5.2 Monthly retail sales tax, Eastern Highlands; food sales, Store A, Kainantu; liquor sales, Store B, Kainantu, January 1982 to December 1984 (Source: EHP provincial government and management of Stores A and B)

(Table 5.1). In contrast with these data from the main coffee producing provinces, sales figures from the Southern Highlands for the same period do not show any influence from the coffee harvesting season (Figure 5.3, Table A9.2).

It is not valid, however, to argue from these consumption data that coffee production is a causative factor in subsistence food shortages.

Coffee Harvesting and Food Shortages

A range of evidence is available from a variety of locations and on various scales that can be used to examine the relationship between coffee harvesting and food supply.

Garden measurements. The first and most direct evidence comes from the garden area measurements for a sample of women at Asiranka and Upa between 1979 and 1982 (Chapter 8). Asiranka Village is a coffee producing village and the number of trees per household is typical of other coffee growing communities (Table 2.7). An insignificant number of people engage in seasonal wage labour harvesting coffee. Coffee growing at Upa is a very minor activity (Table 2.11). Between 1980 and 1982, when the garden planting survey was conducted, 20 to 25 members of the Puit clan out of the resident adult population of 109 went to the Western Highlands as wage labourers, for at least part of the season (Figure 2.8).

The planted area of all food crops, or sweet potato only, did not decline consistently during the coffee harvesting season, in either Asiranka or Upa (Figures 8.4, 8.7, Tables A13.1, A13.4). To examine further the relationship between coffee harvesting and the area of food gardens planted, the crop planting survey data were grouped into three-month periods so that one of the periods corresponds with the peak coffee harvesting months of June, July and August (Table 5.2). During the first year of the survey (1979-80), there was less planting of sweet potato and all food crops during the coffee harvesting season, in both the coffee growing and non-coffee growing villages. This pattern was not repeated in the following years. At Asiranka there was less planting in the September to November period in 1981, and in 1982 less planting was done in the March to May period(3). These recordings from communities where coffee is an important and a minor activity respectively show unequivocally that there was no consistent association between planting of subsistence foods and the coffee harvesting season.

(3) The Asiranka and Upa crop planting survey data were also grouped in four-month periods to be consistent with Grossman's periods, but again there is no consistent time of the year when villagers planted less sweet potato or less of all food crops.

Table 5.1 Ratio of coffee production and sales of certain commodities during the coffee harvesting season to that during the remainder of the year(1)

Parameter	Period	Ratio
Coffee production, Kainantu area	Jan 1974 - Dec 1984	3.7
Beer sales, EHP	May 1978 - Dec 1984	1.6
Liquor sales, Store B, Kainantu	Jan 1982 - Dec 1984	1.5
Food sales, Store A, Kainantu	Jan 1982 - Jun 1984	1.3
Retail sales tax, EHP	May 1982 - Dec 1984	1.2
Rice sales, Goroka and Mt Hagen terminals	Jan 1977 - Dec 1984	1.2

Note

(1) The coffee harvesting season is taken here as June, July and August. The ratio is between production/sales during these three months and the other nine months.

Table 5.2 Asiranka and Upa crop planting survey: mean area of sweet potato and all food crops planted for three month periods, December 1979 to November 1982 (m^2/woman/week)(1)

Year	Period	Asiranka Village		Upa Village	
		Sweet potato	All food crops	Sweet potato	All food crops
1979-80	Dec-Feb	144	186	67	96
1980	Mar-May	57	101	27	31
	Jun-Aug(2)	13	56	23	26
	Sep-Nov	37	77	39	48
1980-81	Dec-Feb	43	59	80	98
1981	Mar-May	40	64	60	68
	Jun-Aug(2)	34	65	55	60
	Sep-Nov	14	39	46	73
1981-82	Dec-Feb	25	35	50	64
1982	Mar-May	17	43	28	37
	Jun-Aug(2)	42	79		
	Sep-Nov	80	111		

Notes

(1) Monthly means are presented in Figure 8.4 and Table A13.1 for Asiranka and in Figure 8.7 and Table A13.4 for Upa.

(2) The greatest concentration of coffee harvesting in the highlands is between June to August.

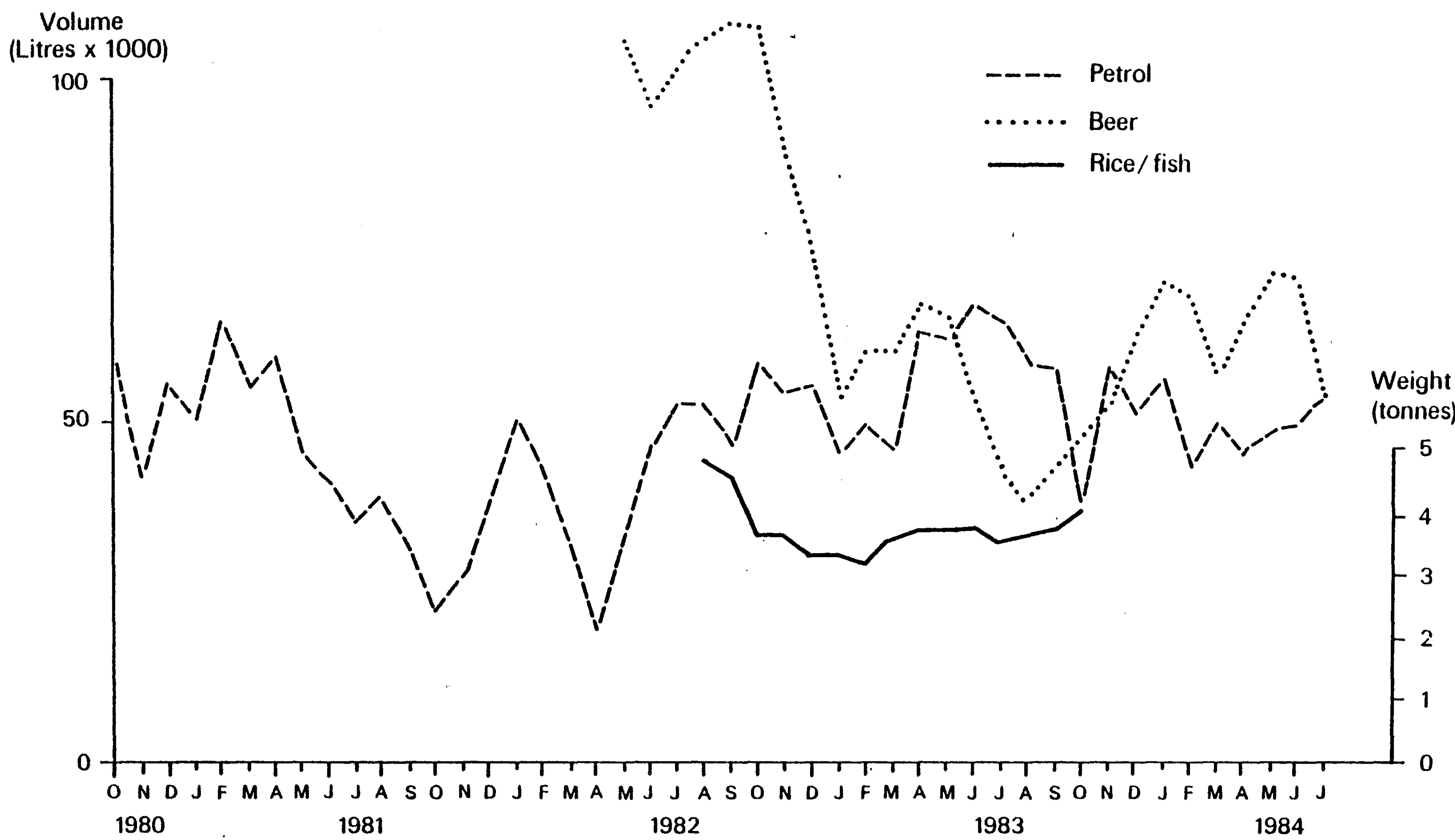

Figure 5.3 Monthly sales of bulk petrol and beer (litres), Southern Highlands; rice plus tinned fish (tonnes), Store A, Mendi, various periods, 1980 to 1984 (three monthly running mean) (Source: SHP provincial government, fuel supplier and Store A, Mendi)

Annual coffee seasons. Because the coffee harvesting season is regular and annual, interference with food crop plantings during the coffee harvest would be expected to occur annually. However, an examination of data sets on sweet potato price and food shortages in the main coffee growing areas since 1970 (Figures 3.5, 3.6, 3.8, 3.10) provides no evidence for annual food shortages or annual episodes of high sweet potato prices.

The pattern of supply of some annual food crops, for example corn, is seasonal both in locations where coffee is important, such as in the Kainantu area, and where coffee is absent or of minor significance, such as on the Nembi Plateau (Figure 3.14). On the Nembi Plateau the supply of all food crops in aggregate, excepting sweet potato, varies in an annual seasonal pattern, whereas in the Kainantu area the supply in aggregate is not seasonal (Figures 3.12, 3.13)(4). Claims that an increased seasonality in the supply of locally produced food is induced by coffee production (Grossman, 1984:214) or that annual food shortages are brought about by coffee harvesting (Lambert, 1976:41; von Fleckenstein, 1976:355) cannot be substantiated.

Coffee income and crop size. The size of the coffee harvest varies from year to year, and prices received by growers have fluctuated considerably, particularly during the mid- to late 1970s. If villagers' food gardening activities were interrupted by coffee production, seasonal wage labour on plantations, or altered consumption/behaviour during the coffee harvesting season, one would expect evidence that more problems occurred with subsistence food supply during years of high production and especially during the years of very high prices. The latter is part of Grossman's (1984) hypothesis.

National coffee production increased rapidly between 1965 and the mid-1970s and then increased at a slower rate (Figure 5.4, Table A9.3). There were large increases in production in 1976 and 1983 at both a national level and amongst Eastern Highlands smallholders(5). If food gardens had been neglected during the 1976 and 1983 coffee harvesting seasons, food shortages or particularly high prices for sweet potato would have resulted between about December 1976/83 and April 1977/84. There were no indications from any of the data sets from the main coffee producing districts that food supply problems or high sweet potato prices followed these particularly good coffee seasons (Figures 3.5, 3.6, 3.8, 3.10).

By the early 1980s people were migrating seasonally from the Nembi Plateau to harvest coffee in the Western Highlands and this peaked in 1983 (Figure 2.8). It could be

(4) The annual seasonality of planting of mixed gardens on the Nembi Plateau was observed in 1978 and pre-dates significant seasonal wage labour by Nembi villagers (Figure 2.8).
(5) The jump in production at a national level was greater in 1983 than is apparent from Figure 5.4 because of stockpiling by exporters.

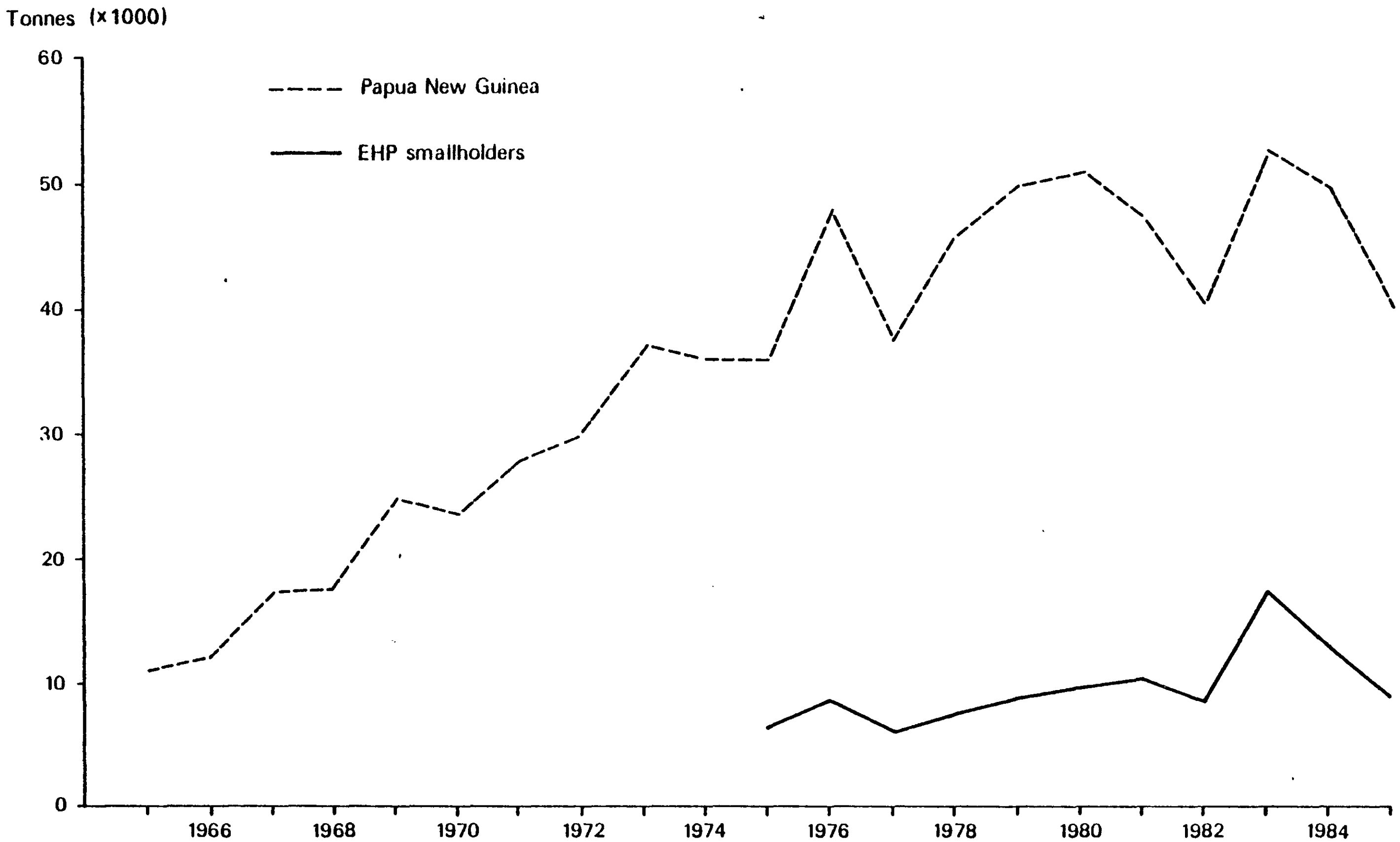

Figure 5.4 Annual coffee exports from PNG, 1965 to 1985; and smallholder coffee production, Eastern Highlands, 1975 to 1985 (Source: PNG Coffee Industry Board, DPI (1984) and Munnull and Densley (1978))

argued that the absence of many people in the 1983 coffee harvesting season contributed to the food shortages which commenced in April 1984. However the 1984 food shortages affected most of the Southern Highlands (Figure 3.8); and the timing and severity of shortages were similar in locations which were important sources of seasonal migrants, such as the Nembi Plateau, and those where seasonal migration was less important in that year. This suggests that seasonal migration from the Nembi Plateau and elsewhere during the 1983 coffee season was not a contributing factor to the 1984 food shortages.

The major change in coffee prices, and consequently in returns to growers, occurred during the "boom years" of 1976 to 1980 (Figure 5.5, Table A9.3). The greatest returns to growers occurred in 1977 when international coffee prices peaked (Figure 5.5), but sweet potato supply, as reflected in market prices, was not scarce in the Goroka area following the 1977 coffee harvest (Figure 3.5). The data sets from the coffee producing areas give no indication of more frequent episodes of high sweet potato prices or food shortages during the coffee "boom years" (Figures 3.5, 3.6, 3.8, 3.10).

Similarly, if events associated with the coffee harvesting season interfered with food supply or were a contributing factor to food shortages, one would expect to find an increase in the frequency of food supply problems over time, particularly since the early 1970s. Again there is no evidence for this from the long term data sets. In Kainantu District, where the data span 50 years, the frequency of food shortages has not altered since the mid-1930s (Figure 3.10). There has been no increasing frequency of peaks in sweet potato price in Goroka market since 1970 (Figure 3.5); and in Asiranka Village food supply problems in 1982-83 and 1984-85 have precedents in previous decades and do not reflect an increasing problem since coffee growing commenced.

Thus evidence from different locations and at different scales clearly indicates that diversion of villagers' labour during the coffee harvesting season does not result in food shortages.

WAGE LABOUR

During the 1960s and early 1970s, some patrol officers in the Southern Highlands attributed the cause of certain subsistence food shortages to diversion of villagers' labour to local development projects and labour migration (for example, Poga, 1968; Setchell, 1970). These suggestions were uncommon prior to the 1967 shortages and even in the late 1960s the patrol officers were not unanimous in their opinions on the relationship between such diversion of labour and food supply. A number of other commentators have suggested that diversion of villagers' labour to development projects, mission work and labour migration was responsible for food shortage. These comments are mostly confined

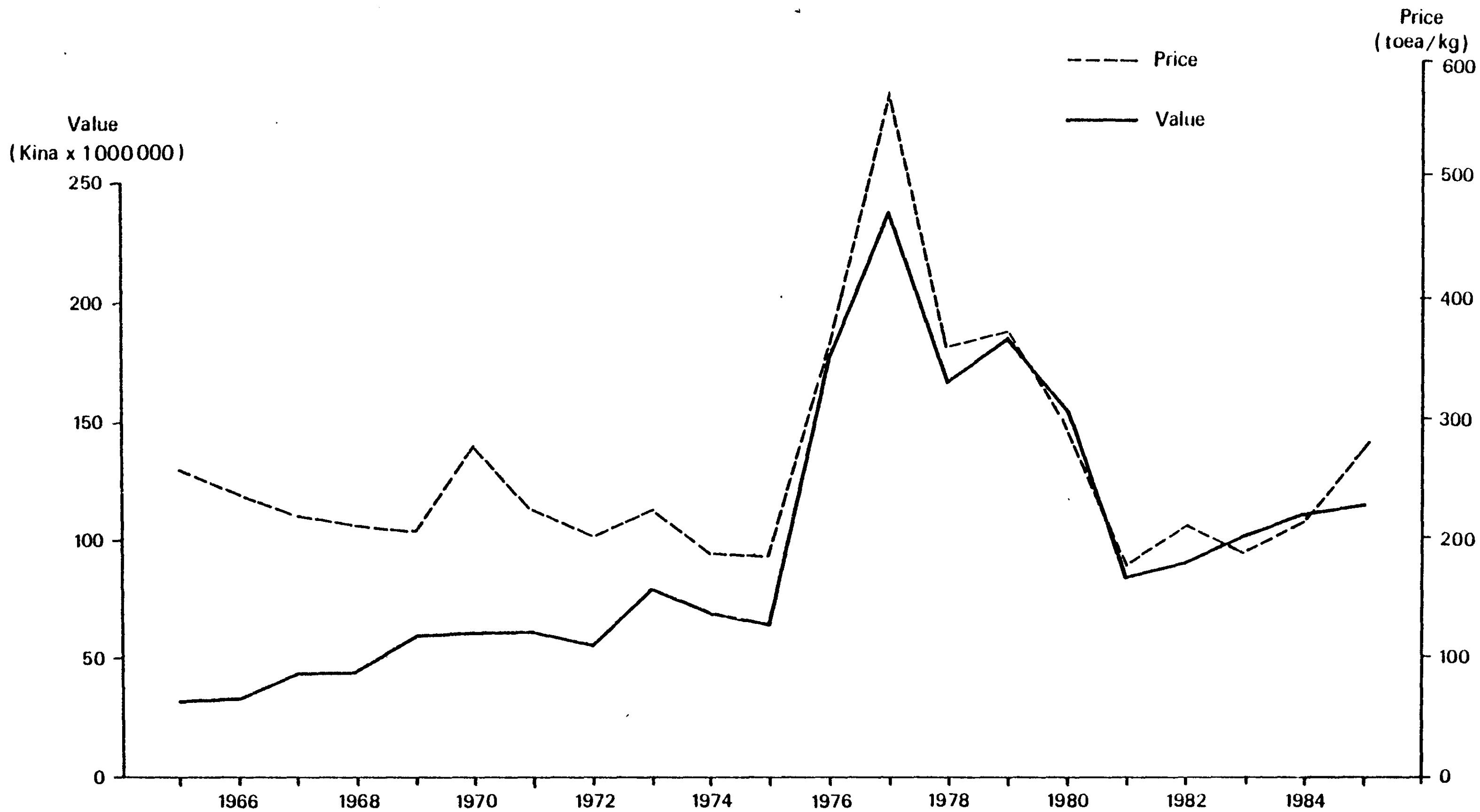

Figure 5.5 Export value of coffee for PNG and mean annual price of Y grade coffee, 1965 to 1985 (constant 1984 currency) (Source: PNG Coffee Industry Board and DPI(1984))

to the Southern Highlands and either reflect the patrol officers' opinions or are based on short term observations. A relationship between demands on labour and food shortages was suggested by Loh (1967) and Roberts (1982) for parts of Koroba District, by Strathern (1978:90; 1984:75-77, 81-82) and Clark (1985:147-149) for Pangia District, by Mathews (1971:34) for the Okapa District of the Eastern Highlands Province, and by Joughin and Thistleton (1987) for the Jimi Valley of the Western Highlands Province. Clark, for example, echoes the patrol reports from the late 1960s and early 1970s and notes that "... short-term famines have probably increased in scale and frequency since pacification" (p147) and that "A propensity for temporary food shortage was exacerbated under colonialism by the time and labour which people had to devote to development projects." (p149)

Demands on Labour over Time

From 1950 onwards, highlands men were recruited as agreement workers(6). The peak period for recruitment varied considerably between locations. It was generally greatest in the mid-1950s to mid-1960s in the Eastern Highlands whereas it was greatest in the mid- to late 1960s in the Southern Highlands (Table A9.4). This is illustrated in Figure 5.6 where the number of agreement workers absent per district is presented for Lufa, Kagua and Ialibu/Pangia Districts(7). The number of agreement workers absent from a location increased and later decreased. This phase was followed by a rise in the number of independent migrants (Ward, 1971). Thus it is possible to identify two distinct periods for any location: the pre-migration period and the period in which workers migrated under the agreement scheme or independently.

In the Southern Highlands, demands on villagers' time for local development projects were greatest between 1967 and 1971. For example, in the Mendi District most patrols between 1968/69 and 1970/71 were devoted to road building. This work was done by villagers who were required to contribute free labour or were paid at a low rate. Data on the number of people involved and the period of employment are not available.

Wage Labour and Food Supply

Data on labour migration (Figure 5.6, Table A9.4) however can be compared with district level data for food shortages in the Eastern and Southern Highlands over the same period (Figures 3.9, 3.11). With the exception of Pangia District, there is no apparent relationship between labour migration and reports of food shortages. For example, in Lufa

(6) Some trial recruitment of labourers occurred in 1949 (Brookfield, 1960) and Siane men had been working at Aiyura in the early 1940s (various Aiyura monthly reports).
(7) The number of workers absent per district is the total of those who left during any given year and during the previous year, as the labour contracts were for two years.

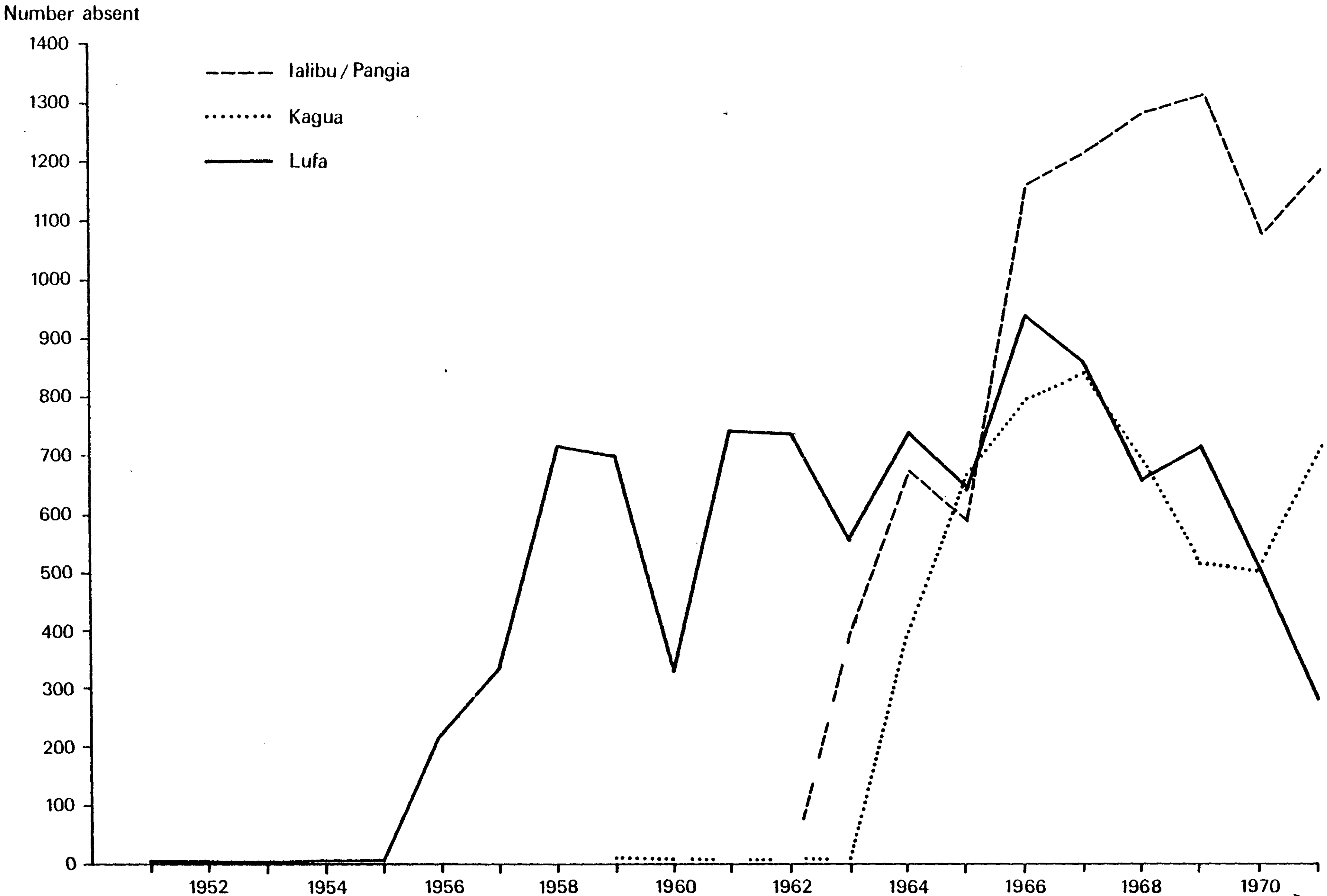

Figure 5.6 Number of agreement workers absent per district, 1951 to 1971, Lufa, Ialibu/Pangia and Kagua Districts (Source: Department of Labour, Goroka and Mt Hagen)

District, food shortages were not reported from 1958 onwards despite the absence of 600 to 900 men from the district as agreement workers (Figure 3.9). In Koroba District, the number of men absent as agreement workers (and local demands on labour for road and airstrip construction) was much greater from 1967 onwards. There is, however, no indication that food shortages were more frequent or more severe in that district after 1967 (Figure 3.11).

In Pangia District, reports indicate that food shortages became more frequent and more prolonged after 1967 than before (Figure 3.11). It is this coincidence of labour migration, local demands on villagers' labour and food shortages in the late 1960s and early 1970s that attracted comment from the patrol officers and later, academics (Strathern, 1978, 1984; Clark, 1985). The buildup in labour migration and other demands on villagers' time also commenced elsewhere in the province at about the same time, for example, in Kagua District (Figure 5.6). But in Kagua District, the increase in demands on villagers' time did not coincide with an increasing frequency of food shortages. The different pattern of food shortages in Pangia cannot be attributed to a particularly high rate of labour recruitment in the late 1960s. The absentee rate was 16 per cent for males in the 16 to 45 years group in 1966 and 19 per cent in 1970 (Harris, 1972).

Subsistence food gardens in the Pangia District are planted more often from forest fallows and the cropping phase is shorter than in other parts of the Southern Highlands above 1200 m (author's unpublished surveys). Generally in PNG, shorter cropping periods and forest fallows are associated with greater input from men into gardening than for grassland gardens because a greater proportion of the total work is clearing. In more intensive systems, the repetitive inputs of planting, weeding and replanting are proportionally more important and these are women's tasks. Thus it is possible that the absence of part of the adult male workforce was more disruptive in Pangia District where subsistence agriculture is more dependent on forest gardens and men's labour inputs than it was elsewhere in the Southern Highlands or Eastern Highlands. This hypothesis is consistent with Boyd's (1981) conclusions on the response of villagers to male labour emigration in the Lamari Valley in the Eastern Highlands. If this hypothesis is correct, male absenteeism would be more disruptive in highlands fringe locations where forest fallows predominate. However an alternative and more likely hypothesis for the pattern of reported food shortage in the Pangia District between 1957 and 1974 is that it is an artefact of the relatively short period of observations.

The present analysis of the relationship between labour migration and food shortages is restricted to district level data. Investigations at the level of community and household are required before more definite conclusions can be drawn. Nevertheless the analysis does not support the general contention that male migration, or demands on villagers' time by government and missions, were responsible for food shortages.

CATTLE PROJECTS

A prolonged but not particularly severe food shortage affected a village community in the Kainantu District between late 1975 and late 1976. Grossman (1984:172-177) gave the major causal factor as the allocation of labour to establishing cattle projects in the village between February and April 1975. No other author has, as far as I know, suggested that diversion of labour to establish cattle projects has resulted in a food shortage(8). Highlanders commenced rearing cattle from the early 1950s onwards. The greatest growth in both numbers of animals and projects occurred during the 1970s, peaking in the late 1970s (Grossman, 1984:48-71). In the early to mid-1980s, many projects failed and village cattle numbers were smaller than they had been during the 1970s.

It is not possible to evaluate independently Grossman's claim that at Barabuna Village diversion of labour in early 1975 was the major contributing factor to a food shortage in 1975-76. It can be noted that food shortages that affect some communities only are not uncommon in the highlands and that Grossman commenced his PNG fieldwork a year after the cattle projects were established (April 1976). Two areas were enclosed for cattle at Asiranka Village in 1977 and they were still stocked up to early 1985 (Figure 2.5). A cattle project was established at Upa on the Nembi Plateau on land not used for food gardens in the mid-1970s. By 1978 all of the animals had perished (Bourke, 1984b). There was no indication in either community that establishment of these projects was followed by food shortages, and villagers denied any connection between cattle projects and food scarcity. Thus there is no real evidence that villagers have been distracted from food gardening by establishment of cattle projects in the highlands.

The next group of suggested causes of diversion of villagers' labour from subsistence food production and consequent food shortages all operated prior to contact and continue to operate.

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(8) Occasionally, other improbable causes are suggested for food shortages. For example, shortages in the Mt Hagen area in 1967 were blamed by some on inattention to food gardens before and during the 1967 Mt Hagen Agricultural Show (Nelson, 1971:106-107). However, as Nelson notes, similar reports of food shortages were made from locations unaffected by the show, including much of the Southern Highlands (Figure 3.11) and the Kandep area of Enga. A purely local explanation is clearly inadequate for a problem affecting a significant part of the region.

KARUKA NUT PANDANUS HARVESTS

A number of authors have suggested that food shortages are induced by karuka nut pandanus harvests. Their argument is that during the karuka nut harvesting season, villagers neglect their food gardens and this results in a food shortage some 6 to 10 months later. For example, Harrison (1976:11) attributed a food shortage in a village near Mendi in June to November 1974 to harvesting of pandanus nuts in late 1974 and early 1975. He states the relationship between the karuka harvest and food supply in more general terms as follows:

> The other obvious problem is the food shortage which occurs after a pandanus nut season every two years. During this season many families migrate to the bush for a month or more to harvest the nuts. Planting has to be done almost continuously all year round in order to provide a steady supply of food; a break of a month or so will cause shortage about 10 months later. (pp51-52)

Other authors who suggest that food shortages are caused by the neglect of food gardens during the karuka nut harvests include Simpson (1978:47) and Eastburn (1984:33) writing about locations in the Mendi Valley; Allen *et al.* (1980) writing about the Nembi Plateau; Cape (1981:176) who attributed a food shortage in 1981 in the Bimin Valley of the Oksapmin area to the 1980 karuka harvest; and Senge (1984) and Muwanli (1984) whose concern was the food shortage in the Upper Jimi Valley in 1984.

Karuka Nut Harvesting Pattern

The two main species of nut pandanus in the PNG highlands are karuka nut pandanus (*Pandanus julianettii*) and wild karuka nut pandanus (*P. brosimos*)(9). The former is cultivated and has a usual altitudinal range of 1800 to 2550 m; the latter is selfsown and grows over a usual range of 2200 to 3100 m (Bourke, 1984c). Nuts of the wild species are not fully harvested by villagers who have access to the cultivated species but when the wild nuts produce an exceptionally good crop, more attention is paid to harvesting them. Villagers who live above the altitudinal limit of the cultivated species harvest the wild karuka more regularly.

During the harvests, there is intense interest in gathering the nuts. Numerous observers have noted that entire households and communities move to the forest for weeks at a time to harvest them: for example, Powell (1982:5) writing on the Tari area; Vicedom and Tischner (1983:206) on the Wahgi Valley; and Waddell (1975:265) on Enga.

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(9) Unless stated otherwise, discussion relates to the cultivated species (*P. julianettii*), but some authors do not distinguish between the two species.

To understand the relationship between karuka nut harvest and subsistence food supplies, data on the frequency of harvest are needed. In 1976 Rose commenced regular observations on karuka nut pandanus husbandry in the north Tari area (Rose, 1982). In 1979 I started data collection on karuka nut harvesting in the Kainantu area. Correspondence was maintained with a group of observers in different parts of the highlands: at Goroka (T. Tarepe), Wabag (B. Carrad), Mendi (J. Tompkins), Tari (C. Rose) and Oksapmin (N. Cape). They noted the timing of the harvests in these locations and provided comments on harvest size. When any of these observers left the location, he was replaced by another. Thus continuous data are available for six locations in the highlands from 1978 or 1979 onwards until the end of 1985 (Figure 5.7, Table A10.1). Data on the supply in Kainantu (1979 to 1985) and Goroka (1979 to 1982) markets are given in Figure 5.8 and Tables A10.2 and A10.3. Patrol reports proved an unexpected source of information on karuka seasonality in the Southern Highlands, a source previously used by Hide (1981:280-285) in Chimbu. Patrol officers were interested in the occurrence of the harvests because this coincided with a marked increase in disputes over ownership of trees. Comments by patrol officers on karuka nut harvesting in the Southern Highlands are summarised in Table A10.4. The only systematic long term observations on the harvesting of wild karuka are those by P. Wohlt from a community in the Kandep District of Enga, and by E. D'Souza in the Tari Basin (Table A10.5).

The conclusions that can be drawn from the different data sources may be summarised as follows: fruiting of karuka nut pandanus (*P. julianettii*) is irregular. The syncarps that contain the nuts may mature in any month of the year; although this is most likely between January and March and least likely between September and November. The size of the crop varies considerably from harvest to harvest and large crops are more likely during the January to March period than at other times. Harvests are more regular in the Eastern Highlands where a regular dry season occurs (Figure 5.8). Throughout the highlands, the best harvests follow severe droughts, such as those of 1941, 1972 and 1982. Observations on the fruiting pattern of wild karuka nut (*P. brosimos*) are limited (Table A10.5). This species appears to have a different production pattern from that of the cultivated species at any location. However the very large harvests of wild karuka, such as those which occurred in 1973 and 1983, did coincide with the large harvests of the cultivated karuka.

Karuka Nut Harvests and Food Shortages

The number of bearing karuka nut trees per person is small at both study villages, Asiranka and Upa (Table 2.7). Hence the relationship between the harvesting times of karuka nuts and changes in food supply cannot be examined in these villages. In contrast, karuka nuts are important in the Upper Mendi Valley and in the Tari Basin and AFTSEMU

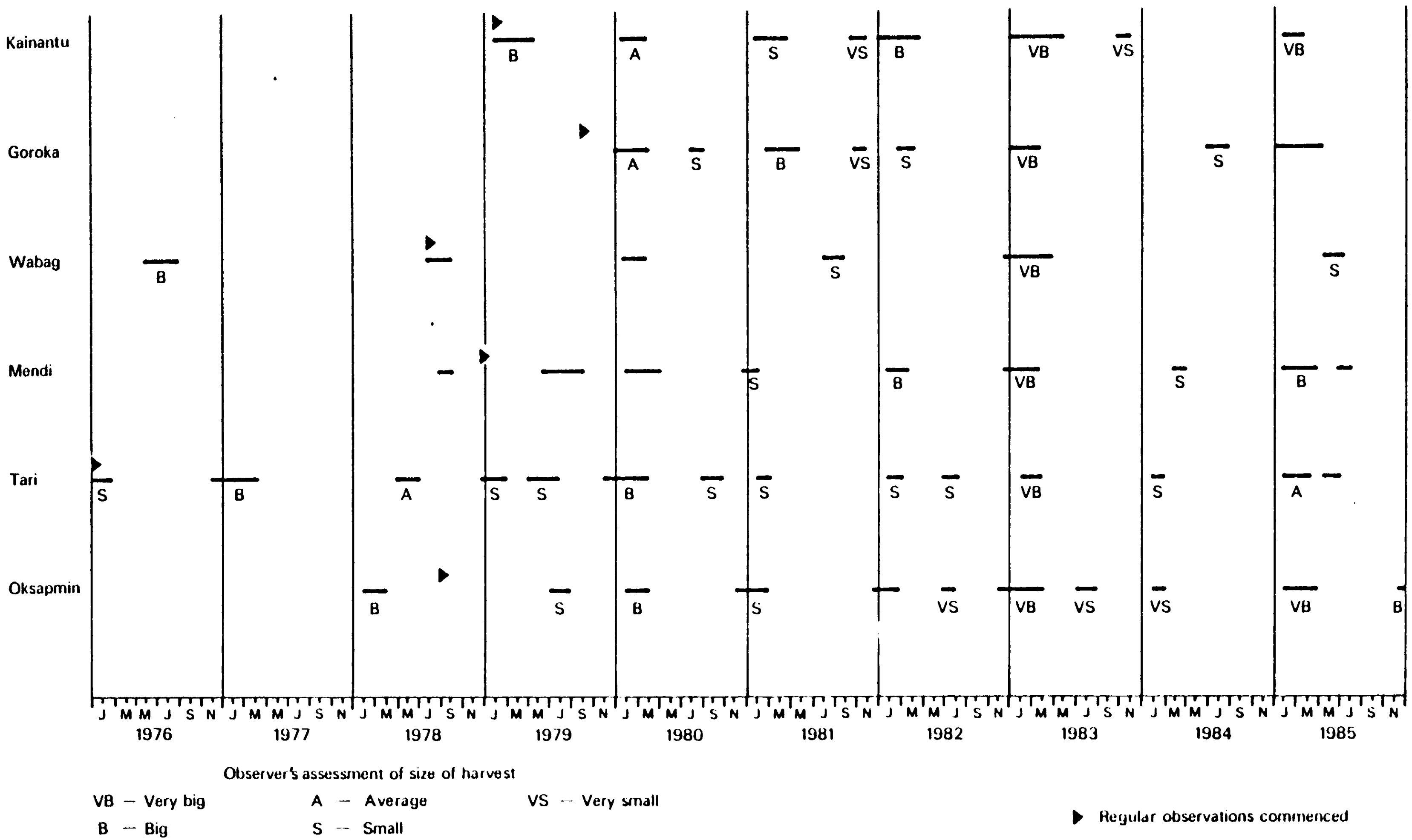

Figure 5.7 Harvesting periods of karuka nut pandanus at six highland locations, 1976 to 1985 (Source: Table A10.1)

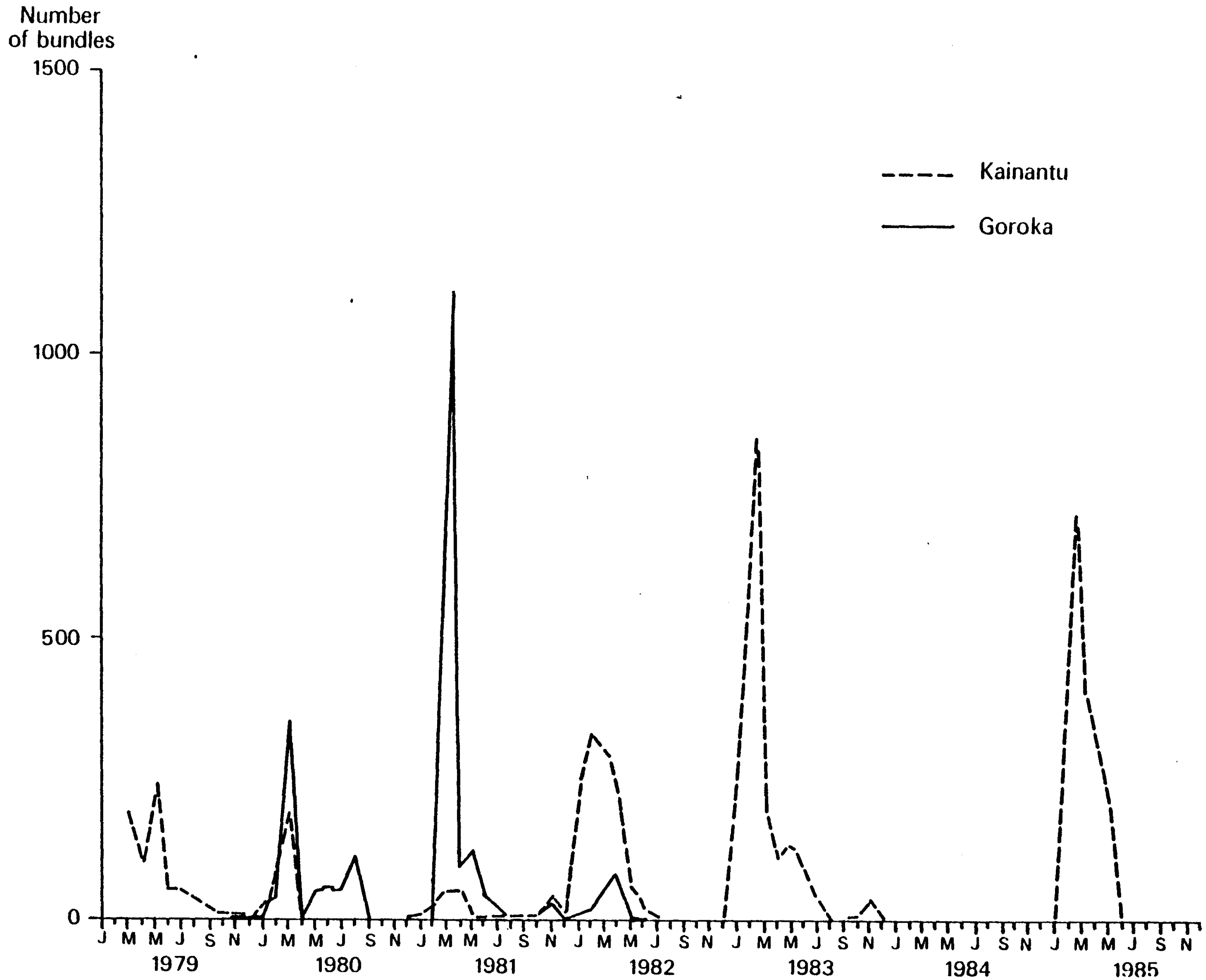

Figure 5.8 Number of bundles of karuka nut pandanus on display, Kainantu market, March 1979 to December 1985; and Goroka market, October 1979 to September 1982 (Source: surveys by R. M. Bourke, K. Nema and T. N. Tarepe)

data on area of food crops planted per month can be used to examine this relationship (Figure 8.9, Table A13.7).

There are very many cultivated karuka nut trees in the Upper Mendi Valley and some villagers have access to forest land containing the wild species. There was a particularly abundant harvest of the cultivated species in the Mendi Valley between mid-December 1982 and March 1983 (Figure 5.7) and probably also of the wild karuka nut. Despite this, the area of food gardens planted per month was fairly constant over this period (Figure 8.9). In the Tari Basin, karuka nut trees are also common and some villagers have access to the wild species in the forest. There was a massive harvest of the cultivated karuka in February-early March 1983 (Figure 5.7) and villagers moved up to the forest during this period to harvest the wild karuka (Table A10.5). The food garden planting rate of the AFTSEMU sample families in the Tari Basin was high in February and March, 1983 (Figure 8.9). Thus in these two locations in the Southern Highlands, even the very large karuka harvest of early 1983 did not influence garden planting rates.

Some observations from Enga by Wohlt (1978:164-169) do suggest that planting rates may sometimes be influenced by karuka nut harvests. He recorded the planting rate over time in a community in Enga where wild karuka is an important food source. He observed a very low sweet potato planting rate in January and February 1975 which coincided with a harvest of the wild karuka nuts. A high sweet potato planting rate both before and after the nut harvest was interpreted by Wohlt as a deliberate strategy by villagers to compensate for the reduced planting rate during the harvest (p169).

The data on harvesting times for the six locations between 1978 and 1985 (Figure 5.7) may be compared with district level data on food shortages between 1979 and 1984 (Figure 3.8). Similarly data on karuka harvests in the Southern Highlands between 1949 and 1971 (Table A10.4) may be compared with the reports of food shortages over the same period (Figure 3.11). Clearly there is no association between the occurrence of karuka nut harvests and food shortages 6 to 10 months later. In particular, the very large harvests recorded in early 1957 and early 1973 in the Southern Highlands and in early 1983 throughout the region were not followed by food shortages later in the year.

The available data indicate that there is no causal relationship between the harvesting time of cultivated karuka nut pandanus and food shortages. Wohlt's data on planting rates from the Kandep area suggest that the planting rate may sometimes be temporarily reduced during a pandanus harvest. This, however, is not sufficient interruption to garden activity to cause a food shortage.

Finally, abundant karuka nut harvests, rather than causing food shortages, sometimes ameliorate them. Comments by patrol officers and agricultural officers that people who are short of sweet potato are surviving on karuka nuts are not uncommon. This was the case in Enga and the Southern Highlands in early 1973 when cultivated and wild karuka nuts provided an alternative food for people affected by the 1972-73 food shortage (Binns, 1976; Waddell, 1973a:32-33; Wohlt, 1978:142-143). The abundant karuka harvests in early 1983 again coincided with a food shortage and people reportedly used the nuts as an alternative to scarce sweet potato(10).

MARITA PANDANUS HARVESTS

Marita pandanus (*Pandanus conoideus*) produces an oblong fruit from which villagers extract an oily liquid used to flavour food. Marita is grown from just above sea level to a mean upper limit of 1700 m in PNG, and is most significant over the range of 500 to about 1500 m (Bourke, 1984c).

Occasionally it is suggested that neglect of gardens during the marita harvest is responsible for food shortages. This was offered as one possible cause of shortages in the Upper Jimi Valley of the Western Highlands in 1984 (Muwanli, 1984). This was most unlikely as the altitude for this location (2000 m) is above the crop's altitudinal limit and food shortages occurred throughout much of the highlands during that year (Figure 3.8).

Our surveys of Kainantu and Hol markets indicate year to year variability in the size of the marita harvest (Figure 5.9, Tables A6.8, A6.9). The good harvest of 1980 in the Kainantu area was not associated with reported food shortage in nearby lower altitude locations, such as parts of the Wonenara District (Figure 3.8). The hypothesis that harvesting of marita fruit interferes with subsistence garden activity cannot be sustained.

PIG KILLING FESTIVALS

In the western part of the highlands, people engage in pig killing ceremonies at intervals of several to many years. A number of authors have suggested that one or several factors associated with pig killing festivals (or other celebrations) cause shortages of subsistence food. These factors are: an increased demand for food by visitors at the festivals; an increased demand for food for pigs because their numbers are greater immediately prior to the festival and because they are being fed particularly well to fatten them; damage to food gardens by the large pig herds which are not being fed adequately; and neglect of gardens during the festival.

(10) The correspondence of food shortages and particularly abundant karuka harvests is not coincidental. The best karuka harvests follow severe droughts and droughts are sometimes a contributing factor to food shortages (Chapter 7).

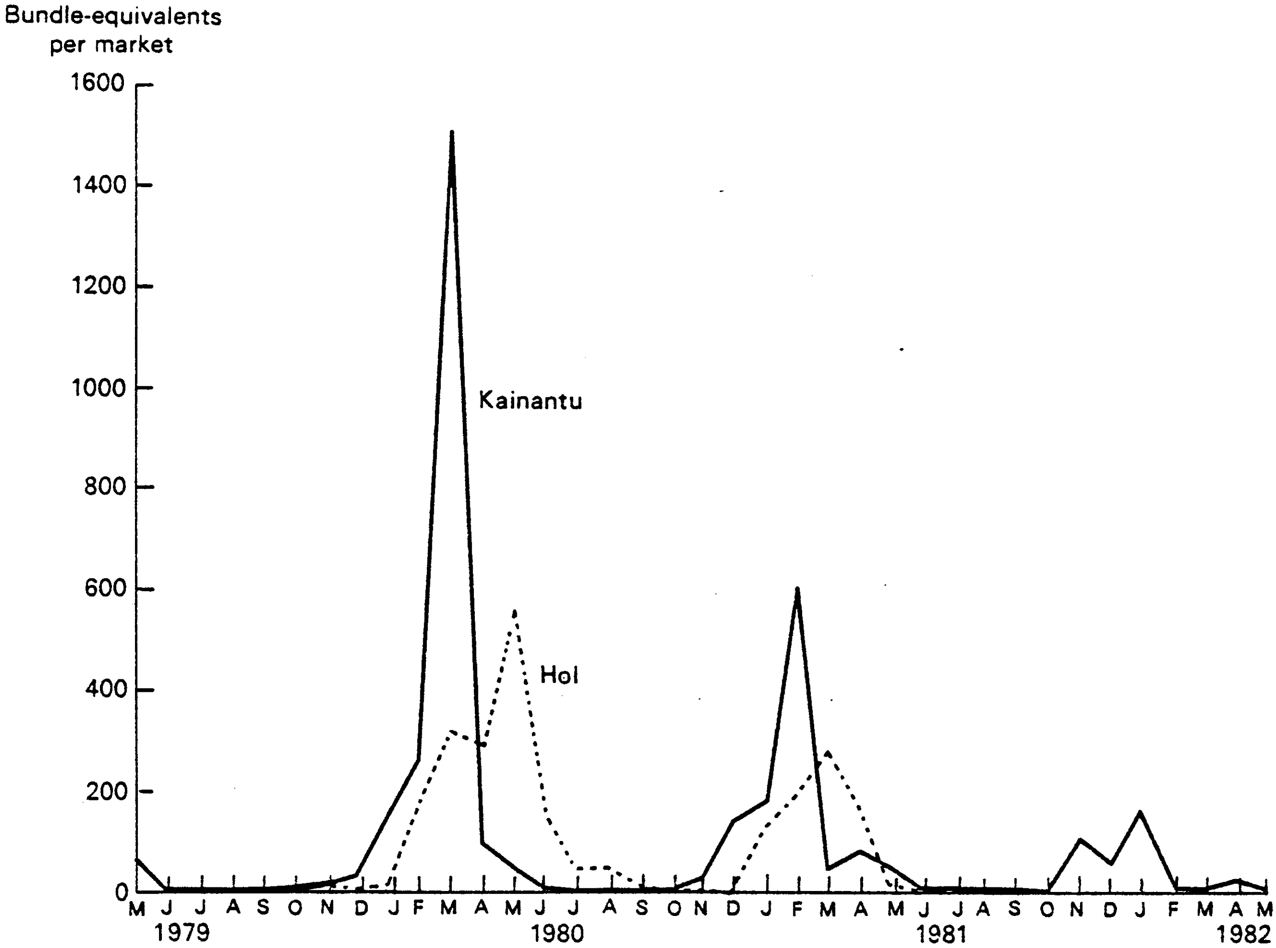

Figure 5.9 Number of "bundle-equivalents" of marita pandanus on display per market, Friday/Saturday mornings, Kainantu and Hol markets, May 1979 to May 1982 (Source: surveys by R. M. Bourke and E. D'Souza)

The suggested relationship between festivals and food shortages has been debated for many years. For example, in 1938-39 an acute food shortage in the Goilala area of the Papuan highlands was reportedly caused by visitors to dances and associated pig damage (Murray, 1940:24-25). Writing on the Chimbu Valley, Criper (1967:248-249) made the following observations:

> Demands on the staple foods rise to a high level after the pig festival ground is built and dancing begins, since there is a continual stream of visitors and friends who have to be given food. This reaches a peak in the week or ten days before the final pig killing. By this stage the gardens are often bare of food, except of inferior size or quality, and a period of semi-hunger can follow, especially for the less hard-working or those lacking in foresight. Also a major drain on food resources are the pigs, which are to be killed. In the months leading up to their death they must be handfed or given access to sweet potato gardens to ensure that they have as much fat on them as possible ...(11).

Other authors who report that pig killing festivals or other ceremonies are a contributing factor to food shortages include Commonwealth of Australia (1950:167) on the highlands in general; Barrie (1956:48) on the Chimbu Valley; Bailey (1963:393) on the Upper Chimbu Valley; Hide (1981:38) on the Dom area of Chimbu; Strathern (1984:88) on the Wahgi Valley; and Zimmer (1985:441) on the Bundi area. Hide (1980) brings together the Chimbu literature on the subject.

Nembi Plateau Observations

Data that can be used to assess the relationship between pig killing festivals and garden food supply are limited. Large scale pig killing ceremonies are not held amongst the Gadsup speakers in the Kainantu area, but some observations are available from the Nembi Plateau for the period 1978 to 1984.

These festivals are held irregularly on the Plateau with up to 1000 or more animals killed in one day. Not all clans participate in the same festivals, so it is possible to examine the effect of these ceremonies on food supply. In March 1981 numerous clans between Pumberel and Enip participated in pig killing ceremonies. This coincided with the end of a mild food shortage on the Plateau and with relatively high sweet potato prices in the local markets (Figure 3.7). Sweet potato prices remained high when the food shortage was over, and this was attributed by E. D'Souza (pers. comm., 1981) to the continuing demand for sweet potato following increased consumption of sweet potato during the pig killing ceremonies. However, clans that did not participate in these

(11) Criper goes on to suggest that the pig killing ceremonies lead to cyclical patterns of gardening and the requirements of the festival act as a spur in the agricultural cycles, forcing men to open garden land from fallow. Brookfield (1973a) also reports long term cycles in land use in another part of Chimbu that are related to the demand for food by pigs. Criper's comment that pig killing ceremonies force men to clear fallow land are similar to my observations that food shortages force men to clear fallow land (Chapter 8).

ceremonies, such as those at Upa Village, were also affected by the food shortage, suggesting that the festival was not a contributing cause of this food shortage. Food was not reported to be short six to eight months later, as would have been expected if gardens had been neglected during the festival.

Another large scale pig killing festival took place on the Plateau in April 1984. At Upa Village, members of the Puit and Palam clans killed pigs but members of the Murupa clan did not. The pig killing ceremony at Upa coincided with the start of the 1984 food shortages that affected most of the Southern Highlands. There was no indication that people in clans who had killed pigs were affected to a greater degree than those in clans who had not killed pigs. The survey of evening meals in the three clans at Upa (Table 3.2) did not indicate that Puit and Palam people were more affected by the food shortage than members of the clan which did participate in the ceremony.

These observations from the Nembi Plateau are an inadequate basis for definite conclusions. The market price data for sweet potato in 1981 suggest that pig killing ceremonies may place some pressure on supply, but there is no indication that clans involved in ceremonies had more serious food supply problems than those who did not. The comments by a number of observers in Chimbu, particularly Criper (1967), do suggest that pig killing ceremonies and associated activities could at times by a contributing cause of food shortages, at least for some clan groups. No unequivocal evidence for this exists and further research is required to understand the relationship between these ceremonies and food shortages. Some ceremonies involve many clans, but they rarely if ever involve a high proportion of people in a district or even several census divisions. Thus even if these ceremonies do contribute to food supply problems at a local level, it is most unlikely that they would cause problems on a wider scale.

TRIBAL FIGHTING

Prior to entry of the Australian Administration into the highlands, tribal fighting was endemic(12). This was virtually halted by patrol officers and police during the colonial period. There was a resurgence of fighting in many parts of the highlands during the 1970s, particularly after independence in 1975 (Strathern, 1977; Gordon and Kipalan, 1982), and this has continued and become more widespread during the 1980s. One major objective of fighting was to destroy the enemies' means of livelihood (Read, 1951). The visible effects of tribal fights are often spectacular: houses, trade stores and vehicles are burnt; coffee and casuarina trees are cut down or ring barked; sweet potato gardens are trampled or destroyed; and hamlets are left deserted.

(12) The term "tribal fighting" is in general use in Papua New Guinea and I use this term, rather than the more accurate "inter-group fighting".

It has been argued that one of the repercussions of tribal fighting is food shortages. The deleterious effects of fighting on food supply occur because of actual destruction of gardens, because of increased demand for food on people who are sheltering those displaced by fighting, and because the fear of attack restricts gardening activity to more secure land near settlements.

During the 1950s a number of patrol officers commented on the effects of fighting on food supply. The comments by Mater (1956) following a patrol to the Mt Karimui area in Chimbu are typical:

> The food supplies in the area that are not engaged in tribal fighting seem to be sufficient, but at Walio, Pelia and Welia, where fighting is in progress, they are hungry. Some men at Walio were seen to be eating sweet potato no bigger than a man's thumb.

Authors who comment on the tribal fighting/food supply relationship include Boyd (1975:60), Jeffries (1978:22), Harvey and Heywood (1983:111), Vicedom and Tischner (1983:215), Grossman (1984:151). Ongka, an important man in the Mt Hagen area, provides a graphic description of how tribal fighting resulted in hunger during one particular encounter (Strathern, 1979:58-59):

> There was nothing to eat. We pulled taro shoots, but these soon finished. We dug the planted stocks of sugarcane, and these were finished. We ate [rungia] greens and these were finished. We were forced to eat mushrooms, tree fungi, fern leaves. There was no sweet potato; all the gardens were burned off. In the days of warfare we did not have big gardens at the best of times, and now we had none. Hunger tore at our insides and our eyes closed in pain. Older men pushed leaves into their bark belts to fill out the space between their stomachs and their belts. They declared they were pleased to be hungry, and went to fight again.

Some Recent Observations

In 1980 a fight occurred during an eight day period in several communities in the Dom area of Chimbu. A detailed study of the history of fighting in the area and of its effects was made by Wohlt and Goie (1986:117-130). By Chimbu standards, it was a small fight and no one was killed. Food gardens of one group were systematically raided by another group. Wohlt and Goie estimated that two thirds of the sweet potato crop in one community were stolen or destroyed and a number of pigs were killed on both sides. Disruption in planting because of fighting, the impact of enemy harvesting and damage to gardens during the fighting combined to produce a food shortage in one of the communities which took 17 months for full recovery.

On the Nembi Plateau, however, it has not been possible to establish a causal relationship between tribal fighting and food shortages, probably because the Nembi fighting did not involve widespread destruction of food gardens. Tribal fighting recommenced on the Nembi Plateau between 1981 and 1983 after about 20 years of peace. Not all clans were involved. At Upa members of the Puit and Murupa clans joined the fighting whilst Palam clan members did not. There was no indication that the degree of food shortage in 1984 was related to involvement in the recent fighting.

The observations by patrol officers during the 1950s and Wohlt and Goie's (1986) Chimbu study suggest that tribal fighting may sometimes be a partial cause of localised food shortages. However, these shortages are likely to be restricted to a number of clan groups rather than operating at a broader scale.

CONCLUSION

Villagers' consumption and other social behaviour patterns are altered during the coffee harvesting season and sometimes during karuka nut harvests. Why then is food production not affected? Firstly, the time devoted to subsistence food production (15 to 19 hours per week per adult) is not great and time devoted to other activities need not necessarily be at the expense of food production. Secondly, there is considerable flexibility within the food production system (Chapter 2) and this absorbs the effects of short term variation in planting rates.

None of the suggested sources of diversion of villagers' labour is a major cause of food shortages. There is no evidence that diversion of villagers' labour during the coffee harvest and karuka nut harvest is responsible for food shortages. Distractions associated with pig killing ceremonies and tribal fighting probably sometimes contribute to food supply problems. However, the evidence for this is limited and the number of people possibly affected would be small. The available evidence does not indicate that organised or voluntary labour migration during the colonial period resulted in an increased frequency of food shortages. There is no indication that several other suggested causes of shortages, including harvest of marita fruit, construction of cattle projects or agricultural shows, were responsible. Further research is required to explore some of these relationships more fully, in particular, the impact of labour migration and pig killing ceremonies, but evidence to be presented later suggests that factors other than these are the primary causes of food shortages.

CHAPTER SIX

CLIMATIC VARIATION AND SWEET POTATO YIELD: EXPERIMENTAL RESULTS

Variation in the supply of sweet potato is an outcome of variation in crop yield and variation in the area planted over time. In this chapter, the influence of climatic variation on sweet potato yield is examined, firstly through a literature review and secondly through survey and experimental results from Papua New Guinea. The survey results are from yield recordings in Asiranka Village and the experiments were conducted on research stations and in village gardens. A brief introduction to some aspects of sweet potato agronomy precedes this presentation.

Some Aspects of Sweet Potato Agronomy

The economic part of the sweet potato plant is the tuberous root. Yield is dependent on both the number and size of the tubers. The number of tubers that a plant will bear is determined very early in the cropping cycle (Lowe and Wilson, 1974; Wilson, 1982; Hahn and Hozyo, 1983). For example, in the Caribbean, tubers are initiated between 2 and 8 weeks after planting for crops that are harvested at 24 weeks (Lowe and Wilson, 1974). In the PNG highlands, tuber initiation is likely to take slightly longer because the cooler climate slows growth (Figure 6.1).

During the second half of the crop cycle, the tubers increase in weight rapidly, a phase known as "rapid tuber bulking". The mean tuber weight is determined during this time. Tuber bulking occurs later in the PNG highlands (Soenarto, 1987; Anders, in press), but the pattern is similar to that reported from warmer climates (Figure 6.1). The onset and duration of the rapid bulking phase varies markedly between cultivars (Lowe and Wilson, 1974; Bourke, 1984a; Anders, in press).

Sweet potato tubers do not mature physiologically like grains, fruits and most other economic plant organs, but are harvested when an acceptable yield has been attained or environmental constraints prevent further growth. In the PNG highlands, yields are judged by tuber size. People prefer larger tubers and those with a weight of less than about 100 g are generally fed to pigs. However, the size distribution is not critical and people readily eat tubers with a large size variation(1). Unlike many other crops, sweet potato plants do not exhibit obvious changes that signal maturity. Changes do occur in the top growth after

(1) In a study of tuber size distribution and taste preferences in the PNG lowlands, Jamieson (1968) found that tubers under 2 ounces (56 g) were considered unpalatable; and tubers in the 2 to 8 ounce class (56-227 g) were slightly less palatable than large tubers because they were judged somewhat "tougher" and more fibrous.

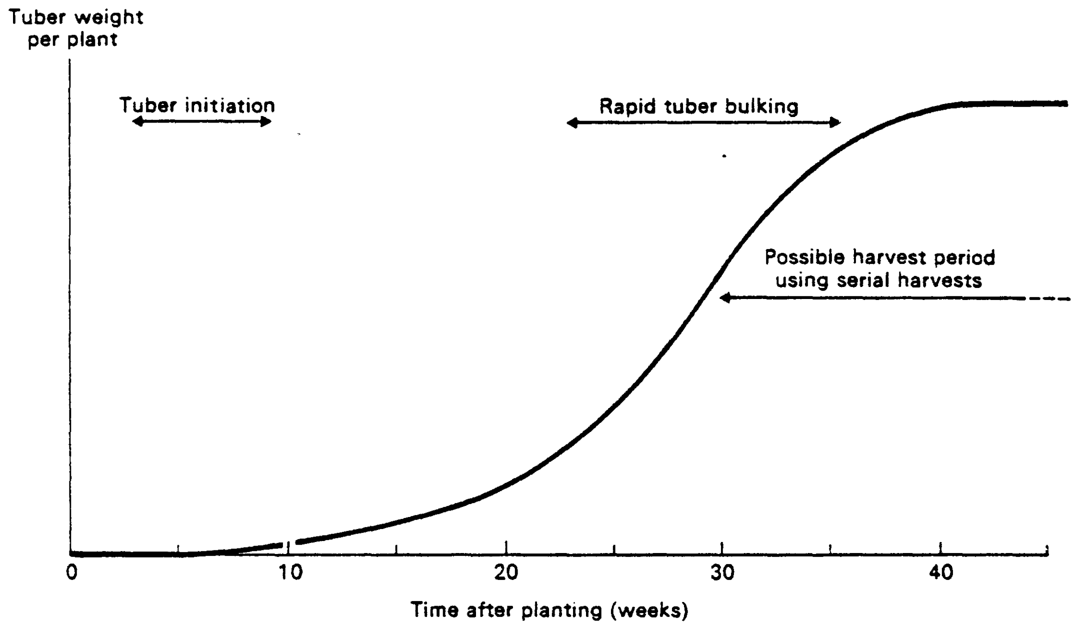

Figure 6.1 Idealized development of sweet potato tuber yield in the PNG highlands

the rapid tuber bulking phase, but these are not particularly marked. One consequence is that assessment of crop maturity is subjective and is dependent on the cultivator's experience and expectations. Another consequence is that it is possible to store tubers on the plant before harvesting, without deterioration.

In the highlands, people practise serial harvesting. The gardeners inspect the tubers by removing the surrounding soil and then selectively harvest the largest ones(2). Up to five such harvests may be made from a single plant over a period of several months. This spreads the harvesting period and increases the flexibility of tuber availability (Figure 6.1).

CLIMATIC INFLUENCES ON YIELD: THE LITERATURE

The four major climatic factors that influence the growth of crops are daylength, solar radiation, temperature and soil moisture. The influence of variation of these factors on sweet potato tuber yield is now reviewed.

Daylength and Solar Radiation

Little detailed information is available on the influence of daylength and solar radiation on sweet potato yield. Short days with low light intensity promote tuber formation while long days tend to favour vine growth at the expense of tubers (Hahn, 1977; Onwueme, 1978:169). However, the annual variation in daylength in the PNG highlands (45 minutes) is small and is unlikely to influence yield.

Experimental findings from the Solomon Islands and Japan indicate that solar radiation may sometimes be a limiting factor for maximum yield. Under conditions of low solar radiation in the Solomon Islands, Gollifer (1980) found that yield was positively correlated with solar radiation for the three, two and one month periods prior to harvest. In Japan mean solar radiation has been found to be positively correlated with the tuber growth rate (Agata, 1982). Solar radiation in the highlands does vary over time, and so may influence yield.

Temperature

The literature on the influence of temperature in sweet potato yield is also limited and is sometimes conflicting. For example, Hahn (1977) states that relatively low temperatures promote tuber initiation and that the crop grows well under high temperature conditions. On the other hand, Sekioka (1970) suggests that best yields are obtained when

(2) Sometimes the largest tubers are left to attain maximum size if they are to be used for prestation (R. Hide, pers. comm., 1987).

plants are grown under relatively high temperatures (25-30 °C) during early crop growth and at somewhat lower temperatures (20-25 °C) later. Contrasting day and night temperatures (29/20 °C) give greater tuber yields than a constant temperature regime (29 °C) (Kim, 1961), suggesting that the moderately large diurnal temperature variation that occurs in the highlands would favour higher yields.

Temperature influences the rate of crop development and the period from planting to harvesting in PNG. In Chimbu the time to first harvest increases in a linear manner from 17 weeks at 1400 m to 49 weeks at 2600 m, but within this altitude range yield per unit area is not related to altitude (Goodbody, in press). Other observations also indicate that crop development is delayed by lower temperatures in PNG but crop yields are not affected. For example, experimental yields of 15 to 30 t/ha are the norm at the HAES at Aiyura (1620 m) for 7 to 9 month crops and yields of up to 40 t/ha are routinely achieved on very fertile soils in the Wahgi Valley at the Highlands Agricultural College (1600 m) (T. Bannister, pers. comm., 1978). These yields are greater than experimental yields in the PNG lowlands which are typically 15-20 t/ha for 5 or 6 month crops. These observations are consistent with an important hypothesis recently proposed by Rawson (in press)(3).

Sweet potato plants are subject to chilling injury when exposed to temperatures in the range of 0 to 10-12 °C (Lewis, 1956; Raison, 1974). If exposure to the chilling temperatures is brief, the changes in plant tissue are reversible, but they become irreversible after prolonged exposure. Cultivars differ in their sensitivity to chilling temperatures (Wu *et al.*, 1974). It is possible that prolonged exposure to temperatures in the range of 0 to 12 °C may reduce sweet potato yields in the highlands, but insufficient information is available to assess this properly.

The intolerance of sweet potato to frost is widely acknowledged and at times frost is an important constraint on sweet potato production in high altitude locations in the PNG highlands. Few detailed studies are available on the effects of frost on yields. In the PNG highlands, Scoullar observed the influence of frost on sweet potato tuber production in the Laiagam area (2200-2700 m) in 1971 (Scoullar, 1972; Wohlt *et al.*, 1982). Scoullar reported that if a crop is frosted before tuber bulking occurs, crop maturity is delayed but the same tuber yield is still achieved. The time of harvesting, which is normally between 9 and 12 months after planting at these altitudes, is extended up to 15 months. Crops

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(3) Rawson (in press) has proposed that for wheat grown in the tropics, the effects of temperature on growth are not due to temperature *per se*, but due to the increased requirements for growth resources per unit calendar time as temperature increases. Rawson suggests that temperatures in the range that do not injure plants have no effect except to change the relationship between plant time and calendar time. The implication is that lower temperatures may influence the rate of crop development, but, within the non-injurious range, they will not influence ultimate yield. When temperatures are higher, plants may not be able to receive growth resources, such as sunlight, quickly enough to achieve their yield potential because of the accelerated rate of plant development.

frosted during tuber bulking (about 6 to 9 months) yield watery, inedible tubers. For crops frosted after nine months, tubers cease growth but remain edible for up to four months after the frost.

To summarise: The small annual temperature variations that occur in the PNG highlands would be very unlikely to influence crop yield, although they could influence the rate of crop development. The available information does not allow prediction of the influences of chilling temperatures on yield. The effect of frost on yield appears to vary with the developmental stage of a crop.

Soil Moisture

Sweet potato is tolerant of drought (Hahn and Hozyo, 1983). This is demonstrated by experimental results which show that the maximum yield response to applied water occurs at soil moisture levels that are well below field capacity (Jones, 1961; Peterson, 1961; Biswas *et al.*, 1980; Hammett *et al.*, 1982)(4). For example, in Alabama, Jones (1961) found that crops irrigated whenever the available water capacity fell to 20 per cent of field capacity produced yields as high as those irrigated to higher levels of soil moisture; and in Louisiana, Hammett *et al.* (1982) recorded no increased yield from maintaining soil moisture at 50 per cent compared with 25 per cent. Nevertheless, there is abundant evidence that sweet potato yields are increased by irrigation when soil moisture levels are very low, indicating that severe moisture stress may depress yield (for example, Hernandez and Hernandez, 1967; Wood, 1976; Biswas *et al.*, 1980; Sajjapongse and Roan, 1982; Ghuman and Lal, 1983).

Some workers report that very low levels of soil moisture are detrimental early in the crop life when tubers are being initiated (Hernandez and Hernandez, 1967; Wilson, 1982), but other results indicate that low soil moisture levels are more critical later in the growing period (Hartman and Gaylord, 1943; Hernandez and Hernandez, 1967; Wood, 1976; Sajjapongse and Roan, 1982).

Waterlogging or very high soil moisture levels are detrimental to tuber yield, particularly when either occurs during the tuber initiation phase (Sajjapongse and Roan, 1982; Wilson, 1982; Hahn and Hozyo, 1983). Hahn and Hozyo note that oxygen deficits

(4) "Field capacity" is the term used to describe the maximum water content that the soil will hold following free drainage. "Permanent wilting point" is defined as the soil moisture content at which the leaves of sunflower plants wilt permanently. The soil moisture content of -15 bars water potential is assumed to represent permanent wilting point. "Available water capacity" is defined as the volume of water retained between the field capacity and permanent wilting point. "Waterlogging" occurs when the soil is saturated beyond field capacity and when the drainage is impeded. This produces an oxygen deficiency in the root zone (Landon, 1984:84-97).

induced by high soil moisture conditions during the first 20 days after field planting inhibit tuber initiation and development. Other results suggest that very high soil moisture levels are most detrimental towards the end of the growing season (Kays *et al.*, 1982) or during the entire growing period (Gollifer, 1980).

Highlands villagers in PNG have also commented on the soil moisture-yield relationship. In both the Eastern Highlands and Southern Highlands, people stated that low yields are obtained when sweet potato is planted into very wet soils following extended periods of high rainfall. At Asiranka the women whose gardens I monitored said that poor yields are obtained from crops planted in the poorly drained soils in the drainage depressions (Figure 2.6), except during a drought when crops planted in these soils yield very well. These observations are in agreement with the international literature which suggests that waterlogged conditions during the tuber initiation phase are most detrimental to high yields.

Variation in soil moisture is clearly a potential source of sweet potato yield variation in the PNG highlands. The above summary of the international literature indicates that yields may be reduced when soil moisture drops below about 20 per cent of field capacity and also by very high soil moisture, particularly when the soil is waterlogged. Waterlogging is probably most detrimental during tuber initiation and very low soil moisture is most detrimental during the rapid tuber bulking phase. However, there is no consensus in the literature as to periods when soil moisture extremes are most critical.

Before turning to the results of PNG surveys and experiments, global studies on sweet potato time-of-planting trials are summarised as these provide further insights into climatic influences on yield. Time-of-planting trials in the Papua New Guinea context are not conducted to find the best period of the year for planting, but to explore the relationship between climatic variation and yield.

Global Studies on Sweet Potato Time-of-Planting

Studies on the best planting time to achieve maximum yield have been conducted in a number of sweet potato growing areas of the world. The results of 20 studies are summarised in Figure 6.2 where the optimum period for planting is plotted against degrees of latitude. Nine of the studies are based on single trials only, four are based on more than one trial or year's results and are presumably therefore more reliable, and the remainder are general recommendations or statements. Details on sources are given in Table A11.1.

Despite the wide diversity of sources, some clear patterns are apparent. In temperate or sub-tropical locations that are more than 26° North or South of the Equator,

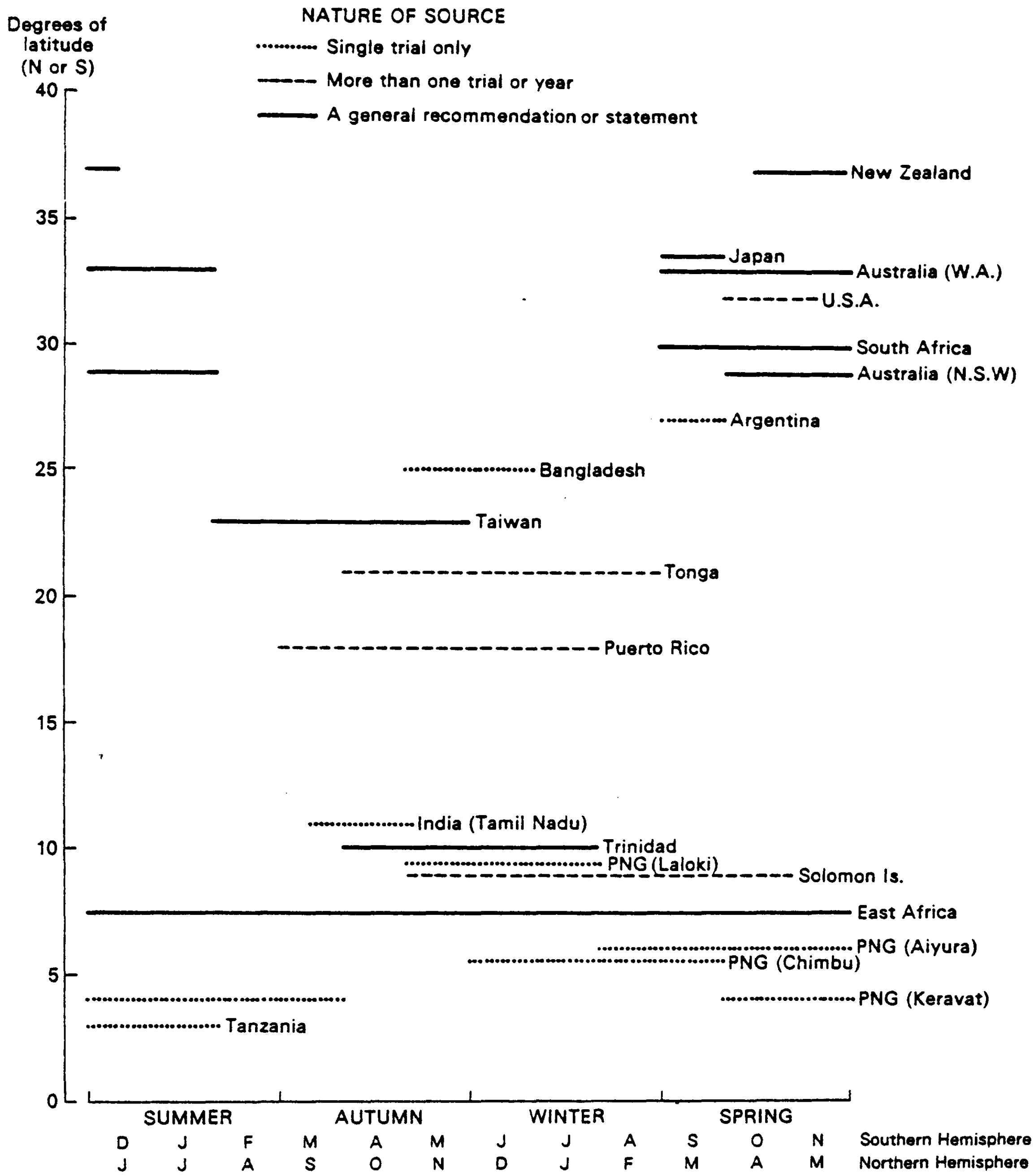

Figure 6.2 Optimum planting period to maximise sweet potato yield by latitude

the best time for planting sweet potato is in the spring or early summer. In contrast, trials and experience in sub-tropical locations between 9° and 25° North or South indicate that autumn and winter plantings give maximum tuber yields. Observations from the equatorial zone (0° to 8° North or South) are restricted to PNG, Tanzania and East Africa generally and some of the PNG findings may not be valid (Table A11.1, notes). Nevertheless, there is no general agreement for the equatorial zone regarding the best time of planting to obtain maximum tuber yield.

The information summarised in Figure 6.2 suggests a number of relationships between climatic factors and tuber yield, although the nature of the data makes it difficult to distinguish clearly between the various climatic factors. At latitudes greater than 26° North or South, the main climatic factor limiting tuber yield and dictating spring and early summer plantings is likely to be temperature. Crops can only be planted after the last frost of winter and must be harvested before the first frost of the following winter. The recommendations for spring rather than summer plantings, even in frost free locations, suggest that tuber initiation may be favoured by shorter days, lower light intensity and cooler temperatures. However the data do not allow separation of the effects of these three factors.

The consistency of the findings from sub-tropical locations between 9° and 25° North or South that autumn and spring plantings give the best tuber yields clearly indicates that shorter daylength, lower light intensity and cooler temperatures are most conducive to tuber initiation (cf Hahn, 1977; Onwueme, 1978). These findings suggest that daylength, solar radiation and temperature, are more important determinants of tuber yield than soil moisture conditions in the sub-tropical zone, at least under the usual range of field conditions for soil moisture.

The absence of any overall optimum time of planting for sweet potato in the equatorial region, which includes the PNG highlands, suggests that variation in soil moisture, and possibly solar radiation, are likely to influence yield, but changes in daylength and temperature are not likely to do so. Highlands villagers in PNG consistently deny that sweet potato yields vary on a predictable annual basis and their observations are consistent with the interpretation of this data set(5).

The above literature review indicates that the most important climatic influence on sweet potato yields in the highlands is likely to be extremes of soil moisture and possibly

(5) Highlanders do claim that yields of certain other crops are dependent on the planting period. For example, at Asiranka best yields of winged beans are said to be obtained from crops planted between May and September; and the best yields of cucumber for crops planted between May and July. On the Nembi Plateau, hyacinth bean, winged bean, *Amaranthus tricolor* and *Nasturtium schlecteri* are said to yield well only when planted during the traditional time for planting the mixed vegetable gardens (October to January).

solar radiation. Daylength and temperature variation are unlikely to be important, except for extremely low temperatures. These factors are examined in the analysis of sweet potato time-of-planting trials which follows.

PAPUA NEW GUINEA TIME-OF-PLANTING STUDIES

Studies on the influence of time-of-planting and climatic variation on crop yield may be conducted in a number of ways. Three techniques have been used in the PNG highlands. The first was recordings of yield from village plantings over a number of months; the second was formal time-of-plantings trials on a research station and in village plots; and the third was analysis of yields from plantings made on a research station at different times but not in a formal time-of-planting trial.

The basic recordings from village plantings are weight of tubers and area from which they were harvested, although other recordings are useful. There is a major problem in recording village yields because gardeners may select tubers of different age for harvest in order to maintain a steady household supply. This means that plants being harvested in any month may have experienced quite different growing conditions and the mean age of plants harvested may vary considerably from month to month. The date of planting of the plots being harvested is generally unknown. This was the case in my surveys, and thus it is not possible to attempt to correct for variable growing periods. Because of the serial harvesting techniques used by villagers, it is necessary to record the number of previous harvests made from each plot currently being harvested. Alternatively the researcher can request people to harvest completely a plot that has not had any tubers previously taken from it, but this represents a departure from the village method. Both techniques were used in a longitudinal study of sweet potato yield at Asiranka Village.

The second technique is formal time-of-planting trial, in which a series of plantings is made on a research station or in village plots, typically at monthly intervals for at least 12 months. A standard experimental design is used. Time-of-planting trials present a number of special experimental problems. These include: variable pre-planting conditions for each treatment, a greater likelihood of changes in technique or stealing because the trials extend over a long period, and the possibility of pest and disease buildups because plantings are made in contiguous areas. Variable pre-planting conditions can be reduced by planting another crop before each treatment planting, and this was done in the second sweet potato time-of-planting trial at Aiyura. Because of these special difficulties, it is important that results are compared with other data sources, such as market prices and villagers' observations. The third technique used is analysis of yields from plantings made for other purposes, where conditions other than climatic variation were reasonably uniform for each planting. Sweet potato yields are available from a soil exhaustion trial at Aiyura for a 19 year period and these yields are analysed for climatic influences.

Because of conceptual faults in the survey design and because of irregularities in data collection, the village surveys did not yield useful information on the relationship between climatic variation and yield. The survey results are presented here so that these problems are not repeated in the future. Results of three of the time-of-planting trials are interpreted as revealing an important flaw in experimental design for crops such as sweet potato. Again results reveal little about the effect of climatic variation on sweet potato yield, but they are presented in full because this finding is potentially important in this and other types of experimental work with sweet potato.

Asiranka Longitudinal Yield Survey

A longitudinal yield survey was commenced in Asiranka Village in July 1981. The purpose of the survey was to document variation in sweet potato yields over time and to relate this to climatic variation. During the regular monthly survey of area of crops planted, I requested each of the ten women being surveyed to do a complete harvest of one of their mature sweet potato plots. The following recordings were made: area harvested, weight and number of tubers, cultivars present, and the number of years of cropping since the previous fallow. The yield per unit area and mean tuber weight were later derived. The area per plot ranged from 3 to 9 m^2. Because the survey disrupted the women's normal harvesting routine, it was possible to obtain only 33 yield recordings in total, and it was discontinued after December 1981.

Given the high variability of sweet potato yields, the number of recordings per month was too small to provide meaningful information on variation in yield over time. The mean tuber yield was 14.6 t/ha (SD 9.3 t/ha) and the mean tuber weight was 280 g (SD 168 g). Despite the small number of recordings, there was an indication that yields declined rapidly with increasing years of cropping since the previous fallow, and then stabilized (Table 6.1). This pattern is similar to that reported for sweet potato yields from volcanic ash soils in the Tari Basin by Wood (1984a:165-170). The finding that higher yields are obtained from crops planted immediately after a fallow is later used to derive a model of variation of sweet potato supply over time (Chapter 9).

Another survey of village yields with a larger sample size of 60 recordings per month was then started. The techniques were tested in August 1981 and the survey ran from September 1981 to August 1982. A village man who was literate in Melanesian Pidgin was employed to conduct the survey and the author and his research assistant participated occasionally. The women gardeners do an incomplete harvest of tubers from a

Table 6.1 Sweet potato yield survey, Asiranka Village, complete tuber harvest: yield vs number of years since previous fallow(1)

Number of years since previous fallow(2)	Number of recordings	Mean yield (kg/ha) Mean	SD	Mean tuber weight (g) Mean	SD
0	2	30,400	15,190	364	132
1	11	19,830	9,130	375	229
2	3	13,900	5,590	319	171
3	5	11,040	3,260	264	23
4	3	7,510	4,630	170	67
≥5(3)	9	9,230	6,050	165	27
Total/mean	33	14,570	9,320	280	168

$Y = 21.96e^{-0.17x}$ $r = 0.821^{*}$

where Y = tuber yield (t/ha)(4)
e = natural log base (2.718...)
x = number of years since previous fallow
r = correlation coefficient

Notes

(1) The survey was conducted between July and December 1981.

(2) Each gardener was asked how many years the plot being harvested had been cropped since its previous fallow, but their answers may also have referred to the number of sweet potato crops planted since the fallow. At this altitude, the interval between plantings approximates to one year. Hence this classification is an approximate one only.

(3) The mean number of years for this category is 7.2.

(4) This exponential curve is based on mean yields for each age since fallow category, not individual yield records. The curve derived from the actual recordings is also significant ($n = 33$; $r = 0.604^{***}$).

discrete section of adjoining mounds and hence it was possible to record the weight of tubers harvested from a known area. The technique used was as follows: In mid- to late afternoon, the surveyor(s) moved through the sweet potato gardens of Asiranka Village seeking women who were harvesting or had just completed harvesting tubers for the evening meal. The following recordings were made: the weight and number of tubers harvested, the area of crop from where the tubers were harvested, and cultivars in the plot. The gardener was asked how many previous harvests had been made from the plot and the number of years of cropping since the previous fallow. The number of yield recordings was usually between three and seven per day.

Checks during the year-long survey suggested that the technique was being followed correctly. However closer examination of recordings on the number of years of cropping since the previous fallow and the number of previous harvests from the plot just harvested indicated that the data were not reliable. Whether this was because of fabrication of results or misunderstanding of the questions was not certain. However, it meant that it was not possible to compute a figure for the total yield per unit area harvested in each month and doubt was thrown on the validity of yield recordings obtained. For this reason the yield data are presented as monthly means of all harvests irrespective of the number of previous harvests from the plot (Table 6.2). Differences between mean monthly tuber yield and mean monthly tuber weight were statistically highly significant ($P < 0.001$, ANOVA). Mean tuber weight declined with time over the survey period and the relationship between tuber weight and the number of the survey month was highly significant ($n = 12$; $r = -0.883$***).

Market prices have been established as a reasonable indication of village supplies (Chapter 3). As a check on the validity of the village yield results, correlations were sought between price of sweet potato being sold by Asiranka villagers and the mean tuber yields. No significant relationship was found, and this reinforces the conclusion that these results were not reliable.

Despite the considerable efforts expended in obtaining these data for the second village yield survey, the results cannot be accepted as valid for two reasons. The first is doubt about the reliability of the data. The second is the problem of unknown age of plants and tubers being harvested which would render interpretation of even reliable data extremely difficult. However, they can be used to derive an estimate of mean sweet potato yield in this community (Table 6.2).

Table 6.2 Sweet potato yield survey, Asiranka Village, partial crop harvest: yield vs month of harvest, September 1981 to August 1982(1)

Year	Month of harvest	Number of recordings	Mean yield (kg/ha)		Mean tuber weight (g)	
			Mean	SD	Mean	SD
1981	Sep	64	5070	4470	245	209
	Oct	57	4290	3580	211	111
	Nov	58	3010	1680	191	95
	Dec	60	1870	740	197	85
1982	Jan	60	2280	1140	197	136
	Feb	60	3230	2180	138	95
	Mar	60	3930	2160	223	174
	Apr	60	3680	2040	151	121
	May	60	3610	1840	131	98
	Jun	60	3790	2090	107	57
	Jul	70	3540	1920	96	61
	Aug	60	3970	2450	99	47
Total/Mean		729	3500(2)	2330	164	126
Level of significance (ANOVA)			***	-	***	-
Least significant difference (0.05)			767	-	42	-

Notes

(1) Data presented are the mean of all recordings. Data collected on the number of previous harvests for each plot harvested were unreliable. Hence it was not possible to calculate the total yield per unit area for each month.

(2) Despite doubts about the validity of the monthly means, the mean of all yield recordings of 3.5 t/ha is likely to be a reasonably good estimate of yield. If it is assumed that four harvests are taken on average for each planting, the overall mean yield is 14 t/ha (3.5 t/ha by 4). This is in close agreement with the estimate of 14.6 t/ha from the smaller but more reliable sample based on complete tuber harvests (Table 6.1), although it is still only a crude estimate of total yield given the large standard deviation.

Published PNG Experimental Results

Prior to presenting my experimental results from time-of-planting studies in the PNG highlands, the published findings of other workers in PNG and the Solomon Islands are reviewed.

Lowland studies. Two studies conducted in the PNG and Solomon Islands lowlands suggested regular seasonal variation in yield and a negative relationship between yield and rainfall during crop life. In the Solomon Islands, a five year experiment indicated that highest yields were obtained from harvests made between September and February (Gollifer, 1980). A positive correlation was found between tuber yield and solar radiation, and there was a negative relationship between yield and rainfall during the crop life. A one year trial in the PNG lowlands gave similar results (King, 1985). In this trial, plantings harvested between October and December gave the greatest yield, and tuber yields were negatively correlated with total rainfall plus irrigation during the cropping period(6).

Kondiu, Chimbu Province. A year long sweet potato time-of-planting trial was conducted at Kondiu (1500 m) in Chimbu by Goodbody (in press). Highest yields occurred from plantings made between June and August 1981 and in April 1982 and August 1982. Goodbody devised a "Growing Period Rainfall Index" (GPRI) by dividing the rainfall between 90 and 120 days after planting by the rainfall during the 30 days preceding planting. He reported a significant positive relationship between tuber yield and the GPRI ($r = 0.68^*$). This result suggests that, for this trial, the best yields were obtained from crops planted when the soil moisture content was relatively low and which received high rainfall during the period of rapid tuber bulking.

Pot trials, Kundiawa, Chimbu Province. Goodbody also conducted three irrigation pot trials with sweet potato at Kundiawa. Little statistical significance was obtained and there are problems in extrapolating the results of pot trials to field situations, but some preliminary conclusions may be drawn. Tuber yields were reduced when water was applied at rates of less than 470 mm per crop; and above this level, yields were not depressed at irrigation rates of up to at least 1870 mm per crop. Drought periods of 50 days reduced tuber yield, and the effect of drought on tuber yield was most severe between 90 and 140 days after planting when rapid tuber bulking was occurring. Tuber yields were least affected by drought during the first 50 days of crop life (Goodbody, in press).

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(6) Sweet potato prices in Port Moresby market exhibit a weak regular seasonal trend, with prices highest at the turn of the calendar year. These price trends are not consistent with King's trial results. A possible alternative explanation is that the findings of both lowlands trials reflect weak seasonal changes in daylength and temperature, which occur at the latitude of the trial locations (9°S) (Figure 6.2).

Karimui, Chimbu Province. Hide *et al.* (1984:262-280) conducted a time-of-planting trial at Karimui (1120 m) on a volcanic ash soil (Hydrandept), with 10 plantings established at monthly intervals. They reported a significant negative correlation between tuber yield and rainfall during the entire cropping period. Changes in soil properties between treatments suggested that the negative effect of high rainfall on tuber yield was caused by leaching of soil nutrients, particularly potassium.

Kiburu, Southern Highlands Province. At Kiburu (1680 m) near Mendi, Anders (in press) conducted another time-of-planting trial on an (Aquic) Eutrandept soil. Preliminary results of the first 18 plantings from the trial were interpreted by Anders as showing weak positive correlations between yield and rainfall during the month preceding planting and the first month of growth. However, this apparent relationship probably occurred because yield and rainfall both declined during the course of the trial. The soil was almost fully saturated (80 to 100 per cent of field capacity) at Mendi for most months of the trial period and only dropped below 20 per cent in two months (Table A12.3). This suggests that water stress could not have been responsible for the yield pattern obtained. Anders' preliminary conclusions are not accepted as a repeatable finding.

Piwa, Southern Highlands Province. Results of two identical cultivar trials conducted at Piwa (1600 m) near Tari by E. D'Souza (pers. comm., August 1985) are useful in understanding the relationship between soil moisture and tuber yield(7).

The trials were located on alluvial silty clay ((Aquic) Entic Eutrandept) (Radcliffe, 1985b). The first trial was planted in May 1982 and harvests were made at 6, 8.5 and 11 months after planting. The second trial was planted with the same cultivars a year later in May 1983 and harvests were made at the same intervals after planting. Mean yields in the first trial were high (8.6, 8.6 and 10.0 t/ha for the three harvests respectively) and they were much lower in the second trial (6.5, 2.6, 0.6 t/ha for the three harvests respectively). Thus the mean total yield in the first trial was 27.2 t/ha and in the second trial it was 9.7 t/ha.

The two trials experienced markedly contrasting growing conditions. Rainfall was low during the bulking period of the first trial because of the 1982 drought, with a mean rainfall in Tari of 55 mm per month between July and November 1982. It was high during much of the growing period of the second crop, particularly between October 1983 and April 1984 when rainfall averaged 300 mm per month. Because this experiment was not designed to evaluate soil moisture-yield relationship, definite conclusions are not possible.

(7) This research was conducted while D'Souza was a member of AFTSEMU and this was not collaborative work with the author.

However, the contrast in tuber yields almost certainly occurred because of these different rainfall conditions. Relatively low rainfall (55 mm per month) during tuber bulking did not diminish tuber yield in the first trial; but very high rainfall during much of the growing period of the second trial appears to have depressed yields considerably.

Summary. In four field trials and one series of pot trials in the PNG highlands and two field trials in the PNG and Solomon Islands lowlands, relationships were found between sweet potato yield and rainfall. Except for the trial at Kiburu, all experiments indicated that tuber yield was at times reduced by very high rainfall. The only indication that drought reduced yield came from the Kundiawa pot trials. In these pot trials, yields were only depressed when applied water levels were low and the effects were most severe during the tuber bulking phase.

There was no general agreement from these experimental results as to when excessive rainfall had the greatest effect on yields. The trials in the PNG and Solomon Islands lowlands and the Karimui trial suggested that it is total rainfall during the crop growing period that is most important; the Kondiu one suggested that high levels of soil moisture at planting were detrimental but high levels in the tuber bulking period were advantageous.

Further Experimental Results

The results of five trials conducted or analysed by the author are now presented.

The first was a long term soil exhaustion trial at Aiyura conducted by various DPI agronomists. The trial provided sweet potato yields over a 19 year period from plantings grown under fairly uniform conditions. The other four experiments were formal time-of-planting trials. Two were done by the author at Aiyura, another by E. D'Souza under the author's direction on the Nembi Plateau, and the remaining trial at Oksapmin in West Sepik Province by J. Darby who kindly gave access to his unpublished results for analysis.

Soil exhaustion trial, Aiyura. The trial was designed to examine changes in soil fertility and sweet potato yield with continuous cropping and 24 plantings were made between 1955 and 1973. There was no clear indication that yields declined greatly over this period. There were large variations in the yields of the various plantings, and this is likely to have occurred because of climatic variation. Experimental details are given in Table 6.3. The trial site was not as well drained as sites typically used for sweet potato in the Eastern Highlands, although the site had been used previously by local villagers for that purpose. A number of problems occurred in the conduct of the trial, and these detract somewhat from the value of the results. These were a change of cultivar used after the 9th planting (Kimber, 1974), and variation in the period between sweet potato plantings (one day to 15 weeks). The trial was modified after the 15th planting in order to compare fallow and non-fallow treatment, but for consistency only results from the fallow treatment are analysed here(8).

Trial results are presented in Tables 6.4 and A11.2 and Figure 6.3. Yields varied considerably between plantings, but there was no indication of any annual pattern (Table 6.4). There was a significant negative relationship between the number of weeks when the soil was fully saturated during the first 30 weeks of crop growth and tuber yield (Table 6.10, Figure 6.3). Conversely, yield was positively correlated with the number of weeks when the soil was very dry (SMS < 20 mm). Yield was not significantly correlated with other measures of rainfall or soil moisture storage (Table 6.10).

Aiyura time-of-planting trial 1. Experimental details for the first time-of-planting trial at Aiyura are given in Table 6.3. The trial site was poorly drained and such a site would usually be considered too wet for best sweet potato yields. A change of technique was made after the first eight plantings when the cropping period was increased from 7 to 8 months. Results are presented in Tables 6.5, A11.3, A11.4, A11.5 and Figure 6.4.

There was considerable variation in the yields of the various plantings (Table 6.5). Differences were statistically significant for treatments 1 to 12 but not for treatments 13 to 24 (Table A11.3). Yields were best for plantings made when the soil was drier at planting and when the soil was fully saturated towards the end of the crop growth (Table 6.10, Figure 6.4). This combination produced a positive correlation between yield and the GPRI (Table 6.10)(9). There was no statistical association between yield and measures of temperature, bright sunshine and solar radiation (Table 6.11).

Aiyura time-of-planting trial 2. Experimental details for the second time-of-planting trial at Aiyura are given in Table 6.3. The trial site was well drained and this soil type is very widely used for sweet potato gardens in the highlands. There were no problems in the conduct of this experiment. All plantings were preceded by a crop of

(8) Kimber (1974) claims that yields after the 15th planting were increased for crops that followed a six week fallow, but my re-analysis does not indicate any relationship between fallow period and yield. Experimental techniques for this comparison are not documented fully but there is no indication that experimental design allowed separation of the effects of climatic variation and fallow period.

(9) Partial correlations did not separate the effects of low soil moisture at planting and high soil moisture towards the end of crop growth (Table 6.12). The available water capacity of this soil was probably greater than the assumed value. Hence, the actual SMS was probably greater than 20 mm, even during the driest period of the trial, and no water stress occurred.

Table 6.3 Experimental details for the soil exhaustion trial and two sweet potato time-of-planting trials at Aiyura

	Soil exhaustion trial	Time-of-planting trial 1	Time-of-planting trial 2
Trial identification	ASF 2	AIB 17(1/2)	AIB 17(3)
Location	Block C2, HAES	Block A5, HAES	Block D10, HAES
Altitude (m)	1620	1620	1620
Previous land use	Short grass fallow	Long grass fallow	Grass fallow; peanuts
Soil class (USDA)	Tropaqualf	Tropaquept	Hydrandept
Soil class (local)	Poreramaka	Irarampa	Poreramaka
Soil drainage	Poorly drained	Very poorly drained	Well drained
Soil texture	Sandy clay loam	Fine sandy clay loam	Sandy clay loam
Treatments	Fallow length	Month of planting	Month of planting
Number of treatments	4/2(1)	24	12
Experimental design	Randomized blocks	Randomized blocks (5)	Randomized blocks
Number of replicates	4	5	5
Plot size (m^2)	83.6	14.4	9
Mounds per plot	8(2)	9	9
Mound height (cm)	30	30	30
Guard rows	None	None	None
Fertilizer; pest and disease control	None	None	None
Cultivar	?(3)	Merikan	Merikan
Planting density (cuttings/ha)	28,700	50,000	80,000

No of cuttings per planting position	1	2	2
Trial duration	Nov1955-Dec1973	Aug1979-Mar1982	Oct1980-Apr1982
Growing period per planting (weeks)	28-47(4)	30-31/34-35(6)	33-34
No of harvests	1	1	1
Time to harvest (weeks)	28-47(4)	30-31/34-35	33-34
Trial conducted by	R.S.Carne,A.J.Kimber, K. Newton, T.J.E. Quinlan, A.J.Schindler	R.M. Bourke	R..M. Bourke

Notes

(1) The soil exhaustion trial was designed to examine changes in sweet potato yield and soil fertility with continuous cropping over a long period. In the original design, there were four treatments, but they differed only in the fallow treatment prior to the first sweet potato planting. At the 15th planting, the trial was split into two treatments to compare a six week fallow between plantings and a no fallow treatment; but fallow lengths deviated considerably from six weeks. The yield data analysed here for the 15th to 24th plantings are from the fallow treatments so as to be consistent with yields for the first 14 plantings.

(2) Eight rows were used, each 1.2 m apart.

(3) There was a change of cultivar after the ninth planting, but records of the cultivars used are no longer available.

(4) Most plantings were harvested at between 28 and 34 weeks after planting, but five plantings between 1967 and 1973 had growing periods of between 35 and 47 weeks. Replanting was done between 1 day and 15 weeks after harvest of the previous planting, although there was a 58 week break between the 22nd and 23rd planting.

(5) Treatments 1 to 12 were located in one block (60 plots) and treatments 13 to 24 in another block (60 plots).

(6) Treatments 1 to 8 were harvested at 7 months (30 or 31 weeks) and treatments 9 to 24 at 8 months (34-35 weeks), except for treatment 10 (36 weeks) and treatment 24 (33 weeks).

Table 6.4 Aiyura soil exhaustion trial: tuber yield and rainfall data

Planting number	Month of planting	Month of harvest	Total tuber yield (kg/ha) (1)	Rainfall (mm) during crop life	Rainfall (mm) 30 days before planting	Rainfall (mm) during first 13 weeks	Rainfall (mm) during final 13 weeks
1	Nov 55	Jun 56	10,190	1250	181	660	356
2	Aug 56	Mar 57	10,750	1297	120	275	786
3	Apr 57	Nov 57	20,000	1330	406	337	602
4	Dec 57	Jul 58	8,490	1293	202	733	176
5	Aug 58	Mar 59	19,660	1220	111	366	696
6	Mar 59	Nov 59	5,590	1063	338	563	363
7	Nov 59	Jun 60	4,780	1770	64	862	565
8	Jun 60	Jan 61	9,920	1197	110	164	709
9	Feb 61	Aug 61	15,310	1434	151	589	423
10	Aug 61	Apr 62	17,480	1321	-	607	476
11	Apr 62	Dec 62	13,490	1014	-	445	438
12	Jan 63	Jul 63	22,530	754	-	297	301
13	Aug 63	Apr 64	20,500	1468	-	471	-
14	May 64	Jan 65	22,930	806	-	189	354
15	Feb 65	Sep 65	15,800	1067	136	747	164
16	Sep 65	May 66	16,970	1629	14	327	835
17	Jun 66	Feb 67	17,960	1012	51	227	536
18	Feb 67	Nov 67	11,420	1506	128	748	402
19	Dec 67	Jul 68	5,470	955	281	499	274
20	Jul 68	May 69	2,930	1985	44	459	564
21	Jul 69	Mar 70	5,320	1314	53	489	490
22	Jul 70	Mar 71	5,850	1761	77	329	818
23	Apr 72	Mar 73	16,510	1929	257	376	889
24	Mar 73	Dec 73	12,480	1772	325	1014	630

Note

(1) A statistical analysis was not done on yields for this trial because individual plot recordings were not available. Other trial data are given in Table A11.2.

Table 6.5 Aiyura sweet potato time-of-planting trial 1: tuber yield and rainfall data(1)

Planting number	Month of planting	Month of harvest	Total tuber yield (kg/ha)	Rainfall (mm) during crop life	Rainfall (mm) 30 days before planting	Rainfall (mm) during first 90 days	Rainfall (mm) during final 90 days
1	Aug 79	Mar 80	30,330	1083	45	203	667
2	Sep	Apr	30,500	1198	56	347	696
3	Oct	May	31,970	1437	48	469	593
4	Nov	Jun	30,470	1435	104	740	555
5	Dec	Jul	19,470	1243	191	666	387
6	Jan 80	Aug	16,470	1158	158	696	197
7	Feb	Sep	15,970	1008	369	590	229
8	Mar	Oct	8,170	872	140	555	289
9	Apr	Dec	22,190	928	195	389	330
10	May	Jan 81	22,260	996	266	188	563
11	Jun	Feb	14,140	1160	102	229	804
12	Jul	Mar	31,100	1475	21	287	940
13	Aug	Apr	13,580	1538	79	271	730
14	Sep	May	13,470	1635	134	322	702
15	Oct	Jan	13,920	1574	76	563	399
16	Nov	Jul	17,390	1712	33	805	452
17	Dec	Aug	19,880	1846	245	814	309
18	Jan 81	Sep	14,810	1367	292	649	390
19	Feb	Oct	17,360	1295	228	678	390
20	Mar	Nov	16,030	1100	339	396	353
21	Apr	Dec	14,440	869	158	438	501
22	May	Jan 82	16,250	1219	199	390	604
23	Jun	Feb	15,330	1519	65	434	876
24	Jul	Mar	13,750	1632	131	389	1004

Note

(1) More detailed data on dates, yields and statistical analysis are given in Table A11.3.

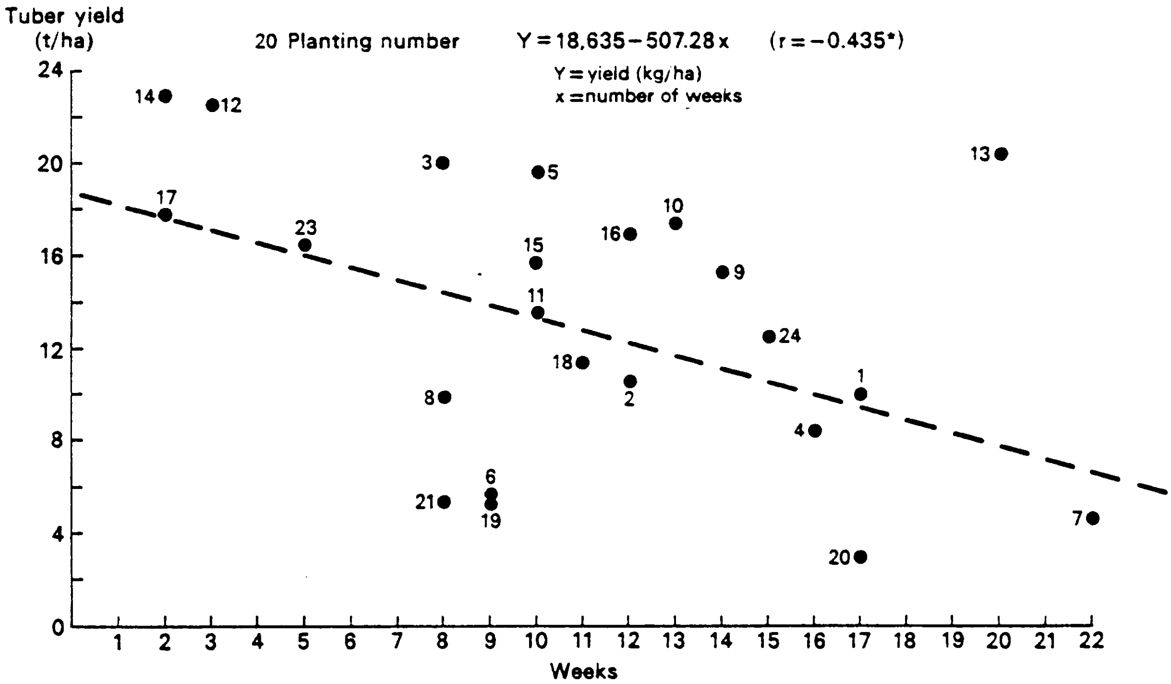

Figure 6.3 Soil exhaustion trial, Aiyura: number of weeks when the soil was fully saturated (SMS = 100 mm) during the first 30 weeks of crop growth vs tuber yield (t/ha)

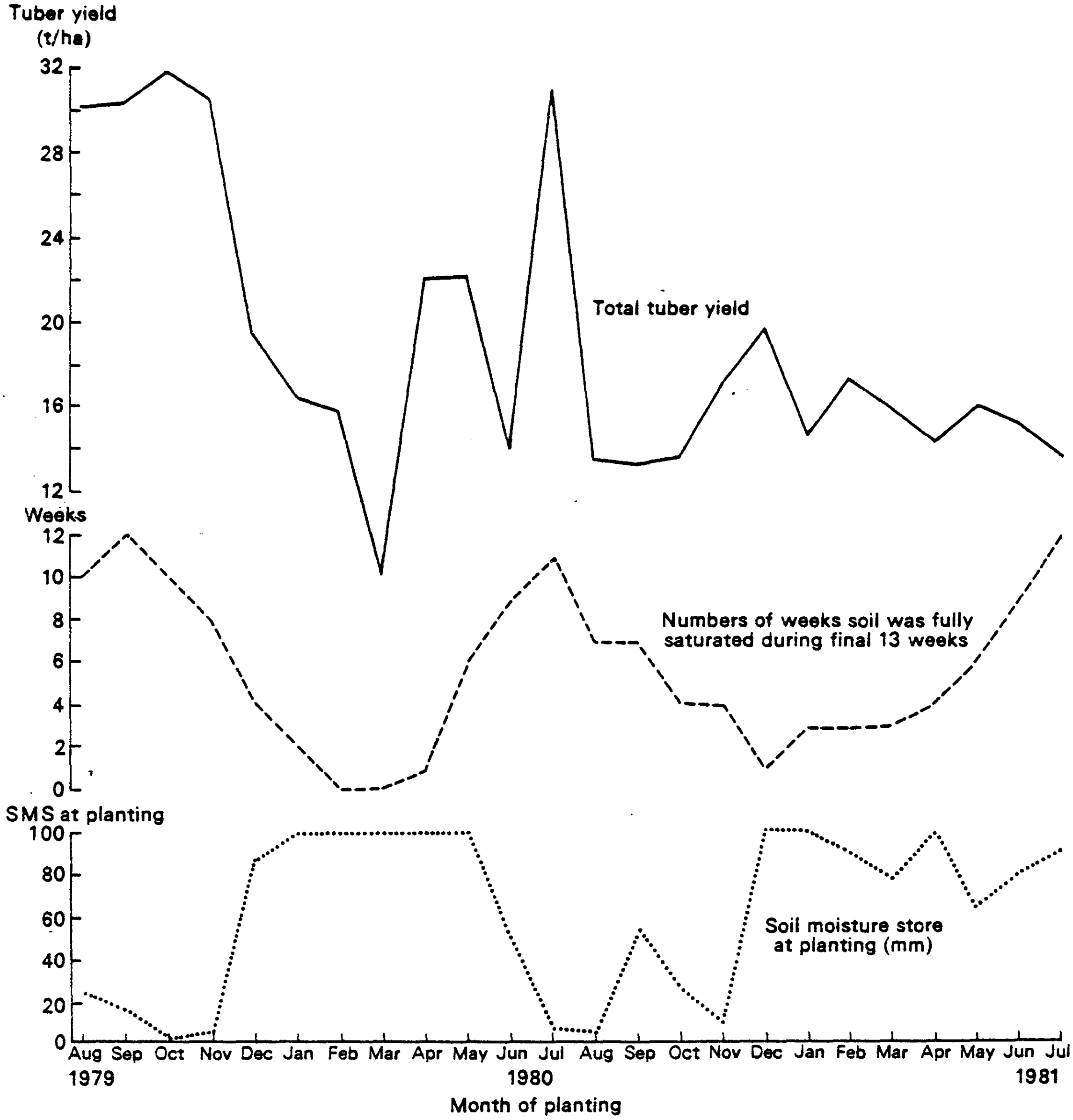

Figure 6.4 Aiyura sweet potato time-of-planting trial 1: tuber yield (t/ha); number of weeks when the soil was fully saturated (SMS = 100 mm) during the final 13 weeks of crop growth; and soil moisture storage (mm) at planting vs month of planting

peanuts to provide a uniform immediate pre-planting history. Results are presented in Tables 6.6, A11.6, A11.7, A11.8 and Figure 6.5.

Yields declined initially with successive plantings and then increased, suggesting an annual pattern of yield variation (Table 6.6, Figure 6.5). The best statistical association between yield and climatic parameters occurred for total rainfall, the number of weeks when the soil was fully saturated, and mean maximum temperature during the crop life (Tables 6.10, 6.11). Partial correlations were derived to separate the effects of these parameters and this analysis suggested that yield was highly correlated with mean maximum temperature during the crop life (Table 6.12)(10).

Nembi Plateau time-of-planting trial. Experimental details are given in Table 6.7. The trial site was not as well drained as typical sweet potato sites on the Nembi Plateau, but it had been previously used for village sweet potato. Results are presented in Table 6.8. Differences between first harvest yields were significant only at $P < 0.10$. The only statistical association between yield and climatic parameters that approached significance was that with mean maximum temperature (Table 6.13).

Oksapmin time-of-planting trial. Experimental details are given in Table 6.7 and results in Table 6.9. Yields declined and then increased with successive plantings (Table 6.9). Yield was significantly correlated with mean maximum and mean minimum temperatures during the crop life (Table 6.13).

Discussion. Both the soil exhaustion trial and the first sweet potato time-of-planting trial at Aiyura indicated that excessive soil moisture depressed yields. In both trials, best yields were obtained when the soil was drier. As with other experimental results in PNG, the findings differed concerning when very wet periods had the most detrimental effects. For the soil exhaustion trial, the total number of wetter or drier weeks during the entire growing period was important (Figure 6.3), a finding similar to that of Hide *et al.* (1984) at Karimui. For the first time-of-planting trial at Aiyura, the indication was that best yields were obtained from plantings made when the soil was drier at planting and wetter later in the crop life (Figure 6.4). This finding is similar to that of Goodbody (in press) for the Kondiu trial.

The second time-of-planting trial at Aiyura, the Nembi Plateau and the Oksapmin trials gave similar results to each other. In these three trials, the best explanation for

(10) In a published note on this trial (Bourke, 1985a), the relationship between temperature and yield was not examined as it was considered unlikely that yield variation would be explained by small temperature differences. Results were then interpreted as suggesting that yield variation was explained by variation in rainfall. The more complete analysis carried out here indicates that the earlier analysis was not valid.

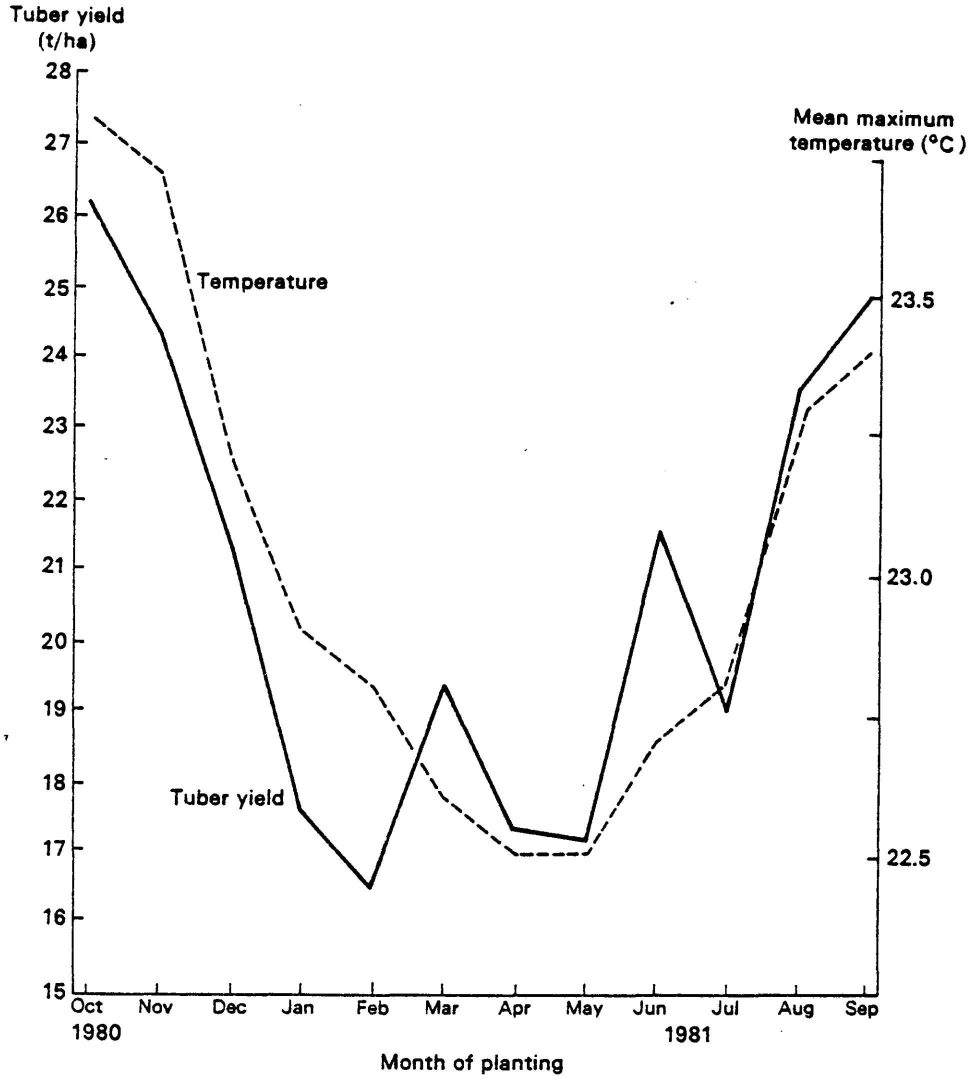

Figure 6.5 Aiyura sweet potato time-of-planting trial 2: tuber yield (t/ha) and mean maximum temperature (°C) during crop life vs month of planting

Table 6.6 Aiyura sweet potato time-of-planting trial 2: tuber yield and rainfall data[1]

Planting number	Month of planting	Month of harvest	Total tuber yield (kg/ha)	Rainfall (mm) during crop life	Rainfall (mm) 30 days before planting	Rainfall (mm) during first 90 days	Rainfall (mm) during final 90 days
1	Oct 80	May 81	26,220	1571	73	564	479
2	Nov	Jun	24,360	1667	29	804	444
3	Dec	Jul	21,310	1572	204	923	291
4	Jan 81	Aug	17,560	1405	382	704	378
5	Feb	Sep	16,580	1287	274	708	398
6	Mar	Oct	19,440	1040	354	399	392
7	Apr	Nov	17,440	1013	133	446	363
8	May	Dec	17,240	1101	275	309	532
9	Jun	Jan 82	21,600	1541	44	423	900
10	Jul	Feb	19,040	1648	151	382	1036
11	Aug	Mar	23,670	1876	104	398	990
12	Sep	Apr	25,000	1927	165	411	822

Note

(1) More detailed data on dates, yields and statistical analysis are given in Table A11.6.

Table 6.7 Experimental details for sweet potato time-of-planting trials, Nembi Plateau and Oksapmin

	Nembi Plateau	Oksapmin
Location	Embi Village	Oksapmin station
Altitude (m)	1700	1580
Previous land use	Sweet potato,then 5 year grass fallow	?
Soil class (USDA)	Hydrandept	Histosol ?
Soil drainage/texture	Well drained, clay	Drained organic soil
Treatments	Month of planting	Month of planting
Number of treatments	12	12
Experimental design	Randomized blocks	Completely randomized
Number of replicates	7	3 or 4
Plot size (m^2)	5	2.25
Mounds per plot	1	1
Mound height (cm)	50	?
Guard rows	None	None
Fertilizer; pest and disease control	None	Mounds were composted
Cultivar	Sokol	?
Planting density (cuttings/ha)	18,000	?
Number of cuttings per planting position	1	?
Trial duration	Feb1980-Mar1981(1)	Jan1981-Apr1982
Growing period (months)	9.5	5
Number of harvests	2	1
Time to harvest (months)	6.5, 9.5	5
Trial conducted by	E. D'Souza	J. Darby

Note

(1) This trial was abandoned in March 1981 because of tuber theft.

Table 6.8 Nembi Plateau sweet potato time-of-planting trial: tuber yield, rainfall and temperature data

Treatment number(1)	Month of planting	Month of first harvest	Month of second harvest	Tuber yield (kg/ha) first harvest (2)	Tuber yield (kg/ha) second harvest	Total
1	Feb 80	Aug 80	Nov 80	8340	3410	11,750
2	Mar	Sep	Dec	8220	3860	12,080
3	Apr	Oct	Jan 81	5490	4290	9,780
4	May	Nov	Feb	8040	5640	13,680
5	Jun	Dec	Mar	6260	4320	10,580
6	Jul	Jan 81	-	6750	-	-
7	Aug	Feb	-	8750	-	-

Treatment number	Rainfall (mm) until first harvest (3)	Rainfall (mm) during month before plant.	Rainfall (mm) during first three months	Rainfall (mm) during final three months (4)	GPRI (5)	Temperature (oC) until first harvest(6) Mean maximum	Temperature (oC) until first harvest(6) Mean minimum
1	1264	287	725	538	0.7	23.4	12.8
2	1505	206	704	801	0.5	23.2	12.6
3	1424	245	556	868	1.1	23.0	12.5
4	1346	274	358	807	1.6	23.0	12.4
5	1317	185	801	515	0.9	23.0	12.2
6	1458	97	868	589	2.0	23.2	12.4
7	1515	256	808	707	0.6	23.5	12.5

Notes

(1) The trial was partially destroyed by theft and the last five treatments gave no yield data. First harvests were obtained from treatments 1 to 7 and second harvests from treatments 1 to 5.

(2) First harvest yields were significantly different at $P < 0.10$ only (ANOVA).

(3) Rainfalls between planting and the first harvest.

(4) Rainfall during the three months before the first harvest.

(5) GPRI is the Growing Period Rainfall Index. This was derived by dividing the rainfall between 90 and 120 days after planting by the rainfall during the 30 days before planting (See Table A11.2 and Goodbody(in press) for further detail).

(6) Temperature data are derived from long term means from Mendi (McAlpine *et al.*, 1975:128), which is the nearest station with temperature data.

Table 6.9 Oksapmin sweet potato time-of-planting trial: tuber yield, rainfall and temperature data(1)

Treatment number	Month of planting (2)	Month of harvest	Total tuber yield (kg/ha) (3)	Rainfall (mm) during crop life	Rainfall (mm) during month before planting	Temperature (°C) during crop life(4) Mean max	Temperature (°C) during crop life(4) Mean min
1	Jan 81	Jun 81	5125	1194	171	24.8	14.6
2	Feb	Jul	5625	1246	249	24.7	14.5
3	Mar	Aug	5250	1246	199	24.4	14.5
4	Apr	Sep	5375	1062	241	24.3	14.5
5	May	Oct	4750	1230	263	24.2	14.5
6	Jun	Nov	3250	1243	242	24.2	14.3
7	Jul	Dec	3750	1249	301	24.4	14.4
8	Aug	Jan 82	3625	1115	199	24.7	14.4
9	Sep	Feb	4875	1311	57	24.9	14.4
10	Oct	Mar	5750	1047	431	24.9	14.5
11	Nov	Apr	6375	1032	255	25.1	14.5
12	Dec	May	6000	978	307	24.9	14.5

Notes

(1) The trial was conducted at Oksapmin by Mr. Jeremy Darby who kindly gave access to his unpublished data.

(2) Each treatment was planted on the first of the month and harvested five months later.

(3) A statistical analysis was not done for tuber yield because plot values were not available.

(4) Temperature data are not available from Oksapmin. The data presented are means from Telefomin (McAlpine *et al.*,1975:130) which is the nearest highland station for which temperature data are available (Figure 2.1).

Table 6.10 Correlation coefficients between sweet potato tuber yield and certain parameters of rainfall and soil moisture storage for three trials at Aiyura

Parameter	Aiyura soil exhaustion trial	Aiyura time of planting trial 1	Aiyura time of planting trial 2
RAINFALL(1)			
During crop life	- 0.364	0.032	0.747**
During 30 days before planting	0.148	- 0.351	- 0.667*
During first 13 weeks	- 0.346	- 0.137	0.080
During final 13 weeks	0.146	0.226	0.303
SOIL MOISTURE STORAGE AT PLANTING(2)	0.129	- 0.548**	- 0.574
NUMBER OF WEEKS WHEN SOIL MOISTURE STORAGE = 100 mm			
During first 30 weeks(3)	- 0.435*	0.323	0.765**
During first 13 weeks	- 0.210	0.144	0.133
During final 13 weeks	0.087	0.510*	0.407
NUMBER OF WEEKS WHEN SOIL MOISTURE STORAGE < 20 mm			
During first 30 weeks	0.445*	0.057	0.571
During first 13 weeks	0.182	0.254	0.571
During final 13 weeks	0.201	- 0.216	-(4)
GROWING PERIOD RAINFALL INDEX	0.188	0.491*	0.598*

Notes

(1) The exact length of the specified time periods varies slightly between trials, depending on the availability and organization of data.

(2) Soil moisture storage was calculated using the soil water balance model described by McAlpine (1970) for an assumed soil available water capacity of 100 mm.

(3) The crop period varied considerably between plantings in the soil exhaustion trial; it varied somewhat in the time-of-planting trial 1 (7 or 8 months); and very slightly in time-of-planting trial 2 (33 or 34 weeks). The standard period used was 30 weeks in the first two trials and 33 weeks in the third trial.

(4) In Aiyura time-of-planting trial 2, the calculated soil moisture storage did not fall below 20 mm during the final 90 days of crop growth for any treatment.

Table 6.11 Correlation coefficients between sweet potato tuber yield and certain parameters of temperature, bright sunshine and solar radiation for two time-of-planting trials at Aiyura(1)

Parameter	Trial 1	Trial 2
TEMPERATURE		
Mean maximum during crop life	0.397	0.884***
Mean maximum during first 90 days	0.177	0.044
Mean maximum during final 90 days	0.091	0.633*
Mean minimum during crop life	0.337	0.655*
Mean minimum during first 90 days	- 0.133	- 0.182
Mean minimum during final 90 days	0.399	0.346
BRIGHT SUNSHINE		
Mean during crop life	- 0.168	0.125
Mean during first 90 days	0.249	0.010
Mean during final 90 days	0.270	0.343
SOLAR RADIATION		
Mean during crop life	0.343	- 0.040
Mean during first 90 days	0.103	0.352
Mean during final 90 days	0.124	- 0.166

Note

(1) Data are not available for these three parameters for the period of the soil exhaustion trial.

Table 6.12 Partial correlation coefficients between sweet potato tuber yield and certain parameters of rainfall, soil moisture storage and temperature for two time-of-planting trials at Aiyura

Parameter(1)	Constant factor	Partial correlation coefficient
TRIAL 1		
Soil moisture storage at planting	Number of weeks when SMS = 100 mm during final 13 weeks	- 0.344
	Growing Period Rainfall Index	- 0.350
Number of weeks when SMS = 100 mm during final 13 weeks	SMS at planting	0.260
	Growing Period Rainfall Index	0.308
Growing Period Rainfall Index	SMS at planting	0.219
	Number of weeks when SMS = 100 mm during final 13 weeks	0.268
TRIAL 2		
Mean maximum temperature during crop life	Rainfall during crop life	0.751**
	Number of weeks when SMS = 100 mm during crop life	0.714**
Rainfall during crop life	Mean maximum temperature during crop life	0.342
Number of weeks when SMS = 100 mm during crop life(2)	Mean maximum temperature during crop life	0.268

Notes

(1) For Trial 1, partial correlations are presented for the parameters which were significantly correlated with yield. They are presented for Trial 2 only for those parameters which were highly significantly correlated with tuber yield ($P < 0.01$).

(2) Some plantings grew for 33 weeks and others for 34 weeks. This parameter is based on the first 33 weeks of crop growth.

Table 6.13 Correlation coefficients between tuber yield and certain parameters of rainfall and temperature for sweet potato time-of-planting trials on the Nembi Plateau and at Oksapmin

Parameter	Nembi Plateau(1)	Oksapmin
RAINFALL		
During crop life	0.124	0.339
During month before planting	0.426	0.107
During first 3 months	0.001	0.217
During final 3 months	- 0.026	0.189
GROWING PERIOD RAINFALL INDEX	- 0.351	- 0.483
TEMPERATURE(2)		
Mean maximum during crop life	0.643	0.601*
Mean minimum during crop life	0.545	0.741**

Notes

(1) Yield figures from the Nembi Plateau trial are for the first harvest only (n = 7). Correlations were also examined for total tuber yield (n = 5) and the corresponding rainfall and temperature data, but no significant relationships were found.

(2) Temperature data are long term means from Mendi and Telefomin for the two trials respectively.

variation in yields from various plantings was variation in the amount of heat received, as measured by air temperature. There are a number of reasons why this finding cannot be accepted(11). Firstly the differences in heat received by the various plantings as measured by mean maximum or minimum temperatures are small. In the second trial at Aiyura, the greatest difference among plantings for mean maximum air temperature was only 1.3 ^{o}C (Figure 6.5). Sweet potato grows and yields well over a wide range of latitudes and altitudes and hence yield is very unlikely to be particularly sensitive to small variations in air temperature. Secondly the small seasonal variations in temperature in the highlands are regular. Therefore, any marked influence of temperature variation on yield, as suggested in these three trials, should be apparent in measures of sweet potato availability. There is, however, no evidence of an annual cycle in the availability of sweet potato in the PNG highlands as measured by market prices or reports on sweet potato availability (Chapter 3).

It is most likely that the yields recorded in these three trials reflected differences in crop maturity. In PNG the time required to attain maximum yield is dependent on altitude (that is, temperature), more time being needed at locations where air temperatures are cooler. In the first trial at Aiyura, the greatest difference among treatments in mean maximum air temperature during the growing period was 1.3 ^{o}C. Based on the relationship between time to crop maturity and altitude/temperature for Chimbu (Goodbody, in press), such a difference would result in an extension of the time to first harvest of about 32 days. For some of the cultivars examined by Anders (in press) and Bourke (1984a), increases in tuber weight during the final month of tuber bulking were of the same order of magnitude as the maximum yield differences among treatments recorded in this trial (10 t/ha). Hence the yield differences among treatments were almost certainly measures of crop maturity rather than yield potential. The same logic applies to the other two trials where yield was correlated with air temperature.

It is well established that plant time (the time required to complete any growth stage) may differ from calendar time for different plantings (for example, Nuttonson, 1948; Nix, 1976; Angus *et al.*, 1981). This assumes special significance for tropical root crops such as sweet potato, *Xanthosoma* taro and cassava, where neither the tubers nor the whole plant undergo marked physiological changes that signal crop maturity. Researchers working with sweet potato must rely on their judgement as to when maximum tuber yield has been attained. For experiments in which the period from planting to harvesting is pre-determined, as in those reported above, or in which the period from planting to maximum yield may be influenced by treatments applied, as in a nitrogen fertilizer experiment,

(11) The same logic that compels rejection of seasonal temperature variation in explaining the results of the Aiyura time-of-planting trial 2 also applies to annual variation in soil moisture storage. Even if SMS was shown to have a greater statistical association with yield than does air temperature, a causal association cannot be inferred and my earlier conclusions are not sustained (Bourke, 1985a).

recorded yield differences may not be a true measure of treatment effects on yield potential, but only the rate of crop development. This hypothesis potentially explains the many conflicting reports in the literature on the influence of nitrogen on sweet potato tuber yield, the great variation in tuber nitrogen content from different chemical analyses and the relationship between tuber yield and above ground growth in sweet potato. It may also explain other aspects of sweet potato physiology reported in the literature, such as the apparent depressing effect of potash fertilizer on dry matter content of tubers.

The results of these three trials indicate that yield per unit area is not dependent on small seasonal temperature variation, but that yield per unit area **per unit time** is temperature dependent. Thus crops growing in the warmer months of the year and maturing in March to June would mature faster than those growing in the cooler months of the year and maturing in September to January (Tables 6.6, 6.8, 6.9). If a villager planted the same area of crop every month of the year, this effect would result in "bunching" of crop maturity during the former group of months and "spreading" of crop maturity during the latter months. This would mean that the availability of tubers sufficiently large to harvest would vary slightly on an annual seasonal basis. In practice a number of factors are likely to mask this weak tendency. These include the use of serial harvesting and the range of cultivars grown. These factors increase the flexibility of the food supply system and would tend to absorb the effects of temperature change on the rate of crop development.

CONCLUSIONS

The relationship between climatic variation and sweet potato tuber yield has been examined firstly by a review of the international literature on climatic influences on yield and time-of-planting trials, and secondly through village surveys and time-of-planting trials in the PNG highlands. The techniques used for the village survey and results obtained were flawed and it was not possible to examine the relationship between climatic variation and yield. Conclusions based on the other methods were similar and these are now summarised.

Daylength variation does not influence sweet potato yield in the PNG highlands. Variation in solar radiation is potentially important, although no evidence for a link with yield was found and it is less likely to be a constraint where plant growth is slower under the cooler highlands conditions (Rawson, in press). Small changes in temperature in the non-injurious range affect the rate of crop development, but not the ultimate yield obtained. Nevertheless temperature fluctuations may sometimes result in spurious experimental results when the time interval between planting and harvesting is fixed. The effect of chilling temperatures (0 to 12 ^{o}C) on sweet potato yields in the highlands is unknown but may be important at times. Freezing temperatures have a major impact on yield, and the severity of this depends on the stage of plant development when frost occurs.

The main climatic influence on sweet potato yield variation is extremes of soil moisture. There is very little evidence from PNG that low soil moisture levels affect yield, although the international literature indicates that soil moisture levels of less than 20 per cent of field capacity depress yield. It is not clear from the literature when low levels of soil moisture are likely to be most injurious, but this appears more likely during rapid tuber bulking than earlier in crop growth. Very high levels of soil moisture, particularly waterlogging, are the most important climatic constraint on tuber initiation and development. Experimental results from the PNG and Solomon Islands lowlands and five trials in the PNG highlands all indicate that excessive soil moisture depresses yields.

Neither the international literature nor the PNG experimental results contain a clear consensus as to the most critical timing of excessive soil moisture. This is likely to be most detrimental when tubers are being initiated in the period immediately after field planting. Highlands villagers using poorly drained soils are particularly vulnerable to prolonged periods of high rainfall, particularly in those parts of the region, such as in the Porgera area of Enga, where most soils are poorly drained. Conversely, plantings made into these soils are likely to give above average yields during very dry periods, as shown by results from the first time-of-planting trial at Aiyura, Goodbody's trial at Kondiu and the Aiyura soil exhaustion trial. Many highlanders have access to a range of soils with different drainage characteristics. For these people, any effects of drought can be greatly reduced by planting crops during a drought into soils that are considered too poorly drained for sweet potato under normal conditions.

In the next chapter, data on soil moisture storage over time are presented from three locations in the Eastern and Southern Highlands. These data are compared with those on recorded episodes of sweet potato scarcity and high market prices in order to examine further the relationship between climatic variation and sweet potato yield.

CHAPTER SEVEN

CLIMATIC VARIATION AND FOOD SUPPLY IN THE HIGHLANDS

The literature review and experimental results described in the previous chapter indicated that the major climatic influences on sweet potato yield variation are extremes of soil moisture, particularly waterlogging, and frosts. The relationship between these climatic extremes and sweet potato yield is examined further in this chapter by comparing the occurrence of these extremes with reported food shortages and peaks in market price which were presented in Chapter 3.

SOIL MOISTURE EXTREMES AND FOOD SUPPLY

Extremes of soil moisture are calculated using soil water balances which are a more appropriate index of soil moisture status than raw rainfall figures.

Water Balance

Water balances were calculated for the three highlands locations for which long term data on food availability have been compiled and for which long term daily rainfall records are available. The three locations are Kainantu, Goroka and Mendi. The water balance model used was developed by the Division of Land Research, CSIRO (McAlpine, 1970; McAlpine *et al.*, 1983:133-144). The water balance of an area is based on the principle that the amount of precipitation must be equivalent to the losses of water from that area plus the water stored within it. In its most usual form, water balance accounting integrates precipitation and evaporation data to produce estimates of run off and soil moisture deficits for a specified area and time period (McAlpine *et al.*, 1983:133).

Available water capacity (AWC) gives a fair approximation of the total amount of soil water available for crop growth. Calculations were made for an assumed AWC of 100 mm based on the AWC of 160 mm per metre for sandy clay loams (Bellamy, 1986:110) and a maximum rooting depth of 60 cm for sweet potato(1). The potential evaporation

(1) An available water capacity of 100 mm is likely to be an overestimate for sweet potato in many situations as sweet potato roots do not generally grow deeper than 30 cm. Radcliffe (1984:90-91) gives AWC values in the range of 50 to 87 mm for the top 30 cm for seven soil series in the Upper Mendi Valley. Hence an assumed AWC value of 75 mm may have been more appropriate. Using a different AWC would give somewhat different estimates of soil moisture storage and water surplus. However, this is unlikely to alter conclusions about the relationship between soil moisture storage/water surplus and food shortages. This is because these conclusions are based on untested assumptions about the period for which a water deficit or surplus is harmful.

Waddell (1972:161-166; 1973b) argues that an unintended side effect of the use of large mounds for sweet potato cultivation in Enga is to render people more vulnerable to coefficient value was assumed to be 0.8 (McAlpine, 1970). Evaporation estimates for Aiyura, Goroka and Mendi are from McAlpine *et al.* (1975:150-152) using a US Class A pan. Weekly rainfall was derived from daily records from Aiyura and Goroka (1952 to 1984) and Mendi (1956 to 1984) and water balances were calculated using the CSIRO WATBAL program.

Results are presented in various formats as follows: mean monthly soil moisture storage (Figure 7.1) and mean monthly water surplus for the three locations for the 33/29 year period (Figure 7.2); monthly plots of soil moisture storage for Aiyura, Goroka and Mendi (Figures 7.3, 7.4, 7.5); monthly means for the two parameters and three locations (Tables A12.1 to A12.6); number of consecutive weeks when soil moisture storage was continuously less than 20 mm (Table 7.1); number of consecutive weeks when a water surplus occurred (Table 7.2); and weeks in which the water surplus exceeded 170 mm per week (Table 7.3).

The mean monthly data demonstrate the lack of any significant seasonality in soil moisture storage or water surplus at Mendi, and the moderately seasonal soil moisture regime in the Eastern Highlands (Figures 7.1, 7.2). This pattern confirms the regional classification of rainfall seasonality using Walsh's method presented earlier (Figure 2.2) and classifications by other authors who present data from the PNG highlands (for example, Fitzpatrick, 1965; McAlpine *et al.*, 1983:135-144; Bellamy, 1986:90; Abeyasekera, 1987)(2). The mean calculated annual water surpluses are 780 mm, 640 mm and 1430 mm for Aiyura, Goroka and Mendi respectively. The literature on the influence of soil moisture levels on sweet potato yield reviewed in the previous chapter indicates that yields are not depressed until available soil moisture levels are quite low. Hence a value of 20 mm of available water was selected as the cutoff point below which tuber yield is likely to be reduced.

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drought. His argument is only partially correct. Mounding enhances drainage and facilitates removal of free water once the soil is fully saturated. However mounding will not by itself reduce the quantity of water that is available for plant uptake (the available water capacity) held within the fine pore portion of the soil. The main effect of mounding on plant-soil relations is to remove quickly water that is in excess of the soil's field capacity, that is, to reduce the effect of waterlogging. The remaining water held by the soil will be removed faster by evapotranspiration than in unmounded soil. In this sense, mounding does increase the hazard of drought, and is less beneficial for crops that are tolerant of waterlogged conditions. But for crops that are vulnerable to waterlogging, such as sweet potato, the advantages of better drainage outweigh any possible disadvantage of greater susceptibility to drought.

(2) Minor differences in interpretation are given by different authors, probably because of the use of different time periods, data sources and methods. For example, Fitzpatrick (1965) using data from Mendi for the period 1951 to 1960 states: "There is no obvious seasonal trend in rainfall, but there is some suggestion of a slight maximum during the south-east season" (May to August). The method used here suggests a maximum water surplus in March and a minimum surplus in May, June and November (Figure 7.2).

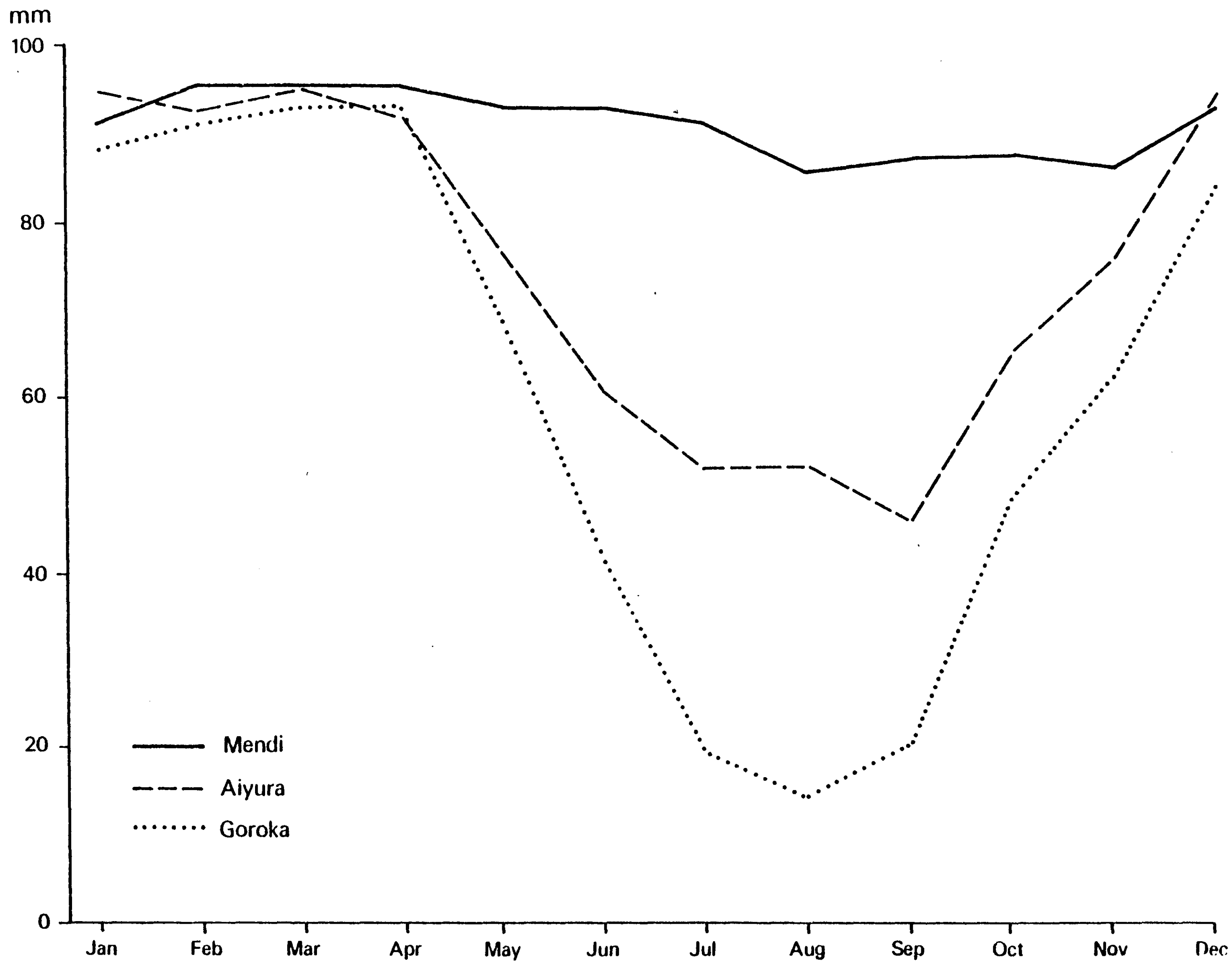

Figure 7.1 Mean monthly soil moisture storage: Aiyura, Goroka and Mendi, 1952 to 1984

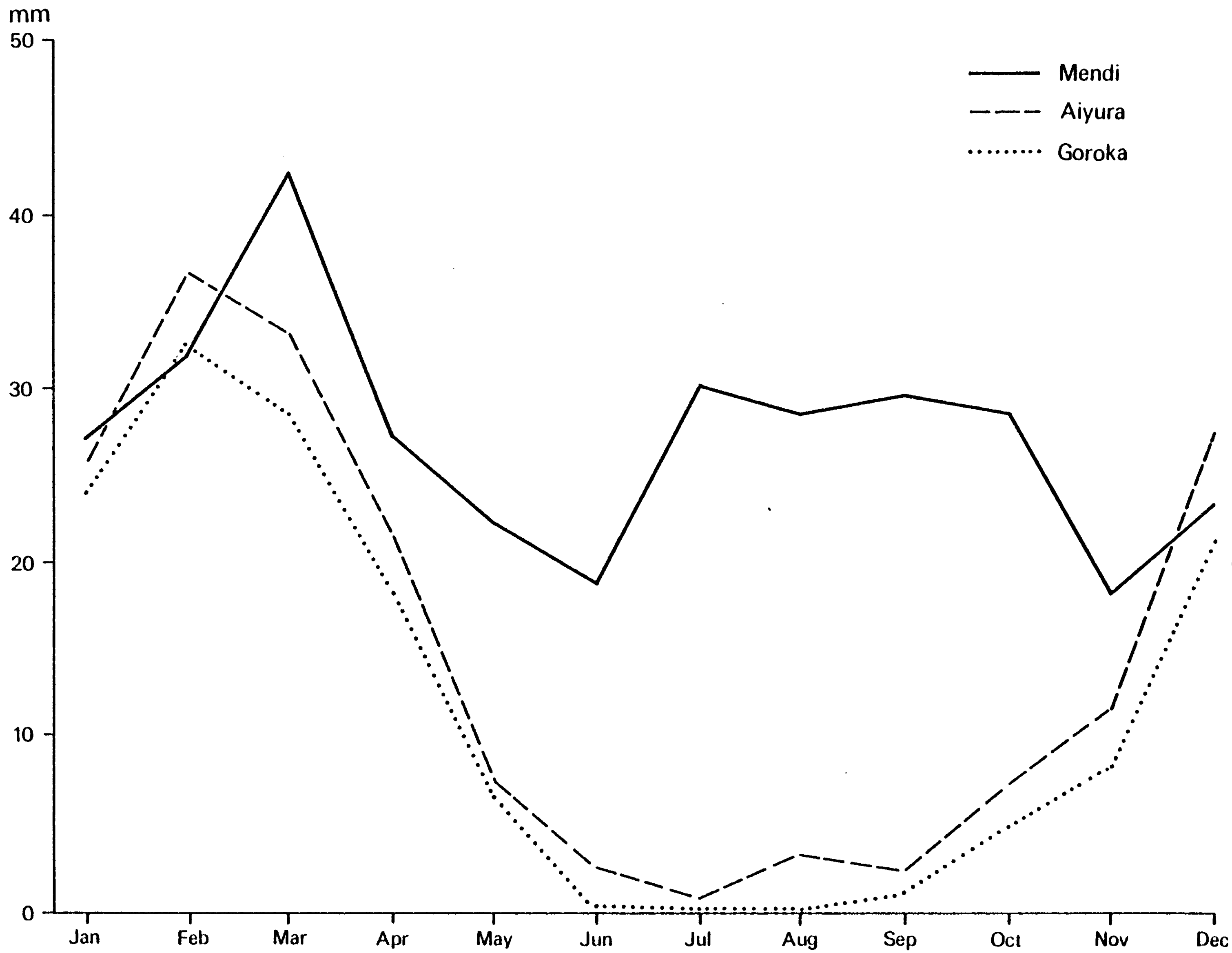

Figure 7.2 Mean monthly water surplus: Aiyura, Goroka and Mendi, 1952 to 1984

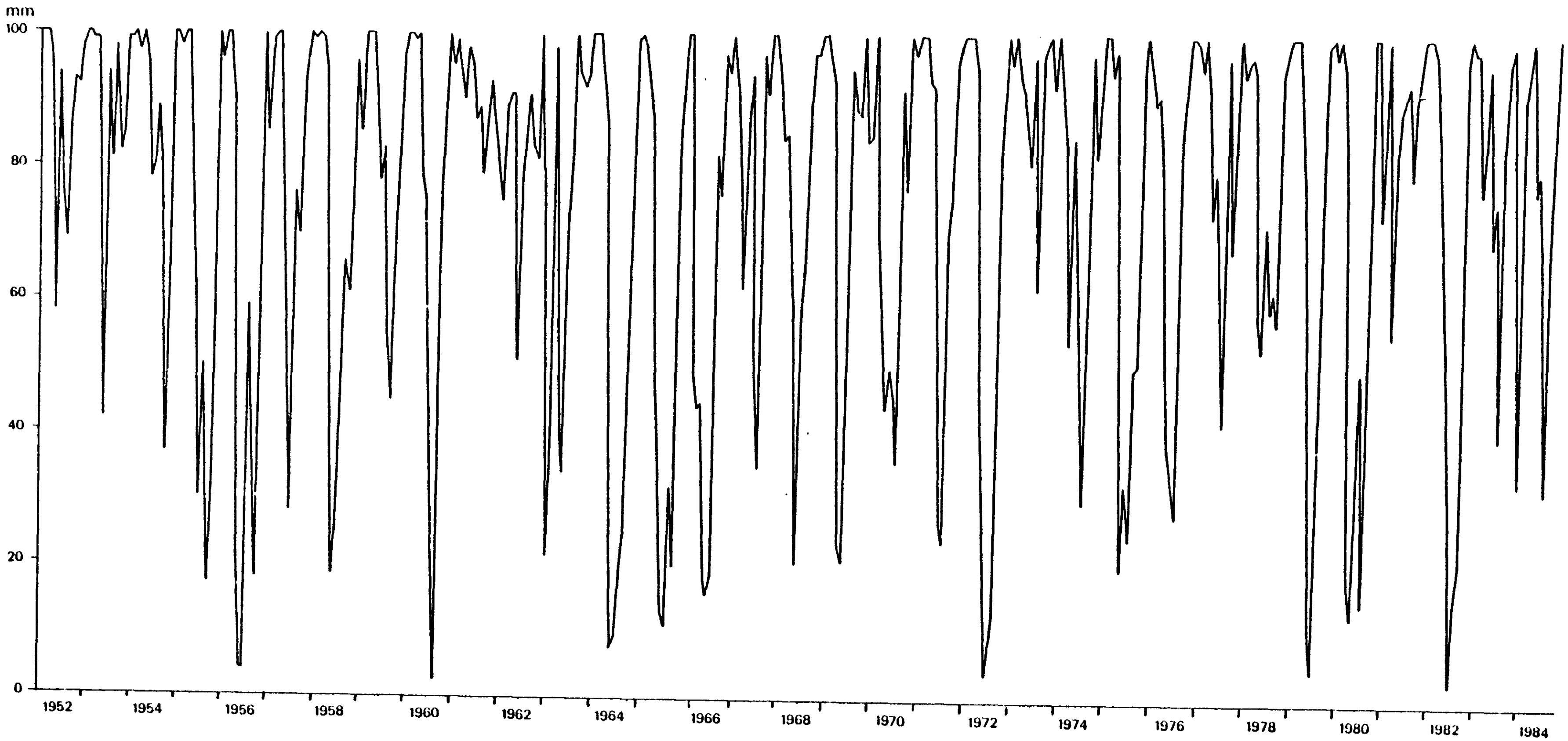

Figure 7.3 Monthly mean soil moisture storage, Aiyura, January 1952 to December 1984

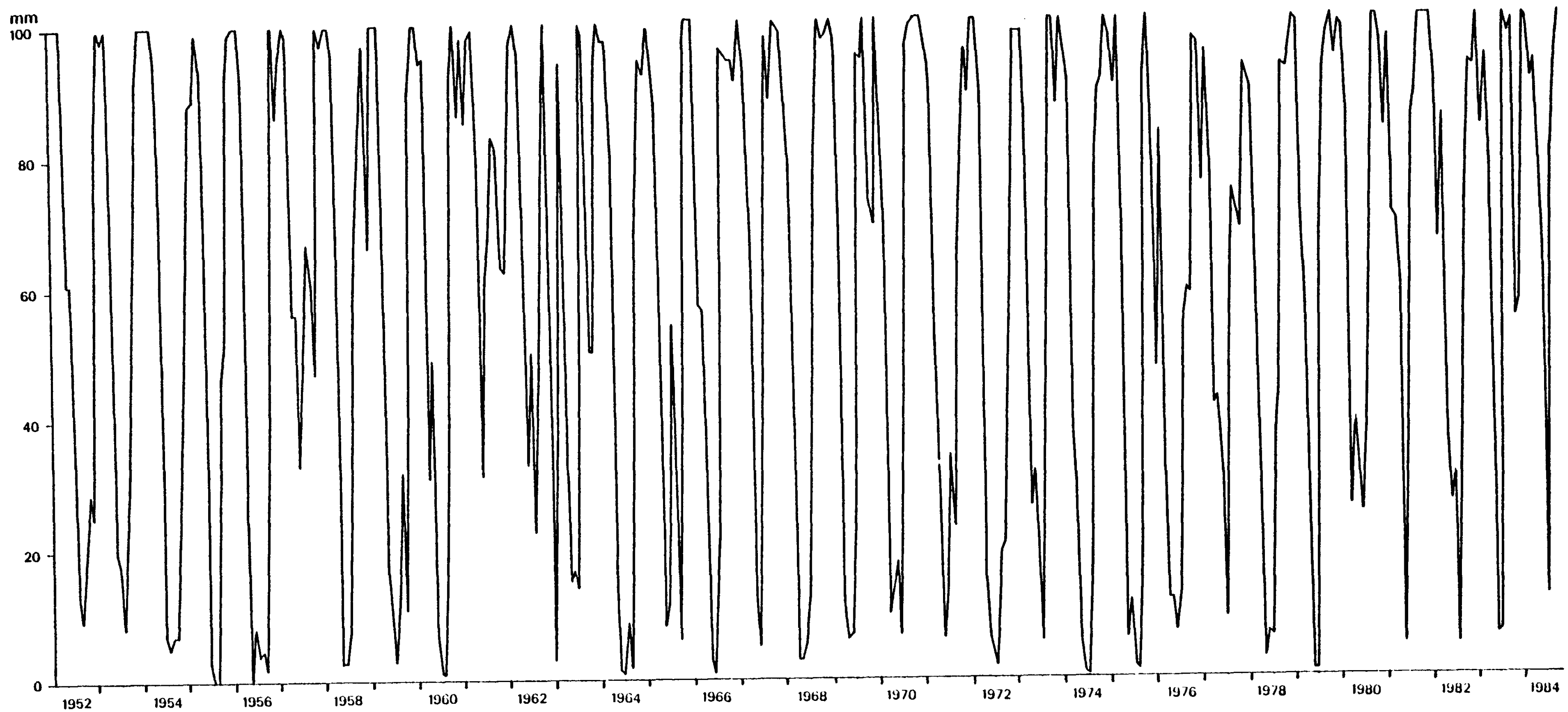

Figure 7.4 Monthly mean soil moisture storage, Goroka, January 1952 to December 1984

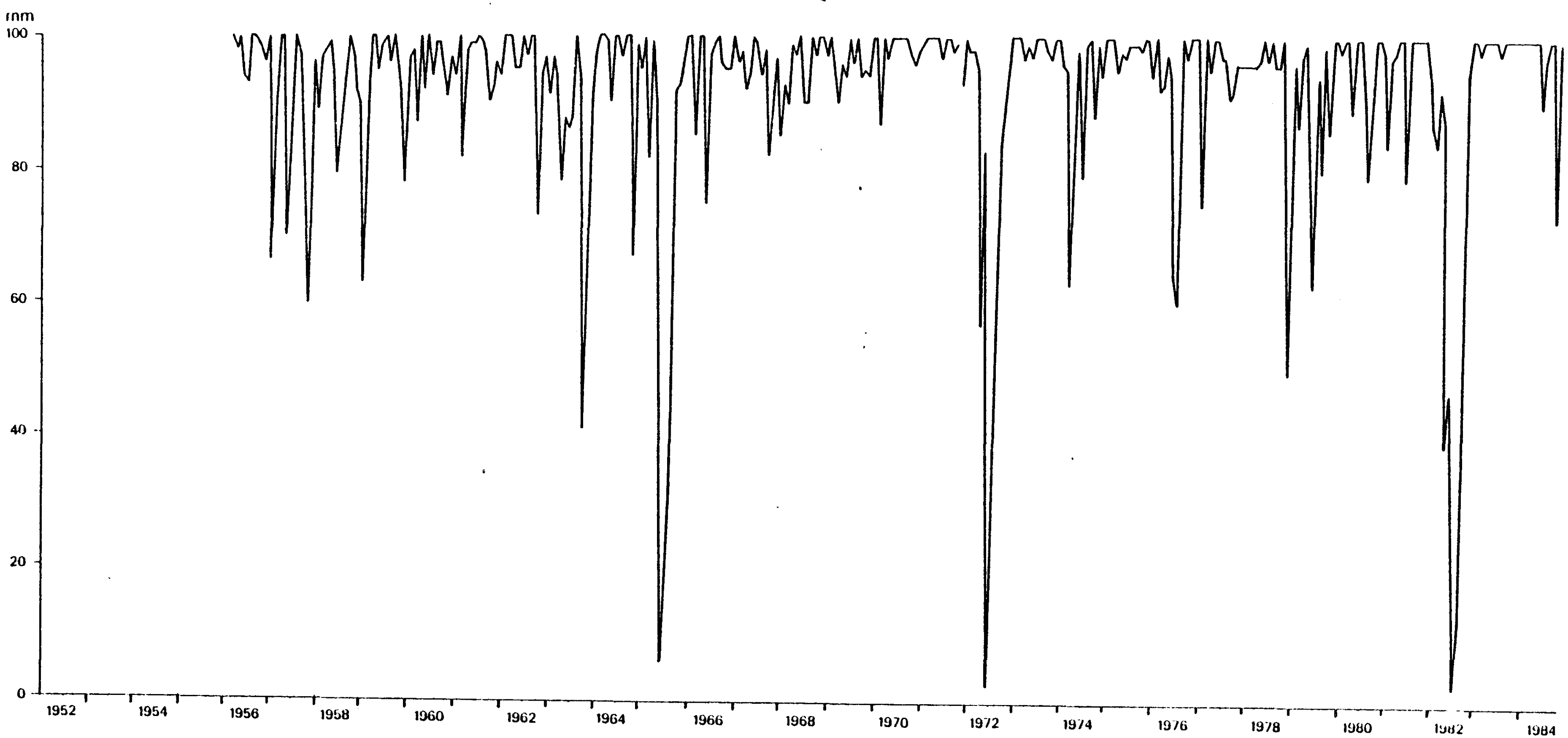

Figure 7.5 Monthly mean soil moisture storage, Mendi, January 1956 to December 1984

Table 7.1 Number of consecutive weeks when soil moisture was continuously less than 20 mm: Aiyura, Goroka, Mendi; January 1952 to December 1984 (1)

Year	Aiyura		Goroka		Mendi	
	No of weeks	Week nos	No of weeks	Week nos	No of weeks	Week nos
1952	0	-	11	30-40	(2)	
1953	0	-	10	29-38		
1954	1	43	20	27-46		
1955	4	37-40	13	27-39		
1956	11	20-30	25	20-44	0	-
1957	1	30	1	22	0	-
1958	4	25-28	13	22-34	0	-
1959	0	-	12	24-35	0	-
1960	7	33-39	13	28-40	0	-
1961	0	-	2	30-31	0	-
1962	0	-	2	37-38	0	-
1963	4	22-25	7/6	5-11/29-34	0	-
1964	12	27-38	22	24-45	0	-
1965	7	32-38	7	28-34	8	31-38
1966	10	29-38	12	27-38	0	-
1967	0	-	9	28-36	0	-
1968	2	29-30	17	21-37	0	-
1969	3	26-28	16	23-38	0	-
1970	2	35-36	6/8	24-29/33-40	0	-
1971	3	34-36	7	31-37	0	-
1972	12	31-42	14	24-37	9	33-41
1973	0	-	6	34-39	0	-
1974	2	37-38	18	25-42	0	-
1975	2	28-29	21	27-47	0	-
1976	2	36-37	12	26-37	0	-
1977	0	-	5	35-39	0	-
1978	0	-	14	26-39	0	-
1979	9	31-39	11	29-39	0	-
1980	8	25-32	2	31-32	0	-
1981	0	-	7	31-37	0	-
1982	13	35-47	5	39-43	9	39-47
1983	0	-	9	30-38	0	-
1984	0	-	3	37-39	0	-
Mean/range	4	20-47	10	20-47	1	31-47

Notes

(1) Soil moisture storage (SMS) and water surplus were calculated on a weekly basis for an assumed available water capacity of 100 mm. When more than one extended period of low SMS or surplus occurred in a year, only the longer period is recorded here, unless both periods are of a similar duration. Periods of low soil moisture storage broken by one week in which SMS was in the range of 20 to 29 mm are treated as a single period. Similarly, periods of water surplus broken by one week only where no surplus occurred are treated as a single period.

(2) Daily rainfall data are not available for Mendi from 1952 to 1955 and the Mendi data commence in January 1956. However monthly rainfall totals were high at Mendi between 1952 and 1955, suggesting that SMS did not drop below 20 mm for these four years.

Table 7.2 Number of consecutive weeks when a water surplus occurred: Aiyura, Goroka, Mendi; January 1952 to December 1984

Year	Aiyura		Goroka		Mendi	
(1)	No of weeks	Week nos	No of weeks	Week nos	No of weeks	Week nos
1952-53	16	47-10	6	4-9	(2)	
1953-54	9	47-3	23	1-23		
1954-55	23	47-17	5	7-11		
1955-56	12	49-8	14	2-15		
1956-57	9	5-13	11	8-18	10	9-18
1957-58	9	47-3	17	49-13	7	5-11
1958-59	13	5-17	13	5-17	11	9-19
1959-60	18	52-17	9	1-9	9	33-41
1960-61	4	47-50	8	47-1	9	30-38
1961-62	4	8-11	10	7-16	24	50-21
1962-63	4	49-52	5	48-52	12	32-43
1963-64	21	48-16	13	2-14	17	6-22
1964-65	7	2-8	7	7-13	23	26-48
1965-66	15	51-13	11	3-13	11	3-13
1966-67	11	51-9	9	6-14	13	50-10
1967-68	12	48-7	12	48-7	10	25-34
1968-69	17	45-9	8	6-13	17	49-13
1969-70	6	9-14	7	46-52	10	4-13
1970-71	17	3-19	14	1-14	32	17-48
1971-72	16	52-15	11	9-19	11	5-15
1972-73	16	52-15	10	6-15	20	3-22
1973-74	8	45-52	10	43-52	20/17	31-50/52-16
1974-75	11	5-15	6	5-10	16	5-20
1975-76	9	50-6	6	1-6	12	47-6
1976-77	15	48-10	9	2-9	14	48-9
1977-78	9	7-15	5	11-15	21	14-34
1978-79	16	2-17	11	6-16	6	10-15
1979-80	17	50-14	13	50-10	9	14-22
1980-81	9	48-4	10	47-4	12	49-8
1981-82	21	51-19	20	47-14	28	35-10
1982-83	11	49-7	10	6-15	34	1-34
1983-84	7	47-1	8	9-16	41	38-26
Mean/range	12	45-19	10	43-23	16	27-26

Notes

(1) The year used here extends from week 27 (July) of one year to week 26 (June) of the following year. This is because the wetter periods commence at the end of the calendar year in the Eastern Highlands, although they occur in all months in the Southern Highlands (Figures 7.1, 7.2).

(2) The Mendi data commence in January 1956.

Table 7.3 Single weeks in which water surplus exceeded 170 mm per week: Aiyura, Goroka, Mendi; January 1952 to December 1984

Station	Week number	Month/year	Surplus (mm)
Aiyura	10	March, 1973	362
Goroka	7	February, 1974	208
Mendi (1)	18	May, 1970	171
	9	March, 1975	294
	33	August, 1977	188
	27	July, 1980	250
	35	August, 1980	172

Note

(1) The Mendi data commence in January 1956.

At Aiyura, the calculated soil moisture storage rarely falls below 20 mm for extended periods. Between 1952 and 1984, it was continuously less than 20 mm for periods greater than 10 consecutive weeks only in 1956, 1964, 1972 and 1982 (Figure 7.3; Table 7.1)(3). In contrast, extended dry periods are not uncommon at Goroka. Over the same period, soil moisture was continuously low for extended periods in 17 out of 33 years at Goroka (Figure 7.4, Table 7.1). At Mendi only three episodes of low soil moisture storage occurred (1965, 1972, 1982) between 1956 and 1984 and these only lasted for 8 or 9 weeks (Figure 7.5, Table 7.1). These droughts tended to coincide with major disturbances of the earth's weather patterns, termed the *El Niño*-Southern Oscillation (ENSO). Droughts in 1941, 1965, 1972 and 1982 in many locations in the highlands region coincided with climatic disturbances elsewhere in the world (Quinn *et al.*, 1978; McDonald, 1984). Other droughts, such as those in the Eastern Highlands in 1956 and 1964, did not occur during ENSO events.

Very extended periods of water surplus are not common at the two Eastern Highlands locations. At Aiyura there were only three periods during which a water surplus lasted for 20 or more weeks continuously (1954-55, 1963-64 and 1981-82); and at Goroka only two such periods occurred (1953-54, 1981-82) (Table 7.2). In contrast, very extended periods of water surplus are common at Mendi. Between 1956 and 1984 there were nine such periods (Table 7.2). The continuous water surplus in 1983-84 was especially long and extended for 18 months broken only by a three week period in August-September 1984.

Extremely high water surplus values for individual weeks are uncommon at Aiyura and Goroka. During this 33 year period, surpluses of greater than 170 mm per week occurred during one week only at both Aiyura and Goroka. There were five such extreme values at Mendi over the 29 year period (Table 7.3).

Previous Literature

Numerous authors have attributed food shortages to inadequate or excessive rainfall in the highlands. For example Read (1951:155), Howlett (1962:148) and Pataki-Schweizer (1980:39-40), writing on various locations in the Eastern Highlands, state that food shortages are caused by drought. This is also the suggested cause of specific food

(3) The cutoff points of 10 weeks for extended low soil moisture storage and 20 weeks for water surplus are arbitrary. For deep and well drained soils that are commonly used for sweet potato production, the available water capacity of the entire soil profile is likely to be in the range of 150 to 250 mm. Radcliffe (1984:91) gives AWC values in the top 1 metre of soil of 162 to 256 mm for seven soil types in the Upper Mendi Valley. If the calculated water surplus was based on an assumed AWC of 200 mm, for example, rather than 100 mm, this would reduce the number of weeks of extended surplus. However the relative values would not change greatly and the relative timing of extended periods of water surplus and food shortages would not differ.

shortages such as those which occurred in 1972-73 (Young, 1973:9; Powell, 1982:83) and in 1982-83 (Defence Force, 1983; Renagi, 1983).

Other observers consider that particular food shortages are caused by periods of above average rainfall. The comment by a patrol officer based at Lake Kopiago in the Southern Highlands after a patrol to the Auwe and Pore Valleys in August 1962 is typical:

> During the past few months, the sweet potato yield has reportedly suffered because of excessively heavy rainfall over the area. The soil has become waterlogged and growth has been retarded. (Permezel, 1962)

Other authors who suggest that exceptionally wet weather results in food shortages include Mathews (1971:33-34) writing on the Okapa area of the Eastern Highlands, Cape (1981:162) on a community in the Oksapmin area, Wohlt *et al.* (1982:33-39) on the Porgera area in Enga and Hide *et al.* (1984:242) on the Karimui area of Chimbu.

Data on variation in sweet potato price and food shortages (Chapter 3) are now combined with data on extremes of soil moisture and presented in Figures 7.6 to 7.12 in order to examine the relationship between soil moisture extremes and food shortages(4).

The Five Highlands Provinces, 1979 to 1984

The first data set covers all districts of the five highland provinces for the period 1979 to 1984 (Figure 7.6). Over this period, food shortages affected much of the region in 1980-81, 1982-83 and 1984-85 and a number of more localized shortages also occurred. Shortages at high altitude locations in early 1981 and in 1982-83 were associated with frost and are considered later.

There was an 11 week long drought in Goroka in 1979 but this was not followed by reports of food shortage, except for one district in Chimbu Province (Figure 7.6). On the other hand, the food shortages in mid- to late 1981 in all districts of the Southern Highlands were preceded by episodes of extremely high water surplus at Mendi in July and August 1980 (Table 7.3, Figure 7.6)(5). It is likely that sweet potato crops planted in the period July to September 1980 failed to develop tuberous roots because of waterlogged soil conditions early in the crop life. Plantings made during these months would have been

(4) For locations where soil water balances have not been computed, a drought is taken as a period of three or more consecutive months when the rainfall was less than 75 mm per month. This estimation gives a similar result to that derived from soil water balances for the three locations. A comparable rule-of-thumb was not obvious for definition of extended periods of water surplus where water balances had not been calculated.

(5) Rainfall was very high throughout the Province in these two months, for example, the combined recordings for July and August 1980 were 800 mm at Mendi, 1000 mm at Erave, 800 mm at Lake Kutubu and 700 mm at Hol.

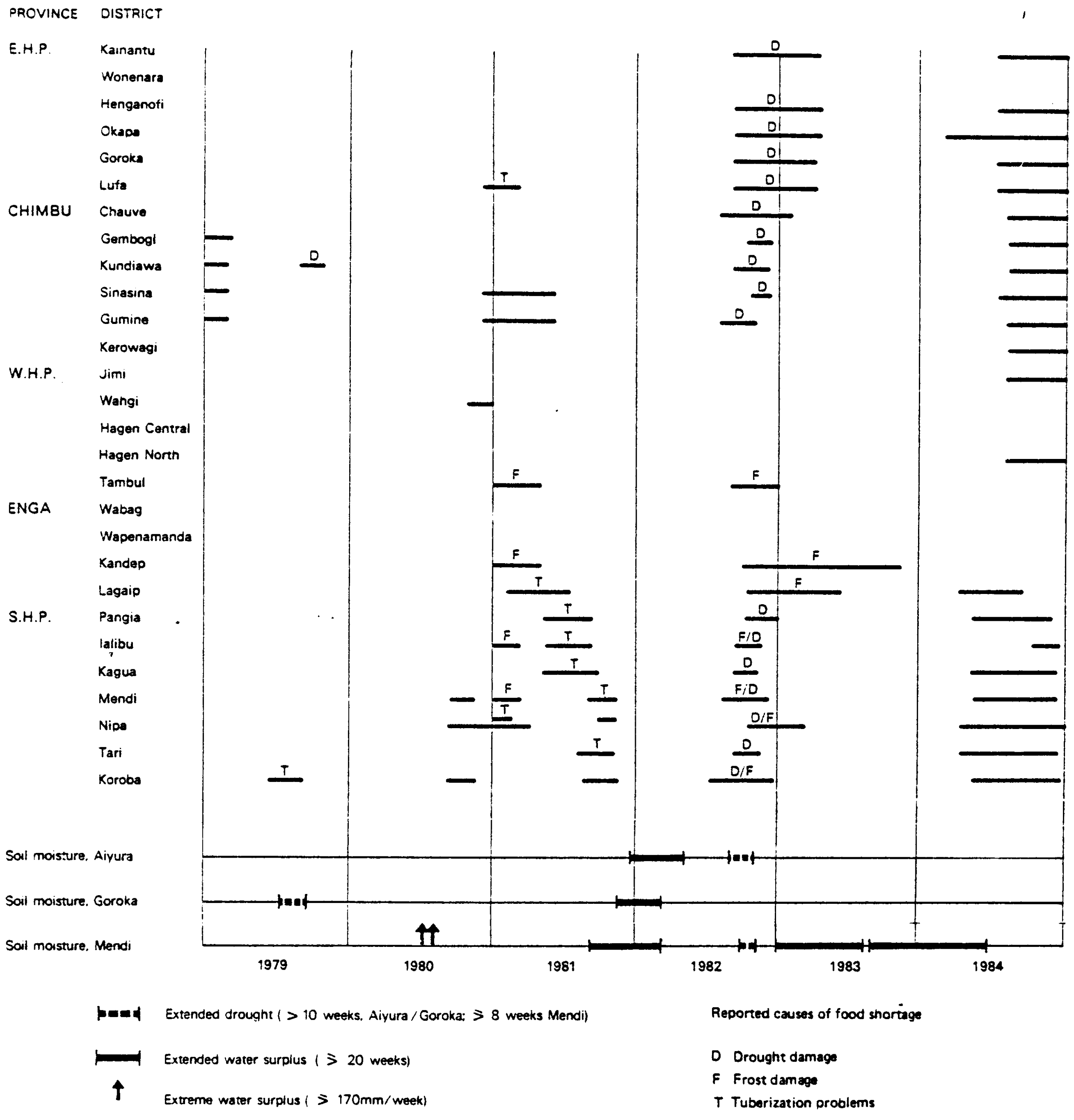

Figure 7.6 Reported food shortages in the PNG highlands, by district; and periods of extended drought and water surplus, Aiyura, Goroka and Mendi, January 1979 to December 1984

ready for harvest from about March 1981 onwards. This timing is consistent with reports of food shortages associated with failure of sweet potato plants to bear tubers between May and October 1981 in the Southern Highlands (Table A6.3)(6). Food shortages were reported from other parts of the highlands in late 1980 and early 1981, as follows: Lufa, Sinasina, Gumine, Wahgi, Lagaip, Mendi, Nipa and Koroba Districts. The widespread coincidence of these shortages does suggest a climatic explanation, but the timing is not consistent with the rainfall extremes in the Southern Highlands in July and August 1980 and rainfall records with which to pursue this fully are not available for most stations for this period.

The food shortages reported in most districts in the Eastern Highlands, Chimbu and the Southern Highlands in late 1982-early 1983 were almost universally attributed by agriculturalists and others to a drought in 1982 and to frosts at high altitude locations. The food shortages coincided with a drought in the Eastern Highlands, Chimbu and the Southern Highlands, but they were also preceded in late 1981-early 1982 by an extended period of water surplus at Aiyura, Goroka and Mendi (Figure 7.6) and at most other rainfall stations for which records are available(7). Rather than attributing food shortages simply to drought or frost, I suggest that the shortages in many parts of the highlands provinces in 1982-83 were caused by the combined effect of the extended wet weather in 1981-82 and the drought in late 1982.

The final reported food shortage covered by this data set happened in early 1984 to early 1985 in much of the Eastern Highlands, Chimbu and the Southern Highlands (Figure 7.6). At Mendi and elsewhere in the Southern Highlands there was an exceptionally long period of wet weather, and water surpluses were almost continuous between January 1983 and mid-1984 (Table 7.2). However, these conditions did not occur in the Eastern Highlands. The exceptionally wet weather of late 1983 to mid-1984 is likely to provide a partial explanation for the food shortage of 1984. The shortages in the Eastern Highlands and Chimbu in 1984 were not associated with abnormal soil moisture conditions and an explanation must be other than climatic.

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(6) Reports of food shortages in 1981 sometimes contained a comment that plants produced masses of hair-like roots instead of tubers. This probably reflects the failure of roots to tuberise because of waterlogging soon after planting. There were numerous hair-like roots on tubers in treatments 7 and 8 in the second sweet potato time of planting trial at Aiyura. These were harvested in November and December 1981 respectively and this coincides with the reports of the "hairy tubers" from the Southern Highlands. There was not an extended period of water surplus at Aiyura in 1981 which would have explained the presence of the hairlike roots in these two treatments.

(7) The water balance calculations for Goroka did not indicate an extended dry period in 1982 (Table 7.1) but rainfall was low at other nearby stations in the region, for example, Omaura and Kundiawa, and the Goroka result is an anomaly. Hide *et al.* (1984:242) attributed food shortages in 1982 to the extended wet period in 1981-82, not the 1982 drought.

Eastern Highlands Province, 1944 to 1971

The second data set is for all districts of the Eastern Highlands and extends from 1944 to 1971 (Figure 7.7). The widespread food shortages in Henganofi District in October-November 1949 were preceded by an extended wet period (January to April) and then a drought (May to August 1949) as shown by rainfall recordings at nearby Goroka. This same combination of climatic extremes occurred in 1954-55 and again was followed by a food shortage in Henganofi District. There was a wet period lasting 23 weeks between January and May 1954 (Table 7.2) followed by a 20 week long drought between July and mid-November 1954 (Table 7.1), and then a food shortage in Henganofi District between October 1954 and March 1955. In Goroka a drought lasting 25 weeks between May and November 1956 coincided with a brief food shortage in the Goroka District in August-September 1956.

Between April and December 1962, there were food shortages in seven census divisions in the Kainantu, Wonenara and Okapa Districts. The analysis of water balance for Aiyura and Goroka does not indicate any association of climatic extremes with these food shortages (Figure 7.7). There was, however, an extended period of very high rainfall (up to 330 mm per month) between October 1961 and May 1962 at Okapa and it is likely that this was a major contributing factor to the 1962 shortage in parts of the Eastern Highlands.

There were food shortages in Kainantu and Henganofi Districts between the middle of 1964 and early 1965. As with some other shortages, these events followed the paired climatic extremes of an extended period of water surplus and an extended drought, as shown by the water balance calculations for Aiyura (Figure 7.7).

Food shortages in Wonenara and Okapa Districts between late 1967 and early 1968 were not associated with climatic extremes at Aiyura and Goroka (Figure 7.7), but recordings at Okapa do show very high rainfalls between October 1966 and February 1967 and this may have interfered with tuber initiation and affected yield (Mathews, 1971:34, Appendix IV). Shortages in parts of Lufa District in 1971 and in 1971-72 were not associated with extremes of soil moisture at Goroka or Aiyura.

Kainantu District, 1935 to mid-1985

The third data set covers Kainantu District only and extends over a 50 year period from 1935 to mid-1985. Water balances have been calculated from 1954 onwards, and

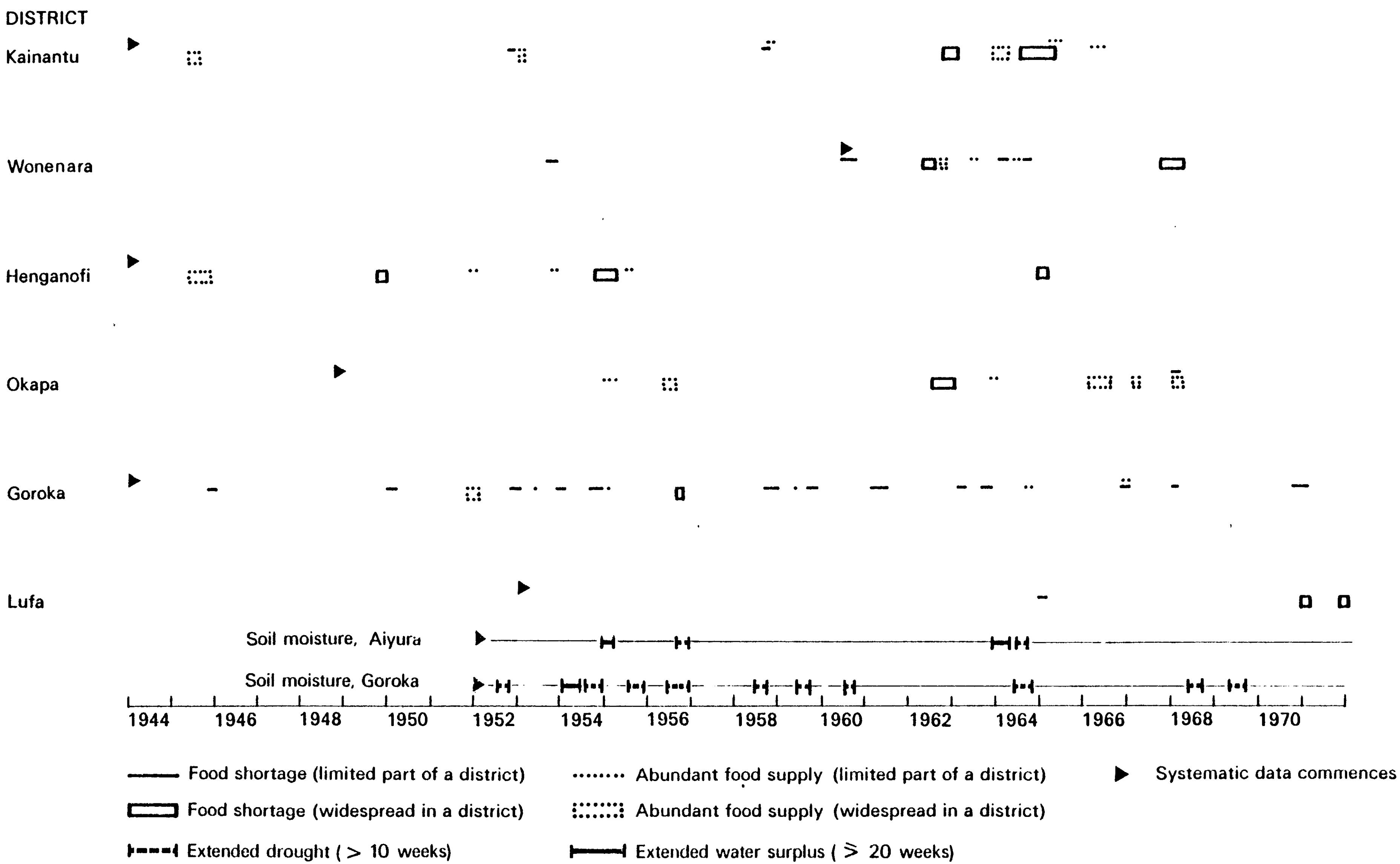

Figure 7.7 Reported periods of food shortages and abundant food supply, by district, Eastern Highlands, 1944 to 1971; and periods of extended drought and water surplus, Aiyura and Goroka, 1952 to 1971

monthly rainfall records are available from 1937 for Aiyura(8). Over this period, there were seven food shortages which affected people in more than one census division. These happened in 1937, 1938-39, 1941, 1962, 1964-65, 1982-83 and 1984-85 (Figure 7.8). The 1938-39 and 1941 events coincided with droughts at Aiyura. Food shortages in 1964-65 and 1982-83 were preceded by the combination of an extended period of water surplus then a drought. The food shortages of 1962 and 1984-85 at Aiyura were not associated with climatic extremes.

During this period there were other extremes of soil moisture at Aiyura in 1954-55 when water surpluses occurred for 23 consecutive weeks (Table 7.2); in 1956 and 1972 when there were droughts of 11 and 12 weeks duration respectively (Table 7.1); and in March 1973 when the calculated water surplus in one week was a massive 360 mm and the average for the month was 130 mm per week (Tables 7.3, A12.4). None of these climatic extremes was associated with food shortages, apart from the 1972 drought which reportedly caused food shortages in some villages in four census divisions in the District (Table A7.1).

Kainantu District, 1977 to mid-1985

The next data set combines sweet potato prices for Kainantu market, reported food shortages from the entire Kainantu District and those from Asiranka Village only (Figure 7.9). A brief shortage in Asiranka Village in late 1980 was not preceded by an extreme in soil moisture. The high prices and reports of food scarcity in late 1982 and early 1983 were preceded by an extended period of water surplus in late 1981-early 1982 and then a 13 week drought in mid- to late 1982. The 1984-85 shortage was not preceded by extremes in soil moisture at Aiyura.

Goroka Market, 1970 to 1985

The fifth data set compares sweet potato prices from Goroka market with extremes of soil moisture at Goroka (Figure 7.10). Large rises in price occurred in 1970-71, 1972-73, 1974-75 and 1978-79 and smaller rises in 1979-80, early 1981 and 1982-83(9). Five of the seven peaks in price followed extremes of soil moisture. Those in 1972-73, 1978-79 and 1979-80 followed an extended period of drought and the 1982-83 food

(8) The first available written comment on rainfall in the Kainantu area (and in the highlands) was made in late 1930 when the New Guinea mining warden John McLean observed that "although no rain has fallen for six months, the gardens were in excellent order." (Radford, 1987:71).

(9) In November and December 1982 insufficient price data for sweet potato were recorded from Goroka market to derive a monthly mean. This was almost certainly due to the small quantity of sweet potato offered for sale. It is likely that the price of the available tubers was very high, as in Aiyura and Kainantu markets at this time (Figure 7.9).

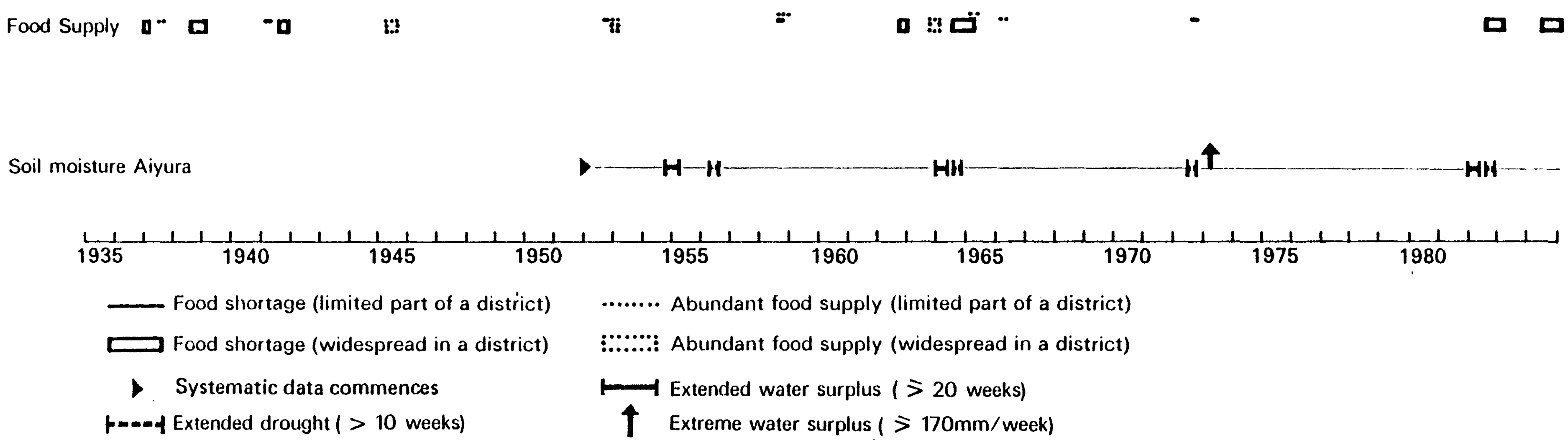

Figure 7.8 Reported periods of food shortages and abundant food supply, Kainantu District, Eastern Highlands, 1935 to 1984; and periods of extended drought and water surplus, Aiyura, 1952 to 1984

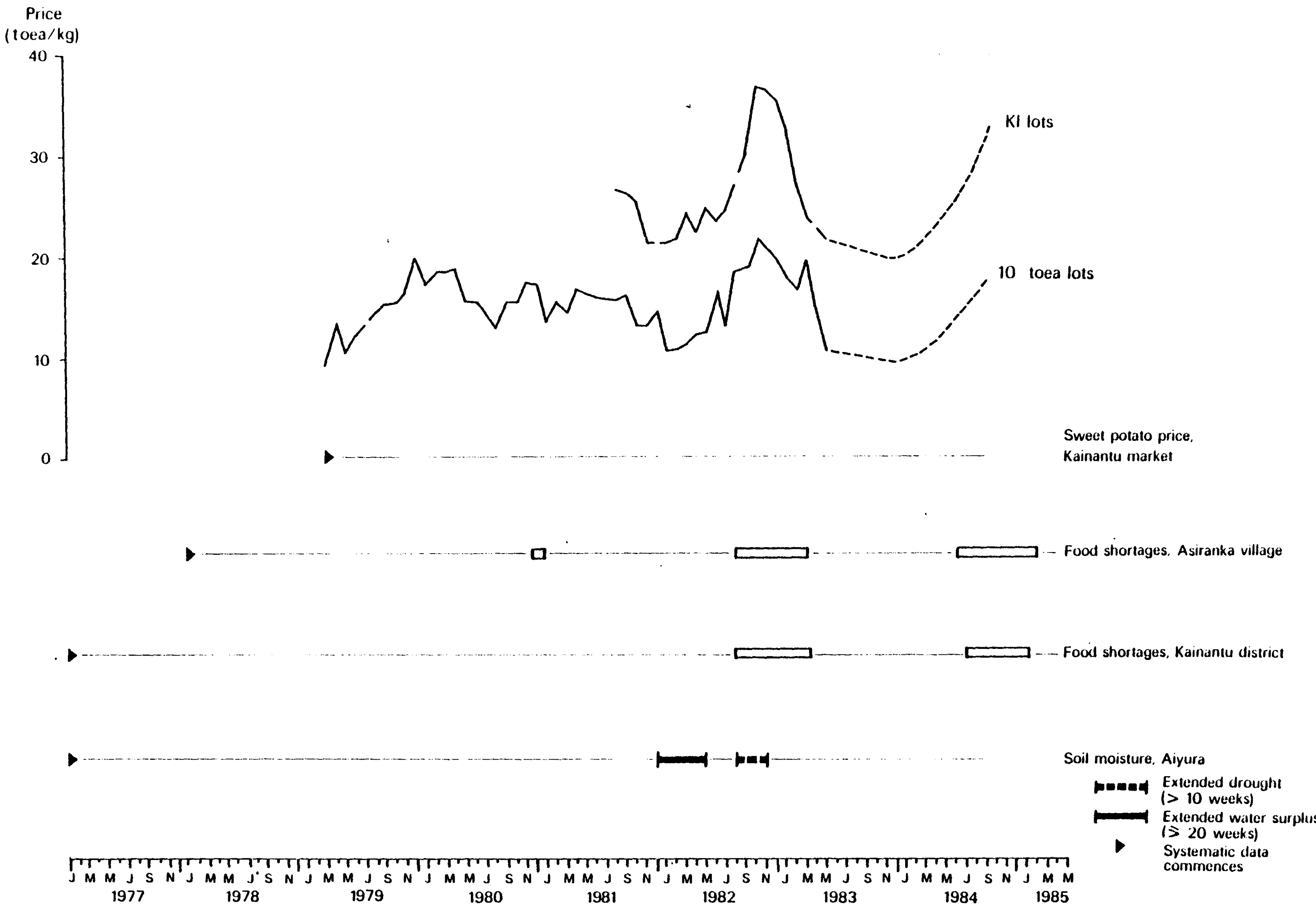

Figure 7.9 Price of sweet potato, Kainantu market, March 1979 to September 1984 (constant 1984 currency); reported food shortages, Asiranka Village, 1978 to mid-1985; reported food shortages, Kainantu District, 1977 to mid-1985; periods of extended drought and water surplus, Aiyura, 1977 to 1984

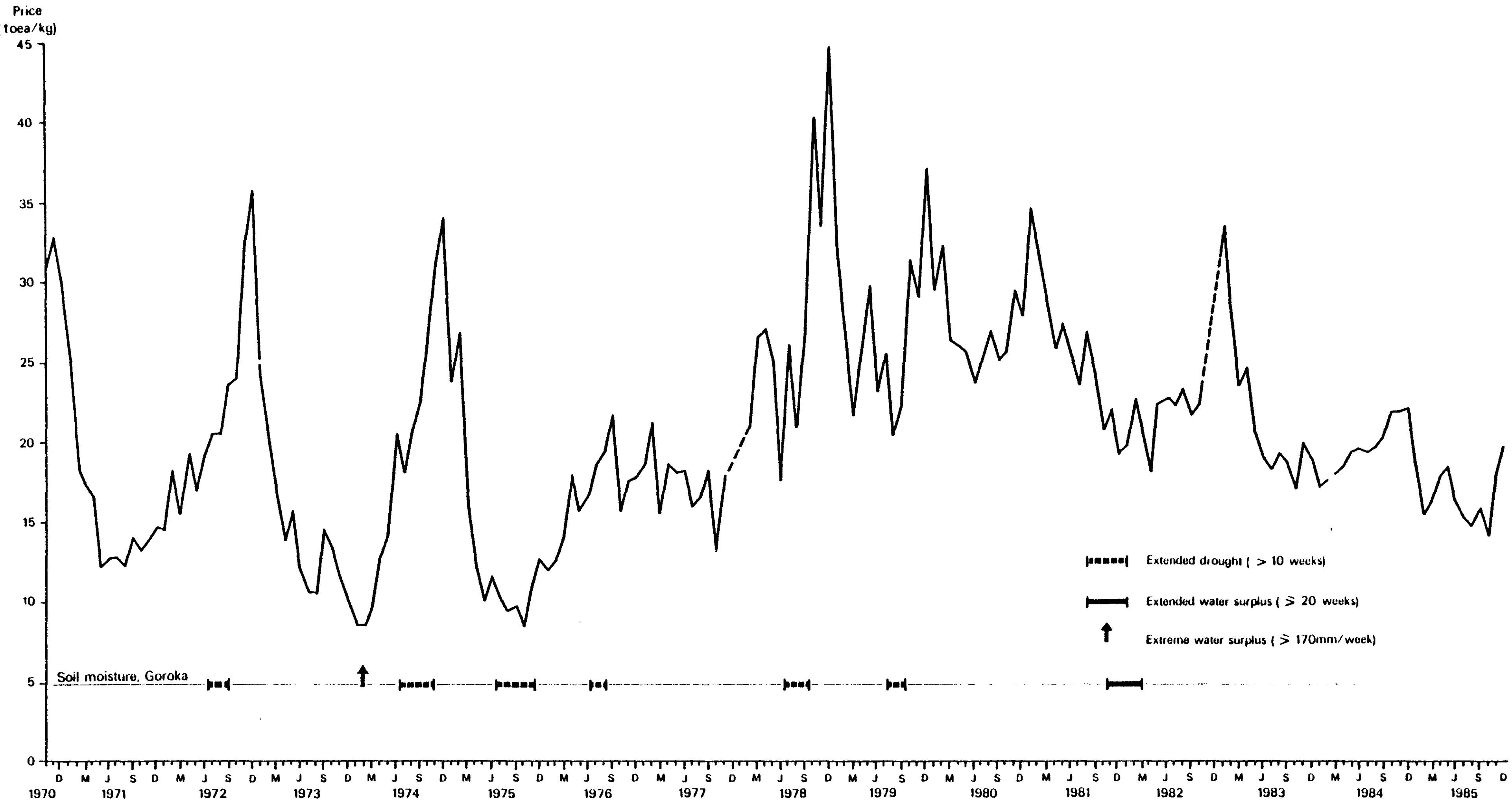

Figure 7.10 Price of sweet potato, Goroka market, October 1970 to December 1985 (constant 1984 currency); and periods of extended drought and water surplus, Goroka, 1970 to 1984

shortage followed 20 consecutive weeks of water surplus between late 1981 and early 1982 (Tables 7.1, 7.2)(10). The steepest price rise was in 1974 and this followed a sequence of a short period of extreme water surplus in February 1974 (Table 7.3) and an 18 week drought in June-October 1974 (Table 7.1).

The large price rise of 1970-71 was not preceded by extremes of soil moisture at Goroka, although it is likely that it was associated with a drought as rainfall was low at the DPI piggery 5 km south of Goroka (less than 65 mm per month) between June and September 1970 (Shannon, 1973). There were no climatic extremes immediately prior to the small price peak in early 1981. An extended drought (21 weeks) in 1975 and a shorter one in 1976 (12 weeks) were not followed by peaks in sweet potato prices in Goroka market, although prices were rising in 1975 and 1976 (Figure 7.10).

Southern Highlands, 1952 to 1974

The sixth data set is based mostly on patrol reports and covers all districts of the Southern Highlands between 1952 and 1974 (Figure 7.11). Food shortages that affected most districts in the province and were widespread at a district level were reported in 1955, 1962, 1965-66, 1967-68, 1970-71 and 1972-73. Particularly abundant food supply was reported in four districts in 1966-67. The reported food shortages in 1955 in five of the six districts then explored by patrol officers were not associated with exceptionally high or low rainfall recordings at Mendi or Tari. The 1962 food shortages followed an extended period of water surplus at Mendi between December 1961 and May 1962 (Table 7.2) and extended high rainfall at other locations, such as Ialibu, Kagua, Nipa, Koroba and Tari.

The shortages that affected people in all districts in the Province in 1965-66 were attributed by patrol officers to an eight week drought that commenced just prior to the shortages. However, the food shortages were also preceded by two very extended periods of water surplus between February and November 1964 throughout the province (Figure 7.11). There is no obvious association between the abundant food supplies of 1966-67 and this soil moisture analysis. The food shortages that were extensively reported for most districts in 1967-68 were not preceded by any soil moisture extreme. Shortages in five districts in 1970 followed a 32 week spell of water surplus and one week of extremely high runoff in May 1970 at Mendi (Tables 7.2, 7.3) and other stations.

The most severe food shortages to affect the province over this 23 year period were in 1972-73 and these were universally attributed to frost damage or a combination of frost and drought. Shortages were most severe where frost damage occurred, particularly at

(10) Rainfall recordings at other nearby stations suggest that a drought also occurred in late 1982 and that the Goroka rainfall figures were an anomaly.

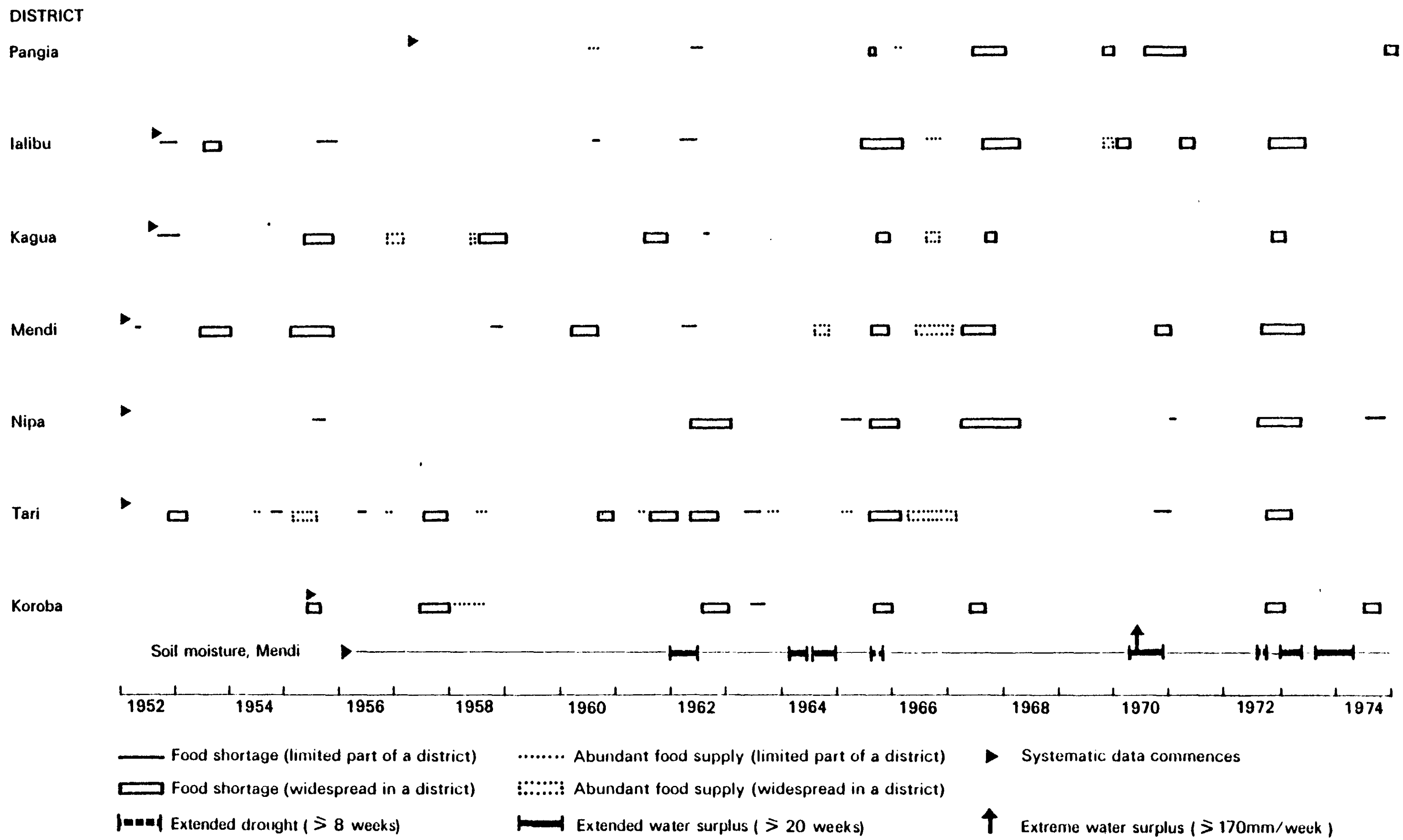

Figure 7.11 Reported periods of food shortages and abundant food supply, by district, Southern Highlands, 1952 to 1974; and periods of extended drought and water surplus, Mendi, 1956 to 1974

high altitude locations, but they also occurred where frost damage was minimal, such as in the Tari Basin. The shortage commenced soon after a nine week drought (Figure 7.11). Shortages restricted to parts of Pangia, Koroba and Nipa Districts in 1974 followed an extended period of water surplus in 1973-74.

Nembi Plateau, 1978 to mid-1985

The final data set in this series concerns the Nembi Plateau where sweet potato prices for two years only, and reports of food shortages between 1978 and mid-1985, are available (Figure 7.12). There were food shortages on the Plateau in 1978, 1980, 1982-83 and 1984-85. The 1978 shortage commenced some 10 months after an extended period of water surplus at Mendi and an exceptionally wet week in August 1977 (Tables 7.2, 7.3). The shortage in 1980 commenced two months after two weeks of extremely high water surplus in July and August (Table 7.3), although the timing of this food shortage and the wet weeks does not suggest a causal relationship. The food shortages of 1982-83 followed the extended wet period in 1981-82 and a drought in 1982; and the 1984-85 shortage followed the extended period of water surplus between September 1983 and June 1984. Extremes of soil moisture therefore seem to provide partial explanations for three of the four food shortages which occurred on the Nembi Plateau between 1978 and mid-1985.

Discussion

Many reported food shortages in the highlands follow extended periods of water surplus, extended periods of low soil moisture storage and brief periods of extremely high water surplus. This suggests that these climatic extremes are causative factors, although the nature of the data is such that the relationship cannot be considered proven. Not all food shortages are preceded by any one of these three factors; for example, those in the Eastern Highlands and Chimbu in 1984 and those in most districts of the Southern Highlands in 1967 are exceptions (Figures 7.6, 7.11). Furthermore, extremes of soil moisture are not always followed by a food shortage, which suggests that some other factors were involved.

An important finding is that the sequence of an extended water surplus and then a relatively mild drought six to ten months later is frequently followed by a food shortage. This sequence occurred in 1954, 1964 and 1982 in the Eastern Highlands (Figures 7.7, 7.8) and in 1965 and 1982 in the Southern Highlands (Figures 7.11, 7.12). The other combination of soil moisture extremes, that is, drought followed by an extended water surplus does not appear to be associated with food shortages. The relative timing of the extended water surplus and subsequent drought suggests that it is the combined effects of

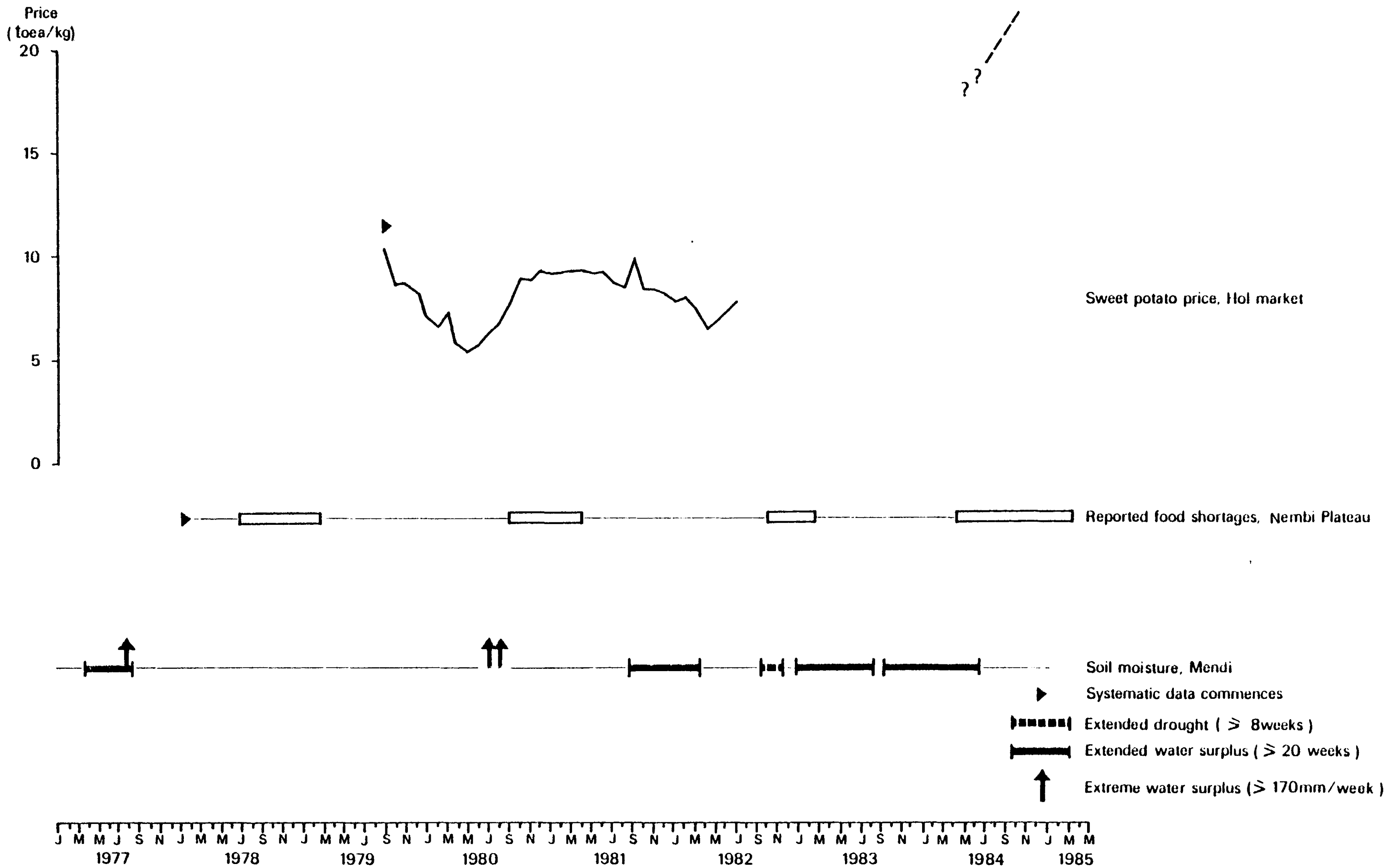

Figure 7.12 Price of sweet potato, Hol market, September 1979 to July 1982, October/November 1984 (constant 1984 currency); reported food shortages, Nembi Plateau, 1978 to mid-1985; periods of extended drought and water surplus, Mendi, 1977 to 1984

excessive soil moisture during the tuber initiation phase and drought during the rapid tuber bulking phase that is most damaging.

A drought by itself is very rarely followed by reports of a food shortage, although price rises in Goroka market do suggest that droughts cause some reduction in supply. Despite the fact that droughts are common in the Goroka area, it seems that only the very extended drought in 1956 resulted in a shortage that affected more than one census division (Figure 7.7). Numerous other droughts were not followed by shortages, such as those in the Goroka area in 1958, 1968 and 1979 (Figures 7.6, 7.7) or droughts in the Kainantu area in 1956 and 1972 (Figure 7.8).

There are a number of possible reasons why the combination of an extended period of water surplus followed by a drought has such a marked effect on food supply. The first is that this only occurs because the effect of the two episodes of different sorts of water stress is cumulative, but this hardly explains why very mild droughts in the Southern Highlands appear to have such a marked effect on tuber production. Another possible reason is that water stress has a hardening effect on individual plants similar to that caused by frost. When plants are subjected to repeated cycles of water stress, the leaves are able to withstand lower leaf-water potential before photosynthesis ceases (Simpson, 1981:131). This is probably because of a build-up in the stress hormone, abscisic acid. It is possible that sweet potato plants which have not been exposed to even mild water stress are more vulnerable to moderately prolonged water stress, but this is speculative.

The most likely explanation for the marked effect of the combination of extended wet periods and droughts relates to depth of rooting. During an extended period of water surplus, the soil is fully saturated or almost so and the water table is very near the surface. Under these conditions, sweet potato plants will only produce feeding and tuberous roots in the uppermost part of the soil profile because there is no need for the plant to seek water at greater depth. These plants are then especially vulnerable to even mild droughts because their root systems are limited in depth. The available water is reduced most quickly from the uppermost part of the profile during a dry period, further disadvantaging the plant.

Drought and sweet potato weevil. The sweet potato weevil is not normally a serious pest in the highlands, although it is a minor problem in the Henganofi area which is the driest part of the region (Figure 2.2). However, in the Eastern Highlands and Chimbu some food shortages have been attributed to weevil damage or to a combination of drought and weevil.

Between September 1954 and January 1955 sweet potato weevil damage was reported in five patrol reports in the following parts of the Eastern Highlands: Benabena, Upper Dunantina Valley, Henganofi area, Kami, Lufa as well as the Nambaiyufa area of Chimbu. These outbreaks coincided with an extended drought in the Goroka area (Table 7.1). Some weevil damage was also reported by patrol officers in the Eastern Highlands in the three years that followed. Comments by Healy (1954) in his report on a patrol in the Benabena area between September and November 1954 are typical:

> Kaukau [sweet potato] was in short supply in the lower areas. The long period of dry weather without even intermittent rain and the tendency of these people to plant just sufficient for their needs from one season to the next are the two main factors causing this shortage. An insect pest [sweet potato weevil] that eats kaukau is causing considerable damage. People say that it is most in evidence when the dry season is prolonged.

There was damage by sweet potato weevil (and sweet potato leaf miner) associated with drought in the highlands in 1972 (Kimber, 1972) and again in 1979 in Kundiawa District in Chimbu. Following the 1982 drought in parts of the Eastern Highlands and Chimbu, weevil damage to sweet potato was noted in the Kundiawa area, Unggai Census Division and in the Henganofi area (DPI files, Kundiawa and Goroka). The problem also occurred in the Pangia, Mendi and Tari areas in the Southern Highlands (Thistleton and Masamdu, 1985:20).

Thus there appears to be an association between outbreaks of sweet potato weevil and drought in parts of the Eastern Highlands and Chimbu. Reports of weevil damage to sweet potato tubers coincided with droughts in parts of the Eastern Highlands and Chimbu in 1954-55, 1972, 1979 and 1982 (Table 7.1). However other extended droughts, for example, in 1956 and 1964 in the Goroka area, were not associated with reports of sweet potato weevil outbreaks. Damage to tubers by weevil appears to be a minor contributing factor to food shortages where drought is a partial cause.

FROST AND FOOD SUPPLY

Frosts sometimes damage crops in the Papua New Guinea highlands. Their frequency and any subsequent damage vary considerably between locations and over time. There is a reasonably large body of literature on the frost hazard, for example, Brookfield (1964), Scoullar (1972, 1973), Waddell (1973a, 1974, 1975, 1983), Brown and Powell (1974), Powell and Powell (1974), Wohlt (1978, in prep.), Wohlt *et al.* (1982) and Goie (1986). Despite these observations, it is not easy to understand the relationship between frosts and subsistence food supply. There are very few long term daily temperature data available for high altitude locations. Even if better temperature data were available, more detailed observations on the relationship between low temperatures, crop yield and food supply would be required for a satisfactory analysis.

In the Eastern Highlands, only a few minor frosts have been recorded since the early 1930s (Table A12.7), but they occur more frequently in the Southern Highlands (Table A12.8). In the Southern Highlands, Enga and the Western Highlands, frost damage has occurred in most months of the year, but it is more common between July and November. Frosts are sometimes associated with drought. Three droughts that occurred in the Southern Highlands between 1952 and 1984 (1965, 1972, 1982) coincided with frosts, but other frosts in 1953, 1958, 1960, 1961, 1974 and 1980 did not coincide with droughts(11).

A preliminary classification of inhabited locations for frost vulnerability has been compiled using these data and other published and unpublished observations from elsewhere in the highlands (Table 7.4). It is clear that the repeated and severe frosts, such as those at very high altitudes in 1941 and 1972, have caused widespread destruction of sweet potato and other crops and have resulted in major shortfalls in food supply. It is also apparent that frosts which result in only minor and localized damage to crops do not lead to food shortages. However, most frost damage lies between these extremes and it is difficult to assess the significance of many frosts in the highlands. It is not clear from the available information that moderately severe frost damage results in shortfalls in food, particularly when only a single frost occurs.

Prolonged periods of chilling temperatures in the range of 0 to 10 °C may also damage sweet potato plants and reduce yields. Detailed data are not available to assess any such possible effects. Reports in the literature are based on experimental conditions, and generally for constant temperatures, from which it is difficult to predict outcomes in field situations. It is possible that some damage attributed to frosts may have been caused by extended periods of chilling temperatures. For example, between July and November 1982, screen temperatures at Tambul and Kuma (Upper Mendi Valley) were below 8 °C on many nights (Radcliffe, 1985a:11) suggesting that chilling damage may have occurred as well as that from frost.

The most severe frosts undoubtedly result in major shortfalls in food supply. This is particularly so at very high altitude locations (above 2200 m) (Table 7.4). Occasionally people in locations classed here as vulnerable experience major food shortages from frost damage, such as occurred in 1972. Frost damage in these locations in other years causes some crop damage and reduces the food supply to some degree, but the effects appear to be overestimated by outsiders.

(11) The ENSO event coincided with frost in 5 of the 10 years in which a frost occurred over this period in the Southern Highlands (1953, 1958, 1965, 1972, 1982); but in the other 5 years frost did not occur during the ENSO climatic disturbance (Quinn *et al.*, 1978; McDonald, 1984).

Table 7.4 Classification of inhabited locations in the Papua New Guinea highlands for crop vulnerability to frost damage (1)

1. **Very vulnerable.** Very severe frost damage to crops experienced occasionally, moderately severe damage frequently, and minor damage very frequently.

   Enga. Marient Basin, Lai Valley and Upper Wage Valley (Kandep District)

   SHP. Lavani Valley (Koroba District), Margarima area (Nipa District)

   WHP. Upper Kaugel Valley (Tambul District)

2. **Vulnerable.** Severe or moderately severe frost damage experienced occasionally, minor damage frequently.

   Enga. Upper Lagaip Valley, Sirunki Plateau (Lagaip District)

   SHP. Upper Mendi Valley (Mendi District), Ialibu Basin (Ialibu District)

3. **Less vulnerable.** Moderate damage experienced only during most severe frosts (for example in 1972), and minor damage infrequently.

   Enga. Porgera and Middle Lagaip Valley (Lagaip District), Middle Lai and Tsak Valleys (Wapenamanda District)

   SHP. Kagua area (Kagua District), Koroba District (other than Lavani Valley), Nembi Plateau, Nembi Valley and Nipa Basin (Nipa District), Lower Mendi Valley (Mendi District), Tari Basin (Tari District)

   WHP. Upper Baiyer Valley (Hagen North District), Middle Kaugel Valley (Tambul District)

4. **Least vulnerable.** Minor crop damage occurs very infrequently.

   All Eastern Highlands, Chimbu and highlands fringe above 1600 m

   All other parts of Enga, Southern Highlands and Western Highlands above 1600 m

Note

(1) This classification is based on Waddell (1973a), Brown and Powell (1974), Wohlt *et al.* (1982) (particularly their map on page 18); unpublished government reports; communications with various government officials and the author's field observations in 1980 and 1982.

OTHER CLIMATIC EXTREMES AND FOOD SUPPLY

Highlands food gardens are occasionally damaged or destroyed by other manifestations of extreme climatic events. These include flooding, landslides (following prolonged high rainfalls or earthquakes) and occasionally hailstorms. Many investigations of reported food shortages by government officers in recent years are concerned with these events. Flooding is the most common and references to flood damage are not uncommon in patrol reports.

There is no doubt that floods, landslides and hailstorms occasionally cause severe and often spectacular damage to food gardens in the highlands. It is doubtful however whether this damage leads to food shortages, except in a very limited number of households. This is because individual households rarely lose most or all of their food gardens. Even when this happens, the effects are able to be absorbed locally because relatives and neighbours who are not affected are able to provide agistment for pigs and food for people. It is also apparent that the effects of these localized but spectacular events are generally overestimated by outsiders. Between 1979 and 1984, food aid was given to victims of floods or landslides on at least five occasions in the highlands, but it was never given to people whose gardens were affected by prolonged water surplus (Table 8.2).

There was a possible exception in the Koroba District of the Southern Highlands in 1984. In April and May, there was extensive flooding in three census divisions. This was reported to have resulted in a food shortage in the district, with 480 people seriously affected and 11,600 people less seriously so (Files NES, Port Moresby; DPI, Mendi). The flooding in the Koroba District in 1984 may have been sufficiently widespread to have resulted in food shortages in some communities.

CONCLUSIONS

Comparisons of recorded episodes of sweet potato scarcity and high market prices in the highlands with extremes of soil moisture clearly indicate that certain extremes of soil moisture depress sweet potato yield and cause food supply problems. Droughts very rarely result in food shortages in the highlands, unless they are preceded by an extended water surplus. Extended water surpluses or brief periods of extremely high water surplus sometimes result in food shortages. However it is the sequence of an extended period of water surplus followed some 6 to 10 months later by a drought that is most damaging.

It is suggested that this sequence operates as follows: The prolonged water surplus interferes with tuber initiation and depresses the yield potential of the plants. This is further reduced when a drought coincides with the rapid tuber bulking phase. The effects of the relatively mild droughts that occur in much of the highlands are increased because the depth of rooting is reduced by the prior water surplus. Outbreaks of sweet potato weevil associated with drought are probably a minor contributing factor to the food supply problems.

Severe frosts undoubtedly depress sweet potato yield and cause major shortfalls in supply, particularly at very high altitudes (above 2200 m). At lower altitudes, frost only very rarely causes food supply problems and the impact of frost is generally exaggerated. Other manifestations of climatic extremes, including floods, landslides and hailstorms, sometimes cause damage to food gardens, but it is doubtful if they are responsible for food shortages at the level of community and above.

Nevertheless, the effects of extremes of soil moisture on sweet potato yield provide only a partial explanation for food shortages in the highlands. Variation in the crop planting rate over time also has a strong influence on food supply. This is examined in the next chapter, together with observations on how people respond to food shortages.

CHAPTER EIGHT

VILLAGERS' RESPONSES TO VARIATION IN FOOD SUPPLY

The previous two chapters dealt with one major source of variation in food supply, that is, the influence of climatic variation on sweet potato yield. Attention now turns to the other major source of variation - changes in the rate of crop planting. One of the most important findings of this thesis is that people vary the planting rate of sweet potato according to the current food supply. This variation in crop planting rate affects future availability of food and may cause cycles in food supply. People also respond in other ways. As would be expected, they alter their consumption patterns when food from their own gardens is inadequate. In recent years, they increasingly use imported foods rather than traditional emergency ones when sweet potato is scarce. In cases of extreme shortage of food, especially at high altitude locations, they may even decide to migrate elsewhere. People may also make changes in the management of their pigs and this serves as an important buffer between variation in supply and people's consumption.

ALTERED FOOD CONSUMPTION

Highlanders alter their food consumption pattern when subsistence food is scarce. The use of special emergency foods is widely reported from throughout the highlands, particularly wild pueraria and yams (Table 8.1). Their use is decreasing as people turn to imported food during food shortages, although some people whose access to cash is limited still use them. In Asiranka, none of my informants had ever eaten tubers of either wild yam or pueraria and there was no indication that these foods were eaten by anyone during the various food shortages in the 1980s. In contrast, some people at Upa had eaten these emergency foods during their lifetime and they were said to be used during food shortages in 1980 and 1984. In November 1984, members of three households were said to be eating tubers of wild yams and people in one household claimed to have been eating wild pueraria because of hunger.

Villagers also make more use of other garden foods when the supply of sweet potato is restricted. People eat more of certain fruits, nuts and green leaves, such as the fruit and leaves of *Ficus copiosa* and *F. dammaropsis*, oenanthe leaves and pandanus nuts. Many of these foods are normally not fully utilised and are available if needed(1).

(1) Most of these alternatives to sweet potato are low energy foods, particularly fruits and leaves, and some of the higher energy ones, such as wild yams, pueraria and *Alocasia* taro, are very unpalatable. There are few alternative foods that are a satisfactory substitute for cultivated root crops.

Table 8.1 Alternative foods to sweet potato eaten during food shortages in the highlands(1)

Location	Period	Alternative foods	Source
Lai Valley, Enga	-(2)	*Alocasia* taro	Meggitt (1958:316)
Highlands	-	Bamboo shoots, wild pueraria	Powell (1976:132-133)
Upper Lamari Valley, EHP	Before contact	Wild yams, wild highland, pitpit, fruit of highland *kapiak*, insects, pueraria, bamboo shoots	Grossman (1979:218)
Haiyapugwa area, Tari, SHP	-	Pueraria, mushrooms, palm shoots, highland *pitpit*, rungia, oenanthe, *N. schlecteri*, *Commelina* sp., *Floscopa scandens*, *Ficus* spp fruit and leaves, taro leaves, banana trunks	Powell (1982:83,86)
Wage Valley, SHP	-	Wild yams, pueraria, *Commelina diffusa*, leaves of highland *kapiak*	Sillitoe (1983:44,48,71,77)
Aiyura Basin, EHP	Before contact	Wild yams, wild pueraria, leaves of highland *kapiak* and *Ficus copiosa*	Bourke (thesis)
Nembi Plateau, SHP	Before contact	Wild yams, wild pueraria, oenanthe, ferns, wild banana stems, cultivated banana corm, stem of *Saccharum robustum* and *Pennesetum macrostachyum*, *Alocasia* taro (?)	Bourke (thesis)
Kandep, Marient Sirunki, Enga	1941-42	*Solanum nodiflorum*, Oenanthe, *kunai*, *Miscanthus floridulus*, highland *kapiak* fruit, karuka nut pandanus, sweet potato vines, cordyline shoots	Waddell (1973a:18-19)
Enga	Early 1973	Karuka nut pandanus	Binns (1976:234) Waddell (1974:43)
Upper Wage V, Kandep District, Enga	Early 1973	Wild karuka pandanus, potato, greens	Wohlt (1978:142)
Tumbudu Valley, Koroba District, SHP	Early-mid 1979	Wild yams, wild taro (*Alocasia*?), giant ferns	DPI files, Mendi

Nembi Plateau, SHP	Sep 1980/ Nov 1984	Pumpkin fruit, wild yams, wild pueraria	Bourke (thesis)
Lufa area, EHP	Early 1981	Marita and karuka nut pandanus	DPI files, Goroka
Sirunki Plateau, Enga	Late 1982- early 1983	Karuka nut pandanus, cabbage, *N. schlecteri*	A. Brown, pers.comm., (Nov 1983)
Menyamya area, Morobe	Late 1982- early 1983	"Bush foods"	D. Leonard-Thompson, pers.comm. (Nov 1983)
Henganofi area, EHP	Late 1982- early 1983	Bamboo shoots	T. Renagi, pers. comm. (Nov 1983)
Auyana CD, Okapa area, EHP	Early 1983	Corn, cucumber, winged bean, pumpkin, sugarcane	DPI files, Goroka
Hamdei CD, Kaintiba District, Gulf Province	Nov 1984	Wild berries, leaves, karuka nut pandanus	Soso (1984)

Notes

(1) This is a selected list only. Pueraria tubers are referred to as "famine" foods by other authors, for example Watson (1968) and Hide *et al.* (1979:61).

(2) Where no year is given for the period or it is given as "Before contact", the information is for previous unspecified food shortages.

People reduced their food intake during past shortages and this is still done by those who do not have access to sufficient cash to purchase food. During the various shortages observed in Upa, people ate very small tubers that normally would be considered fit only for pigs. In 1984 many people complained of reduced intake and their statements were supported by the survey of evening meals in which people in 16 per cent of households claimed to have eaten no food at all or low energy foods only on the evening of the survey (Table 3.2). In the past, men in the Nembi area tucked a belly-pad (*tambok*) between their bark belt and body when they were chronically hungry (Williams, 1940:48, 50). This practice was not uncommon on the Nembi Plateau in the early 1970s during food shortages (D. Eastburn, pers.comm., 1987). In late 1984, one old man at Upa, who was suffering the effects of reduced food intake, was still using such a belly-pad made from bark and cloth.

Stealing from gardens has been reported during previous food shortages, for example, during the 1941 famine in Enga (Waddell, 1973a:19). At Asiranka young men were said to be stealing food from gardens during the 1982 food shortages. Many people complained of children stealing from gardens and damaging them during the 1984 shortages at Upa and evidence of damage to immature gardens was apparent.

Imported food purchases. An increasingly important response to food shortages is the consumption of imported food. From the 1960s onwards, and possibly earlier, villagers bought imported food, particularly rice, when subsistence food was scarce. For example, an increase in rice consumption was reported in the Western Highlands in 1967 during a food shortage then (Nelson, 1971:106-107), in the Goroka area during the 1970 shortage (Shannon, 1973:19), and in the Laiagam area of Enga in 1971 following frost damage (Scoullar, 1972:9-10).

Consumption of imported food during food shortages is illustrated using both village level and provincial data. In both Asiranka and Upa, people diverted cash income to food purchases. Much more imported food was eaten in Asiranka than in Upa because of insufficient cash in Upa. All unsolicited statements about food purchases referred to income from wage labour, sales of coffee and non-staple food such as oenanthe or pig meat. Nobody mentioned the use of cash savings for food purchases. People sought ways to earn extra income in order to buy food. One example illustrates this: On one day in September 1984, an Asiranka woman from a household with a limited cash income spent six hours collecting oenanthe from a forest garden and selling it in Kainantu market. She raised K14 and used this to buy rice and other imported food in Kainantu.

The increased purchase of imported food when subsistence supplies are scarce is apparent in the purchase records for 10 trade stores on the Central Nembi Plateau for a 14 month period (Figure 8.1, Table A14.1). Imported foods or food made locally from imported ingredients, such as rice, tinned fish and meat, biscuits and bottled drink accounted for most sales in these stores, with cigarettes, kerosene and miscellaneous items such as playing cards the remainder. Purchases, and presumably sales, increased rapidly from mid-1984 onwards and peaked in October 1984. The proportion of rice of all sales was much greater in the second half of 1984 (40 per cent) than in the first half of the year (25 per cent). The timing of the increased sales of rice and all commodities coincides with the food shortage which was most severe between about June and November 1984(2).

Rice sales from the two wholesale terminals in the highlands also illustrate how people vary their rice consumption depending on subsistence food supplies (Figure 8.2, Tables A14.2, A14.3). There is a regular sales peak every year during the coffee harvesting season. In addition, there were unseasonal peaks in sales between September and December 1982 and again between September and November 1984. These unseasonal peaks coincided with subsistence food shortages in much of the highlands (Figure 3.8). The decline in sales in 1983 coincided with particularly good subsistence food supplies in much of the region as a result of high planting rates in late 1982 and early 1983 (Figures 8.2, 8.4, Table A14.2)(3).

National level import data for rice and flour/wheat show how consumption of imported food varies depending on the supply of subsistence food, although such aggregated data are less useful than regional level data (Figure 8.3, Table A14.4)(4). The large increases in rice imports in 1972-73 occurred because of the food aid provided by the Australian Administration during widespread food shortages in the highlands and because of increased village purchases throughout the nation. There was a large decline in imports in the following year as surplus government stocks were sold, and probably because of particularly good subsistence production. Flour/wheat imports declined dramatically in 1983 when subsistence food was in particularly good supply in the highlands, and then increased in 1984 when subsistence food was scarce in the highlands (Figure 8.3).

Food aid. Prior to 1972, very little food aid was provided by the Australian Administration (Table 8.2). In 1972-73 a large scale food relief operation was conducted

(2) The increase in trade store sales in 1984 is unlikely to have occurred merely because of the availability of cash from coffee sales, although this cash facilitated the food purchases. Other sales data from the Southern Highlands do not indicate a seasonal rise in consumption during the coffee harvesting season (Figure 5.3) and the peak month for trade store purchases (October 1984) occurred after the completion of the main harvesting period. However, a longer data run than is available here is needed to confirm this conclusion.

(3) The large variation in rice sales between 1982 and 1984 does not reflect variation in income from coffee sales. Returns from coffee did not vary greatly between 1982 and 1984 (Figure 5.5) and in fact coffee production was greatest in 1983 when rice sales were lowest (Figure 5.4).

(4) Unmilled wheat has replaced flour imports in PNG since 1977 (Table A14.4).

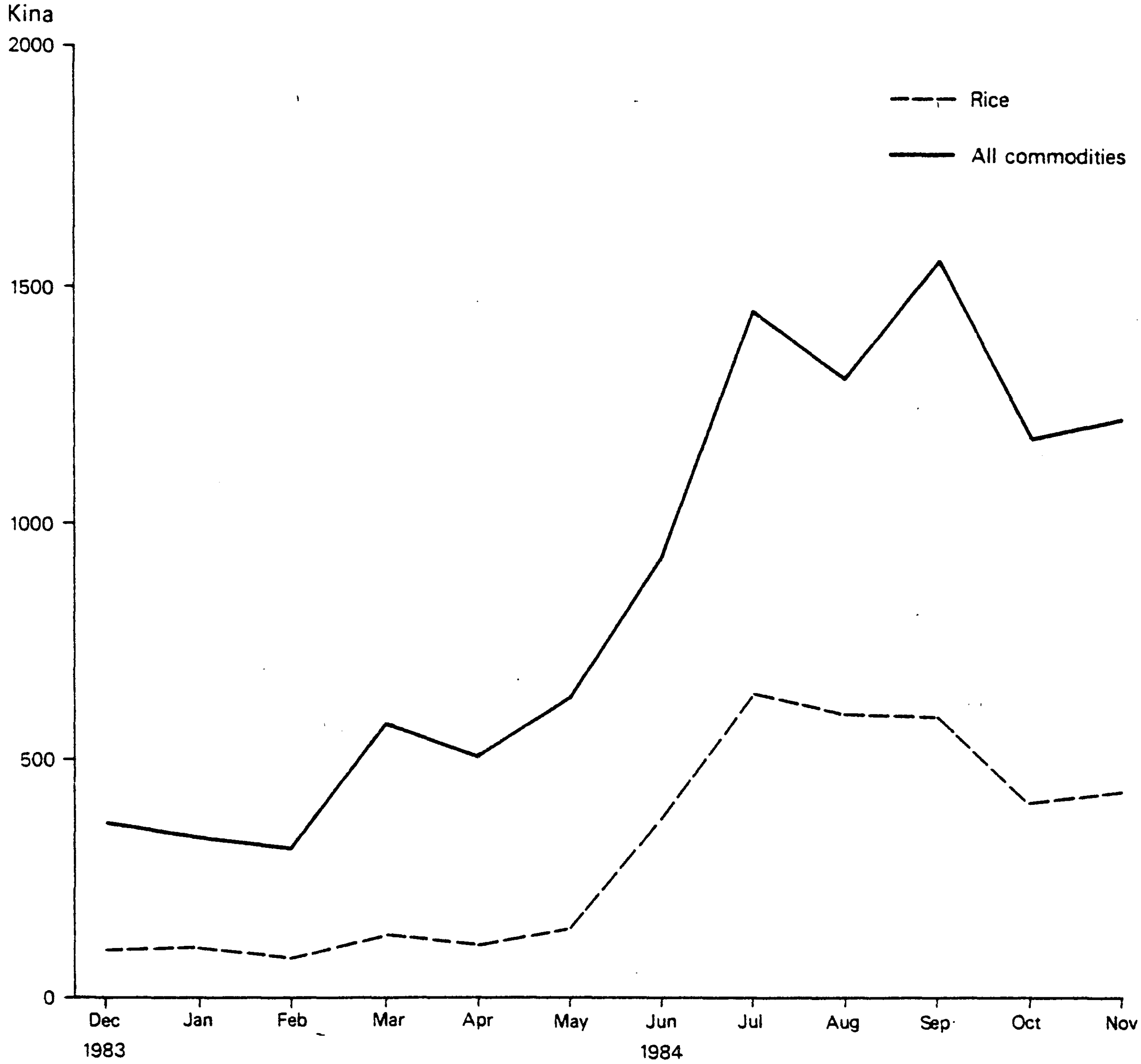

Figure 8.1 Monthly purchases of rice and all commodities by 10 trade stores, Central Nembi Plateau, November 1983 to December 1984 (three monthly running mean) (Source: store purchases receipts)

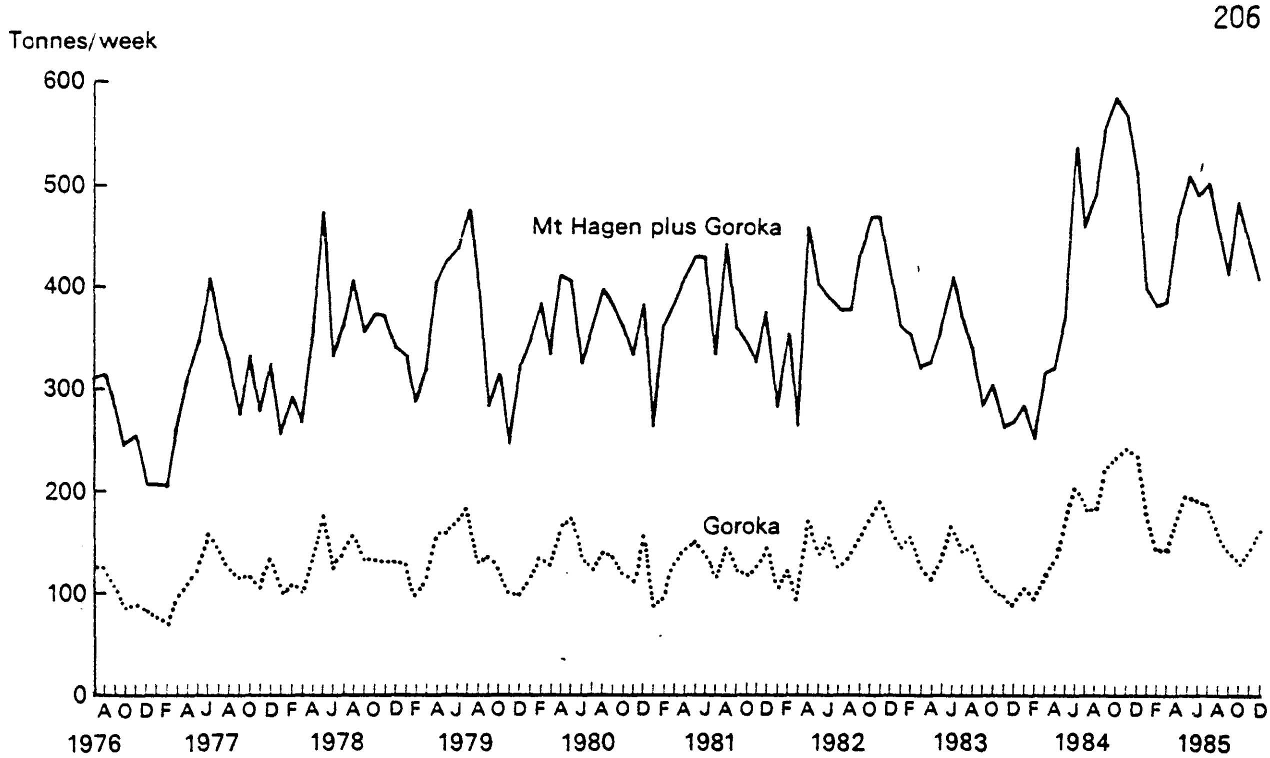

Figure 8.2 Monthly rice sales from Mt Hagen and Goroka terminals, July 1976 to December 1985 (Source: Rice Industries Ltd)

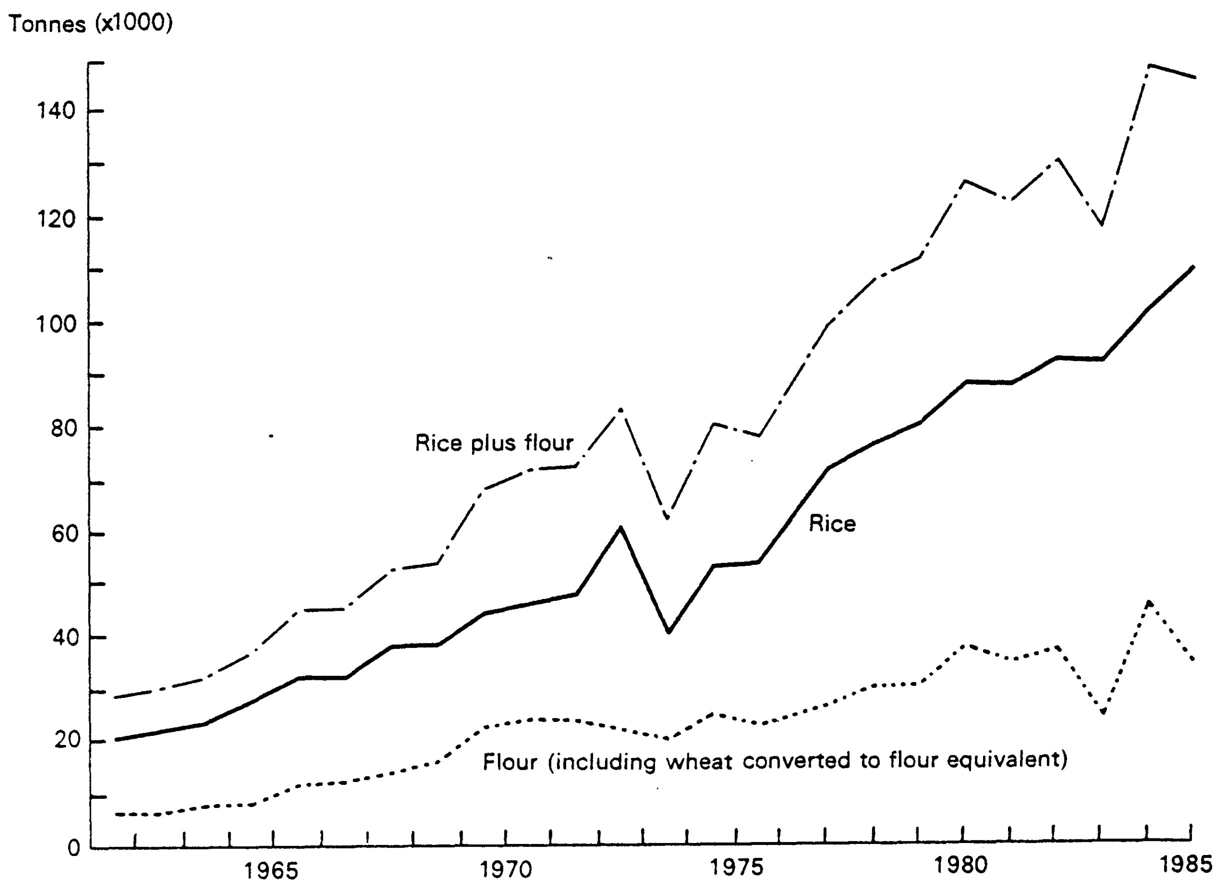

Figure 8.3 Imports of rice and flour/wheat into Papua New Guinea, 1961 to 1985 (Source: NSO and DPI, Port Moresby; Rice Industries Ltd)

by the Administration in the western part of the highlands. Food was given to as many as 143,000 people, with a mean of 129,000 people being given food in late 1972 (Table 8.3). Since 1972, food aid has been provided irregularly in the highlands.

Villagers now routinely request assistance from local, provincial and the national governments during a *taim hangre*. Local government councillors in both Asiranka and Upa approached provincial government staff seeking food aid during the 1982 shortage, but no assistance was received. Aid was not sought in either village in 1984. In Asiranka the councillor said this was because help had not been received in 1982, while the Upa councillor said the government was displeased with the Nembi people because of recent tribal fighting and would be unsympathetic.

It has been suggested, for example, by Waddell (1974), that food aid would decrease villagers' ability to find solutions to their food supply problems. I do not believe that this has happened, for the following reasons: Food aid is generally distributed to victims of spectacular, but frequently not very serious natural disasters, particularly following flooding, landslides and frost damage. However, it is not distributed when food is scarce but there is no obvious cause, as in 1981 in the Southern Highlands or in 1984 in much of the region. With the exception of the 1972-73 relief operation, the amount distributed has been too small to have any widespread impact. Thus in 1982-83, a total of K187,000 was spent on food relief in three highlands provinces (including transport costs) (Table 8.2). The official estimate of the cost of providing sufficient food aid to those affected in the highlands region was K757,000 **per month** (Defence Force, 1983). Finally, there are considerable organisational and logistic problems in distributing food in Papua New Guinea and this has sometimes resulted in food being given to the wrong people and at an inappropriate time (Wohlt *et al.*, 1982:57-61).

Occasionally other sources of aid are used by villagers. When food was scarce in Asiranka in 1982, people approached expatriate members of the Summer Institute of Linguistics who are based in the Aiyura Basin. Some expatriates provided rice and tinned fish regularly to individual households in Asiranka for some months between late 1982 and early 1983. Another source of help in 1982 for some people in the Kainantu area was a local businessman. This individual distributed bags of rice to people short of food and cash. During the following coffee harvest, the individuals repaid him by returning the bag filled with coffee parchment. Many people in Asiranka claimed to have participated in this exchange. The businessman said that he distributed 140 bags of rice (3500 kg). Depending on assumptions made about the amount of coffee repaid and the price of coffee at the time, the venture would have yielded him a profit of between K1600 and K2800.

Table 8.2 Food aid provided by government in the PNG highlands, 1939 to 1984(1)

Location	Period	Stated cause of food shortage(2)	Popul. affected(3)	Source of funds(4)	Amount spent(5)	Data source
Mt Hagen area	1939	Dry winds	-	Admin/ Cath.Miss	-	Gitlow (1947:66)
Pangia area, SHP	1965	-	-	Admin	-	Sisley (1967)
Yongamugl CD, Chimbu	Nov 1965	Drought	-	Admin	(6)	Hide (1981:37)
Upper Lagaip V, Sirunki Plat, Enga	Sept(?) 1971-early 1972	Frost	12,500	Admin	(7)	Scouller (1972) Waddell (1973a)
Enga/SHP/ WHP	Aug 1972-May 1973	Frost/drought	130,000 (8)	Admin Public donations	1,600,000 1,000,000 (9)	NES files, Prime Minister's Dept, Port Moresby
Henganofi Dist, EHP	Feb 1979	Landslide	750	NatGov	700	NES files, P. Moresby
Tumbudu V, Koroba, SHP	Jul-Aug 1979	Inadequate agric techniques	1,500	ProvGov	1,200	DPI files, Mendi Roberts (1982)
Asaro V, EHP	Dec 1979	Flooding	1,400	NatGov	3,000	NES files, P. Moresby
Enga SHP WHP	Nov 1980-Jan 1981	Frost	? 42,000 ?	NatGov NatGov NatGov	115,000 161,000 95,000	ProvGov Archives, Mendi(10)
Upper Chimbu V	1981	Landslide	-	ProvGov	12,000	DPI files, Kundiwa
Ofafina R, EHP	Jan 1982	Flooding	200	ProvGov	8,000	DPI files, Goroka
Enga	Jul 1982-early 1983	Frost	37,000	NatGov ProvGov Other	29,400 32,000 8,600	NES files, P. Moresby
SHP	Sep 1982-early 1983	Frost	70,000	NatGov ProvGov Donations	39,700 17,000 8,300	DPI files, Mendi NES files, P. Moresby

Tambul Dist, WHP	Jul-Dec 1982	Frost	52,000	NatGov ProvGov Other	38,500 7,000 6,500	DPI files, Mt Hagen NES files, P. Moresby
Koroba Dist, SHP	Aug 1984	Flooding	16,400	NatGov ProvGov	15,000 4,000	DPI files, Mendi NES files, P. Moresby

Notes

(1) Food aid was provided earlier in the lowlands. For example, rice was provided by the government to New Britain villagers who were very weakened and "in the last stages of starvation", sometime between 1914 and 1920 (Overell, 1923:115). In 1931 the government provided food to villagers in the Rigo area during a food shortage caused by drought (Murray, 1933).

(2) Stated causes of reported food shortages are not necessarily accepted.

(3) Estimates of affected populations are sometimes very crude.

(4) Admin refers to the Australian Administration (prior to independence).

(5) Amounts spent on food aid are for direct costs only, such as cost of food and additional transport costs. Sums are in Australian dollars (pre 1975) and kina (post 1975)(unconverted currency).

(6) Four tons of rice was advanced to Yongamugl people by the government in November 1965 (Hide, 1981:37).

(7) Following frosts and food shortages in the Laiagam area in August 1971, a relief programme was initiated whereby construction of the Wabag to Laiagam road was paid for in rice (Scoullar, 1972). The scheme was unpopular with villagers and it eventually reverted to cash payment.

(8) The source is Waddell (1973a)(Table 8.3). The National Emergency Service (NES) files indicate that an estimated 115,000 people were given food aid and 130,000 people were affected by the shortage. Powell and Powell (1974:27), Brown and Powell (1974:2) and Waddell (1983:33) give a slightly higher figure (150,000) as the number of people being supplied with food. Food distribution started in the Kandep area in late August 1972 (Waddell 1973a:13).

(9) Documents in files of the Prime Minister's Department give the amount spent by the Administration as $2.6 million, of which $1 million came from public donations. Records held by the National Emergency Service give the figure as $2.3 million. Waddell (1975:39) states the direct cost of the relief programme as some $3 million, of which $1 million was covered by voluntary contributions. He gives a figure of $3-4.5 million in a later paper (Waddell, 1983:33).

(10) Data extracted by B. J. Allen from Provincial Government Archives, Mendi. The total sum allocated for all PNG (highlands and lowlands) was K775,000 with another K495,000 held in reserve. The UN Disaster Relief Organization offered K7,000 and the UN World Food Program K650,000, but funds offered by these UN agencies were not taken up.

Table 8.3 Mean number of people receiving food aid per week, PNG highlands, November and December 1972(1)

Province	District	Centre	Number of people
Western Highlands	Tambul	Tambul	14,340
Enga	Wapenamanda	Wapenamanda	3,580
	Kandep	Kandep	18,880
	Lagaip	Laiagam	19,810
Southern Highlands	Pangia	Pangia	0
	Ialibu	Ialibu	16,380
	Kagua	Kagua	30
	Mendi	Mendi	15,880
	Mendi	Lai Valley	3,060
	Nipa	Margarima	7,900
	Nipa	Nipa	15,370
	Nipa	Poroma	6,430
	Tari	Tari	340
	Koroba	Koroba	7,360
Western Highlands/Enga total			56,610
Southern Highlands total			72,750
Highlands total			129,360

Notes

(1) The source is Waddell (1973a:45) who gives weekly numbers from late October to late December 1972. Data presented here are the means for eight weeks in November and December. The number of people receiving aid peaked in late November when 143,000 people were given food.

MIGRATION

Probably the most extreme reaction to food shortages is the migration of entire communities, particularly from high altitude and frost-vulnerable locations in Enga. These migrations are well documented, particularly by Wohlt (1978:110-123, 141-146; in prep.) who lived in a high altitude community between 1972 and 1975 when a series of migrations took place, and also by Dwyer (1952), Meggitt (1956:120, 125, 130; 1958:282), Timothy *et al.* (1974), Waddell (1973a; 1974; 1975), Goie (1986) and Clarke (in prep.).

Migration from other high altitude locations has also been documented. People moved from the Margarima area to the Tari Basin following severe frost damage in 1972 (B. J. Allen, pers. comm., 1986). Migration occurred from the Upper Kaugel Valley following severe frosts and food shortages in the early 1940s (Bowers, 1968:30). Following severe frosts and damage to sweet potato gardens in the high altitude Lavani Valley west of Koroba in mid-1982, villagers and their animals migrated to lower altitude communities. They returned to their homes in early 1983 when karuka nut pandanus commenced bearing (E. D'Souza, pers. comm., November, 1983).

The length of time such migrants may spend away from home varies considerably. The moves may last for some months only, as illustrated by the Lavani Valley case in 1982-83. People may make a series of moves between their homes and their hosts' homes over several years, as documented for migrants from the Upper Wage Valley between 1972 and 1975 (Wohlt, 1978:141-146). They may only return home after a decade, as reported from the Marient Basin in 1952 (Dwyer, 1952). In some cases they may even settle with their hosts and never return home, as illustrated by the life of the late Sir Tei Abal whose family moved from the Kandep area to near Wabag in about 1941 and never returned to their high altitude home.

As the example from the Lavani Valley shows, migration is not a thing of the past. People moved from the Upper Wage Valley in Kandep District in 1980, 1982 and in 1986 in response to frost damage and food shortage (P. Wohlt, pers. comm., 1981, 1983, 1986). Some people moved from the Gumine area of Chimbu in 1982 when food was scarce there to other communities in the area and to the Western Highlands (SLUP files, Kundiawa).

With the exception of the report from Gumine, all accounts of migration in response to food shortages come from high altitude locations in Enga, the Southern Highlands and the Western Highlands which are very vulnerable to frost damage (Table 7.4). No accounts of migration were offered from the two study communities(5).

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(5) However, the Aiyura Basin has been a destination of men seeking work in response to food shortages in their own communities. As early as 1941, Brechin recorded that local

VARIATION IN CROP PLANTING RATE

The Literature

There is no consensus in the highlands literature on the pattern of variation in planting rate over time. Some authors assert that sweet potato plantings are concentrated during certain periods of the year, for example, Meggitt (1958), Mathews (1971:31), Godyn and Godyn (1980:27), Manner (1981), Bourke and Lea (1982:83-84), Crittenden (1982:426-431; 1984:167-169) and Zimmer (1985:112-114). On the other hand others others state that sweet potato plantings are not seasonal in the highlands and highlands fringe, for example, Howlett (1962:65), Waddell (1972:117), Du Toit (1975:168), Powell *et al.* (1975:9), Modjeska (1977:3), Sillitoe (1983:18-21) and Hide *et al.* (1984:213).

None of these authors made any longitudinal recordings of garden planting rates to support their conclusions. However, a number of longitudinal studies have been conducted. These indicate that large variation in planting rate may occur over time, but that there is no regular annual variation in the planting rate of sweet potato gardens. These studies were done by Wohlt (1978:164-166, 395-399) in a high altitude location in Enga, by Grossman (1984:210-213) in a community in the Kainantu District of the Eastern Highlands, by Crittenden *et al.* (1985) in three locations in the Southern Highlands and by Wohlt and Goie (1986:48-52, 83-87) in two locations in Chimbu. A summary of their findings follows.

Wohlt's record of garden planting rate extended over a period of 2 years and 9 months. The rate of planting was particularly high in early 1973, when people re-established gardens after the devastation of the 1972 frosts, and again in late 1974, prior to the harvesting of wild karuka nut pandanus. Grossman's 11 month time allocation study was presented as means for three periods and interpreted as showing the depressing effect of the coffee harvesting season, as discussed in Chapter 5. An AFTSEMU team recorded crop planting rates in the Tari Basin, Upper Mendi Valley and in the Pangia area of the Southern Highlands and their survey lasted for up to 25 months (Crittenden *et al.*, 1985). There was no indication of an annual cycle in planting rates in any location. Some of the AFTSEMU findings are similar to mine and are presented later in the chapter. The surveys by Wohlt and Goie (1986) ran for just over a year, but again there was no indication of any annual cycle in planting rates.

A number of writers have suggested that cycles of exceptionally low and high planting rates or inadequate planning are responsible for food shortages. This is illustrated

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and Benabena men were seeking employment at Aiyura because of restricted food supplies from their own gardens (Brechin, 1941).

by two quotations, the first by an agricultural officer who described subsistence agriculture in Chimbu in 1957 and the second by two researchers who were interested in subsistence agriculture in the Okapa area of the Eastern Highlands.

> Serious food shortages do occur from time to time. However, there does not appear to be any definite time or period when shortages may be expected. Nor does there appear to be any one definite contributing cause of the recurrent shortages ... Perhaps the most significant factor influencing the time and duration of food shortages are periods of plenty when there is an abundance of food for all ... In such times of plenty an atmosphere of complacency is apt to pervade the community. Very little planting of food gardens is carried out whilst the complacent attitude prevails. Fortunately this short-sighted perspective usually does not last for perhaps more than two months. It is then replaced by a period of haste and hurried plantings. (Barrie, 1956:48)

> Occasionally, in some villages, a cycle of plenty followed by shortage develops as too many gardens are created when food is in short supply, and then too many of them are given up when they start producing an excess. (Sorenson and Gajdusek, 1969:323)

Other authors who suggest that cycles in planting rates or inadequate planning are contributing factors to food shortages include: Nilles (1953:4) on Chimbu; Hoban (1967) after a patrol in the Mendi area; Mathews (1971:34) on the Okapa area; Shannon (1973:13) on the Goroka area; Vicedom and Tischner (1983:215) on the Wahgi Valley; Bourke (1984d:18-19) on the highlands in general; Clark (1985:149) on the Pangia area; Crittenden *et al.* (1985:40-43) on the Southern Highlands; Wohlt and Goie (1986:52, 84-85, 128-136, 220-221) on Chimbu; and Wohlt (in prep.) on a community in the Kandep area.

Asiranka and Upa Surveys

Surveys were conducted in Asiranka and Upa Villages between 1979 and 1982 on the area of food gardens planted per month. The survey at Asiranka was done by the author and extended over a 41 month period and the Upa survey was done by E. D'Souza over a period of 32 months.

Methods. The surveys were conducted by measuring the area of gardens planted by a group of 10 women in each community every month. Recordings were made on all gardens planted since the previous survey, including area, garden type and prior land use. The women were paid a small amount of money to compensate for their time. The sample groups in both communities ranged in age from the early 20s to 50s. All the women were married, except for one at Asiranka who provided part of the food for her parents' household(6). The number of dependants of the sample group fluctuated slightly over

(6) In one of the Asiranka households, virtually all gardening was done by a male and it was his gardens that were measured. His wife was said to be lazy, although she died soon

time. The sample groups and the households of which they were members were representative of the larger communities in both villages, except that the group in Asiranka was responsible for more pigs per person than the community as a whole (Table 2.9).

The Asiranka survey was done by the author and a research assistant, except on several occasions when the author was absent and the research assistant made the recordings. D'Souza did all the Upa recordings. Garden areas were recorded with a tape measure and compass. At Asiranka the survey usually required one working day, but at Upa two to three days were needed because of lack of road access to more remote gardens.

One change of technique was made during the surveys. For the first two recordings at Asiranka, and the first at Upa, the women were asked to identify all plantings made during the previous week. The areas measured were an overestimate of planting and the data are not presented. In subsequent surveys, they were asked to identify plantings made during the previous two weeks. It is likely that these recordings also overestimate to some degree the area planted. After the surveys had been running for some months, the women were asked to identify all plantings that had not been previously measured, thus giving a 4 or 5 week survey period. In both villages, two women were replaced during the course of the survey because of temporary migration and an injury.

Asiranka results. Results of the Asiranka survey are presented in Figures 8.4, 8.5 and 8.6 and in Tables A2.5, A2.6, A13.1, A13.2 and A13.3. Particularly high planting rates for sweet potato and all crops occurred between late 1979 and early 1980 and again in mid- to late 1982 (Figure 8.4). The area of sweet potato planted was especially low between February and April 1982 (Table A13.1) and this coincided with an exceptionally wet period (Figure 7.9). It was again very low in July 1982 when gardening was disrupted by damage by pigs, frost damage and the relocation of gardens to new sites (Appendix 2).

Correlations were derived between garden area planted per month and certain market and environmental parameters (Table 8.4). The area of sweet potato planted by the 10 women of Asiranka Village was positively correlated with the price of sweet potato in Kainantu and Aiyura markets in the same month. It was negatively correlated with an index of the quantity of sweet potato offered for sale in local markets. The area of sweet potato planted was not statistically associated with rainfall or mean soil moisture storage during the month. Because of the dominance of sweet potato in the farming systems and the very high correlation between the area of sweet potato planted and the area of all food crops planted ($n = 39$; $r = 0.874^{***}$), the same relationships held between the area of all food crops planted and price/quantity of sweet potato in local markets, rainfall and mean

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after these recordings were completed, suggesting that ill health may have been the cause of her perceived laziness.

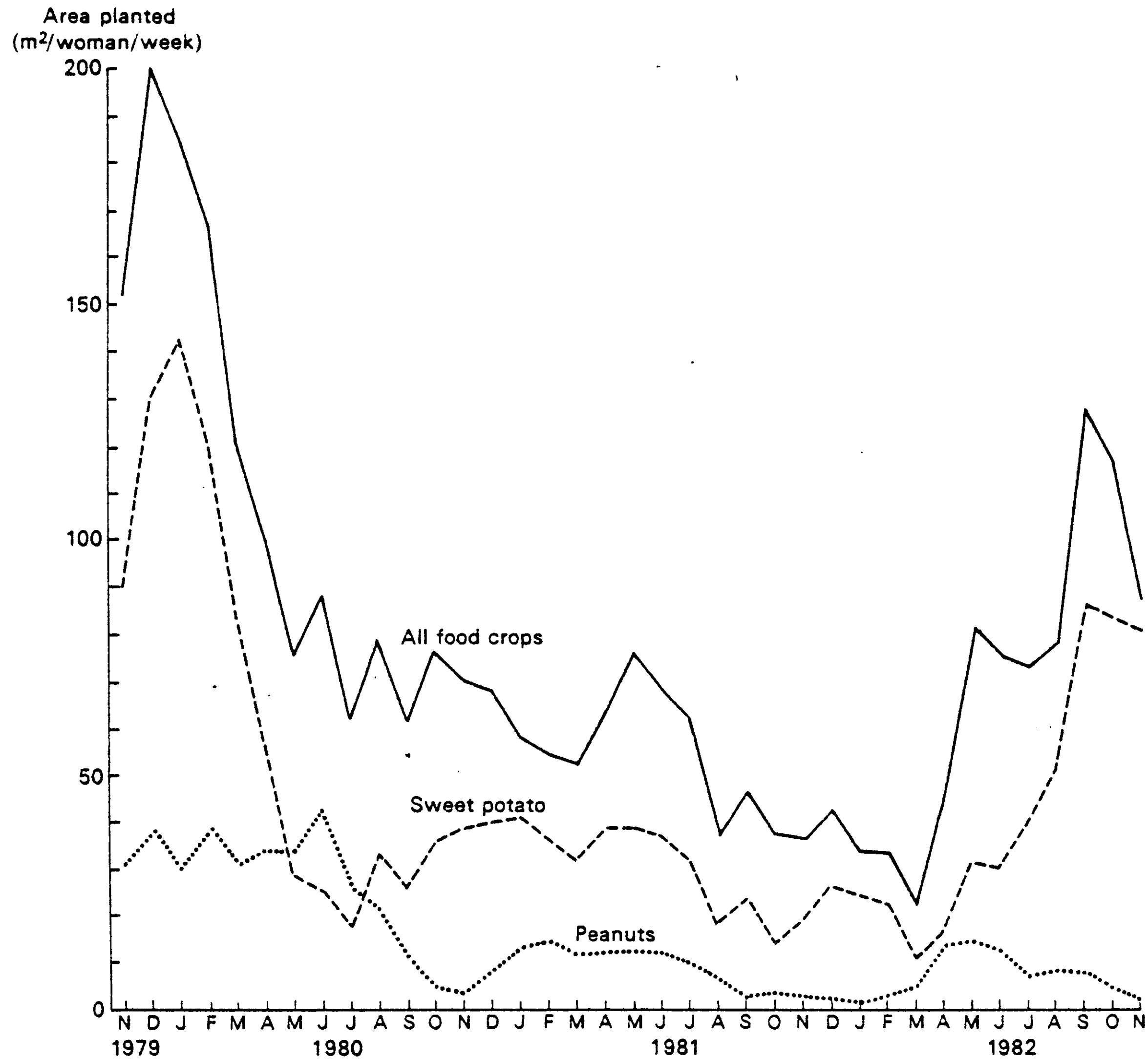

Figure 8.4 Asiranka crop planting survey: mean area of all food crops, sweet potato and peanuts planted, October 1979 to December 1982 (three monthly running mean)

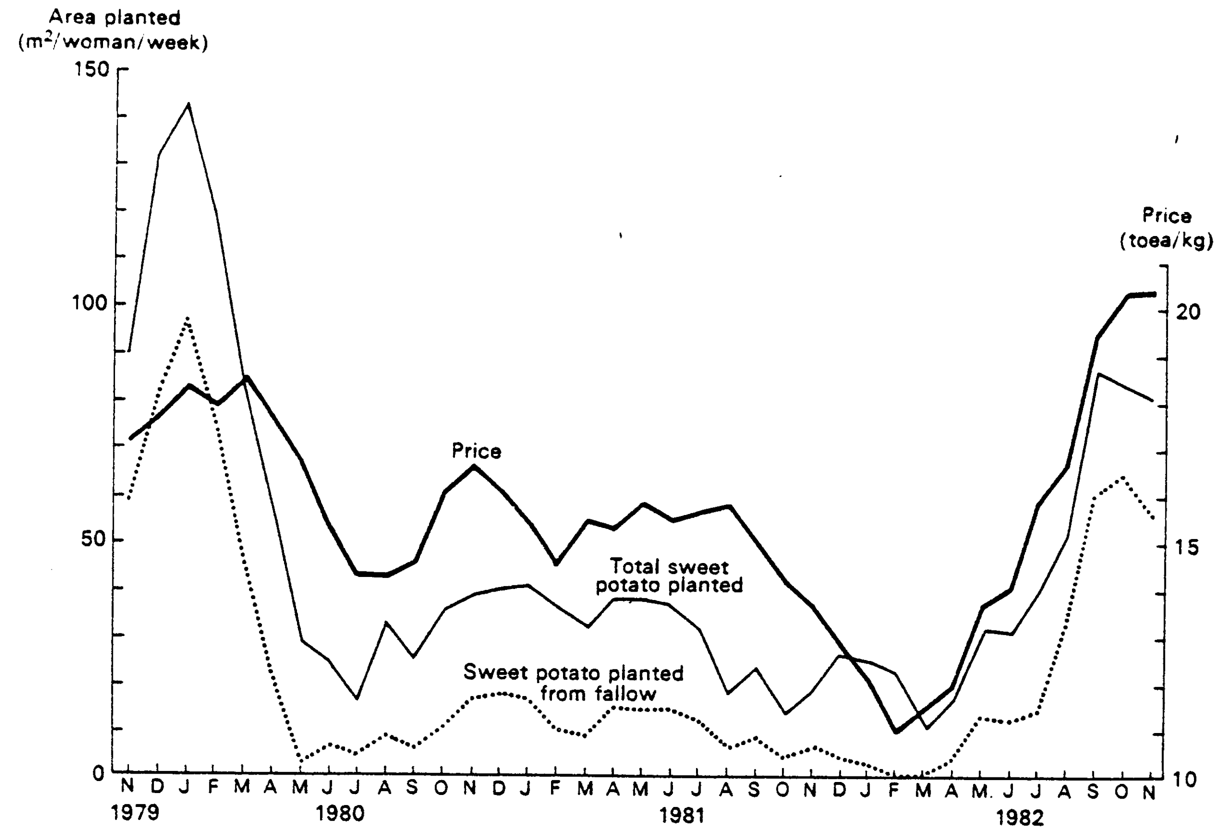

Figure 8.5 Asiranka crop planting survey: mean area of sweet potato planted (in fallow land and total) and price of sweet potato in Kainantu market (constant 1984 currency), October 1979 to December 1982 (three monthly running mean)

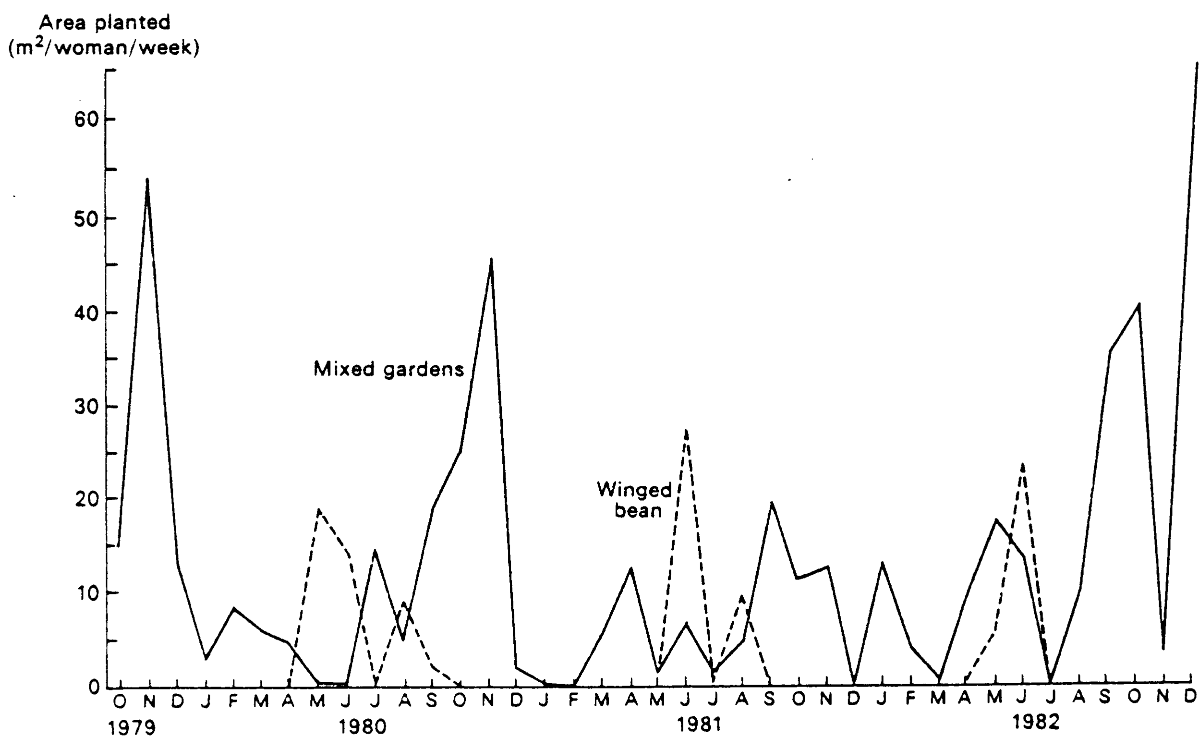

Figure 8.6 Asiranka crop planting survey: mean area of mixed gardens and winged bean planted, October 1979 to December 1982

Table 8.4 Asiranka crop planting survey: correlation coefficients between garden area planted and certain market and environmental parameters, October 1979 to December 1982(1)

Comparison	Correlation coefficient
AREA OF SWEET POTATO PLANTED vs	
Price of sweet potato, Kainantu market(2)	0.638***
Price of sweet potato, Aiyura market (Asiranka sellers only)	0.571***
Weight of sweet potato offered for sale in local markets(3)	- 0.556***
Rainfall at Aiyura	0.044
Mean soil moisture storage(4)	0.097
AREA OF ALL FOOD CROPS vs	
Price of sweet potato, Kainantu market	0.582***
Price of sweet potato, Aiyura market (Asiranka sellers only)	0.643***
Weight of sweet potato offered for sale in local markets	- 0.541***
Rainfall at Aiyura	- 0.054
Mean soil moisture storage	- 0.027
AREA OF SWEET POTATO PLANTED FROM FALLOW(5) vs	
Price of sweet potato, Kainantu market	0.576***
Price of sweet potato, Aiyura market (Asiranka sellers only)	0.571***
Weight of sweet potato offered for sale in local markets	- 0.601***
Rainfall at Aiyura	- 0.010
Mean soil moisture storage	0.030
AREA OF MIXED GARDENS vs	
Number of bundles of vegetables offered for sale, Kainantu market(6)	0.337
Rainfall at Aiyura	- 0.011
Rainfall, previous month	- 0.356*
Rainfall, 2 months previous	- 0.332*
Mean soil moisture storage	- 0.206
Mean soil moisture storage, previous month	- 0.639***
Mean soil moisture storage, 2 months previous	- 0.446**

Notes

(1) All comparisons are of monthly means for the same month, unless stated otherwise. The number of comparisons is 39 for most parameters. Data on mean areas of crop planted per woman are given in Tables A13.1.

(2) Prices are in constant currency. The relationships between area planted and unconverted prices are also significant. Unconverted prices are given in Table A6.5.

(3) The weight of sweet potato offered for sale in local markets is an index derived from the number of 10 toea equivalent bundles offered for sale in Kainantu, Aiyura and Ukarumpa markets (Table A6.6) at the time of the fortnightly survey divided by the mean price (toea/kg) of sweet potato in those markets for that month.

(4) Mean soil moisture storage is the mean of the calculated weekly soil moisture storage at Aiyura, for an assumed available water capacity of 100 mm.

(5) Area of sweet potato gardens that follow a fallow rather than another arable crop.

(6) Crops classed as vegetables are listed in Table A6.6. The number of comparisons is 32 for this parameter. This is only a crude index of the output of mixed gardens.

soil moisture storage. The area of sweet potato planted from fallow gave similar correlations with these five parameters.

Most of the sweet potato was planted in the grasslands (76 per cent) rather than forest; and about a third of the grassland gardens were planted after a fallow (Table A13.3). Almost all of the sweet potato gardens in the forest followed a fallow. There was no seasonal bias in the planting rates for either grassland or forest gardens, whether they were planted after a fallow or after other crops. However, the proportion of sweet potato planted from fallow was greatest when the total planting rate was high, that is, in late 1979-early 1980 and in late 1982 (Figure 8.5).

In late 1984, the same relationships between area of sweet potato planted, the proportion planted after a fallow and the market price were again observed, although comparable longitudinal garden measurements are not available. At this time, large areas of land had been cleared from fallow in preparation for planting during a period of low sweet potato supply and high market prices (Figure 7.9).

In contrast with the pattern for sweet potato, plantings of mixed gardens and winged beans were clearly concentrated during certain periods of the year (Figure 8.6). Most of the mixed gardens were planted between September and December each year (at the start of the wetter period of the year), and the planting rate was also high in April, May and June 1982. Winged beans were planted in monospecific stands for tuber and bean production between May and August each year, and very small areas for bean production were also planted in the mixed gardens later in the year (Figure 8.6). There was no regular seasonal variation in the planting pattern for peanuts (Figure 8.4). The area planted of introduced vegetables, potato, coffee, *Xanthosoma* taro, taro and yams was small (Table A2.6) and there was no indication that planting followed any seasonal pattern for these crops (Table A13.2). Cucumbers were planted seasonally between about May and July.

In contrast with sweet potato, the area of mixed gardens planted was correlated with measures of rainfall and soil moisture storage, but not with the quantity of food from this garden type in Kainantu market (Table 8.4). The greatest statistical association was a negative correlation with mean soil moisture storage during the previous month or two months, that is, most of the mixed gardens were planted after the driest months of the year.

Upa results. Results of the Upa survey are presented in Figures 8.7 and 8.8 and in Tables A13.4 and A13.5. In general, the major findings from the Upa survey are very similar to those from the Asiranka survey, although the agricultural system is less diverse at Upa. Sweet potato (81 per cent) and mixed gardens (18 per cent) account for most plantings at Upa. Most of the sweet potato plantings (86 per cent) followed a sweet potato crop; and most mixed gardens (97 per cent) were planted from a fallow (Table A13.5). The monthly rate of sweet potato planting varied greatly, particularly during 1980 (Figure 8.7). This suggested a seasonality pattern in the planting rate in that year, but this pattern did not occur in 1981 and the first half of 1982(7). There was a highly significant positive correlation between the area of sweet potato planted by this group of women and the price of sweet potato in the nearby Hol market (Figure 8.8, Table 8.5). As at Asiranka, there was no statistical association between the area of sweet potato planted and rainfall or soil moisture storage.

Sweet potato plantings that followed a fallow constituted on average only 16 per cent of all sweet potato plantings (Table A13.5). This proportion was greatest in late 1979-early 1980 when the total sweet potato planting rate and the market price of sweet potato were both high (Figure 8.8). The association between the proportion of sweet potato planted from fallow and market price did not recur in late 1980-early 1981 and there was no statistical association between these parameters (Table 8.5).

The same association between high market price, high planting rate and a high proportion of crop planted from fallow occurred again in late 1984. These observations are supported by cross-sectional recordings on garden planting (Table A13.6) and market price (Table A6.5). In November 1984 I recorded the area under crop of the 12 women who had participated in the 1979 to 1982 longitudinal garden survey. The area of sweet potato planted within the previous five months was just under 2000 m^2 per woman. This planting rate was much greater than the rate of 2500 m^2 per woman **per year** recorded between mid-1980 and mid-1982 (Table A13.5). Almost half (48 per cent) of the sweet potato plantings made in the latter half of 1984 followed a fallow (Table A13.6). This was much greater than the two year mean of 14 per cent in 1980 to 1982 (Table A13.5). The high garden planting rates and proportion of sweet potato gardens planted from fallow in the latter half of 1984 coincided with a major food shortage and exceptionally high market prices for sweet potato (Chapter 3).

As at Asiranka, villagers in Upa planted the mixed gardens seasonally, but the seasonal concentration was more marked. Mixed gardens were mostly planted between October and January each year (Figure 8.7). Again the mixed gardens were planted after the drier months, although the statistical association between the area of mixed gardens planted and soil moisture storage was weaker than at Asiranka (Table 8.5). The area of mixed gardens planted was not correlated with the quantity of food from mixed gardens offered for sale in the local market.

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(7) The very marked seasonality in sweet potato production on the Nembi Plateau described by Crittenden (1982, 1984) was based on observations made by him in 1980.

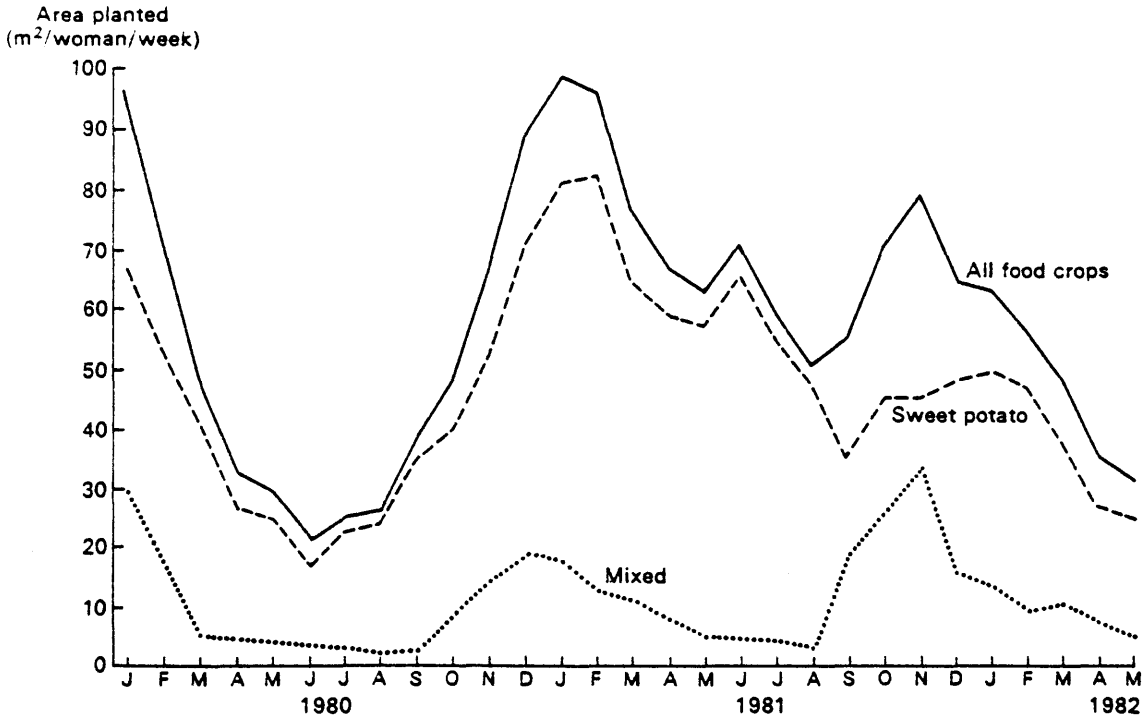

Figure 8.7 Upa crop planting survey: mean area of all food crops, sweet potato and mixed gardens planted, December 1979 to June 1982 (three monthly running mean)

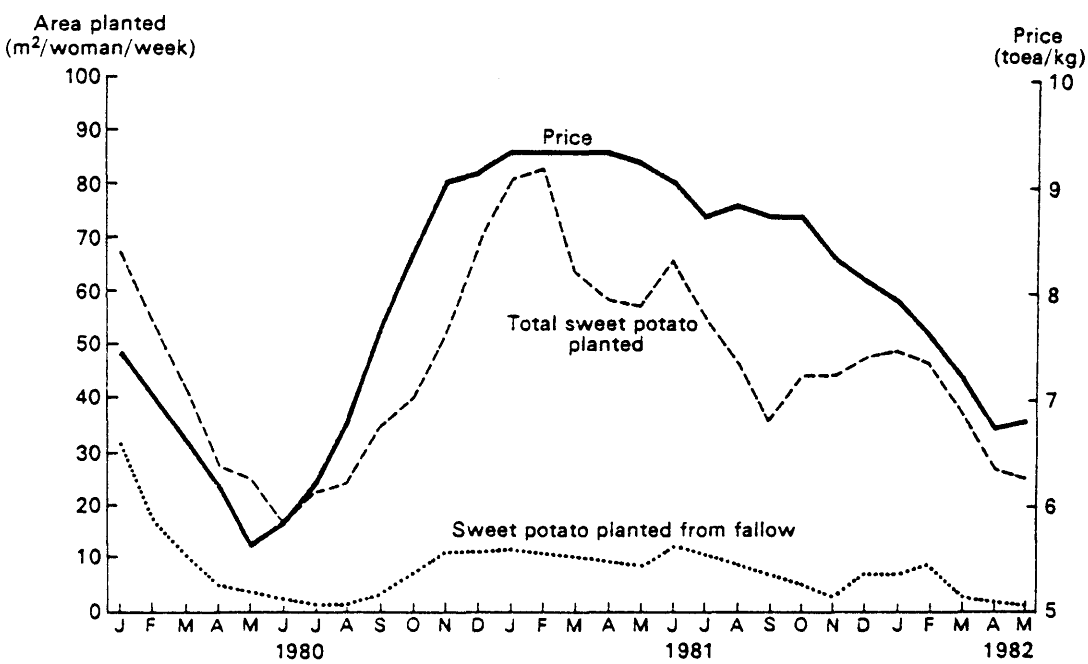

Figure 8.8 Upa crop planting survey: mean area of sweet potato planted (in fallow land and total) and price of sweet potato in Hol market (constant 1984 currency), December 1979 to June 1982 (three monthly running mean)

Table 8.5 Upa crop planting survey: correlation coefficients between garden area planted and certain market and environmental parameters, December 1979 to June 1982(1)

Comparison	Correlation coefficient
AREA OF SWEET POTATO PLANTED vs	
Price of sweet potato, Hol market(2)	0.670***
Weight of sweet potato offered for sale, Hol market(3)	- 0.177
Rainfall at Hol	0.204
Mean soil moisture storage(4)	0.203
AREA OF ALL FOOD CROPS vs	
Price of sweet potato, Hol market	0.597***
Weight of sweet potato offered for sale, Hol market	0.002
Rainfall at Hol	0.175
Mean soil moisture storage	0.200
AREA OF SWEET POTATO PLANTED FROM FALLOW(5) vs	
Price of sweet potato, Hol market	0.216
Weight of sweet potato offered for sale, Hol market	0.308
Rainfall at Hol	0.009
Mean soil moisture storage	- 0.043
AREA OF MIXED GARDENS vs	
Number of bundles of all food crops (except sweet potato) offered for sale, Hol market(6)	0.132
Rainfall at Hol	0.087
Rainfall, previous month	- 0.155
Rainfall, 2 months previous	- 0.413*
Mean soil moisture storage	0.104
Mean soil moisture storage, previous month	0.097
Mean soil moisture storage, 2 months previous	- 0.434*

Notes

(1) All comparisons are of monthly means for the same month, unless stated otherwise. The number of comparisons is 31 for sweet potato price and soil moisture storage; and 21-23 for rainfall, weight of sweet potato offered for sale and number of bundles of vegetables offered for sale. Data on mean area of crop planted per woman are given in Table A13.4.

(2) Prices are in constant currency. The relationship between area planted and unconverted price is also significant (0.596***).

(3) The weight of sweet potato offered for sale in Hol market is an index derived from the number of 10 toea equivalent bundles offered for sale in the market at the time of the weekly survey (Table A6.7) divided by the mean price of sweet potato.

(4) Mean soil moisture storage is the mean of the calculated weekly soil moisture storage figures for Mendi, for an assumed available water capacity of 100 mm.

(5) Area of sweet potato gardens that follow a fallow rather than another arable crop.

(6) The number of bundles of all food crops (except sweet potato) offered for sale at Hol market (Table A6.7) is likely to be a reasonably good index of the output of the mixed gardens on the Nembi Plateau.

AFTSEMU Surveys

In 1981 members of an agricultural research team in the Southern Highlands (AFTSEMU) initiated a series of village surveys to determine the relationship between gardening activity and people's nutritional status (Crittenden *et al.*, 1985). As part of this study, garden surveys based on the methodology developed by this author were done each month in three locations. The AFTSEMU study was done in the Tari Basin, the Upper Mendi Valley and on the Poru Plateau (Pangia area). The survey period ranged from 13 to 26 months and the survey households were from different communities within these locations.

Results of the AFTSEMU surveys are presented as monthly means for each study area in Figure 8.9 and Table A13.7. These results are in broad agreement with those from the Asiranka and Upa surveys. There was no indication of any annual cycle in planting rate at any of the three locations(8). A very low planting rate in July 1982 in the Upper Mendi Valley was associated with frost damage (Crittenden *et al.*, 1985:21). In the Tari Basin and the Pangia area, people planted larger areas during the 1982-83 food shortage. In the Tari Basin, the proportion of gardens planted from fallow was greatest during this period. Market prices were recorded at Pangia only, and here a close and positive relationship existed between market price of sweet potato and the area of food garden planted per month (Figure 8.9). The correlation coefficient between these two parameters was highly significant ($n = 11$; $r = 0.79^{**}$) (Crittenden *et al.*, 1985:42-43).

Discussion

Sweet potato gardens. The Asiranka and Upa surveys confirm the findings of other surveys showing that a marked variation in planting rate occurs over time. These changes in the planting rate are large enough and extend over a sufficiently long period to produce significant variation in the supply of food from subsistence gardens.

The major finding is that in three locations (Asiranka, Upa, Pangia areas) a strong association was recorded between the area of sweet potato planted and the quantity available, as indicated by the price in local markets. It is not suggested that villagers alter their planting rates in response to market price. Rather it is suggested that people's decisions on the area of crop to plant are based in part on the quantity of food available to the household at the time. When food is more abundant, people plant less. When it is scarce, they plant more. The aggregate pattern recorded here for these communities

(8) In these three locations, there is not a clear differentiation of food gardens into sweet potato and mixed gardens (Figure 8.10) and data are for all garden plantings.

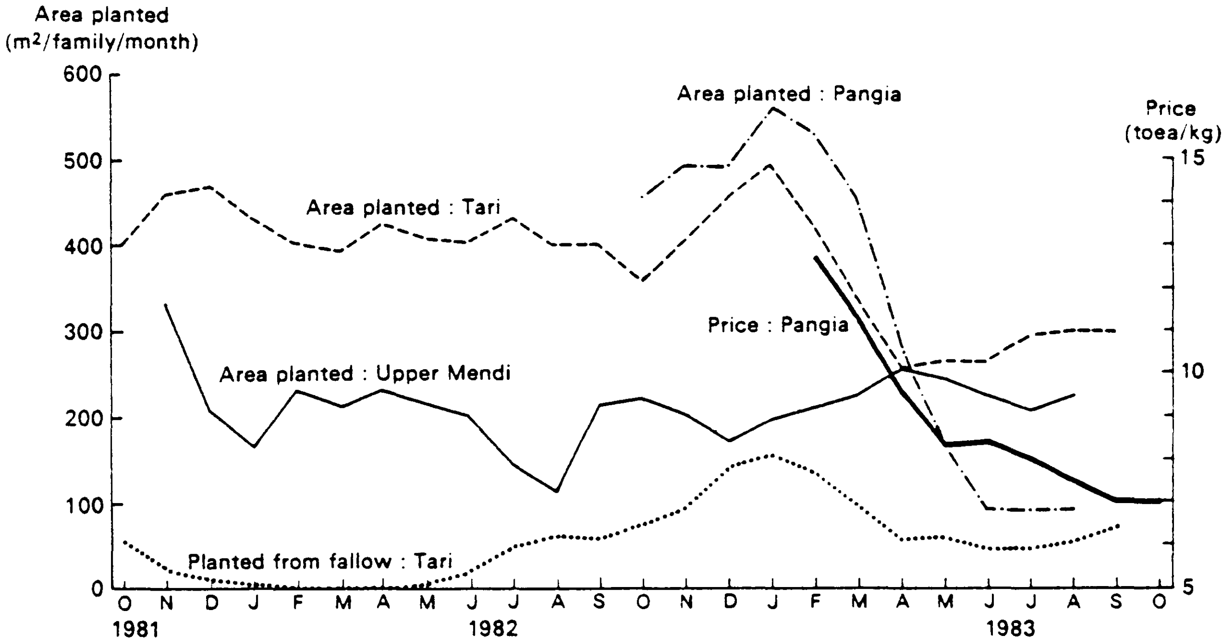

Figure 8.9 Tari, Upper Mendi and Pangia crop planting surveys: mean area of all food crops planted; gardens planted in fallow land (Tari); and sweet potato price (Pangia), September 1981 to October 1982 (three monthly running mean) (Source: AFTSEMU surveys)

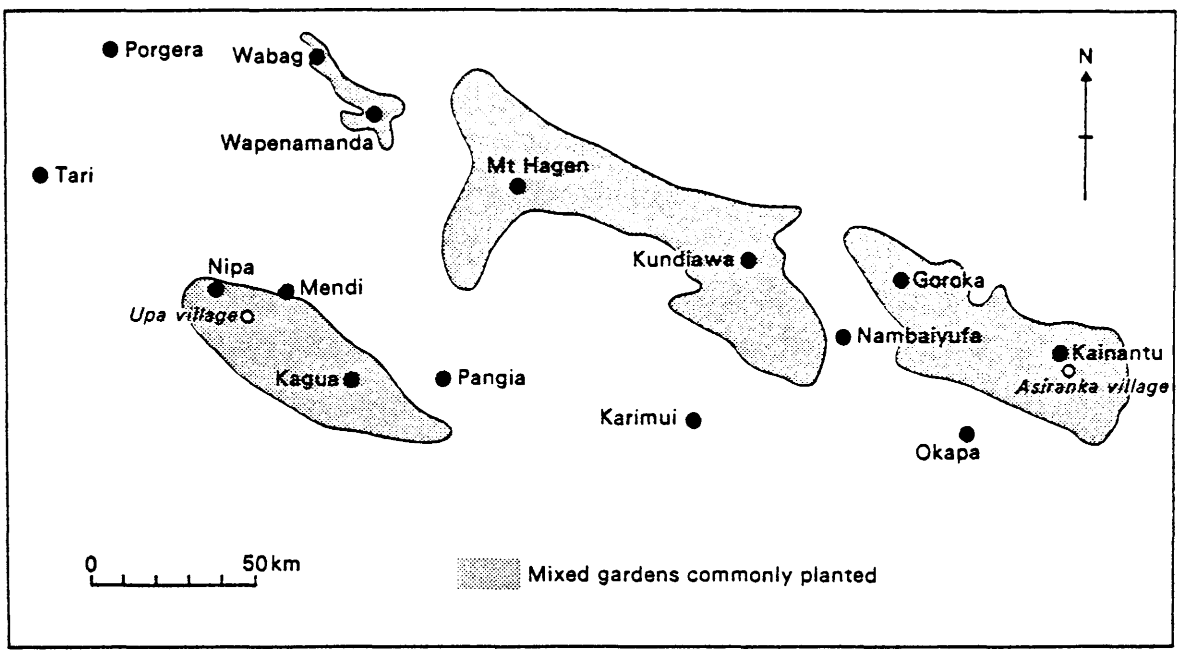

Figure 8.10 Locations in the Papua New Guinea highlands where mixed gardens are commonly planted (Source: author's surveys)

reflects similar decisions made in the various households within these communities where individuals are responding to a common food supply situation.

This variation in crop planting rate in response to the current food supply is sufficient by itself to influence the availability of food at a later date. This pattern is reinforced by changes in the proportion of food garden that is planted from fallow land. The recordings from Asiranka, Upa and in the Tari Basin indicate that people plant a greater proportion of garden from fallow land when sweet potato is relatively scarce. These plantings are likely to produce higher than average yields per unit area (Table 6.1; Wood, 1984a:165-170). An increase in the proportion of garden planted from fallow indicates a greater involvement of men in subsistence agriculture because they are more involved in heavy clearing work, fencing and digging drains than in the more repetitive work of planting, weeding and harvesting which are generally women's tasks.

The combined effect of a higher than usual planting rate and a greater proportion of land planted from fallow is a particularly abundant supply of food some six to ten months later. When food is particularly abundant, people plant less sweet potato, men are less involved in gardening and a smaller proportion of gardens follow fallows. This may result in a second period of food scarcity some six to ten months later. The cycles are not self-perpetuating and rarely continue beyond three years.

In some of the data sets presented in Chapter 3, attention was drawn to food shortages that commonly occur about two years apart and which are sometimes separated by a period of particularly abundant food supply. It is the variation in planting rate described above that is responsible for this sequence of events. It is suggested that this sequence caused many of the shortages in the highlands, for example, those in the Eastern Highlands and Chimbu in 1984 and in the Southern Highlands in 1967 (Figures 7.6, 7.9, 7.11). The effect of these cycles in planting rates is increased when they coincide with a climatic extreme, such as occurred in the Southern Highlands in 1984 (Figure 7.6). It is also likely that cycles in planting rate have exacerbated food supply problems whose cause was primarily climatic, for example, those in the Southern Highlands in 1972 (Figure 7.11).

The food supply situation at any time is an outcome of both variation in area of crop planted per unit time and yield per unit area. These large variations in planting rate also explain why certain climatic extremes are not always followed by a food shortage. When an extreme climatic event, such as an extended drought or period of water surplus, occurs immediately after a food shortage, it is unusual for another food shortage to occur. For example, an extended drought in the Eastern Highlands in 1975 that followed a period of very high sweet potato prices in Goroka market was not followed by another rapid rise in price (Figure 7.10). Similarly in 1983 the extended period of water surplus in the Southern Highlands was not followed later in the year by another food shortage (Figure 7.6) even though tuber yields were probably depressed by these wet conditions. In both years the deleterious effect of extreme soil moisture conditions on tuber yield was compensated for by the higher than normal planting rate and the higher yields from crops that followed a fallow.

Villagers themselves have pointed to cycles in the planting rate as being partly responsible for some food shortages. In Upa Village, one group of male informants suggested that large variations in planting rate, which occur in response to the food situation at the time, were responsible for some food shortages.

Similar production cycles are widely recognised amongst western farmers. They are known to economists as "hog price cycles" (Heady and Jensen, 1954:492-493), and their behaviour is described in more general terms by "the cobweb theorem" (Baumol, 1970:111-115). The "hog price cycle", named after the price/supply relationship of pigs in the USA, may be set in motion by a change in the price of corn. Farmers produce more pigs when pig prices are high. This collective behaviour produces a greater supply of pigs and consequently prices fall. Farmers respond to falling prices by producing fewer pigs for market. The supply, and hence the price, of pigs then varies in a cyclical manner with a wavelength of 5-6 years. Once in motion, the cycle continues because pig producers in general base their production plans on present rather than prospective prices (Heady and Jensen, 1954). The tendency of the cycle towards equilibrium or instability depends on the supply/demand relationship (Baumol, 1970). To the writer's knowledge, this is the first time a similar behavioural pattern has been described among subsistence farmers. The strong tendency of the cycles described in this thesis towards equilibrium parallels Wohlt's (in prep.) observations that cycles of planting initiated by frost damage and maintained by consequent migrations decay to continuous planting until a new cycle is activated by another frost.

My study was not an intensive one of how villagers perceive food supply or how women adjust the area of crop planted over time, and further studies are needed for a fuller understanding. However, some brief comments are offered on the causes of the cyclical planting behaviour described here. The nature of the sweet potato tuberisation process makes planning difficult. Because the tubers bulk up in size rapidly, it is not easy to predict crop yields some months ahead. When crops yield very poorly, there is little prior warning and this may make people overreact in deciding the area of crop to plant. Secondly sweet potato plantings are made more or less continuously. Hence it is more difficult for people to assess the area of crop planted per unit time, and this may hinder prediction of future food supplies. Thirdly there are other causes of food shortages and these cycles are not common events. Hence people in general may not be conscious that they are inducing a food scarcity by their planting behaviour, even though some people are aware of the planting cycles.

The rate of sweet potato planting is sometimes affected by climatic extremes, such as the very wet period in Asiranka in early 1982 or the frosts in the Upper Mendi Valley in mid-1982. However, the available data indicate that such fluctuations rarely last very long and therefore do not result in marked changes in food availability. The major influence of climatic extremes, such as extended wet periods and frost, is on crop yield, not on the planting rate. In all surveys of crop planting rate that extended for more than 12 months, there was no indication of any annual cycle in the planting rate for sweet potato. On the northern fringe of the highlands, villagers commonly state that sweet potato gardens planted from fallows are planted seasonally following the drier period of the year, that is, most plantings are made between September and December. I have recorded such statements in the Jimi Valley and the Bundi area. A number of authors state that sweet potato plantings are seasonally concentrated in this region, for example, in the Simbai Valley (Rappaport, 1968:42-43; Buchbinder, 1973:29), in the Jimi Valley (Manner, 1981) and in the Bundi region (Zimmer, 1985:112-114)(9). It is possible that sweet potato gardens that follow forest fallow are planted seasonally on the northern highlands fringe, but long term studies would be required to establish this.

Mixed gardens. Food from the mixed gardens provides a small, and generally unknown, proportion of villagers' food requirements in the highlands. Variation in the supply of food from these gardens contributes in a minor way to variation in the total supply of food. Hence variation in the planting rate of mixed gardens is of some interest. The differentiation of subsistence agriculture into high intensity sweet potato gardens and low intensity mixed gardens is not universal in the highlands. In general, the distinction between garden types is most marked where agriculture is most intensive, although there are exceptions(10). Locations where mixed gardens are commonly planted in the highlands are shown in Figure 8.10.

(9) Clarke (1971:160) states that in the Simbai Valley, the taro-yam gardens are planted seasonally following clearing during the drier period of the year, but sweet potato gardens are not.
(10) This differentiation most commonly occurs between 1400 m and 2000 m, although mixed gardens are sometimes planted as high as 2500 m. In the Tari Basin, this distinction is not made, despite the intensity of agriculture there.

In both study communities, people planted mixed gardens seasonally(11). During the survey years, most plantings were made between September and December in Asiranka and between October and January in Upa (Figures 8.6, 8.7). This seasonal concentration of planting after land preparation during the drier months of the year resulted in statistical associations between the area of mixed garden planted and the lagged soil moisture conditions (Tables 8.4, 8.5). The seasonal planting of mixed gardens at the end of the drier months and the start of the wetter months is widespread in the highlands. Apart from the Kainantu area and the Nembi Plateau, this has been reported from the Wahgi Valley (Gitlow, 1947:62; Powell *et al.*, 1975:5) and the Ambum, Lai, Minyamb, Tsak, and Upper Sau Valleys in Enga (Meggitt, 1958:314; Waddell, 1972:50; Bourke and Lea, 1982:82).

This seasonal planting of the mixed gardens does not necessarily result in a seasonal concentration of annual foods other than sweet potato. This is because the crops that are planted in the mixed gardens may also be planted in sweet potato or other garden types. The seasonality of supply of any annual food crop in a community is dependent on the proportion of that crop which is planted in the mixed gardens. On the Nembi Plateau, most plantings of the food crops other than sweet potato are made in the mixed gardens because of the reduced soil fertility in the sweet potato gardens. This results in a marked seasonal supply of most of the supplementary food crops. These include the food groups of staples other than sweet potato, vegetables and beans (Figure 3.13) as well as individual crops such as corn, cooking bananas and common beans (Figures 3.14, 3.15, 3.16).

In the Kainantu area, the species planted in the mixed gardens are also planted in other garden types, including sweet potato gardens. This results in a non-seasonal supply of these food crops in aggregate (Figure 3.12) and of many individual foods (Figures 3.15, 3.16). Some foods do have a marked seasonal concentration in the Kainantu area, for example corn (Figure 3.14), but this does not influence the aggregate pattern.

In general, the proportion of food crops planted in the mixed gardens and the consequent seasonality in supply of the supplementary foods depend on the intensity of subsistence production and the soil fertility. The situation on the Nembi Plateau represents one end of a continuum, whilst that in the Kainantu area is typical of many highlands areas. In locations where land use is more intensive, such as in the densely populated valleys in Enga, the availability of the supplementary foods is likely to be more seasonal

(11) Throughout the highlands, villagers traditionally identified different periods of the year by the location of sunrise and by the flowering and fruiting of certain vegetation. These methods are used in both study villages. At Asiranka, the point where the sun emerges over the rim of the Basin at dawn moves through an arc of almost 60^{o} between June and December. The commencement of the drier period of the year is now recognised by the flowering of molasses grass (*Melinis minutiflora*) which is common in the local grasslands. At Upa, villagers say that they commence preparing land for mixed gardens when three trees flower. These are known as *nemb* (*Pittosporum* sp), *usa* (*Mearnsia cordata*) and *ump* (*Euodia* sp).

than in the Kainantu area. Where subsistence agriculture is less intensive, particularly on the highlands fringe and where mixed gardens are not widely used, their availability is likely to be less seasonal than in the Kainantu area.

MANAGEMENT OF PIGS

In 1961 Vayda, Leeds and Smith claimed that pigs are vitally important to the management of subsistence systems in Melanesia. They suggested that pigs can be moved out of communities, fed less and killed when garden produce is in reduced supply; and that they serve as repositories of surplus garden produce during periods of especially good supply. Whilst quantitative data on village pig management and performance are still almost completely absent, my observations and those by others on how pigs are managed when food is scarce give strong support to this theory.

In both Asiranka and Upa, people said that they feed pigs less when food is scarce. I have no quantitative data on pig rations, but pigs in Asiranka were noticeably thinner during the food shortage in 1984. The practice of reducing rations fed to pigs during a *taim hangre* has been reported from elsewhere in the Eastern Highlands (Shannon, 1973:10; Grossman, 1979:243) and from Enga (Waddell, 1973a:34; Wohlt, 1978:150; Goie, 1986).

Sometimes when food is scarce, pigs are agisted out. In mid-1984 some Tari people who were short of food agisted animals out to people in the high altitude Margarima area with whom they maintain a long term relationship. When the high altitude dwellers were themselves affected by the shortage from about August onward, the Tari pigs were returned (E. D'Souza, pers. comm., November, 1984). In parts of Chimbu pigs were moved between people in 1972-73, partly in response to a changing food supply situation (Hide, 1981:418-433).

Another aspect of pig management is the slaughter and consumption of pigs when food is scarce. This is not done in either study village, although in Upa in 1984 some men did kill pigs and sell the pork to raise cash for food purchases. Reports of pigs being killed are confined to the Tari-Koroba area of the Southern Highlands and high altitude locations in Enga. For example, pigs were reportedly killed in the Iumu area near Tari in 1972 in response to a food shortage (Williamson, 1972). Similar observations were made during a food shortage in the Tumbudu Valley near Koroba in 1979 (DPI files, Mendi), and in the Tari Basin in 1984 and 1986 (E. D'Souza and B. J. Allen, pers. comm., 1984, 1986).

The other part of the region where pigs are reportedly killed during a food shortage is the very high altitude valleys and basins in Enga. A number of authors state that pigs were killed after various food shortages following severe frosts, for example, Waddell (1975:262), Goie (1986:13-14) and Clarke (in prep.:14). However, observations by Wohlt (1978) indicate that claims for pig slaughter cannot be accepted uncritically. He recorded pig numbers every month over a three year period in a community severely affected by frost damage and food shortages. People did not slaughter pigs during the 1972 food shortage, but most animals were taken when people migrated to lower altitude locations (p170). No animals were killed in this community during food shortages in 1980, 1982 and 1986 (P. Wohlt, pers. comm., 1983, 1986), although people claimed to have killed pigs following the 1941 frosts.

These observations support the following conclusions: Variation in the ration fed to pigs depending on the availability of sweet potato is probably universal throughout the highlands. Some people at least agist animals when their food supplies are scarce. Reports of animals being slaughtered in response to food shortage are restricted to the Tari-Koroba area and high altitude locations in Enga. However, Wohlt's long term and rigorous observations suggest that reports of animals being killed may be exaggerated. These aspects of pig management provide a considerable buffer between variable food supply and people's food intake. However, they are not sufficient to prevent food shortages from occurring.

CONCLUSIONS

Highlands villagers make a number of major and minor responses when subsistence food is in scarce supply. These include increases in the rate of garden planting and the proportion of land planted from fallow land, changes in food consumption patterns, alteration of pig management strategies and, in extreme situations, migration.

The widespread use of emergency foods in the past provides further evidence that food shortages are not a recent phenomenon. The use of cash to buy imported food is an increasingly important strategy. Rather than causing food shortages, the cash economy, particularly cash cropping, provides a solution to subsistence food shortfalls. Highlands Papua New Guinea villagers' responses to food shortages are similar to those recorded in parts of modern Africa in that efforts are made to earn income which can be used to buy food (Miracle, 1961:279; Hunter, 1967; Watts, 1983:430-441). At the present time there is a marked contrast in the highlands between communities where cash incomes are relatively high and those where incomes are low. In the former, such as Asiranka Village, cash can be used to replace most if not all of the subsistence food deficit with imported food. In the poorer communities, such as those on the Nembi Plateau, cash incomes are so low that only a limited amount of imported food can be purchased to offset subsistence shortages. In addition there are marked contrasts among households in individual communities in their command of cash and ability to buy imported food. Despite the large food relief operation conducted by the government in 1972-73 in the highlands, food aid is not an important factor in village strategies in the highlands. Food aid has not reduced highlanders' ability to cope with subsistence food problems.

Management of pigs is not a major focus of this study. However, observations by myself and others provide support for the claim of Vayda *et al.* (1961) that pigs are an integral part of highlands food production systems and act as a buffer between variable food supply and people's intake. The observations reported here highlight the need for further in-depth studies of the role of pigs in the highlands. Villagers migrate from high altitude and frost-vulnerable locations when they are affected by severe food shortages. The continuing use of this strategy by high altitude, low income people does point to the major impact that frosts have on food supply in some very high altitude locations. This also provides further support for the argument that food aid has not diminished people's ability to seek solutions to food supply problems.

Another important response to variable food supply is variation in the planting rate of sweet potato, and this influences future food supply. People plant larger areas of sweet potato when food is relatively scarce and they plant less when it is abundant. The effect of higher planting rates during a food shortage is increased because of an increase in the proportion of land that is planted from fallow at this time and the consequent higher yields obtained from these plantings. Thus one of the responses that people make to food shortages may ultimately cause a second shortage about two years after the first.

Food supply at any time is an outcome of the planting rate and climatic conditions that prevailed some months earlier. Thus a fuller understanding of the causes of variation in food supply can be obtained by combining data on planting rate, climatic conditions and crop yield. This I do in the next chapter, where a model is presented that integrates soil moisture extremes, crop yields, planting rate, calculated food supply, and recorded food shortages. In addition, some data are given on how people respond to food shortages and on the effects of such shortages upon children's nutritional status.

PART THREE

CHAPTER NINE

A MODEL OF SWEET POTATO SUPPLY

The supply of sweet potato varies because of changes in both the yield per unit area and the area planted over time. It has been established that the major influence on yield variation is climatic, particularly extremes of soil moisture. It has also been shown that an important determinant of the area of sweet potato planted is the current supply of sweet potato. In this chapter, a model of supply is presented that integrates variation in yield and area planted(1).

The model is derived from various data sets from the Kainantu area and the Nembi Plateau and covers a five year period (1980 to 1984). Some of the figures on sweet potato price and area planted are estimated. The data sources used and assumptions made in calculating the supply of sweet potato are given in Appendix 15. The model considers the role of pigs as a buffer between subsistence food supply and people's intake, although numerical data are not available on changes in pig rations and pig body weight over time.

An index of sweet potato yield in the Kainantu area and on the Nembi Plateau is based on the reasoning that the main effect of an extended or extreme water surplus occurs during tuber initiation and this reduces yield eight or six months later respectively(2). It is reasoned that the main effect of a drought occurs during the rapid tuber bulking phase. Hence, yield is reduced during the drought and in the month following its cessation. It is assumed for purposes of calculating this index that an extended water surplus, an extreme water surplus, or a drought depress yield to 80 per cent of the long term mean. The combined effect of water surplus and drought is assumed to depress yield to 60 per cent of the long term mean. During periods of exceptionally high planting rate when a higher than normal proportion of crop is planted on previously fallowed land, yields are assumed to be 25 per cent greater than the long term mean. No allowance is made for climatic conditions that result in better than average yields because of insufficient information on this relationship.

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(1) The model derived here is for sweet potato supply only. The supply of foods other than sweet potato varies in an irregular manner in the Kainantu area and regularly on the Nembi Plateau. For the Nembi Plateau, a model that incorporated other foods would give a slightly different supply curve from that presented here, but it would not alter conclusions based on the model.

(2) Lag periods of eight months were used for the Kainantu area and six months for the Nembi Plateau. This is because the time from planting to harvest for sweet potato differs between the two locations. Where soils are infertile, as on the Nembi Plateau, tuber yields are achieved earlier than where soils are more fertile.

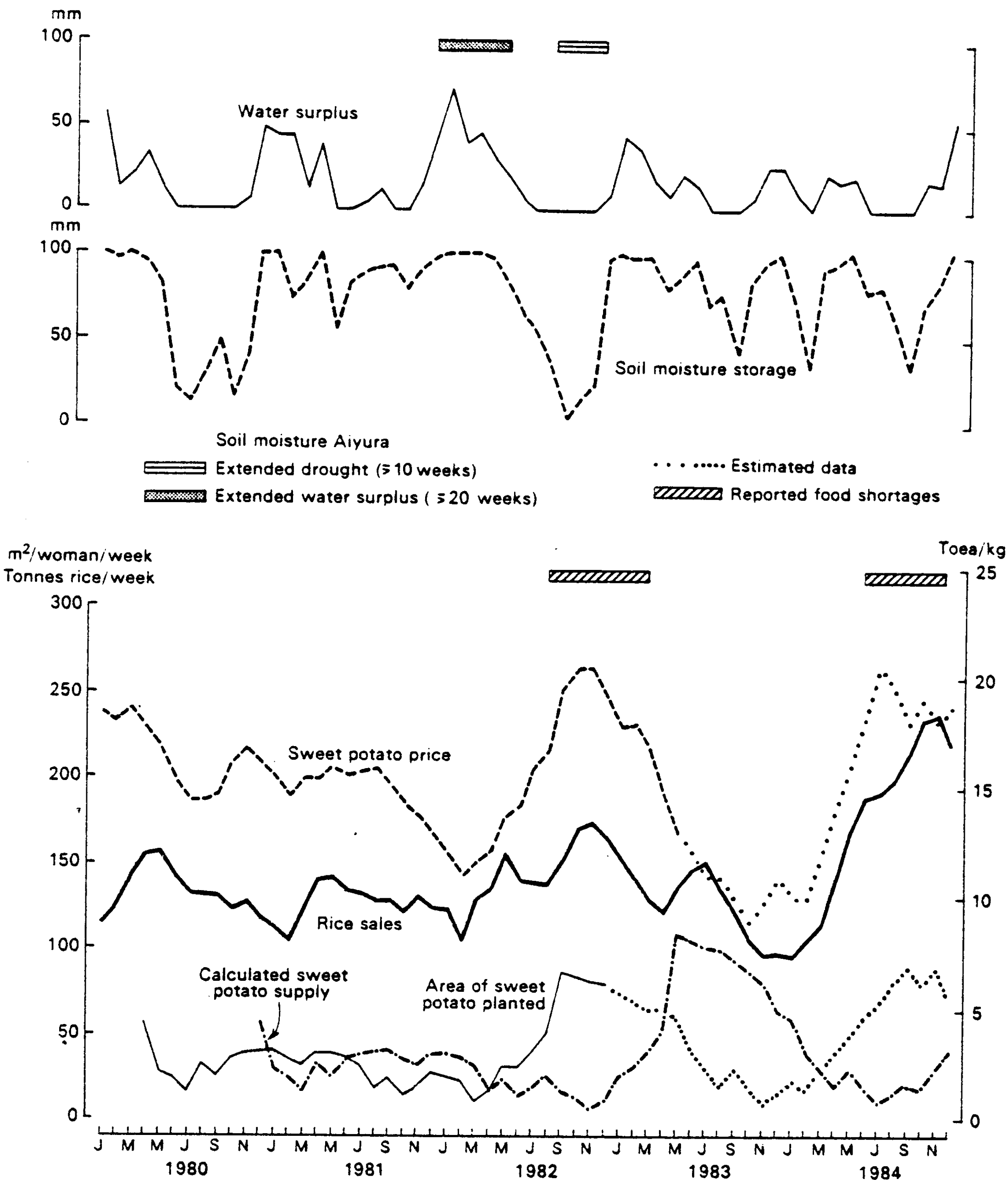

Figure 9.1 Model of sweet potato supply, Kainantu area, 1980 to 1984 (three monthly running mean; some data estimated)

Water surplus is the calculated monthly surplus for Aiyura (mm)
Soil moisture storage is the calculated monthly soil moisture storage (maximum 100 mm) for Aiyura (mm)
Reported food shortages are for the Kainantu area
Sweet potato price is for Kainantu market (toea/kg)
Rice sales are from the Goroka rice terminal (tonnes/week)
Calculated sweet potato supply is for the Kainantu area (Appendix 15)
Area of sweet potato planted by 10 women, Asiranka Village (m^2/woman/week)

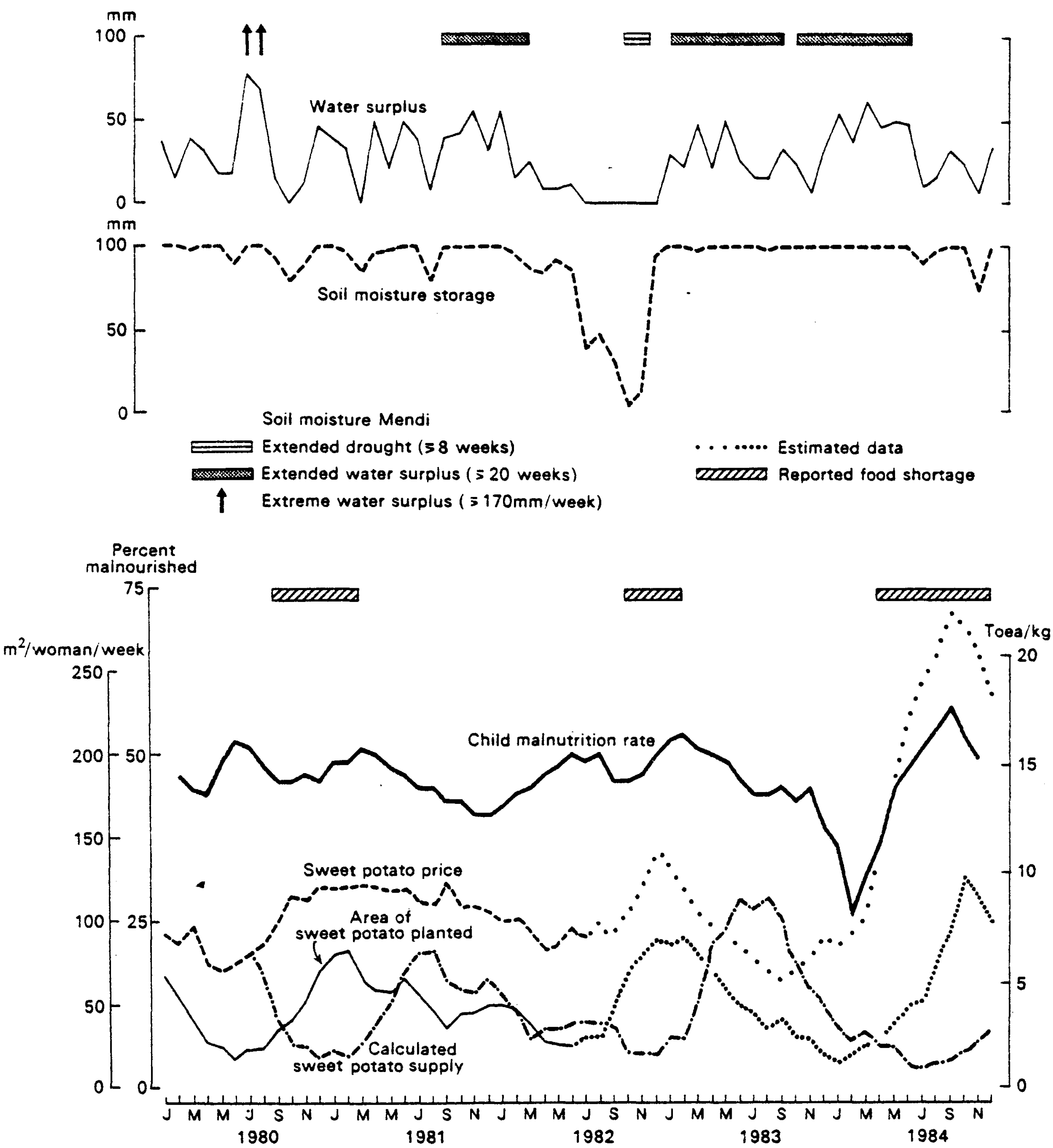

Figure 9.2 Model of sweet potato supply, Nembi Plateau, 1980 to 1984 (three monthly running mean; some data estimated)

Water surplus is the calculated monthly surplus for Mendi (mm)
Soil moisture storage is the calculated monthly soil moisture storage (maximum 100 mm) for Mendi (mm)
Reported food shortages are for the Nembi Plateau
Sweet potato price is for Hol market (toea/kg)
Child malnutrition rate is for children aged 1 to 5 years, Central Nembi Plateau (percentage < 80 per cent weight for age)
Calculated sweet potato supply is for the Nembi Plateau (Appendix 15)
Area of sweet potato planted by 10 women, Upa Village, (m^2/woman/week)

An index of sweet potato supply was calculated from the product of the yield index described above and the recorded area planted by the sample households eight months or six months previously. The model is presented in Figure 9.1 (Kainantu area) and Figure 9.2 (Nembi Plateau). For the Kainantu area rice sales data are given, and for the Nembi Plateau child malnutrition rates are presented. The difference in the type of data presented arises because reliable longitudinal malnutrition data are not available in the Eastern Highlands and rice sales are not available for the Southern Highlands.

In the Kainantu area, the calculated sweet potato supply varied considerably over time (Figure 9.1). It is likely that there was sufficient flexibility in the food system, particularly in the quantity of sweet potato fed to pigs, to buffer this variation. The two periods of calculated lowest supply coincided with actual food shortages in 1982-83 and in mid- to late 1984. People reported food shortages only when the buffering capacity of the system was exceeded. There is a close and positive association between the area of sweet potato planted, the market price of sweet potato and sales of imported rice.

The suggested sequence of events over this period is as follows: In late 1979-early 1980 subsistence food in the Kainantu area was somewhat scarce and the planting rate was higher than usual. The supply of sweet potato improved during 1980 and stabilised by early 1981, as reflected in market price. The supply improved again in the latter half of 1981 and early 1982. The reason for this is unknown but it most likely reflects particularly favourable climatic conditions in mid- to late 1981. Between May and November 1981 the calculated monthly mean soil moisture storage at Aiyura was in the range of 60 per cent to 90 per cent of field capacity and there was little soil water surplus. These conditions may be ideal for high sweet potato yield.

The favourable supply of sweet potato led to a reduced planting rate throughout the area in early 1982, although this was not marked at Asiranka. By chance, this coincided with an extended wet period. The combined effects of the wet period in early 1982 and the drought in late 1982, and the low planting rate in early 1982, produced a shortage of sweet potato in late 1982-early 1983 throughout this area. Villagers responded in a number of ways which included a greatly increased planting rate, particularly of gardens planted from fallow, an increased consumption of imported food, and a reduced ration for pigs. This high planting rate, which lasted for about six months, and favourable climatic conditions in mid-1983, produced a particularly good food supply from about April to December 1983. This is reflected in the low market price of sweet potato and low levels of rice consumption in that year. The low planting rates in mid- to late 1983 reduced the supply of sweet potato which resulted in high rice consumption in mid- to late 1984. It is likely that the impact of the variable sweet potato supply on child malnutrition was not great for villagers who had access to cash which they used to buy rice and other foods, although reliable data are not available to test this proposition.

On the Nembi Plateau, there is also good agreement between the calculated sweet potato supply and reported food deficits (Figure 9.2). Shortages in 1980-81, 1982-83 and in 1984 coincided with low points in the calculated sweet potato supply. The child malnutrition rate is in general inversely related to the calculated food supply. There is a lag of about two to four months between extremes in the calculated food supply and extremes in the malnutrition rate.

The close agreement between the calculated food supply and the recorded indices of food availability in two areas of the highlands lends confidence to the assumption on which the model is based. This also suggests that it has general application in the highlands region. The model presented here depends on variation both in the area planted and in yield per unit area. A model that depends on variation in only one of these factors has less explanatory power. This is why the analysis of soil moisture extremes presented in Chapter 7 provides only a partial explanation for food shortages. It also explains why similar climatic extremes may result in very different food supply outcomes.

PREVIOUS MODELS

This model of food supply is now compared with those presented by other workers in the highlands. The first was proposed by Wohlt (1978:158-169). Wohlt incorporated both variation in the planting rate, as indicated by the rate of mound construction, and a crude estimate of crop yield. As with my model, the supply of sweet potato was dependent on variation in both factors although independent data such as longitudinal price or food intake records were not available to him to test the model. The planting patterns recorded by Wohlt were greatly influenced by a series of migrations from and back to this community, and this complicates further comparisons between Wohlt's and my results.

Crittenden (1982:409-432; 1984:153-171) proposed a model of food availability on the Nembi Plateau following fieldwork there in 1980-81. He suggested that most planting of sweet potato takes place at the beginning of the longer of two wet seasons of the year (October to February or November to January). He considered that women do this in order to avoid the deleterious effects of frost, drought or intense rainfall at different times of the year. He argued that frost is most likely between October and December; waterlogging is most likely early in the year (January to May) and later in the year (August-September); and drought is most likely between May and July and again in October-November. He also suggested (1984:164) that waterlogging on two occasions in

1980 reduced sweet potato yields. Crittenden (1982:430; 1984:169) presented his hypothesis as a "schematized annual cycle" of sweet potato planting and harvesting which resulted in a *taim hangre* in August to October each year.

Crittenden's climatic analysis was again presented in a later paper with the rider that adverse climatic conditions do not occur with any annual regularity (Crittenden and Baines, 1986). The authors give conflicting statements about the planting pattern of sweet potato but say that the best time of year to plant sweet potato for optimum yield is between September and April (p218).

The long term data and model presented in this thesis contradict virtually all of Crittenden's (1982, 1984) and Crittenden and Baines' (1986) statements about annual cycles of climatic extremes, planting rates and food shortages on the Nembi Plateau. My data also contradict their claims that women adjust the planting rate in accordance with their perceptions of the probability of annual climatic extremes and that this is responsible for variation in food supply on the Nembi Plateau.

A third model of the relationship between climate, planting activity and sweet potato supply in the Papua New Guinea highlands is presented by the AFTSEMU team members in the Southern Highlands (Crittenden *et al.*, 1985:40-43). Their model covers the period between late 1982 and the end of 1984 and uses both recorded and estimated data. They propose a cycle of planting rates between mid-1982 and late 1984 similar to that suggested here. They attributed the food shortage in mid- to late 1984 to a combination of the low planting rates in mid-1983 (as I do) and premature harvesting of sweet potato in late 1983 and early 1984. The AFTSEMU members rejected the hypothesis that yields were reduced by excessively wet weather in early to mid-1984 because AFTSEMU trials did not show low yields(3). They suggested that the perceived low yields resulted from premature and excessive harvesting by hungry villagers. My model is in partial agreement with the AFTSEMU one. It differs in that I offer no comment on premature harvesting because of lack of evidence, but I do consider that variation in crop yield per unit area is important.

CONCLUSIONS

The calculated subsistence food supply over a five year period at two locations in the highlands is in good agreement with recorded indices of supply. This result increases confidence in the underlying assumptions of the model. These are: first, that variation in both the rate of crop planting and in yield per unit area determines the food supply;

(3) No yield data were presented by Crittenden *et al.* (1985) to support this conclusion. However, AFTSEMU trials conducted at Piwa by D'Souza did give very low yields in early 1984 (Chapter 6).

second, that extended periods of high rainfall during the tuber initiation phase depresses yield and that drought during the rapid tuber bulking phase further depresses yields if the drought is preceded by an extended wet period; and third, that there is sufficient flexibility in the system, particularly in the management of pigs, to allow buffering of considerable variation in the food supply.

Two other findings are likely to be widely applicable in the highlands beyond the locations where the data were gathered. The first is that in one part of the highlands where cash incomes are comparatively high, the consumption of rice, which is the main alternative to sweet potato, varies inversely with sweet potato supply. The second finding is that in another part of the region where cash incomes are low, there is a reasonably strong negative relationship between the calculated food supply and the proportion of children who are malnourished.

CHAPTER TEN

CONCLUSIONS

The central problem of this thesis is the cause of variation in subsistence food production in the highlands of Papua New Guinea, and in particular the cause of shortfalls in supply which are known as *taim hangre.*

Many causes of food shortages have been posited in the highlands. The general forces of colonialism, modernisation and development have been evoked. Some commentators have argued that cash cropping, the labour demands of the colonial government or labour migration were causes. Others have thought that the problems lay in the inadequacy of planning, the distraction of pandanus nut harvests, the demands of pig killing ceremonies, or tribal fighting.

Climatic extremes, especially drought and frost, have also been suggested as causes of *taim hangre.* In addition, explanations based on climatic seasonality have been argued, and recent interest in seasonality in the African literature has given further impetus to this line of thought in PNG.

After describing relevant aspects of the highlands region and the two study communities, my first task in this thesis was to examine the evidence for variation in food supply. Archival material was assembled and analysed. The relationship between market price of the staple food, sweet potato, and food supply in the surrounding region was established as a further way of examining the long term record of food shortages. These sources demonstrate clearly that the frequency of food shortages has not altered since contact between highlanders and outsiders some 60 years ago. There is no evidence of a regular or annual cycle in sweet potato supply. Analysis of these data sources reveals that food shortages tend to occur in pairs. It also shows that there are marked differences in the vulnerability to food shortages in different parts of the highlands.

The findings that the frequency of food supply problems has not altered since contact and that they do not occur annually suggest that they do not originate from the effects of colonialism, development or cash cropping. The relationship between some of the suggested causes of food shortages was then examined in detail. This analysis showed unequivocally that cash cropping and associated consumption and the harvest of nut pandanus are not responsible for food shortages. The available evidence indicates that diversion of villagers' labour from food production, particularly through male migration, is not a contributing factor. Pig killing ceremonies and tribal fighting are possibly contributing factors, but the impact of such activities is localised.

Cash cropping, rather than being responsible for subsistence food shortages, in fact provides a partial solution to them. Villagers use cash, much of which is derived from cash cropping, to buy imported food when subsistence food is scarce. Thus the impact of food shortages has been reduced since the Pacific war as villagers' cash incomes have risen. The available evidence is that increases in the death rate which used to accompany severe food shortages prior to the colonial period in parts of the highlands no longer occur because of access to imported foods and, on one occasion, because of government food aid. Nevertheless, food shortages still impact negatively on children's nutritional status, at least in locations where cash incomes are limited, and this has negative implications for their health.

Having eliminated some of the claimed causes of food shortages, attention was focussed on the relationship between the staple food in the highlands, climatic variation and human behaviour. A review of agronomic literature and experimental work in PNG revealed that sweet potato is vulnerable to excessively high soil moisture. Results are not unambiguous, but excessive soil moisture appears most damaging during the tuber initiation phase, that is, between about 3 and 10 weeks after planting under highlands conditions. An analysis of the food shortage record, price data and extremes of soil moisture confirmed the relationship between high soil moisture levels and reduced sweet potato production.

Only the most severe droughts are followed by food supply problems, although market price data suggest that droughts do place some pressure on supply. However, a drought preceded by an extended period of soil moisture surplus frequently results in food shortages. This combination of an extended wet period followed some months later by a drought of several months duration is not uncommon and is often associated with the global climatic disturbances known as the *El Niño*-Southern Oscillation. Droughts have an immediate influence on food supply, suggesting that they depress tuber development during the rapid bulking phase toward the end of the crop growth cycle. The other combination of soil moisture extremes, that is, drought followed by an extended wet period, is much less likely to produce food supply problems. The analysis done here indicates that a water surplus that lasts for a minimum of 20 weeks combined with a drought of at least 10 weeks duration depresses sweet potato yield.

Frost and drought have long been considered the most severe environmental hazards to sweet potato production in the highlands. The present work demonstrates that the effects of frost and drought have been overestimated. Severe and repeated frosts may cause considerable damage to sweet potato crops and result in major food shortages, particularly at locations above 2200 m. At times this damage may be so severe that it necessitates migration of entire communities. However, at lower altitudes, the effects of frost, whilst imperfectly understood, are not as great as sometimes considered.

Nevertheless, climatic factors provide only a partial explanation for food shortages in the PNG highlands. Not all shortages are associated with climatic extremes and this analysis does not explain the tendency of shortages to occur as paired events some two years apart. This pattern was further investigated through an analysis of planting rates. When sweet potato supplies are low, as measured by high market prices, the rate of planting is increased and when sweet potato is plentiful, the planting rate falls. Villagers vary the rate of planting, and the proportion of garden planted in previously fallowed ground, on the basis of the current supply of food.

It is this combination of variation in the rate of garden planting and the effects of extremes of soil moisture on sweet potato yield, that provide the best explanation for variation in the supply of the staple food in the PNG highlands. Either factor may operate singly but the combined effect produces the most severe shortfalls in food supply. To test further these findings, a model was derived, based on recorded and estimated planting rates and an index of sweet potato yield based on the analysis of the effects of soil moisture extremes on yield. The calculated supply of sweet potato was in strong agreement with recorded indices of supply at two locations in the highlands over a five year period.

Pigs are another important factor. They act as a buffer, absorbing excess food in times of plenty and being fed less when supplies are short. Other factors too act as buffers between a variable garden supply and people's intake. For example, people harvest tubers earlier or later depending on the current supply, and this complicates any village yield recordings. Thus variation in supply is moderated, so that only when the supply of sweet potato is particularly poor, do people consider that they are experiencing a *taim hangre*.

A key factor in understanding the cycles in planting rates is the inability of villagers to predict, by observation, that tubers will not follow the normal process of rapid expansion in size during the final few months of crop development as a result of excessively wet conditions in the first 10 weeks after planting. The long time lag between this interference with normal tuber initiation and poor yield, as well as variation in planting rate also explain why so many spurious reasons are offered for food shortages and why the effects of immediate and spectacular events, such as drought and frost, are overestimated.

A number of important topics require further research. These include:

1. The relationship between soil moisture conditions or frost at different stages of crop growth and sweet potato yield.

2. Management of pigs, including feeding, breeding and agistment.

3. People's perceptions of future food requirements and their responses to variation in food supply.

4. The effects on food production and villagers' wellbeing of long term male migration, other demands on villagers' labour, and seasonal migration of families.

The need for long term monitoring and the inadequacy of studies of one or two years only of, for example, people's body weight, market price or crop planting rates is clearly demonstrated. Most of these parameters do not vary on an annual seasonal basis and short term studies or a series of several cross-sectional recordings only are not adequate to understand trends over time.

Finally to return to the literature which was discussed at the beginning of this thesis, are we now able to say anything from the highlands of Papua New Guinea which informs the wider debate on the causes of food shortage, distress and famine? During the colonial period, and subsequently, this region has experienced numerous instances of food shortage, but all the evidence has indicated that the effect of cash cropping, monetisation and wage work has been to expand the buffering capacity of the basic system of food production, distribution and consumption. We find no reason here to accord with those writers who have found colonialism, intervention and partial incorporation in the global economy to have increased the vulnerability of society as a whole, or any section of it, to hazard of famine. Indeed, the comparison between commercialised Asiranka and mainly-subsistence Upa suggests the exact opposite.

If we look beyond this region no further than adjacent Irian Jaya in Indonesia this conclusion is strengthened. Reliable reports indicate that the climatic events of 1982 and 1984 also impacted the Irian Jaya highlands, and did cause severe distress, even if less serious that press reports indicated. The almost total absence of cash cropping and external employment in most of the Irian Jaya highlands is implicated as one reason for this contrast, though in the absence of reliable data we cannot say for certain than the climatic events were not themselves more serious than they were a few hundred kilometres to the east.

This degree of uncertainty in explanation, even within the same basic production system and natural environment, should reinforce the doubts which have been expressed throughout this thesis about any form of uni-causal explanation of food shortage and famine. Even where distress has been enormously greater, climatic extremes more serious and prolonged, and colonial and post-colonial interference far more penetrating and disruptive, as in the Sahel, there remains room for doubt over the distribution of "blame". This thesis has sought to demonstrate that the interaction of natural variability, the behaviour of people and the behaviour of the staple food crop plant itself all have to be studied in depth, and evaluated together, if a satisfactory level of explanation is to be achieved. Perhaps the final message, therefore, is that the proper explanation of outcomes elsewhere in the world is not likely to require less.

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APPENDIX 1

SCIENTIFIC NAMES OF PLANT AND ANIMAL SPECIES DISCUSSED IN TEXT

Common name(1)	Scientific name
Aibika	*Abelmoschus manihot*
Amaranthus	*Amaranthus* spp
Avocado	*Persea americana*
Banana	*Musa* cvs
Banana, wild	*Musa ingens*
Bean, common	*Phaseolus vulgaris*
Bean, hyacinth	*Lablab purpureus*
Bean, winged	*Psophocarpus tetragonolobus*
Betel nut, highland	*Areca macrocalyx*
Betel pepper, highland	*Piper gibbilimbum*
Breadfruit	*Artocarpus altilis*
Broccoli	*Brassica oleracea* var. *botrytis*
Cabbage	*Brassica oleracea* var. *capitata*
Cabbage, Chinese	*Brassica pekinensis*
Candle nut	*Aleurites moluccana*
Cardamom	*Elettaria cardamomum*
Cassava	*Manihot esculenta*
Castanopsis	*Castanopsis accuminatissima*
Casuarina	*Casuarina oligodon*
Chilli	*Capsicum annuum*
Choko	*Sechium edule*
Coffee, Arabica	*Coffea arabica*
Cordyline	*Cordyline fruticosa*
Corn	*Zea mays*
Coconut	*Cocos nucifera*
Cucumber	*Cucumis sativus*
Ficus copiosa	*Ficus copiosa*
Ginger	*Zingiber officinale*
Highland kapiak	*Ficus dammaropsis*
Karuka nut pandanus	*Pandanus julianettii*
Karuka nut pandanus, wild	*Pandanus brosimos*
Kunai	*Imperata cylindrica*
Lettuce	*Lactuca sativa*
Mandarin	*Citrus reticulata*
Mango	*Mangifera indica*
Marita pandanus	*Pandanus conoideus*
Molasses grass	*Melinis minutiflora*
N. schlecteri (Rorippa)	*Nasturtium schlecteri*
Oenanthe	*Oenanthe javanica*
Okari	*Terminalia kaernbachii/T. impediens*
Pak choi	*Brassica chinensis*
Passionfruit, purple	*Passiflora edulis* f. *edulis*
Pawpaw	*Carica papaya*
Peanut	*Arachis hypogaea*
Pineapple	*Ananas comosus*
Pitpit, highland	*Setaria palmifolia*
Pitpit, lowland	*Saccharum edule*
Potato	*Solanum tuberosum*
Pueraria	*Pueraria lobata*

Pumpkin	*Cucurbita moschata*
Pyrethrum	*Chrysanthemum cinerariaefolium*
Rungia	*Rungia klossii*
Sago	*Metroxylon sagu*
Silverleaf desmodium	*Desmodium uncinatum*
Sis	*Pangium edule*
Spring onion	*Allium cepa* var. *cepa*
Strawberry	*Fragaria* cvs
Sugarcane	*Saccharum officinarum*
Sweet potato	*Ipomoea batatas*
Sweet potato weevil	*Cylas formicarius*
Sweet potato leaf miner	*Bedellia somnulentella*
Taro	*Colocasia esculenta*
Taro, *Alocasia*	*Alocasia macrorrhiza*
Taro, *Xanthosoma*	*Xanthosoma sagittifolium*
Tobacco	*Nicotiana tabacum*
Watercress	*Nasturtium officinale*
Yam	*Dioscorea* spp
Yam, greater	*Dioscorea alata*
Yam, potato	*Dioscorea bulbifera*
Yam, wild	*Dioscorea* sp

Note

(1) The common names are those used in English in Papua New Guinea.

APPENDIX 2

FIFTY YEARS OF AGRICULTURAL CHANGE IN A NEW GUINEA HIGHLAND VILLAGE*

ABSTRACT

Changing land use and subsistence agriculture are described from Asiranka Village in the Aiyura Basin of the Eastern Highlands from the 1930s until 1983. Major environments are grassland flats; steep slopes vegetated with long grasses and scrubby regrowth; and forested ridges. The villagers are dependent upon food produced by subsistence farming. The periods considered are 1930s to 1942; 1942 to 1945; 1946 to mid 1982; and mid 1982 to 1983. The first period is characterized by low intensity agriculture, mostly on the steep slopes and higher grassland areas. Following a series of traumas in 1942 and 1943 associated with wartime conditions, a change was made to more intensive grassland agriculture. Between 1946 and mid 1982, intensification of production occurred. This included an increased ratio of cropping to fallow periods, increased use of specialized mixed vegetable gardens, and use of a legume/sweet potato rotation. Agriculture was extended into lower areas from 1960 following drainage of the Basin. In mid 1982 subsistence production underwent another major change when people largely abandoned the grasslands and returned to the forest and scrub regrowth areas to practise lower intensity agriculture. The immediate reason for this change was widespread damage to gardens by domesticated pigs that were breaking an out of repair communal fence that younger men were no longer prepared to maintain. Other possible distal causes of the change discussed include declining opportunities for wage employment and income from coffee production.

INTRODUCTION

This paper is concerned with changing patterns of land use by the people of Asiranka Village (6°20'S, 145°55'E) in the Aiyura Basin, some 7 km south-east of Kainantu in the Eastern Highlands of Papua New Guinea (Figure A2.1)(1). The period covered commences just prior to European contact (1920s) and extends to late 1983. The 1980 resident population was 420 with another 100 people absent from the village. The people are part of a larger grouping who call themselves the Aiyura people (1980 population was 930) and are speakers of the Gadsup language. Their first direct contact with outsiders, apart from nearby neighbours, was probably in 1928 when a German missionary did a patrol through the area(2). The people experienced first direct contact with the Australian administration after the nearby Upper Ramu Patrol Post (Kainantu) was established in 1932. This contact intensified when part of their land was alienated to the Administration in 1937 to form part of the Highlands Agricultural Experiment Station in the Aiyura Basin.

Over the six year period 1978 to 1983, I conducted a study of food shortages and food seasonality in the village and over part of this period (August 1979 to December 1982) made monthly measurements of garden area planted by 10 women in the village. The 10 women had a wide range of ages, number of dependents and status as gardeners. This provides part of the data base of this paper. The major source is information given by the village people. Dating of events has been done by relating changes in land use and agricultural practices to events external to the village. Some of these dates are given in Table A2.1. Mr A. J. Schindler, who was the Officer-in-Charge at the nearby Agricultural Station between 1944 and 1962 and who had a close relationship with the villagers, has published observations on land use and agriculture over the period 1945 to 1951 (Schindler, 1952). This paper and conversations with him provide further information.

* Presented at First Papua New Guinea Food and Nutrition Conference, Goroka, Papua New Guinea, 1983. Cited as "Bourke (in press)" in thesis.

Other data sources are the monthly and annual reports of the Agricultural Station (1937 to 1979), patrol/ANGAU reports from Kainantu (1935 to 1957) and four sets of aerial photographs of the Basin (Table A2.1).

POPULATION AND THE ENVIRONMENT

Details of the 1980 resident population are given in Table A2.2. Almost half (46 per cent) of the resident population are infants and children (0 to 17 years). The population of the Aiyura villages during the 1930s is said to have been about 30 households (150-200 people). The resident population of the Aiyura villages was 370 in 1950 (Schindler, 1952). In 1980 the combined population of the Aiyura villages (Asiranka, Anamunapa, Ukarumpa, Aianora) was 930, giving an annual growth rate of 3.1 per cent over the 30 year period. Despite out-migration to urban areas elsewhere in Papua New Guinea, this high growth rate has been achieved because of a net influx of people from other parts of the region. Another characteristic of the population is the large number of adults in wage employment (34 per cent of resident male adults; 52 per cent of non-resident male adults) (Table A2.3). Most of the resident wage-earners are employed within the Aiyura area. They earn a total of K1130 per week.

Details of land area and population density are given in Table A2.4. The gross population density (94/km^2) is high by Papua New Guinean standards. The density on the grassland flats (546/km^2) that provided most food for the people and pigs from 1946 to mid 1982, is particularly high(3). The villagers' land covers an altitudinal range of 1600 to 2000 metres. Mean annual rainfall at the Agricultural Station in the bottom of the Basin is 2100 mm (38 years of records). The period May to October is, on average, drier than the period from November to April. Rainfall intensity is generally low to moderate (less than 12 mm/hour). The mean monthly minimum temperature at the Agricultural Station (1640 metres) is 13.2 ^oC and the mean monthly maximum temperature is 24.1 ^oC. Mean temperatures in the cooler months of July to September are up to 2 ^oC lower than in the warmer months (December to April) (McAlpine *et al.*, 1975).

The major environments in the villagers' land are the grassland flats, steep grassy (and scrub) slopes, and forested ridges (Figures A2.2, A2.3). The grassland flats have an altitudinal range of 1580 to 1620 metres. The vegetation is short grasses, such as *Capillipedium*. Most of the soils are colluvial and are characterized by deep dark topsoil with a strong granular structure (loam to clay loam texture) merging into a grey clayey subsoil. These soils are known as "poreramaka". The flats are dissected by smaller areas of drainage depression. These soils are deep clays, very poorly drained, and very high in organic matter. They are known as "aramaka". The dominant vegetation is *Phragmites* cane grass.

The steep slopes (10^o to 30^o slope) range from 1600 to about 1750 metres altitude. They are vegetated by tall grasses (especially *Miscanthus*) and some woody regrowth. Soil depth is generally thin because of previous soil erosion. The ridge tops and adjacent areas (1750 to 1985 m) are covered in forest(4). The slope soils consist of a thin yellowish brown clay loam (0 to 20 cm) overlying a yellowish brown clay. They are known as "kakimaka" or as "makomaka" if they contain Fe/Mn concretions.

The villagers are horticulturalists dependent on sweet potato (*Ipomoea batatas*) as their staple food. Major supplementary foods are *Xanthosoma* and *Colocasia* taro, bananas, highland "pitpit" (*Setaria palmifolia*), sugarcane, various leafy green vegetables, peanuts (*Arachis hypogaea*), maize and winged beans (*Psophocarpus tetragonolobus*). A list of the cultivated and self-sown food species is given in Table A2.7, with information on the crops' relative importance(5). Domesticated pigs are important social and dietary items. There is no long-term pig cycle comparable to that practised in the western part of the Central Highlands. Imported food, especially rice, flour, tinned fish and meat, biscuits, dripping and beer are now consumed in significant quantities.

CHANGING CROP BASE

The agricultural crop base has not been static in Papua New Guinea and crops vary greatly in their antiquity (Bourke, 1983). A number of crops reached the country as a result of European exploration in the Americas, but before European settlement in Papua New Guinea, and a large number of species has been introduced since European settlement, some of which have become major food items.

Tobacco (*Nicotiana tabacum*) is a crop of American origin that had diffused to New Guinea by about 1600 AD (Feinhandler *et al.*, 1979) and was well established in Papua New Guinea by the time of permanent European settlement (1870 onwards). Villagers say that the narrow leaf form ("brus" in Melanesian Pidgin) is a very ancient crop, but the larger leaf type ("tabak" in MP) is a post-European introduction. Watson (1967) reported that, in the Kainantu area generally, numerous informants in the 1960s remember when they did not have tobacco. The discrepancies between the Asiranka data and Watson's account may exist because Watson had asked about the origin of "tabak" rather than "brus".

Maize (*Zea mays*) is said by older Asiranka people to have arrived before contact with Finschhafen missionaries or Europeans. It was obtained from Kamano speakers, most likely between 1922 and 1927. The traditional type is said to be red grained, but only a limited number of people had it. It became a more important food after European settlement and by the early 1950s Schindler recorded that significant areas of maize were being grown. Watson (1967) records that maize was a pre-European crop in the Kainantu area, but that some men said that it was unknown to their ancestors. He suggests it may possibly have reached the Kainantu area much later than tobacco.

Cassava (*Manihot esculenta*) is another American species that may have been grown in Papua New Guinea before European settlement in the 1870s. Watson records cassava as a pre-European crop in the Kainantu area. It is a minor crop at Asiranka where it is considered to be a post-European introduction. Cucumber (*Cucumis sativus*) is a pre-European crop at Asiranka, as it is in most of Papua New Guinea, although it is often assumed by outsiders to be a recent introduction.

A large number of recently introduced species have been adopted as food plants by the Asiranka people. These include peanuts, *Xanthosoma* taro, potato (*Solanum tuberosum*), common beans (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*), pak choi (*Brassica chinensis*), pumpkin (*Cucurbita moschata*), spring onion (*Allium cepa*), choko (*Sechium edule*), peas (*Pisum sativum*) and *Amaranthus caudatus*. Recently introduced fruit species grown and eaten include mandarin (*Citrus reticulata*), orange (*C. sinensis*), avocado (*Persea americana*), passionfruit (*Passiflora edulis* f. *edulis* and *P. ligularis*), pineapple (*Ananas comosus*), tree tomato (*Cyphomandra betacea*), and pawpaw (*Carica papaya*). Other introduced vegetables such as lettuce, capsicum and broccoli, are grown mainly for sale to expatriates (Table A2.7).

Of the recently introduced foods, peanuts are now the most important and occupy an area second only to that of sweet potato (Table A2.6). People say that peanuts were introduced by the Seventh Day Adventist missionaries in the 1930s. By 1951, Schindler estimated that peanuts occupied some 8 per cent of the area planted in the village for two families. Most of the crop grown now is consumed within the village. *Xanthosoma* taro was another crop that was rapidly adopted following its introduction in the 1930s. By 1951 Schindler recorded it as a major crop in the forest gardens. *Phaseolus* beans were introduced in the 1930s and were becoming popular by 1943 (McAdam, 1943). They are now grown in significant quantities in sweet potato and mixed vegetable gardens for subsistence consumption and for sale. Despite the changes over the past 50 years, there is a continuity in the crop and animal base of subsistence agriculture, with sweet potato and pigs dominant throughout the period. For example, in 1951 Schindler recorded that sweet potato occupied 55 per cent of the garden area of two families, an almost identical figure to that recorded for 10 women by this author (57 per cent, Table 6). Many of the traditional supplementary foods are still very important, including *Colocasia* taro, winged bean, highland "pitpit", bananas, sugarcane, oenanthe and rungia.

CHANGING LAND USE PATTERNS

1920s to 1942

Prior to contact with outsiders, the people lived east of the Aiyura Basin in the Onamuna area. Gardens are said to have been located on both the slope soils ("kakimaka") and the colluvial soils ("poreramaka"). After contact with outsiders, which was mainly with Finschhafen evangelists at first, people moved to a number of sites in the Aiyura Basin during the 1930s. When the Agricultural Station was established in 1937, people were living at Onamunta, which is at the base of the steep slopes in the Basin (Figure A2.2). Again gardens were located on both the slope soils and the colluvial soils (Table A2.5).

The major garden type in both environments was sweet potato gardens with most other food crops mixed-planted in these gardens. Yams (*Dioscorea alata* and *D. bulbifera*) and winged beans were planted in separate sections of the sweet potato gardens. Mixed vegetable gardens were sometimes planted in swampy drainage depressions. Villagers nowadays say that up to 4 or 5 crops of sweet potato were planted and harvested on the same plot before it was abandoned to fallow. However, it is more likely that land was rarely planted with a second crop before fallowing on the slope soils(6). Only one planting was made in the mixed vegetable gardens. People say that common fences (to exclude pigs) enclosed groups of gardens owned by different families.

Subsistence agriculture in this period appears to be characterized by low intensity (cropping:fallow periods ratio) gardening, in both the short grasslands and on the woody regrowth/cane grass slopes. The major elements present in late 1970s/early 1980s, such as drainage of swampy depressions to make mixed gardens, a winged bean/sweet potato rotation and the use of both short grasslands and regrowth areas, were also present during this period. These elements were less important than they became in later years.

1942 to 1945

This period was one of trauma and change for the villagers. Informants from the village say that four people were shot to death, probably sometime in mid 1942. The village was destroyed and people fled to other villages outside the Aiyura Basin. Later on another five people who had fled were shot dead by police near Ontenu Village(7). The Aiyura area was bombed and strafed by Japanese aircraft during May and June of 1943.

The people lived in the forest area and in other villages during this period. Aerial photographs (22,000 ft) taken in September 1943 confirm this story. There were no houses at Onamunta or Asiranka. The only garden was at the Asiranka site. From the middle of 1944 to the end of 1945, the villagers moved down to a new site at Asiranka where the main village is now located(8). People then changed to family houses from the traditional housing pattern of separate men and women/children dwellings.

1946 to mid 1982

This period is characterized by a build-up in intensity in land use and agriculture in the grasslands. After the move to the site at Asiranka, gardens were made initially on the slope soils near the village in cane grass and regrowth. Gardening was progressively extended into the colluvial soils. By the time Schindler described the villagers' agriculture in 1951, 85 per cent of the gardens were in the grasslands (Table A2.5). Very few gardens were made in the forest until the late 1970s. After the return of Government land to the villagers in 1976, a few of the more energetic gardeners returned to the forest, so that over the period 1980-1981-mid 1982, some 12 per cent of new gardens were planted in the forest area (Table A2. 5).

The major change in land use during this period was drainage of the swamps and extension of cultivation into the drained land, mainly since 1960. A major drain was built through the bottom of the Basin in 1945 by the Agricultural Station workers. Asiranka and Anamunapa people combined to build a smaller drain that better drained village land, sometime before 1956. There was an increase in the use of swampy areas for mixed vegetable gardens on sites that were too wet for sweet potato. Another important change was the increasing intensity of land use. Over the period 1946 to 1951 the grassland sweet potato gardens were cropped for three years or more (Schindler, 1952 p305). By the early 1980s, some of these gardens commonly remained in production for 8 or 10 years. According to the villagers, the use of a peanut/sweet potato rotation facilitated this increased intensity. The peanut/sweet potato rotation has supplemented the traditional winged bean/sweet potato rotation practised in the grassland soils. A more recent innovation (post 1970) is the rotation of sweet potato and potato in the sweet potato gardens.

During the first part of this period gardens were individually fenced. Schindler's description corroborates the villagers' account of fencing: "... the picture is presented of islands of fences scattered over the landscape". With increasing intensity of land use on the grassland flats, a common fence was erected to enclose the entire garden area of Asiranka. This was done between 1951 and the end of 1956 (when the CAJ aerial photographs were taken). In the early 1960s, a common fence 2.5 km long was erected that enclosed all of the garden land of the Asiranka and Anamunapa people. This remained in service until 1982.

Other changes during this period were the demise of hunting of wallabies, "kapul", birds and rats; and the advent of coffee and market gardening as cash crops. Up to 1951 (and probably later) people hunted mammals and birds in the forest and rats in the grasslands (Schindler, 1952). By the late 1970s, hunting and trapping had declined to a minor activity because of the availability of tinned meat/fish and stories about the dangers of eating rats promoted by missionaries. The first village coffee was planted early in 1949 in a communal block. Individually owned coffee plots were planted soon after. Coffee has increased in importance to become the major cash crop. Opportunities for selling fresh food to outsiders arose soon after the Agricultural Station was established. During the 1960s and 1970s the market for introduced vegetables and fruit expanded rapidly because of the large number of expatriates living in the Basin. People responded by planting the desired crops for marketing. By 1981-82 annual sales of fresh food at the Ukarumpa market in the Aiyura Basin were K30,000. Most of this money went to residents of the Basin, including Asiranka people (Bourke and Nema, 1985). By 1978 people from the original Asiranka hamlet had formed 5 hamlets. In 1978 they formed a further two hamlets.

Village agriculture over the period 1980 to mid 1982 was as follows: a large number of crop species was grown, with sweet potato (57 per cent of garden area planted), the mixed vegetable gardens containing numerous species (17.5 per cent), peanuts (15.5 per cent), and winged bean (4.5 per cent) accounting for almost 95 per cent of all plantings (Table A2.6). The most important garden type was the sweet potato gardens in the grasslands. In these gardens, the soil was always tilled completely; drains were dug 4 to 8 metres apart up and down the slope; and small mounds 30 cm high were made. When land was first opened up for fallow, species demanding high fertility conditions were interplanted with the sweet potato, including *Phaseolus* beans, maize, pak choi and *Nasturtium schlecteri*. As the fertility declined with additional cropping, these species were excluded. Soil fertility was enhanced by a peanut or winged bean rotation. Winged beans were planted seasonally (May-August) and were managed for tuber rather than bean production. Measurements of sweet potato yields from 729 small plots over a 12 month period indicate a mean yield of 14 t/ha. Sixteen sweet potato cultivars were grown, 9 of which were pre-contact ones.

Swampy drainage depressions were used for mixed vegetable gardens containing numerous food species (Table A2.6). Most of these gardens were planted at the end of the dry period (September to December). After clearing of fallow vegetation (mostly *Phragmites* cane grass), the depressions were drained and then planted to a mixture of species with minimal soil tillage. Space occupied by short term crops, such as pak choi and amaranthus, was taken over by the slower growing crops, such as taro and sugarcane. After the initial period of planting, no replanting of food crops occurred before fallowing. Most new coffee plantings made since 1970 have been made in these drainage depressions in the mixed gardens. Initially shade for coffee seedlings is provided by taller food crops, such as bananas, maize and sugarcane. Seedlings of *Casuarina oligodon* are planted at the same time as the coffee or later. As the other food crops die out, bananas take over as the shading of coffee and are supplemented (and eventually replaced) by the casuarina. The households of the 10 women surveyed owned a mean of 464 coffee trees per household in 1984 (95 per cent mature).

Only 12 per cent of new food garden plantings were made in the forested area (Table A2.5). These consisted of sweet potato gardens, made without mounding or complete soil tillage, and small areas of mixed vegetable gardens. A few gardens consisted of almost pure stands of *Xanthosoma* taro. Some winged beans were grown in rotation with sweet potato, but most gardens were only planted to the one crop before fallowing. The steep slopes between the forested ridge and grassland flats were used by only one of the women studied. She made a garden similar to the forest gardens, that is, a sweet potato garden mixed cropped with vegetables, with minimal soil tillage. A few minor areas of "household" gardens were planted also. Two of the 10 women planted four sweet potato plots on relatives' land at Ukarumpa Village over the three year survey period. The ten women studied supported a total of 45 people and 52-53 pigs (excluding piglets younger than about two months) giving a pig:person ratio of 1.2:1. The pigs were excluded from the garden area in the bottom of the Basin by the communal fence and roamed amongst the hamlets and on the steep slopes.

A number of perennial food crops are also grown. Fruit trees are planted around the hamlets, especially bananas, but also avocado, mandarins, passionfruit, tree tomato and other species. Nut pandanus (*Pandanus julianettii*) is cultivated in the forest above about 1700 metres. Highland betel nut ("kavivi") (*Areca macrocalyx*) is planted in the bottom of the Basin and in the forest. "Marita" (*Pandanus conoideus*) is planted in the lower parts of the Basin near the hamlets and in the drained drainage depressions, below 1630 metres. Mean tree ownership for the 10 households surveyed (in 1984) were 176 "karuka" (28 per cent mature); 137 "kavivi" (23 per cent mature); 19 "marita" (32 per cent mature); 5 avocados (35 per cent mature) and 1 immature mandarin tree.

There are now some 30 cattle owned by 9 individuals. These are grazed in two fenced enclosures on land that was returned to the villagers from the Agricultural Station in 1976 (Figure A2.2). The grazed area is not used for food gardens. The fences are constructed from timber posts and barbed wire, and have not required major repairs so far.

Mid 1982-1983

In the latter half of 1982, there was a sudden withdrawal of gardening from the grassland flats which continued throughout 1983. There was a corresponding increase in gardening in the forest and scrubby regrowth areas (Table A2.5). The gardens that remained in the grasslands flats were either: adjacent to the hamlets; adjacent to the Agricultural Station and enclosed by an old Government fence; or small plots enclosed by individual garden fences in the largely abandoned Basin floor. After gardens were abandoned in the grassland flats, pigs were allowed to graze in the area from which they had been previously excluded.

Overall the intensity of cropping declined rapidly as people switched from the intensively used gardens to low intensity forest and regrowth gardens where the techniques of complete soil tillage, drainage and legume rotation were not used or were of only minor significance.

REASONS FOR CHANGE

Over the past 50 years, numerous changes have occurred in subsistence agriculture and land use of the Asiranka villagers. The two major changes were the move into the grassland flats (colluvial soils) after the Pacific War and the sudden withdrawal from this land type in 1982-83. What prompted these changes(9)? It is tempting to attribute the move from the slope soils to the colluvial soils in 1944-45 to the introduction of steel tools, especially spades. Amongst the nearby Fore, the introduction of the steel spade is said to have allowed a shift from forest to grassland gardening (Sorenson, 1972). Schindler (1952, p303) suggests that "the change to the steel axe, knife and spade can be regarded as an agricultural revolution". The villagers today, however, reject such an explanation. They insist that the move to the grassland flats was made possible because of the cessation of tribal fighting imposed by the Australian administration during the 1930s. Prior to this, it was too dangerous to garden the flatter land where an enemy could easily escape detection. Movement of gardening to lower alluvial soils, made possible by the cessation of tribal warfare, occurred elsewhere in the Kainantu area (Pataki-Schweizer, 1980 p20). In a nearby Tairora speaking village, the increased use of the wetter valley bottom for gardens after pacification is attributed by Grossman (1979 p214-216) to the cessation of warfare and the introduction of steel tools. In Asiranka, the traumas of 1943, that is, the killing of 9 people, the destruction of the village, the Japanese air raids and the move to other locations, may have made people more susceptible to changes such as that in housing style and the conversion to more intensive grassland agriculture. The influence of the Australian Administration and Lutheran Mission in encouraging people to move hamlet location is unknown, but this may have been a factor.

The changes that occurred between 1946 and mid 1982 are more amenable to explanation. The population was increasing rapidly (3.1 per cent per annum) and commercial production of coffee and vegetables commenced or expanded greatly. Drainage of the Basin, firstly by the Government (1945) and later by the people themselves, allowed a greater part of bottom of the Basin to be used. It also opened the way for greater use of the drainage depressions for mixed vegetable gardens and coffee. Production of supplementary crops in the specialized mixed vegetable gardens was necessitated as the intensity of sweet potato production increased. As this occurred and soil fertility was reduced, it was no longer possible to grow the supplementary crops with sweet potato and a second major garden type was developed. The reverse situation applied when agriculture disintensified after mid 1982.

And what of the events of 1982-83? The immediate reason for the move away from the Basin floor was damage to gardens by domesticated pigs. Until then pigs had been excluded from the garden area by a single fence 2.5 km long that enclosed the entire grassland flats. By 1982 individual men were no longer prepared to maintain their sections of the communal fence. I heard complaints about pig damage from late 1980 onwards. The pigs belonged to both Anamunapa and Asiranka people, but it was claimed that the neighbouring Anamunapa pigs did most damage at first. This intensified during the first half of 1982. A crisis was reached in July of that year when virtually no new gardens were planted that month because of pig damage. From August, people relocated their gardens out of the Basin floor and returned to the forest or regrowth. Land was opened up that had not been used since the mid 1940s.

There were two other less important reasons. "Raskals" had been killing pigs within the village and stealing food. Both villagers and outsiders in the Aiyura Basin reported a rapid increase in stealing during 1982 and 1983(10). The ten women I worked with owned a total of 52 and 53 pigs (excluding piglets younger than about two months) when censused in May 1980 and March 1982 respectively. By November 1983, pig numbers had declined by 50 per cent to 25 pigs. The pigs' deaths were attributed to slaughter because they had damaged other people's gardens (14 deaths), stealing by "raskals" (9 deaths), as well as the usual consumption at minor feasts (4 animals killed). A similar situation was reported in Barabuna Village by Grossman (1979 p242-246;1981 p228). Between July 1976 and March 1977, the Barabuna pig herd declined by 43 per cent. The decline was largely due to slaughter of pigs by their owners to reduce the effects of a food shortage being experienced at the time.

The year 1982 had an unusual weather pattern. The early months were especially wet, and there were two periods of drought later in the year. However it was two frosts in July 1982 that were particularly significant. The frost caused moderately severe damage to sweet potato, peanuts, corn, highland "pitpit", banana, choko and winged beans in the grassland gardens on the flatter land. Production was not affected greatly, partly because of the already severe damage from pigs, but some people took the unprecedented frost as an omen that they should move from the Basin floor.

Extensive damage to food gardens by pigs, and to a lesser degree, a perceived problem with "raskals" and two unprecedented frosts were the immediate causes of the dramatic changes in land use that occurred in 1982-83. The distal causes are less obvious however. Between the early 1960s and 1982, section of the long communal fences were maintained by individual men who owned gardens adjacent to it. By 1980 the younger generation of men were no longer prepared to maintain their section of the fence and pig damage to gardens increased as fence maintenance lapsed. The village councillor attempted to persuade people to repair the fence in the latter half of 1982 and early 1983, but without success. The community had lost its ability to resolve the problem of repairing the communal fence. The food supply crisis of 1982 resulted in a shift to a form of land use (individual family forest/slope gardens) that did not rely on community co-operation for maintenance.

By the 1970s, the villagers had been incorporated into the monetary economy. The three major sources of cash income were wage employment, sale of coffee and sale of fresh food. The period from 1976 to 1979 was characterized by high coffee prices (Figure A2.4). From 1980 until 1983 coffee prices declined and, given continuing inflation, the prospect is for a continuing decline in prices relative to the cost of other goods and services. Low coffee prices are not unique to the period 1980-1983. They were low in the years 1972 to 1975 (Figure A2.4). The difference between the earlier period and the more recent one is the prospect of employment. By 1981 the Papua New Guinea government was under severe financial pressure, because of low commodity prices for the major export commodities. The response was a reduction in public spending and loss of employment opportunity. In the local context, this meant that some men lost their jobs at the Agricultural Station and everyone knew that prospects for finding work, especially for young men leaving school, were low. I suggest that low and falling coffee prices and reduced opportunity to obtain wage employment in 1981, 1982 and 1983 were directly responsible for the increase in lawlessness in 1982 and 1983 (the "raskal" problem). This perceived problem was a contributing factor in people's decision to abandon their gardens in the fenced grassland flats where gardens were accessible to all and to return to the comparative security of individual forest/slope gardens.

INFLUENCE OF THE AGRICULTURAL STATION

Asiranka village is situated adjacent to the major agricultural research station in the highlands. It is reasonable to ask what effect the Station has had on village agriculture. As Radford (1979a,b) notes, the Agricultural Station from its beginning maintained a two-way relationship with its neighbours which was generally an amicable one. Asiranka people have provided labour for the Station over a long period and hence gained early access to goods and cash. They assisted in building the Aiyura airstrip in 1937, and were first recruited to work as labourers on the station in March 1939 (R. F. Brechin, Aiyura Monthly Report March, 1939). Their involvement as labourers has continued until the present time. Labourers were initially paid with rations and a knife or axe, but after February 1947, all payment was in cash (A. J. Schindler, Aiyura Annual Report 1946-47).

The villagers also had access to some assistance earlier than most other highlanders. For example, from 1938 to 1940, imported pigs were farmed out to local villagers by the Agricultural Station to upgrade the local pig strain (R. F.Brechin, Aiyura

Monthly Report June, 1940). Schindler was involved in planting village coffee plots among Agarabi and Gadsup speakers in the Kainantu area as early as 1945 (Patrol Report 1944/5. Asaroka Patrol Post). In February 1949, Station staff assisted the Aiyura villagers in establishing a communal coffee block (G. K. Graham, Aiyura Monthly Report, February 1949), although this block was later taken over by an individual from Asiranka who had been working on the Agricultural Station. The Station purchased village grown coffee, at least until the mid 1950s (Aiyura Annual Report 1955-56). In 1951 the Aiyura villagers were given three head of cattle for various services rendered (to the Agricultural Station ?) and they became the first owners of village cattle in the area (Young, 1973 p37).

Schindler believed that it would be advantageous to start an extension project in the Kainantu area. The aims would be to: 1) encourage and develop the growing of vegetables, coffee and chinchona by villagers; 2) encourage re-forestation; 3) establish a small demonstration farm at Kainantu; and 4)take any other measures which present themselves for encouraging mutual understanding of black and white people (A. J. Schindler, Aiyura Annual Report 1949-50). The older people at Asiranka recall that Schindler gave the people coffee and vegetable seed, timber seedlings and a cross saw. Schindler distributed seed and seedlings to other highlanders who worked as Department of Agriculture trainees or employees (Donaldson and Good, 1981).

Nevertheless casual observations in Asiranka do not suggest a strong influence from the Station. The farming systems described here can be found elsewhere in the highlands, including recent changes such as the coffee/mixed vegetable gardens/casuarina integrated system. It is likely that innovations from the Agricultural Station, such as introduced sweet potato varieties and new food crops, were also widely distributed by labourers returning to their villages elsewhere in the highlands. Asiranka was one of many villages that received new technology and ideas at about the same period. Some of this has been adopted into village agriculture, much has been rejected. The continuing close relationship between the Asiranka people and the Agricultural Station staff may have benefitted the latter, in the form of contact with village agriculture, more than the villagers.

CONCLUSIONS

There is sufficient land available under forest and scrub regrowth to allow low intensity gardening in these environments for some years before a return to more intensive systems in the grassland flats is necessitated. The move back to the forest has been facilitated by the advent of steel tools because, before the people had steel tools, they were mostly restricted to areas of secondary regrowth.

The present study, whilst very incomplete, does indicate the need for a long term perspective. Even a 30 year study period in this village, for example from 1950 to 1980, would not have recorded the two major changes in land use and intensity of subsistence production that have occurred since the 1930s. B. J. Allen (pers.comm.) has for some years been advocating the need for long term monitoring of subsistence production systems in Papua New Guinea. Even the most complete long term study to date, that of Brookfield (1973) in Chimbu, is too short to allow definite conclusions to be made about parameters such as a change in the pig to people ratio. The present study supports Allen's call for long term monitoring projects.

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Postscript

In August to October, 1984, I lived in Asiranka for 5 weeks to continue a long term study of variation in food supply. The move of agriculture out of the grassland flats had continued during 1984 (Table A2.5).

Notes

(1) For reviews and discussion on related topics, see: Radford (1979b) for the most complete account of European exploration of the Kainantu area from 1919 until 1942; Radford (1979a) (which is an extract from her thesis) on the development of the Highlands Agricultural Experiment Station at Aiyura; Du Toit (1975) for an ethnography of a Gadsup village; Berndt (1952/3) on the reaction of nearby Kamano speaking people to European contact; Pataki-Schweizer (1980) for much information on the environment and ecology of the Gadsup, Tairora, Auyana and Awa speaking peoples; Donaldson (1982) for a review of social relations and structure in the Eastern Highlands; and Bourke (1983) for a recent review of changes in food production systems in Papua New Guinea.

(2) Some older informants say that first contact was with Finschhafen evangelists who were not accompanied by a European so first contact may not have been in 1928, but at some other period in the mid to late 1920s.

(3) Schindler (1952 p303) calculated the area of village land as 1093 ha for a population of 370 persons. These figures include both present day Asiranka and Anamunapa villages. He states that the area under cultivation was 93 ha which gives a garden area of 2500 m^2 per person. This estimate is much higher than the recorded 834 m^2/person in the present study (Table A2.6). A figure of 2500 m^2 per person is one of the highest for garden area per person in Papua New Guinea. I am reluctant to conclude that crop area per person has declined to a third over a 30 year period.

Pataki-Schweizer (1980 p42) calculated the Asiranka village area as 620 ha for a population of 295 persons in 1963. His population figure is presumably derived from the Government census and would include absentees. The discrepancy between Pataki-Schweizer's figure of 620 ha and my figure of 445 ha is probably caused by the difficulty in separating village land on the forested ridges. The forest is used jointly by a number of villages and there are no clear-cut boundaries between the various villages in the forested area.

An annual growth rate of 3.1 per cent for Asiranka is comparable with the figures of 3.2 per cent (crude growth rate) and 3.5 per cent (estimated annual population growth) for Gadsup speakers as a whole (Pataki-Schweizer, 1980 p116). Young (1973 p49) gives the growth rate for Asiranka and Aiyura Villages as over 4 per cent per annum over the period 1952 to 1972. These villages had the highest growth rate of all Gadsap and Agarabi villages because of inward migration due to local employment prospects.

(4) Asiranka people planted gardens in the forest over an altitudinal range of 1750 to 1830 metres in 1980-1981-1982.

(5) The women are responsible for planting food gardens. They also weed and harvest the gardens and feed pigs. Men may assist with soil tillage and planting but their main input is clearing areas from forest and cane grass fallow, fence building, and digging and maintaining the major drains. Men plant the "male" crops of sugar and bananas.

(6) People today say that forest gardens are planted to 4 successive crops before fallowing. In the 3-1/2 years that I measured garden areas planted, only one part of one garden was replanted after the first sweet potato crop in the forest area. My experience elsewhere in Papua New Guinea is that the stated number of crops planted on land before fallowing is a maximum rather than an average.

(7) The alleged sequence of events is as follows: "Chimbu" labourers caused trouble between the villagers and the Officer in Charge of the Agricultural Station (R. F. Brechin) when one labourer claimed to have been shot with an arrow by a villager. Police from Kainantu were called in. Police, under the control of Brechin, shot dead a man (Dawame) in the forest area and burnt the village houses. People ran away to Ontenu and to nearby hamlets. Later an army aircraft crashed on landing at Aiyura (May, 1942). The villagers were called to pull the aircraft off the airstrip. Three people who did not assist (two men Akaiya and Kafoiya; and a woman Mavene) were shot dead by the police for not helping. The police were not under a European's control at the time. No official records of these alleged killings have been found.

Later, it is claimed, police shot dead five Asiranka people near Ontenu (a man Konano; a woman, Nontano; her daughter, Useko; a woman Bebako; and a young girl, Nonendoru). Another woman shot in the leg recovered. The police were under the control of a Patrol Officer, although the PO was not with the police when the shooting happened. This is likely to be the incident reported by PO (WO1) Haviland near Sonofi (which is near Ontenu) in November 1943 (ANGAU Monthly Report for Kainantu Sub-District, November 1943). These incidents are not isolated. Stories of beatings, gaolings and summary executions by the Australian New Guinea Administrative Units and the Papua New Guinean policemen serving with it are widespread in PNG (Allen, 1982).

(8) Aub Schindler remembers this as the period when people moved down from the forest. Village informants suggest that it may have been about two years after the road to Kainantu was completed (1944), that is, in 1946.

(9) Gorecki (1979) postulates that the Wahgi swamp was abandoned prior to European penetration because of an epidemic, possibly of malaria. Malaria is not a consideration in changing land use in the Aiyura Basin. An early survey (1945) indicated that there was little or no malaria in the Kainantu/Aiyura area (Ewers and Jeffrey, 1971 pp96,101), although some transmission of malaria does now occur in the Basin.

(10) "Raskal" is a Melanesian Pidgin term (from the English rascal) that translates as scoundrel. It is applied to people who commit both petty and major crimes. The outsiders complaining of a breakdown in law and order were both Papua New Guineans and expatriates.

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Table A2.1. Dates of some external events that can be used to date changes in villagers' lives and land use

July 1928	Missionary L. Flierl walked through the Gadsup area. His 1927 patrol passed to the north of Kainantu. (Radford, 1979b).
September 1932	First Government station in the highlands started at Upper Ramu Patrol Post (now Kainantu) in adjacent valley.
April 1937	Patrol made to the Aiyura Valley seeking (and obtaining) land for an agricultural research station.
May 1937	Operations commenced at research station.
May 1942	Three US Army Air Force aircraft crashed at Aiyura airstrip (one B25 on 15/5/1942 and two A24s on 31/5/1942).
June 1942	Founder of Aiyura Station (R. F. Brechin) killed in an aircraft crash.
May-June 1943	Aiyura airstrip and agricultural station bombed and strafed by Japanese aircraft on five separate days.
November 1943	Patrol under the command of WO1 Haviland attacked by villagers near Sonofi. Police (in the absence of Haviland) fired and killed a number of people. Arrows wound 11 carriers.
July 1944	A. J. Schindler took over as OIC of Aiyura.
September 1944	Kainantu-Aiyura-Arona Valley road opened.
May 1945	Major drain built by Agricultural Station that drains village and station land into the Akwitana River.
February 1949	Work commenced on Asiranka Village "co-operative" coffee block, with assistance from Agricultural Station staff.
February 1953	School commenced for villagers by Professor C. Schindler.
February 1956	Summer Institute of Linguistics Station at Ukarumpa in the Aiyura Basin founded.
February 1962	A. J. Schindler left Aiyura to live on his coffee plantation at Koranka.
July or August	Part of Agricultural Station (275 ha) returned to the 1976 people of Asiranka, Kamanakera and Amamunta Villages.
August 1979	R. M. Bourke commenced monthly garden surveys in village.
July 1982	Village land and gardens frosted.

Aerial photography of Aiyura Basin:

September 1943	(US Army)
November 1956	(CAJ series)
July 1973	(Skypiksa) (Too high for detailed interpretation)
April(?) 1980	(National Census) (Not available to author)

Table A2.2. Population of Asiranka Village, 1980(1)

	Males	Females	Total	
Resident infants/children (0-5 yrs)	35	29	64	
Resident older children (6-17)	78	52	130	194
Resident adults (18-45)	84	82	166	
Resident older adults (over 45)	24	35	59	225
Total resident population	221	198		419
Absent population(2)	61	40		101
Total population	282	238		520

Notes

(1) Source: Data from Provincial Data Systems books collected at the time of the 1980 National Census.

(2) The population absent from the village includes people who have moved to other locations on marriage.

Table A2.3. Number of people in wage/salary employment (and percentage of adult population), Asiranka Village, 1983/84(1)

	Males	Females	Total
Residents	37 (34%)	16 (14%)	53 (24%)
Non-residents	16 (52%)	3 (12%)	19 (33%)

Note

(1) Source: Household census by author, November 1983 and September 1984.

Table A2.4. Land areas and population density, Asiranka Village, 1980-1983(1)

	Area (ha)	Population density (persons/km²)
Total available land(2)	445	94
Grassland flats(3)	77	546
Total land available for gardens(4)	180	232

Notes

(1) Boundaries were marked in the field on to a print of the 1956 aerial photograph (1:20,000) and areas calculated from this. Population densities are based on a resident population of 419 persons in 1980.

(2) This includes forest that is jointly used by Amamunta villagers. In practice Asiranka people could not use all of this land.

(3) In 1980-1981-June 1982 86 per cent of all garden plantings were made on this land type.

(4) This includes the grassland flats and those parts of the total land area that were available for agricultural use in July 1982-December 1983. The remainder of the land is cattle pasture; forest and scrub not presently used for gardens; village areas and roads.

Table A2.5. Location of food crop gardens (as percentage of total garden area) at different periods, Asiranka Village

Period	1937-1942	1950-1951	1980-June 1982	July 1982 -Dec 1982	July-Dec 1983	1984
Grasslands flats	40	85	86 (1)	50 (2)	20	9 (3)
Forest area (forest fallow)	10	15	11	48	40	37
Forest area (grassland fallow)	0	0	1	2	15	14
Scrub regrowth (steep slopes)	50	0	2	0	25	40
Total	100	100	100	100	100	100
Source	Estimated from villagers' stories	Schindler, 1952	Areas planted by ten women. Measured by author		Estimated from garden visits, Nov 1983	(4)

Notes

(1) Plots of sweet potato, peanuts, winged bean, potato and yams on the better drained colluvial fans accounted for 84 per cent of these plantings. The remaining 16 per cent were mixed vegetable gardens, introduced vegetables, *Colocasia* and *Xanthosoma* taro plots in the wetter drainage depressions.

(2) Of this total, 75 per cent were on colluvial fans and 25 per cent were in the drainage depressions.

(3) Eighty eight per cent were on colluvial fans, 12 per cent were in the drainage depressions.

(4) Area planted by 10 women. Measured by author in September, 1984.

Table A2.6. Crops planted during a 36 month survey period (January 1980 to December 1982) by 10 women of Asiranka Village(1)

Crop	Garden area planted (m^2/woman/year)	Percentage of garden planted
Sweet potato	2135	56.9
Mixed gardens(2)	657	17.5
Peanuts	582	15.5
Winged bean	167	4.4
Introduced vegetables(3)	78	2.1
Potato	67	1.8
Xanthosoma taro(3)	45	1.2
Colocasia taro(3)	16	0.4
Yams (*Dioscorea* spp)	4	0.1
Others(4)	4	0.1
Coffee(5)	(60)	(1.6)
Total	3755	100

Notes

(1) The ten women surveyed supported ten other adults (8 husbands, 2 aged parents) and 25 resident children (mean 4.5 persons/woman). Thus to obtain mean garden area planted per person, divide by 4.5. The gardens also fed 52-53 pigs (excluding young piglets) in 1980 to early 1982.

(2) Mixed gardens are planted with numerous species in a mixed planting arrangement. Crops grown include *Colocasia* taro, highland "pitpit" (*Setaria palmifolia*), bananas, sugarcane, common beans, *Oenanthe javanica*, *Rungia klossii*, pak choi (*Brassica chinensis*), maize, *Nasturtium schlecteri*, pumpkin (*Cucurbita moschata*), cucumber (*Cucumis sativus*), *Cyanotis moluccana*, tobacco, cabbage (*Brassica oleracea*), *Amaranthus* spp, peas (*Pisum sativum*), spring onion (*Allium cepa*), lowland pitpit (*Saccharum edule*), ginger (*Zingiber officinale*), aibika (*Abelmoschus manihot*) and choko (*Sechium edule*).

(3) These are areas of predominantly these crops and do not include plantings in other garden types.

(4) Strawberries, pineapple, maize grown in pure stands.

(5) All new coffee plantings were interplanted with food crops and the area has been included under the interplanted food crop. Recordings of coffee plantings cover the period August 1980 to December 1982 (29 months).

Table A2.7. Species of food crops and narcotics grown by Asiranka people in 1979-1982(1)

Scientific name	Common name	Pre/post contact(2)	Status(3)	Part consumed
Abelmoschus manihot	Aibika	Pre	3	Leaf
Allium ampeloprasum	Leek	Post	5	Bulb
Allium cepa	Shallot	Post	4	Bulb/stem
Allium cepa	Spring onion	Post	3	Bulb/stem
Amaranthus caudatus	-	Post	4	Leaf
Amaranthus cruentus	-	Post	3	Leaf
Amaranthus dubius	-	Post	4	Leaf
Amaranthus lividus	-	Post	6	Leaf/stem
Amaranthus tricolor	-	Pre	3	Leaf
Ananas comosus	Pineapple	Post	4	Fruit
Apium graveolens	Celery	Post	5	Stem
Arachis hypogaea	Peanuts	Post	1	Nut
Areca macrocalyx	Highland betel nut	Pre	3	Nut
Beta vulgaris	Beetroot	Post	5	Bulb
Beta vulgaris	Silverbeet	Post	5	Stem/ leaves
Brassica chinensis	Pak choi	Post	2	Stem/ leaves
Brassica juncea	Indian mustard	Post	4	Stem/ leaves
Brassica oleracea	Broccoli	Post	5	Flowering head
Brassica oleracea	Brussels sprouts	Post	5	Leaves
Brassica oleracea	Cabbage	Post	3	Leaves
Cajanus cajan	Pigeon pea	Post	4	Seed
Capsicum annuum	Capsicum (sweet pepper)	Post	5	Fruit
Capsicum annuum	Chilli	Post	4	Fruit
Carica papaya	Pawpaw	Post	3	Fruit
Citrus paradisi	Grapefruit	Post	5	Fruit
Citrus reticulata	Mandarin	Post	3	Fruit
Citrus sinensis	Orange	Post	4	Fruit
Coffee arabica	Coffee	Post	1	Seed
Colocasia esculenta	Taro	Pre	2	Corm
Cucumis sativus	Cucumber	Pre(4)	3	Fruit
Cucurbita moschata	Pumpkin	Post	3	Fruit/ leaves
Cyanotis moluccana	-	Pre	3/6	Leaves
Cyathea ?aenifolia	Tree fern	Pre	6	Leaves
Cyphomandra betacea	Tree tomato	Post	4	Fruit
Daucus carota	Carrot	Post	5	Root
Desmodium repandum	Wild desmodium	Pre	6	Leaves
Dicliptera papuana	-	Pre	4	Leaves
Dioscorea alata	Greater yam	Pre	3	Tuber
Dioscorea bulbifera	Potato yam	Pre	4	Tuber
Eriobotrya japonica	Loquat	Post	4	Fruit
Ficus copiosa	Kumu musong	Pre	4/6	Leaves/ fruit
Ficus dammaropsis	Highland kapiak	Pre	6/4	Leaves
Finschia chloroxantha	Finschia	Pre	6	Nuts

Fragaria ananassa	Strawberry	Post	5	Fruit
Ipomoea batatas	Sweet potato	Pre	1	Tuber
Lablab purpureus	Hyacinth bean	Pre	4	Beans
Lactuca sativa	Lettuce	Post	5	Leaves
Lagenaria siceraria	Bottle gourd	Pre	4	Fruit
Lycopersicon esculentum	Tomato	Post	3	Fruit
Manihot esculenta	Cassava	Post(4)	3	Tuber
Morus alba	Mulberry	Post	4	Fruit
Musa cvs	Bananas	Pre	2	Fruit
Nasturtium officinale	Watercress	Post	4/6	Leaves
Nasturtium schlecteri	-	Pre	3	Leaves
Nicotiana tabacum	Tobacco	Pre(4)	2	Leaves
Oenanthe javanica	Oenanthe	Pre	2	Leaves
Pandanus antaresensis	Wild karuka	Pre	6	Nuts
Pandanus conoideus	Marita	Pre	3	Fruit
Pandanus julianettii	Karuka	Pre	3	Nuts
Passiflora edulis f. *edulis*	Purple passionfruit	Post	4	Fruit
Passiflora ligularis	Yellow passionfruit	Post	4	Fruit
Persea americana	Avocado	Post	4	Fruit
Petroselinum hortense	Parsley	Post	5	Leaves
Phaseolus lunatus	Lima bean	Post	4	Beans
Phaseolus vulgaris	Common bean	Post	2	Beans
Physalis peruviana	Cape gooseberry	Post	6	Fruit
Piper gibbilimbum	Highland betel pepper	Pre	4	Leaves
Pisum sativum	Pea	Post	4	Seed
Psidium guajava	Guava	Post	4	Fruit
Psophocarpus tetragonolobus	Winged bean	Pre	2	Tubers/ leaves/ beans
Raphanus sativus	Radish	Post	5	Root
Rheum rhaponticum	Rhubarb	Post	5	Stem
Rubus lasiocarpus	Black raspberry	Post	6	Fruit
Rubus moluccanus	Red raspberry	Pre	6	Fruit
Rubus rosifolius	Red raspberry	Pre	6	Fruit
Rungia klossii	Rungia	Pre	2	Leaves
Saccharum edule	Lowland pitpit	Pre	3	Inflor-escence
Saccharum officinarum	Sugarcane	Pre	2	Stem
Sechium edule	Choko	Post	3	Leaves/ fruit
Setaria palmifolia	Highland pitpit	Pre	2	Stem
Solanum nodiflorum	-	Pre	6	Leaves
Solanum tuberosum	Potato	Post	3	Tuber
Trichosanthes pulleana	-	Pre	6	Fruit
Vicia faba	Broad bean	Post	4	Beans
Xanthosoma sagittifolium	Chinese taro	Post	2	Cormels
Zea mays	Maize	Pre(4)	2	Cobs
Zingiber officinale	Ginger	Pre	3	Rhizome

Notes

(1) Does not include food species in the village area that are not consumed (eg, lemon, mountain pawpaw, naranjilla), non-food cash or shade crops (eg, crotalaria, casuarina). *Pueraria lobata* tubers are no longer grown at Asiranka, although some nearby villagers still grow a little. Only a minute proportion of the coffee crop is consumed in the village.

(2) This indicates whether the species was acquired before or after direct contact with Europeans (about 1928).

(3)
1. Major cultivated food or narcotic species
2. Significant cultivated species
3. Minor cultivated species
4. Very minor cultivated species
5. Very minor cultivated species, mainly grown for sale
6. Self-sown minor/very minor species

(4) See further discussion in the text.

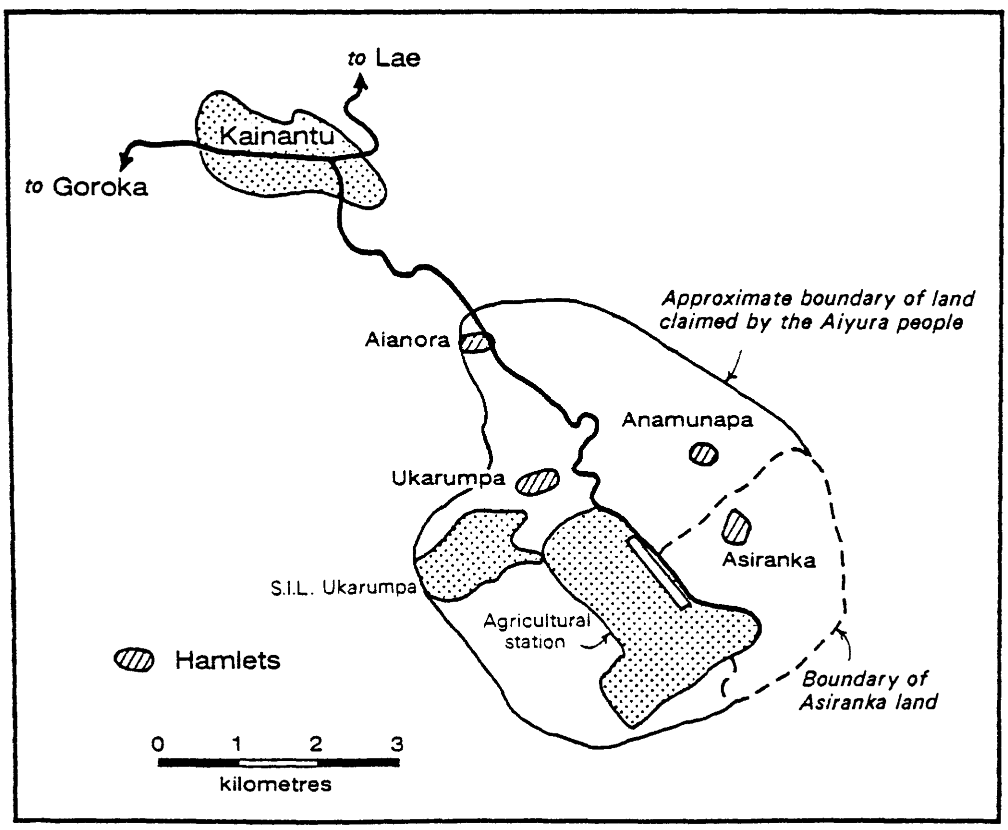

Figure A2.1 Location of Asiranka Village and Aiyura Basin

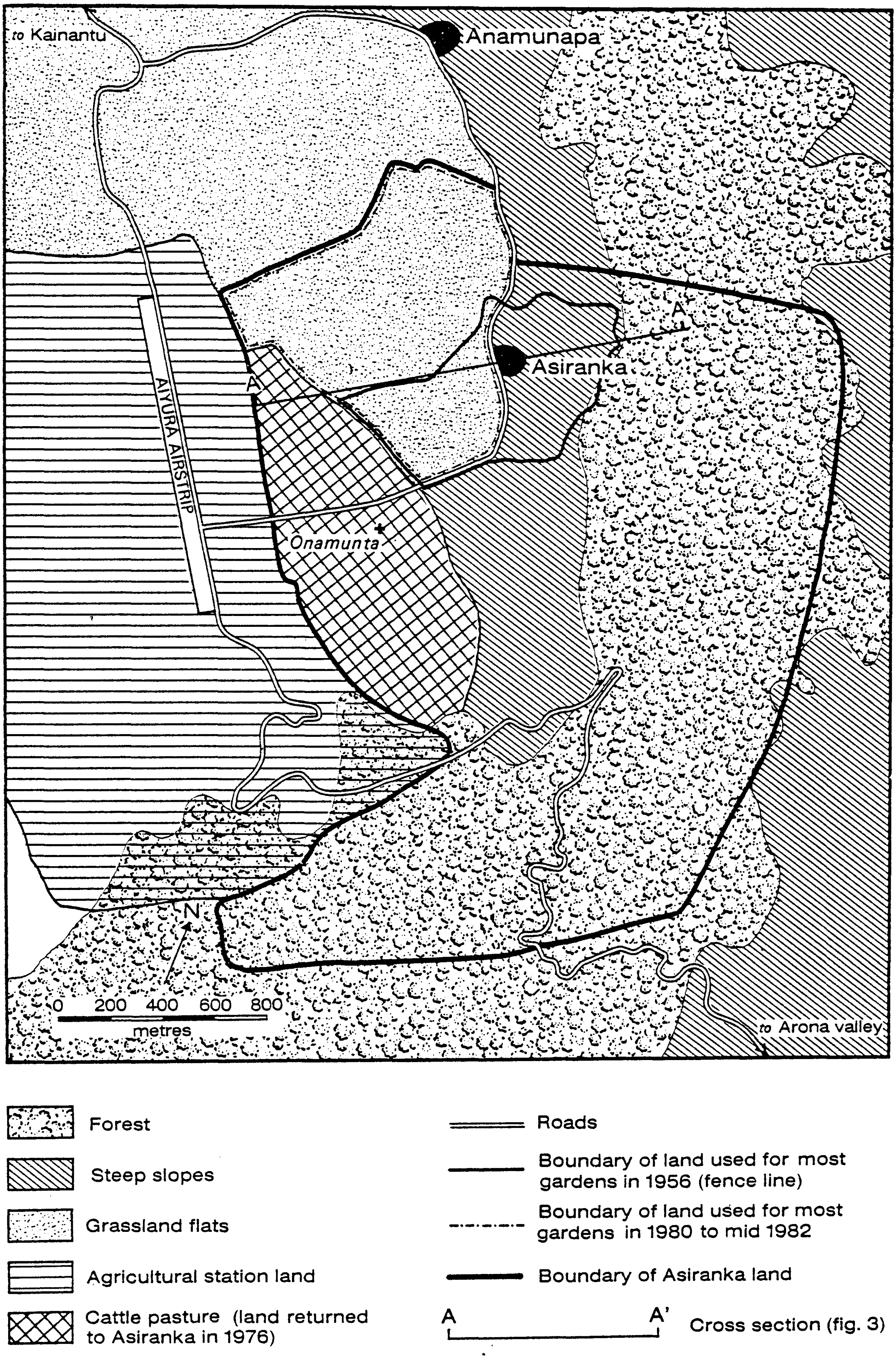

Figure A2.2 Land types and use, Asiranka Village

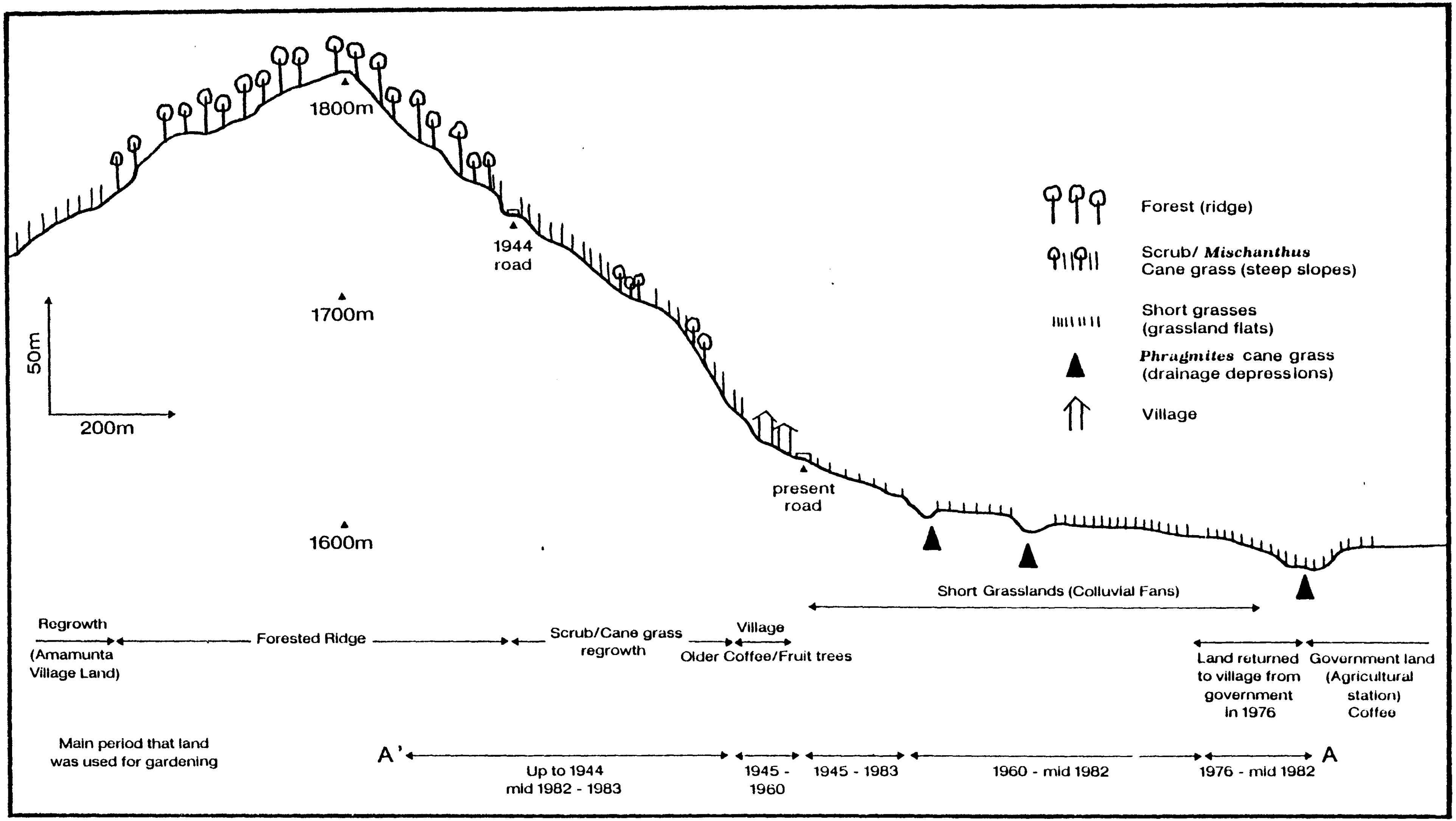

Figure A2.3 Cross section through Asiranka Village (50/230° mag.) showing land types and land use

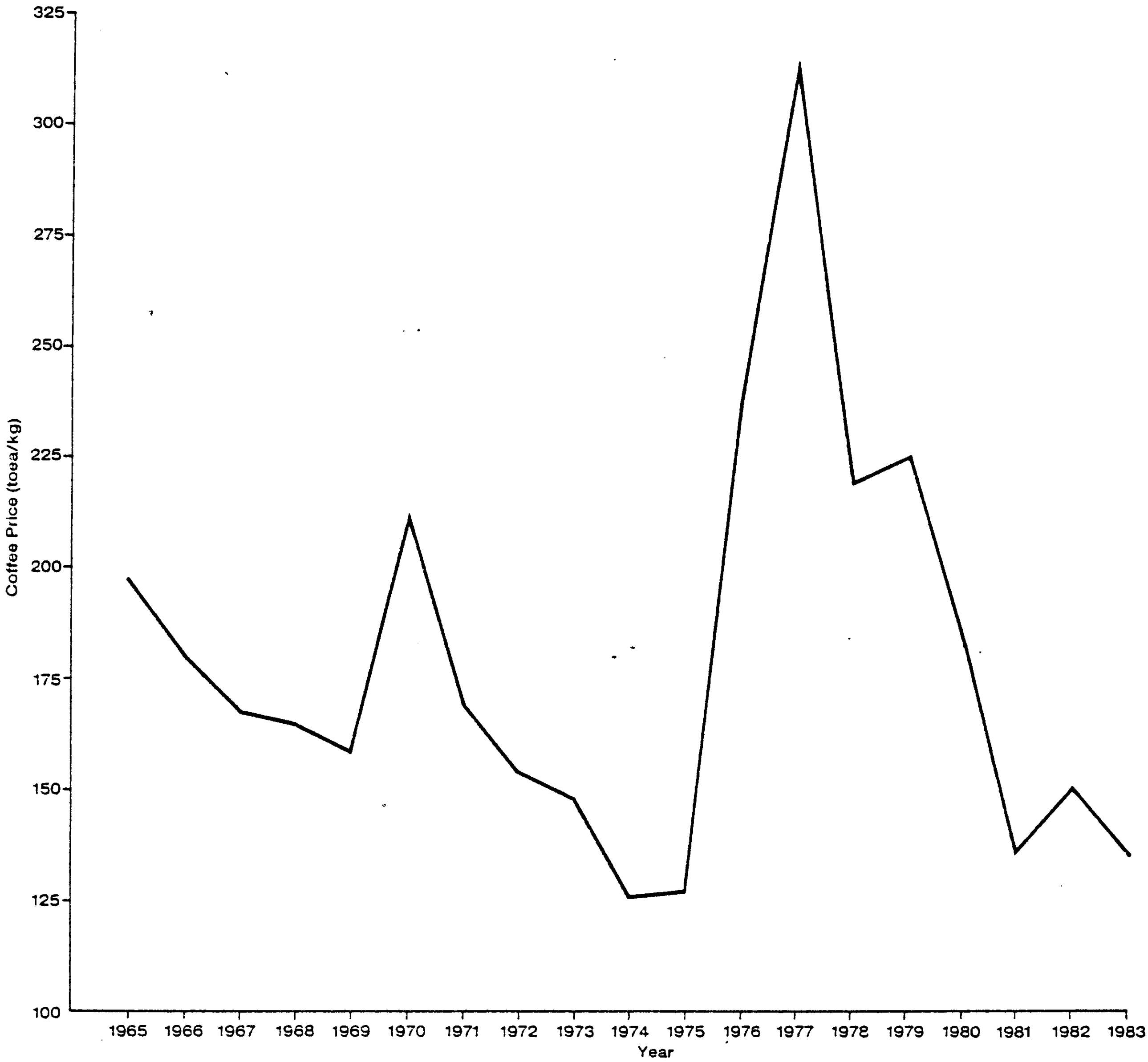

Figure A2.4 Mean annual price of arabica coffee (Y grade green bean DIS, Lae) between 1965 and 1983 in constant 1980 currency

APPENDIX 3

EARLY PATROLS TO THE NEMBI PLATEAU (1935 to 1964)(1)

PRE-WAR

Strickland-Purari Patrol
J. G. Hides and L. J. O'Malley. Jan-June, 1935. Patrol moved across the Nembi Plateau.

Lake Kutubu Patrol Report (PR) 1 of 1938/39
I. Champion and C.T.J. Adamson. July, 1938. Patrol followed Emia Creek up to Plateau to the Pumberel area.

Lake Kutubu PR 9 of 1938/39
C.T.J. Adamson and K. C. Atkinson. May-June, 1939. Patrol moved down Pwe Creek (Pou-e Creek) and Emia Creek.

Lake Kutubu PR 1 of 1939/40
C.T.J. Adamson and J.B.C. Bramell. July, 1939. Patrol moved from Nembi Valley to Pwe Creek.

POST-WAR

Mt Hagen PR 4 of 19(49)/50
A. Timperley. November 1949-January 1950. Passed across Plateau en route to and from Lake Kutubu.

Kutubu PR 2 of 1949/50
S. S. Smith. April-May, 1950. Patrol moved from Nembi Valley across Plateau to Wage Valley.

Kutubu PR 2 of 1950/51
S. S. Smith. August-November, 1950. Brief visit to Plateau from Nembi Valley.

Mendi PR 5 of 1953/54
J. A. Frew. September-October, 1953. Patrol visited Pwe and Emia Creeks areas on Plateau.

Kutubu PR 2 of 1954/55
C.E.T. Terrell. November-December, 1954. Patrol went from Nipa down Pwe Creek to Karamela, thence to Wage River.

Erave PR 3a of 1957/58
Patrol crossed the Plateau. (Not seen. Cited by Crittenden, 1982: 235).

Nipa PR 5 of 1959/60
D. N. Butler. June, 1960. Visited Emia Creek area.

Kagua PR 7 of 1960/61
G. P. Jensen-Muir. November-December, 1960. Exploratory contacts in the Emia Creek area.

Nipa PR 3 of 1960/61
Not seen. Cited by Crittenden (1982:236).

Mendi PR 10 of 1960/61
Not seen. Cited in Kagua PR 2 of 1961/62 and by Crittenden (1982:236).

Erave PR 4 of 1960/61
R. T. Fairhall. November-December, 1960. To Emia Creek area.

Kagua PR 12 of 1960/61
G. P. Jensen-Muir. March, 1961. To Emia Creek area.

Lake Kutubu PR 1 of 1961/62
F. J. Howard. June-November, 1961. Enjua and Pumberel visited on Plateau.

Kagua PR 2 of 1961/62
G. P. Jensen-Muir. July-August, 1961. Passed through Emia Creek area with CSIRO party en route to Lake Kutubu.

Nipa PR 1 of 1961/62
D. N. Butler. July-August, 1961. To Emia Creek area.

Mendi PR 4 of 1961/62
A. C. Jefferies. September-October, 1961. Visited Merut and Pumberel.

Mendi PR 5 of 1961/62
Not seen. Cited by Crittenden (1982:237) as going to Pumberel.

Mendi PR 7 of 1961/62
A. C. Jefferies. November, 1961-January, 1962. Visited Pumberel/Upa.

Nipa PR 9 of 1961/62
N. D. Lucas. March-April, 1962. To Emia Creek area.

Nipa PR 2 of 1962/63
N. D. Lucas. August, 1962. To Pumberel, Penerop and Upa.

Nipa PR 8 of 1962/63
P. J. Barber. March, 1963. To Nembi Census Division.

Nipa PR 1 of 1963/64
P. J. Barber. July, 1963. Visited Upa and Kum Villages.

Mendi PR 3a of 1962/63
A. Jefferies. July, 1963. Refers to an incident at Upa.

Nipa PR 1 of 1963/64
P. J. Barber. July, 1963. To Semin, Upa and Kum areas.

Nipa PR 12 of 1963/64
W. R. Read. January-February, 1964. To Nembi Census Division.

Nipa PR 15 of 1963/64
W. R. Read. April-May, 1964. To Nembi Census Division.

Nipa PR 5 of 1964/65
W. R. Read. November-December, 1964. To Nembi Census Division.

Note

(1) Other patrols passed to the west of the Plateau near Nipa, including the Bamu-Purari Patrol by I. Champion and C.T.J. Adamson (April-December, 1936). The regular patrol route from Lake Kutubu to Mendi followed this route and bypassed the Nembi Plateau. After 1964, patrols became more regular until the late 1970s when they ceased.

APPENDIX 4

SYSTEMS OF AGRICULTURE, NEMBI PLATEAU*

INTRODUCTION

Sweet potato is the staple food of the Nembi people. It is supplemented by a large number of other cultivated foods and a limited amount of gathered plant and animal foods and pig meat from domesticated pigs. The most important supplementary food crops are highland pitpit (*Setaria palmifolia*), taro (*Colocasia esculenta*), sugarcane, bananas, pumpkin, *tani* (*Rungia klossii*), corn, common bean and winged bean. A complete list of food plants used by Puit group members is given in Table A4.1 and a list of some important non-food plants is given in Table A4.2.

Two main garden types are cultivated, the open fields of sweet potato and the mixed crop gardens. The sweet potato gardens contain mostly sweet potato and occupy most of the cultivated land. The mixed crop gardens contain a mixture of many crop species and are located on the most fertile soils. Coffee is the main cash crop grown. Results of the intensive garden surveys are summarized in Table A4.3. An "average" household of 8.4 persons maintains 6000 m^2 of sweet potato gardens in 5 separate plots, 700 m^2 of mixed gardens in 2 separate plots, 300 m^2 of coffee and 6.5 pigs. The coffee would provide an income of about K16.00 per household per year at late 1980 prices.

A clear division of labour exists between men and women. Men decide where to locate new gardens, are responsible for clearing new areas, and for building and maintaining fences. Men also plant sugarcane, bananas, yam and taro. The women do most of the work in the sweet potato gardens such as soil tillage, planting, weeding and harvesting. They decide which varieties of sweet potato to plant. Crops such as bean and corn may be planted by either men or women. Women do most of the weeding and harvesting in the garden, although the men tend to harvest the sugarcane and bananas. Because sweet potato cultivation dominates subsistence agriculture, the women provide most of the labour in maintaining food supplies. The women do most food preparation and cooking, although men not uncommonly cook food for themselves to avoid illnesses they believe are caused by adult female contamination.

AGRICULTURE

Sweet Potato Gardens

The sweet potato gardens are located on the upper hillslopes and on the upper doline slopes. The crop is planted in beds up to 20 m long and 1-2 m wide. The beds are longer on the upper slopes of gardens and more regular in shape on the lower slopes. Where the soil is thickest, the beds are regular squares 1-2 m long and broad. A typical sweet potato garden is divided into a number of plots belonging to women of the same household or extended family. The plots are delineated by banks up to 50 cm high, and by drains and paths. The sweet potato gardens occupied 90 per cent of garden land of the Puit group in September 1978, although at this time most gardens had ceased production and were being prepared for planting or were recently planted.

The sweet potato gardens occupy sites of lesser soil fertility. Many are located on land in which the surface soil is shallower rather than deeper, although a great deal of variation can occur in soil types within a garden. A very minor type of sweet potato garden is made in secondary forest on steep hillsides. The crop is planted in pockets of soil between the limestone outcrops. Such gardens are used for one year only before

* This paper was published in Allen (1984b) and is cited as "Bourke (1984b)" in the thesis.

fallowing. The soil is not mounded. Tubers are used for pig feed. This type will not be discussed further.

The surveyed area of sweet potato garden per person was .072 ha (Table A4.3). Small numbers of other crops are planted with the sweet potato. These include sugarcane, highland pitpit, bananas, pumpkin, taro and *tani* (*Rungia klossii*). The Puit people plant some 25 varieties of sweet potato, 11 of which are traditional pre-European contact varieties and 14 are post-contact (Table A4.4). A typical garden contains about 9 varieties. The most important is *sokul*. Other important ones are *sumbil*, *koroka*, *peripam*, *konime* and *kiko*. All of these were acquired on the Plateau after European contact. At least 25 varieties have been lost in the past 50 years, and 11 of these have been lost in the past 25 years (Table A4.4). The planting density of about 155,000 plants per hectare is high. Rats are the main pest problem of sweet potato.

People claimed to place compost in the sweet potato beds, as is done in areas to the north and some composting is practised, but the quantities involved are small and only some of the women do it. Vines from the previous crop are the main material used.

On the Plateau it is customary to make progressive harvests of the tubers from plants at intervals of several months. Generally, two harvests are made at which large and small tubers are taken. At the final harvest all tubers are removed, including very small ones. During the September 1978 survey, it was not possible to record yields because the region was experiencing a food shortage and very little of the staple food was available. Most of the tubers examined (90-100 per cent) were less than 100 grams in weight which is the division used for tubers suitable for human consumption and stockfeed at the HAES. During a re-visit in March 1979, new crops were being harvested and it was possible to obtain yield data. Yields were recorded from 22 plots which ranged from 5 to 49 m^2 in area. Plots were classified as first, second, third or fourth harvest. The mean yield of the first harvest was 2.9 t/ha, and of subsequent harvests was 1.7 t/ha. If three harvests are taken, this would give a yield of 6.3 t/ha (2.9 + 1.7 + 1.7). A yield of 6.3 t/ha represents one of the lowest sweet potato yields ever recorded in subsistence agriculture in Papua New Guinea (Bourke, 1982). A close relationship exists between mean tuber size and number of harvests of the crop as follows:

$$Y = 65.65 - 8.65x, r = - 0.9994, (P < 0.001)$$

where Y = mean tuber size in grams and x = number of harvests (up to maximum of 4).

Sweet potato gardens are initially cleared from tall cane grass or short grass fallows by cutting, burning and digging out the roots. The work is generally done by the men. The men also fence gardens or dig banks and ditches to exclude pigs. The women do all the work in the gardens. They form the beds, place compost inside the bed if it is used, plant, weed and harvest the crop.

After a new area is opened up from a long fallow, it is cropped continuously with sweet potato for up to 30 years with a short fallow period between crops before the land reverts to a fallow. The short fallows range from a few months up to a year. The cultivation period ranges from two to 30 years with a mean of approximately 14 years. However the cultivation period within any one garden varies considerably. A bed is cropped until yields decline to an unacceptable level and then it is abandoned. So land in higher parts of a garden where the soil is poor may be cropped for a much shorter period than the best land at the bottom of the garden.

Planting is fairly seasonal(1). The follow-up research programme on the Plateau has shown that planting is greatest at the end of the drier months and beginning of the wetter months (October to February). The exact reason for this has yet to be determined, but the reasons appear to be social as much as environmental. There is little evidence that disruption of garden work by other activities such as harvesting seasonal crops of coffee, nut pandanus or mushrooms is responsible for this. The implication of this seasonal concentration of sweet potato plantings is that the staple food becomes short each year, as the older gardens cease producing before the new gardens are in production, that is, from about September to February. In September 1978 people were surviving on pumpkins, bananas, sugarcane, tiny sweet potato tubers, vegetables such as *Rungia* and a little rice. In 1980 people on the Plateau complained of shortages of sweet potato from the end of September.

Mixed Gardens

The mixed gardens contain a large number of supplementary food crops planted seasonally in mixed plantings. They occupy some 11 per cent of garden land. Of the 22 households surveyed, only two did not have any mixed gardens. They are located on the most fertile land. This is usually in the bottom of the dolines, but also along stream flats and occasionally on more fertile sites on the hillsides. In September 1978 members of the Puit clan had 1.63 ha of mixed garden or 0.009 ha per person (Table A4.3). The gardens are generally not replanted. They produce most of the food in the first year after planting but long term crops such as bananas keep producing for several years. Stated fallow periods range from 2 to 10 years.

The main crops grown in the mixed gardens are taro, highland pitpit, sugarcane, bananas, pumpkins, common bean, winged bean and *tani* (*Rungia*). Other crops include Chinese taro (*Xanthosoma*), cabbage, sweet potato, *tege* (*Oenanthe*), *tulup* (*Ficus copiosa*), *kormp* (*Amaranthus*) and lowland pitpit (*Saccharum edule*). Both leaves and fruit of the *tulup* are eaten. The fruit are eaten raw or cooked. Tubers and pods are eaten from the winged beans, although they appear to be mainly grown for their pods. Pumpkin tips and fruit are both eaten. Choko plants provide leaf tips, fruit and tubers for food. Usage of the other crops conforms to the general highland patterns. There are at least 14 varieties of bananas and 9 varieties of sugarcane grown (Table A4.4).

The new gardens are prepared towards the end of the drier months (August-September). Fallow vegetation (grass and trees) is cut and burnt. Casuarina trees have lateral branches removed rather than the entire tree being killed. The soil is not tilled in these gardens. The gardens are mostly planted in October-November. Smaller areas continue to be planted until March and there is virtually no further planting of mixed gardens until the following October. The crops are harvested as they mature. Thus quick growing crops such as the amaranths are ready for harvest by December whereas the longer term crops such as taro are harvested up to a year from planting. After about a year the gardens revert to fallow and crops such as bananas are harvested as they continue to produce. The maturity of taro and availability of the setts for planting material may provide a stimulus for planting of the following year's mixed gardens. Taro becomes ready for harvest at about the time the sweet potato supply is becoming scarce, that is, from September onwards. This too may provide a stimulus for replanting the new mixed gardens as the taro setts must be quickly planted once they are harvested. Taro is declining in importance in the mixed gardens. Sweet potato is often planted in its place and provides some tubers. The decline in taro cultivation is likely to accentuate the food shortages that occur toward the end of the year.

Increasingly the mixed gardens are being converted into coffee plots. Coffee and casuarina seedlings are planted in with the food crops. Initially the food crops provide shade for the young coffee, but later this is provided by the bananas and then the casuarina. Occasionally a mixed garden is converted to a sweet potato garden. After a fallow period it is re-used for a mixed garden.

Taro Gardens

A minor type of garden is the pure taro garden. Only two were surveyed in the Puit territory. The gardens are similar to the mixed gardens in management but are distinguished by consisting of an almost pure taro stand. They occupy a tiny proportion of the total garden area and their area is included with the mixed gardens in Table A4.3. Taro beetle (*Papuana* spp) is said to be a problem with taro.

Household Gardens

Most households maintain small gardens near the house. These range from a few banana trees to gardens of 150 m^2 in area. They were not included in the survey of garden area. Soil fertility is maintained by addition of household refuse. They are sometimes situated in old house sites. Crops in some of these gardens are very vigorous. Bananas are the most common crop grown but others include *tulup* (*Ficus copiosa*), corn, sugarcane, Chinese taro, highland pitpit, *tani* (*Rungia*), lettuce, carrots, *Amaranthus*, cucumber, tomato and spring onions.

Other Plant Food Sources

People gather a limited quantity of food from wild plants. These include various ferns, wild acorns (*Castanopsis* nuts), mushrooms, red raspberries (*Rubus rosifolius*) and *Trichosanthes* fruit. The immature seeds of Job's tears are eaten. The mature seeds of *ularut* (*Mucana albertisii*) were cooked and eaten until recently, although they do not appear to be used any more. Tubers of wild yams and wild *Pueraria lobata* are eaten in times of famine (such as in November, 1980). Pandanus nuts are not cultivated or gathered by the Puit people, although they are traded into the area from Nipa. There are a few red pandanus (*Pandanus conoideus*) grown, but the Plateau is at their usual upper altitudinal limit (1650 m), so they perform very poorly.

Tips of the following wild ferns are gathered for food: *enk* and *weim* (*Cyathea* sp), *kamkam* and *ke*. *Koink* (*Diplazium* sp) is both gathered from the forest and transplanted into gardens. *Oil* (*Cyathea* sp) grows on the Plateau, but the people say they eat it only in the Wage Valley.

Reed Gardens

Small gardens of reeds (*Eleocharis dulcis*) are planted in flooded dolines and occasionally in drains. These are used to make the women's skirts. Taro is occasionally planted in these gardens when they are dry. Later the taro is flooded in the wetter months. People say that the taro yields and varieties are the same as for dryland taro.

Cash Crops

Coffee is the main cash crop grown, although small areas of chillies are also planted. The coffee is grown under casuarina and banana shade. Older plots are located on the hillsides, but younger coffee is mostly planted in mixed garden land in the dolines. It is established at the same time as the mixed gardens. The level of husbandry of coffee is low. Fifteen of the 22 households surveyed had at least one coffee grower, and three had two growers. All owners were men or boys. These 18 growers owned 1770 trees which occupied approximately 0.63 ha. The average number of coffee trees per adut man is 44. The coffee growers owned an average of 98 trees each. This is low compared with other highland provinces where growers own 400-600 trees each (Anderson, 1977). Two-thirds of the coffee surveyed is not yet producing, indicating that much of the crop has been planted in the past 3-4 years only.

A few chilli gardens were seen. Again these are mainly located in dolines in former mixed gardens. Apparently more chillies were grown several years ago, but people are discouraged by the low price received, and only some of the chilli growers gather and sell their produce.

ANIMALS

Pigs

Domesticated pigs form an important part of the local economy and are an essential part of exchanges and compensation payments associated with deaths and marriages. Spectacular pig kills are sponsored by individual clans and are held every 10 to 15 years. A reliable observer estimated that between 2000 and 3000 pigs were killed during a recent pig kill at a location outside the study area but nearby. Most pigs are herded in the tall cane grass fallows and housed away from the main sweet potato gardens. After an area is cleared and fenced for gardens following a fallow, pigs are grazed in the area to break up the soil.

The ratio of pigs to people at the time of the survey was 0.77:1 (Table A4.3) which is at the lower end of the range found in the highlands. This ratio does vary over time however. The mean number per household was 6.5 with a range from 17 to 1. The average number of pigs per adult woman was 2.5.

Other Domesticated Animals

An area of approximately 25 ha of Puit and Palom clan land was formerly enclosed with barbed wire as a cattle pasture. About 20 beasts were purchased, but in 1978 they were all dead, either as a result of becoming stuck in a bog in the pasture, from disease or because they were slaughtered for exchanges. People say the land was not suitable for subsistence gardens because of very heavy soils and waterlogging. This project illustrates all the worst aspects of smallholder cattle projects and should be used as a practical example of the problems should other groups wish to become cattle owners.

A few dogs and chickens are maintained by many people but are not considered of any great economic importance. One cassowary is kept by one clan member. Rats and small insects are eaten by women and children and provide protein and concentrated energy to these people.

NOTE

(1) The long term garden measurements reported in the body of the thesis did not substantiate this observation which was based on the first year's recordings only.

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Bourke, R. M. (1982). Root crops in Papua New Guinea. In *Proceedings of the Second Papua New Guinea Food Crops Conference*. R. M. Bourke & V. Kesavan (Eds). Dept. Primary Industry, Port Moresby. pp51-63.

Table A4.1. Food plants used by Puit clan members

Scientific name	Common name	Puit name
Abelmoschus manihot (c)	Aibika	Elsambe, usis
**Allium cepa* (c)	Spring onion	Onyen
**Amaranthus lividus* (c,s)	-	Langap
Amaranthus tricolor (c,s)	Amaranthus	Kormp
**Ananas comosus* (c)	Pineapple	Pinap
**Arachis hypogaea* (c)	Peanut	Kalop
**Brassica chinensis* (c)	-	Koasi, pimulusa, salsale
**Brassica oleracea* (c)	Cabbage	Kabis
**Carica papaya* (c)	Pawpaw	Porpor
Castanopsis acuminatissima (w)	-	Pe
Colocasia esculenta (c)	Taro	Ma
Coix lachryma-jobi (w)	Job's tears	Olo
Commelina diffusa (s,c)	Wandering Jew	Embiamu
Cucumis sativus (c)	Cucumber	Olak
Cucurbita moschata (c)	Pumpkin	Pamken
Cyathea spp (w)	Ferns	Eng, oil, wein
**Daucus carota* (c)	Carrot	Karot
Dicliptera papuana (c)	Hemigraphis	Kenjulo
Dioscorea alata (c)	Greater yam	Berl
Dioscorea bulbifera (c)	Potato yam	Segil or kekil
Diplazium sp (c)	Fern	Koink
Ficus copiosa (c,w)	Kumu musong	Tulup
Ficus pungens (w)	-	Woik
Finschia chloroxantha (?) (w)	-	Togma
Ipomoea batatas (c)	Sweet potato	Orle
Lablab purpureus (c)	Hyacinth bean	Tekean
**Lactusa sativa* (c)	Lettuce	Letis
Lagenaria siceraria (c)	Bottle gourd	Ombua
**Lycopersicon esculentum* (c,s)	Tomato	Tomat
**Manihot esculenta* (c)	Cassava	Tapiok
Mucuna albertisii (w)	-	Ularut
Musa cvs (c)	Banana	Evael
**Nasturtium officinale* (c)	Water cress	Wara karas
Nasturtium schlecteri (c)	-	Kimbil, oka
Nastus elatus (c)	Bamboo	Pekomo
Oenanthe javanica (w,s,c)	Oenanthe	Tege
Pandanus conoideus (c)	Marita	Abere
**Phaseolus lunatus* (c)	Lima bean	Balean tekean
**Phaseolus vulgaris* (c)	Common bean	Besa
**Pisum sativum* (c)	Pea	Balean far
Psophocarpus tetragonolobus (c)	Winged bean	Far
Pueraria lobata (w)	Pueraria	Orleoron
Rubus rosifolius (w)	Red raspberry	Meminie
Rungia klossii (c)	Rungia	Tani
Saccharum edule (c)	Lowland pitpit	Konjuromo
Saccharum officinarum (c)	Sugarcane	Wal
**Sechium edule* (c)	Choko	Lipsoko
Setaria palmifolia (c)	Highland pitpit	Kore
Solanum nigrum (s)	Karakap	Suragur
**Solanum tuberosum* (c)	Potato	Asbus

Trichosanthes pulleana (c,w)	-	Tahr
**Xanthosoma sagittifolium* (c)	Chinese taro	Mausa
**Zea mays* (c)	Corn	Kanap
Zingiber officinale (c)	Ginger	Sembi

* recent introduction
c = cultivated in gardens, including transplanting of self-sown seedlings
w = wild plants used for food
s = self sown plants grown in gardens

Postscript

The following species are also eaten (based on 1984 fieldwork):

**Amaranthus cruentus*	-	Aelobi, aluli
Pennesetum macrostachyum	-	Wakma
Saccharum robustum	-	Webkombol

A.cruentus was introduced about 1930. *Ficus dammaropsis* (balank) leaves were previously eaten with pig meat, but are no longer used. The young stems of *P. macrostachyum* and *S. robustum* are eaten.

Table A4.2. Some important non-food plants used by Puit clan members

Scientific name	Common name	Puit name	Use
Areca macrocalyx	Highland betel nut**	Waranil	Stimulant
**Capsicum annuum*	Chilli	Sili	Cash crop
Casuarina oligodon	Yar	Napu	Timber,fallow,shade
**Coffee arabica*	Coffee	Kopi	Cash crop
Cordyline fruticosa	Tanget	Apul	Clothing, boundary marker
Desmodium sequax	-	Torawa	Cigarette paper
Eleocharis dulcis	Reed	Uru	Women's skirts
**Eucalyptus* sp	Gum tree	Porestri	Firewood
Imperata cylindrica	Kunai	Yangi	Fallow
Ischaemum polystachyum	-	Jamara	Fallow
Mischanthus floridulus	Wild pitpit	Kambe	Fallow
Nicotiana tabacum	Tobacco	Soko	Stimulant

* Recent introduction
** Grows only in the Wage River area, not on the Plateau

Table A4.3. Demographic and subsistence data for Puit clan (derived from census and garden surveys)

Parameter	Total	Per household	Per person
No of adult men	40	1.8	-
No of adult women	56	2.5	-
No of children(1)	89	4.0	-
Total population surveyed(2)	185	8.4	-
Area of sweet potato (ha)(3)	13.2	0.60	0.0716
Area of mixed garden (ha)(4)	1.63	0.07	0.0088
Total area of food gardens (ha)	14.9	0.68	0.0804
Area of coffee (ha)	0.63	0.63	0.0034
No of coffee trees	1770	80	9.6
No of coffee growers	18	0.82	-
No of sweet potato gardens	113	5.1	0.61
No of mixed gardens	44	2.0	0.24
No of pigs	142	6.5	0.77

Notes

(1) Less than 16 years of age

(2) Does not include all clan members

(3) Includes some garden land under a short fallow with a cover of old sweet potato plants

(4) Includes some taro gardens

Table A4.4 Sweet potato, banana and sugarcane varieties of the Puit clan

SWEET POTATO

Pre European Varieties Still Used

Givale(1), Gelo, Kiroro(1), Kul, Kunjip(1), Makà(1), Merile, Moma, Morawel, Tul, Yam

Post European Varieties Used

Asult, Balus, Bulop, Foamun(2), Gipale, Karoka, Kiko, Komine, Perimpam, Porinonk, Sokul, Sumbil, Tumun(2), Wanmun(2)

Pre European Varieties Now Lost

Arget(3), Barl, Imu, Ipop, Kowa(3), Kur(3), Memane, Mendl, Merere, Mormor(3), Mormarde(3),Moruwel(3), Mudiyame, Peke, Sekeri, Sigil, Sopa(3), Tangeold, Tenso(3), Tongult, Tul(3), Wapkank, Wep(3), Yeselup, Yom(3)

BANANAS

Kimpeme, Kombolu, Meruko, Molumpa, Omu, Ondo, Pengip, Pem, Porapora, Tomei, Tomone, Tul, Tume, Wiana

SUGARCANE

Ao, Engim, Kengel, Koomp, Makip, Ore, Pore, Sesip, Toal

Notes

(1) Very little material of these varieties is now left.

(2) Introduced by students of the Highlands Agricultural College in 1977

(3) Lost in past 25 years or so

APPENDIX 5

CALCULATIONS AND ASSUMPTIONS USED TO DERIVE EXTERNAL CASH INCOME IN TWO VILLAGES IN 1983 AND 1984

Wage income. This is based on surveys of all households in Asiranka and Puit clan in September-November, 1984. Figures collected were net fortnightly wages, after tax if any. Tax payments are small or zero for most employees. The 1983 figure at Asiranka is the 1984 figure reduced by the CPI change between the two years. The 1983 figure for the Puit clan is the rounded wage of the only person in receipt of wage income (a village magistrate). The estimates for both villages are likely to be quite accurate.

Sale of coffee. Estimates of income are based on the number of bearing coffee trees per person in the 10 sample households; multiplied by the number of people in the village/clan; multiplied by an estimate of mean parchment yield in that year; multiplied by the mean price of parchment in Kainantu or for roadside buyers on the Plateau in that year; divided by the mean number of coffee trees per hectare for a sample of trees. The actual figures used are given in Table A5.1.

Table A5.1. Figures used to derive income from coffee sales in two villages

Parameter	Asiranka Village 1983	Asiranka Village 1984	Puit clan, Upa Village 1983	Puit clan, Upa Village 1984
Number of bearing coffee trees/person	109	113	40	40
Yield parchment (kg/ha/year)	1250	750	1250	750
Price received (kina/kg)	1.45	1.55	0.80	0.80
Mean number of trees/ha	2850	2850	2600	2600

Members of the 10 households in each village were asked about actual receipts from coffee sales in 1983 and 1984. At Upa, there was reasonable agreement between coffee income as recalled by individuals and my calculated returns. At Asiranka, most people could not recall coffee income very clearly, and the figures provided did not agree well with the calculated incomes. I believe the difference between the villages reflects both the contrast in levels of cash income; as well as cultural differences between groups for whom exchange transactions are important (Upa) and unimportant (Asiranka).

My estimates of income from coffee sales are not likely to be very accurate as they depend on the assumptions made for yield and price and the accuracy of estimates of number of bearing trees. Nevertheless they do indicate the year to year variation in income and differences in scale of income from coffee sales in the two villages.

Sales of fresh food and pig meat. These are based on mean sales per seller per market day for a sample of sellers from the village/clan; the number of market days per year for each market; and the mean number of sellers per market per day. Asiranka people sell at Ukarumpa, Aiyura and Kainantu markets. Upa people sell at Hol market and directly to Embi Mission.

An example of calculation for Asiranka sellers at Ukarumpa market follows: Eight Asiranka women on average sell a mean of K2.35 worth of produce per seller per market day and there are 150 market days a year. The product of these three figures suggests a village income of about K2800 per year from this market. Estimates for sale of food by Asiranka people for 1984 are K2800 (Ukarumpa market), K2000 (Kainantu market), K600 (Aiyura market), K600 (miscellaneous sales, such as directly to high schools). The 1983 figure is the 1984 figure discounted by the difference in CPI value, but with rounding this is the same as the 1984 total of K6000.

The 1984 figure for the Puit clan is based on 8 women each selling K1 worth of vegetables per market day and 50 market days a year (K400 total); plus sales of K100 a year to Embi Mission; plus sales of K150 worth of pig meat in the market by men. The 1983 figure is assumed to be slightly greater because of higher cash flows in that year associated with a better season for coffee and casual wage labour.

The estimates of income from sale of garden produce and pig meat are likely to be of the correct order of magnitude.

Casual labour picking coffee. At Asiranka the estimate is based on 10 people working for 30 days at K3.25 per day in 1983 and no available work in 1984. These figures are based on a number of individual cases. At Upa, where this provides a much greater proportion of clan cash income, estimates are based on 18 single men earning K25 per fortnight for 8.5 fortnights plus 11 families earning K35 per fortnight for 8.5 fortnights in 1983 (Table A5.2). In 1984 one unmarried man earned about K200. The 1983 figures are based on mean earnings for a number of single men and families. The estimates are for cash earned in the Western Highlands, and actual amounts saved at the end of the coffee harvesting season are much less. Mean estimated savings from seasonal wage labour at the end of the season were K135 per man per year (sample of 5 married men's savings in 1981, 1982, 1983 seasons). The estimates from the two villages are likely to be of the correct order of magnitude.

Gifts/remittances from non-residents. The Asiranka figures are based on the following assumptions: 28 non-resident Asiranka people remit K30 a year each to assist with school fees etc.; and spend K150 each year on relatives when they visit the town (a one way ticket from Port Moresby to Goroka plus the cost of upkeep in the town). A man who lives and works in Goroka and maintains a family in the village is assumed to spend and remit K2000 a year for the family's upkeep. The figures are based on those provided by a number of people who have worked out of the village in the past and by households who receive financial assistance from relatives working elsewhere.

The Upa figure is based on 9 men who work outside the village and who still maintain close ties with relatives in it. It is assumed that they remit or spend on visiting relatives K50 a year each. Estimates for both villages are indicative only.

Other. The figure of K1000 for profits from trade store sales, public motor vehicles, gambling, black-market beer, social nights and sale of cattle to non-village members at Asiranka is a guess only. The figures that I obtained on trade stores and public motor vehicles suggest that they do not make any profit at Asiranka. Sale of cattle to non-villagers yielded K400 in 1984. Gambling and social night profits may well be more than K600 per year but I could not separate profit derived from residents and non-residents (mainly labourers at the nearby agricultural station).

At Upa the only source of "other" income is sale of woven baskets which I calculated from 16 men who sold an average of K38 worth of baskets a year in 1984. The average sale is based on earnings of a sample of basket makers. Men were less active in basket making in 1983 because of the absence of many men during the coffee harvesting season and I assume that income was half the 1984 level.

Other clans receive income from road repair contracts, but not members of the Puit clan. Trade stores appear to be profitable at Upa (K1000 profit per year for Puit clan) but as sales are mostly within the clan or at least the three clans of Upa, they are not included.

The estimate of basket sales at Upa is likely to be a reasonable one; the estimate for "other" income at Asiranka is indicative only.

Table A5.2 Number of Puit clan members who participated in seasonal wage labour, 1976 to 1984(1)

Year	Men	Women	Total
1976	2	0	2
1977	2	0	2
1978	6	0	6
1979	12	2	14
1980	14	6	20
1981	16	9	25
1982	16	8	24
1983	29	9	38
1984(2)	1	0	1

Notes

(1) The data are based on interviews conducted in Upa Village in November 1984. The seasonal work is on coffee plantations in the Wahgi Valley in the Western Highlands Province. Figures for 1977 and 1982 may be slight underestimates.

(2) In November 1984, the resident population was 107 males and 118 females. The number of adult men (16 years and over) was 49 and the number of adult women was 60.

APPENDIX 6

SOME DATA AND TECHNIQUES USED IN CHAPTER THREE

In this appendix, some of the data used in figures in Chapter 3 are presented and some of the techniques used are discussed in more detail.

Market Survey Techniques

CPI data. Prices of 14 fresh foods and betel nut are recorded in six urban markets every week by provincial DPI staff. They are compiled by the National Statistics Office and used to compute the consumer price index (CPI). The only highland town represented is Goroka where prices are recorded at the main Goroka market on Saturday mornings. The weight and price are recorded for six lots of produce for each commodity. Continuous data are available from January 1971 (or late 1970) until the present. The quality of data collecting appears to fluctuate over time. However the sample size of 24 (or 30) price records per month appears adequate, provided prices are recorded from separate sellers.

Six highland markets. In early 1979 regular surveys were commenced by the author at markets in the Kainantu area and these surveys were conducted regularly in six highland markets between 1979 and 1982. Details of the surveys are given in Table A6.1. Kainantu, Goroka and Asaro are urban markets where produce is sold by rural villagers to urban and rural people. Aiyura market is located on the Highlands Agricultural Experiment Station and caters for station workers. Ukarumpa serves staff (mostly expatriate) at the headquarters of the Summer Institute of Linguistics near Kainantu. Hol is a rural market on the Nembi Plateau and almost all sales are to villagers.

Table A6.1 Survey details for six highland markets

Market	Main survey period(1)	Frequency of survey (2)	Survey time(3)	Supervisor	No of assistants
Kainantu	Jun79-May82	FN	10am-noonFri	R. M. Bourke	2-3
Aiyura(4)	Feb79-May82	FN	3-4pmFri	R. M. Bourke	1-2
Ukarumpa	Jun79-May82	FN	6-7am Fri	R. M. Bourke	1-2
Goroka	Oct79-Sep82	FN	10am-noonSat	T. N. Tarepe	1-2
Asaro	Oct79-Sep82	FN	9-10amSat	T. N. Tarepe	1-2
Hol, Nembi	Sep79-Sep81	W	9-10am Sat	E. D'Souza	1

Notes

(1) Some surveys were conducted for up to three months before the main survey period whilst techniques were being tested. Certain data were collected regularly for several years after the main survey period.

(2) The fortnightly surveys (FN) were done on the Friday or the Saturday of the Government pay week as turnover is much higher on these days than any other during the fortnightly business cycle. There is not a fortnightly cycle in Hol market and hence the survey was done weekly (W).

(3) Surveys were timed for the period when most sellers were in position but buying had not started or had not peaked. The actual time of the survey depended on weather conditions. Following wet mornings, market activities and the surveys were delayed.

(4) The Asiranka village sellers were also surveyed separately at Aiyura market.

Identical techniques were used in these six markets. Food is offered for sale in lots or bundles of a fixed price in PNG markets. People vary the price of a bundle by altering the size of the bundle rather than the price per bundle. Mean prices were derived from recordings of the weight and price of a sample of sweet potato bundles offered for sale. Sweet potato prices were recorded at Kainantu, Aiyura and Hol markets, and for Asiranka sellers only at Aiyura. Initially 10 samples were selected per market day but the standard deviation was too great and this was increased to 20 samples for survey. This gave 40 (or 60) price records per month which appear to be adequate. During the period of the survey, people started to sell sweet potato in one and two kina bundles as well as 10 and 20 toea bundles. As the price per kilogram was greater in the K1/K2 bundles than in the 10 or 20 toea bundles (Bourke, 1986), 20 samples were also collected for the K1/K2 bundles.

Quantity data were collected for all locally grown or manufactured commodities in all six markets. This was done by recording the number of bundles and asking price for all commodities on display at the time of the survey. This was converted into 10 toea equivalents. For example if there were 100 bundles of sweet potato on display at 10 toea per bundle and 40 bundles at 20 toea per bundle, this was recorded as 180 units (K18 worth). This technique is adequate to indicate quantities offered for commodities that are very seasonal, such as certain fruits and nuts. However it is only a crude index of total produce offered for sale for commodities that exhibit less variation over time. The technique does not take into account produce kept in bags prior to display nor does it allow for variation in the size of bundles with a fixed price.

FMC purchase data. Purchase records of the Food Marketing Corporation, Goroka office, were collated for the period January 1976 to August 1981. Because of changes in prices paid and some change in purchasing policy for various foods, details of which are not available, the FMC purchase records are of limited use as an index of village food production over time.

Constant Kina Conversion

Recorded kina have been converted into constant kina using an index derived from the retail price index (1961-62 to 1971), and two series of consumer price index (1971 to 1977; 1977 to 1985). The various indices and the combined index are given in Table A6.2.

Reported Food Shortages, 1979 to 1985

This data set is compiled from a variety of sources, which are shown in Table A6.3. Sources used are: Reports from Provincial Division of Primary Industry files from Goroka (1971 to 1984), Kundiawa (1980 to 1984), Mt. Hagen (1976 to 1984), and Mendi (1979 to 1984); National Emergency Service files in Port Moresby; fieldwork by R. M. Bourke in all highland provinces (1978 to 1984); personal communications with T. Renagi, E. Cena and T. Tarepe (Eastern Highlands Province), P. Barker, G. Grayson, P. Harvey, A. Goie, R. Gere, G. Simpson (Chimbu Province), B. Allen, A. Goie, A. Brown and P. Wohlt (Enga Province), E. D'Souza, G. Roberts, M. Anders, R. Crittenden and F. Aiyora (Southern Highlands Province)(1978 to 1985); files of the Simbu Land Use Project (1980-1982) and data in Harvey and Heywood (1983), Roberts (1982), Wohlt *et al.* (1982) and Wohlt and Goie (1986). Many of the food shortages are reported independently by different sources. Some of the reports on DPI files originate from other government divisions, particularly health staff and patrol officers.

Correspondence on DPI files typically takes the following form:

1. A letter from provincial headquarters to district level staff asking that complaints of food scarcity be investigated.

2. A report by DPI field staff on the food supply situation in a certain region after field trips. Where the field officer agrees that staple foods are relatively scarce, comments on the causes of this are often provided.

3. Follow-up reports by DPI field staff as the food supply deteriorates or improves.

There are some limitations in this data set:

1. The observations were made by numerous people and hence the quality of reporting is uneven.

2. The exact start and particularly the end of reported food shortages are often poorly defined.

3. Data were collated at the district level. The criterion for inclusion was some indication that a significant proportion of people in a district was affected. Hence very localized food shortages were excluded, as were events in lower altitude parts of highland provinces (<1000 metres).

Most districts include diverse environments and not all parts of a district may be affected by a food shortage. This applies particularly to districts which include a wide altitudinal range, such as Nipa and Lagaip Districts.

4. The data refer to reports that sweet potato was scarce. There is very little evidence to assess the severity or effects of reported shortages.

Analysis of Time Series Data

Many of the data sets used are based on variables measured over time, for example, market prices, proportion of children who are malnourished and garden area planted per month. Statistical analyses of these time series present special problems because the value of each data point is influenced by the value of previous data. For example, a child's weight in any given month is closely correlated with the weight in previous months. Thus the condition that the data at each time point are normally distributed about a value determined by that time point is not satisfied and special analytical techniques must be used.

Data gathered over long time periods also present other problems, including: particular problems of consistency or comparability; variations associated with calendar variables (for example, the number of Saturdays in a month); and the occurrence of several independent variables with one dependent variable (for example, currency inflation and seasonal patterns in market price data) (Cangelosi *et al.*, 1976). Some of these factors can be compensated for. For example, the effect of inflation can be removed by adjustment using the consumer price index.

Some of the long term time series data sets used exhibit these problems. For example, the market price data from Goroka exhibit greater month to month fluctuations and have more missing months after about 1978 than before 1978, presumably because of deterioration in the quality of supervision of data collection. Even when the effect of price inflation is removed, prices after 1978 are greater and more variable than before that year for some commodities including sweet potato.

These problems would necessitate an especially complicated model for time series analysis. For this reason, I was advised by statisticians that time series analysis modelling, such as the Box and Jenkins (1970) analysis, would be unlikely to provide better interpretations of the data sets. Accordingly this analysis was not attempted.

Table A6.2 Conversion used to derive constant currency from recorded currency(1)

Year	Retail price index(2)	Consumer price index Base year 1971	Consumer price index Base year 1977	Combined index'
1961-62	100††			81.2
1962-63	97.8			79.4
1963-64	99.5			80.8
1964-65	102.7			83.4
1965	105.1			85.3
1966	110.2			89.4
1967	113.0			91.7
1968	114.3			92.8
1969	113.9			92.5
1970	115.7			93.9
1971	123.2	100††		100††
1972		106.1		106.1
1973		114.9		114.9
1974		141.6		141.6
1975		156.4		156.4
1976		168.4		168.4
1977		176.0	100††	176.0
1978			105.8	186.2
1979			111.9	196.9
1980			125.4	220.7
1981			135.5	238.5
1982			143.0	251.7
1983			154.3	271.6
1984			165.8	291.8
1985			171.9	302.5

Notes

(1) The retail price index ("A" series) is a combined index for Port Moresby, Lae and Rabaul. It is based on prices of food, tobacco and certain household items consumed by expatriates. The consumer price index (base year 1971) is based on prices of a group of goods selected on the basis of an urban expenditure survey of PNG public servant households. The consumer price index (base year 1977) is based on prices of a group of goods and services purchased by urban PNG wage-earning households. The index used is the weighed urban index for 6 urban areas. The combined index was derived by the author from the other three series and is used for conversions into constant kina. Source: Various CPI Bulletins issued by the National Statistical Office.

(2) The base year for the various indices is shown as 100††.

Table A6.3 Reported periods of food shortages in the Papua New Guinea highlands, by district, 1979 to mid-1985

Province	District	Reported period of food shortage	Sources(1)
Eastern Highlands	Kainantu	Aug82-Mar83	AF, DPI, PC
		Jul84-Feb85	AF, PC
	Wonenara		
	Henganofi	Sep82-Mar83	DPI, PC
		Jul(?)84-Dec(?)84	AF, PC
	Okapa	Sep82-Mar83	DPI, PC
		Mar84-Mar85	PC
	Goroka	Sep82-Mar83	DPI, PC
		Jul(?)84-Mar85	PC
	Lufa	Late80-Feb81	DPI
		Sep82-Mar83	DPI
		Jul84-Mar85	PC
Chimbu	Chuave	Aug82-Jan83	DPI, SLUP
		Aug84-Feb85	AF
	Gembogl	Jan79-Feb79	NES
		Oct82-Nov82	SLUP
		Aug84-Apr(?)85	PC
	Kundiawa	Jan79-Feb79	NES, PC
		Sep79-Oct79	NES, PC
		Sep82-Nov82	DPI, SLUP
		Aug84-Mar85	DPI, PC
	Sinasina	Jan79-Feb79	PC
		Dec80-May81	PC, Wohlt & Goie (1986)
			Harvey & Heywood (1983),
		Oct82-Nov82	SLUP
		Jul84-Feb85	PC
	Gumine	Jan79-Feb79	PC
		Dec80-May81	PC
		Aug82-Oct82	DPI, SLUP
		Aug84-Jan85	PC
	Kerowagi	Aug84-Dec(?)84	AF, PC
Western Highlands	Jimi	Aug84-Dec84	DPI, PC
	Wahgi	Nov80-Dec80	DPI
	Hagen Central		
	Hagen North	Aug84-Dec84	DPI
	Tambul	Jan81-Apr(?)81	DPI, Wohlt *et al.* (1982)

		Sep82-Dec82	DPI, NES, PC
Enga	Wabag		
	Wapenamanda		
	Kandep	Jan81-Apr(?)81	AF, DPI, PC, Wohlt *et al.* (1982)
		Oct82-Oct83	DPI, PC
	Lagaip	Feb81-Jun(?)81	AF, DPI, PC, Wohlt *et al.* (1982)
		Oct82-May83	DPI, PC
		Apr84-Aug84	DPI, PC
Southern Highlands	Pangia	May81-Aug81	DPI, PC
		Oct82-Dec82	DPI, NES
		May84-Nov84	DPI, PC
	Ialibu	Jan81-Mar81	DPI
		May81-Aug81	DPI, PC
		Sep82-Oct82	DPI
		Oct84-Nov84	DPI
	Kagua	May81-Sep81	DPI, PC
		Sep82-Oct82	DPI
		May84-Nov84	DPI, PC
	Mendi	Sep80-Oct(?)80	DPI
		Jan81-Feb(?)81	DPI, Wohlt *et al.* (1982)
		Sep81-Oct81	DPI
		Aug82-Nov82	DPI, PC
		May84-Nov84	AF, DPI, PC
	Nipa	Sep80-Mar81	AF, DPI
		Jan81-Feb81	DPI, Wohlt *et al.*(1982)
		Oct81	DPI
		Oct82-Feb83	DPI, PC
		Apr84-Jan85	AF, DPI, PC
	Tari	Aug81-Oct81	DPI
		Sep82-Oct82	DPI, PC
		Apr84-Nov84	AF, DPI, PC
	Koroba	Jun79-Aug79	DPI, PC, Roberts (1979)
		Sep80-Oct(?)80	DPI
		Aug81-Oct81	DPI
		Jul82-Nov82	DPI, PC
		May84-Nov84	DPI, PC

Note

(1) Abbreviations for sources used are:

AF Author's fieldwork (conversations with villagers)
DPI Provincial DPI files in Goroka, Kundiawa, Mt. Hagen, Wabag and Mendi
NES National Emergency Service files, Port Moresby
PC Personal communication with various observers (see text)
SLUP Simbu Land Use Project files

Table A6.4 Price (toea/kg) of sweet potato in Goroka market in unconverted currency, October 1970 to December 1985(1)

Month	1970	1971	1972	1973	1974	1975	1976	1977
Jan		8.6	5.3	9.5	4.2	12.8	7.0	11.2
Feb		6.2	6.6	8.1	4.2	14.3	7.3	12.8
Mar		5.9	5.7	6.8	4.8	8.6	8.1	9.5
Apr		5.7	7.0	5.5	6.2	6.6	10.3	11.2
May		4.2	6.2	6.2	7.0	5.5	9.2	11.0
Jun		4.4	7.0	4.8	9.9	6.2	9.7	11.0
Jul		4.4	7.5	4.2	8.8	5.5	10.8	9.7
Aug		4.2	7.5	4.2	10.1	5.1	11.2	10.1
Sep		4.8	8.6	5.7	11.0	5.3	12.5	11.0
Oct	10.1	4.6	8.8	5.3	12.8	4.6	9.2	8.1
Nov	10.6	4.8	11.9	4.6	15.2	5.9	10.1	10.8
Dec	9.7	5.1	13.0	4.0	16.5	6.8	10.3	N/A

Month	1978	1979	1980	1981	1982	1983	1984	1985
Jan	N/A	19.6	22.3	28.0	17.0	31.0	17.2	19.4
Feb	13.4	N/A	24.3	25.9	19.5	26.4	N/A	16.1
Mar	16.9	14.8	19.8	N/A	N/A	21.9	N/A	16.9
Apr	17.2	N/A	N/A	21.1	15.6	22.8	18.4	18.3
May	15.8	20.0	19.4	22.3	19.2	19.1	19.3	19.0
Jun	11.3	15.7	17.9	N/A	19.6	17.7	19.5	16.9
Jul	16.5	17.1	N/A	19.3	19.2	17.0	19.3	16.0
Aug	13.4	13.8	20.3	21.8	20.0	17.9	19.6	15.4
Sep	17.2	15.0	19.0	19.7	18.7	17.3	20.2	16.2
Oct	25.5	21.0	19.3	16.9	19.2	16.0	21.9	14.9
Nov	21.3	19.6	22.2	18.0	N/A	18.4	21.8	18.4
Dec	28.3	24.8	21.1	15.7	N/A	17.6	22.0	20.0

Note

(1) The source is the National Statistics Office.

Table A6.5 Price (toea/kg) of sweet potato in Kainantu, Aiyura and Hol markets in unconverted currency, March 1979 to May 1983(1)

Year	Month	Kainantu market 10/20 toea lots	Kainantu market K1/K2 lots(2)	Aiyura market (3)	Hol market
1979	Mar	6.4		7.3	
	Apr	9.0		7.8	
	May	7.1		7.6	
	Jun	8.3		9.0	
	Jul	14.7		9.2	
	Aug	9.7		9.3	
	Sep	10.4		9.2	6.9
	Oct	10.5		12.2	5.9
	Nov	10.9		12.5	5.9
	Dec	13.1		11.5	5.6
1980	Jan	13.0		13.1	5.4
	Feb	13.8		11.5	5.1
	Mar	13.9		11.6	5.5
	Apr	14.1		12.3	4.4
	May	12.0		12.1	4.1
	Jun	11.7		11.1	4.3
	Jul	11.0		11.0	4.7
	Aug	9.8		10.3	5.0
	Sep	11.7		10.7	5.8
	Oct	11.5		10.7	6.7
	Nov	13.2		10.3	6.6
	Dec	12.9		13.5	7.1
1981	Jan	11.1		10.3	7.5
	Feb	12.6		10.2	7.6
	Mar	11.8		10.9	7.7
	Apr	13.5		10.1	7.6
	May	12.3		11.0	7.4
	Jun	12.8		10.9	7.5
	Jul	12.9	17.9	10.1	7.0
	Aug	12.8	21.9	11.0	6.9
	Sep	13.1	21.3	10.0	7.8
	Oct	10.9	20.7	9.5	6.8
	Nov	10.9	17.3	8.3	6.9
	Dec	11.8	-	-	6.6
1982	Jan	9.3	18.2	8.1	6.6
	Feb	9.4	18.8	9.2	6.8
	Mar	9.8	21.1	9.6	6.2
	Apr	10.5	19.6	11.5	5.5
	May	11.5	21.5	9.7	5.7
	Jun	14.3	20.3	11.0	6.3
	Jul	11.3	21.2	9.4	6.5
	Aug	15.5	17.6	15.3	
	Sep	16.3	25.9	13.5	
	Oct	18.6	31.7	15.6	
	Nov	17.8	31.4	22.5	
	Dec	16.5	30.6	17.1	
1983	Jan	16.5	29.8	12.4	
	Feb	15.3	24.7	15.0	
	Mar	17.9	22.1	15.1	
	Apr	13.8	28.6	14.0	
	May	9.5	20.4	14.6	
	Nov	9.2	18.4		

1984	Sep	17.9	32.6		
	Oct/Nov				21.3

Notes

(1) Surveys were conducted fortnightly at Kainantu and Aiyura markets and weekly at Hol market. Thus monthly figures are a mean of two (or three) figures for Kainantu and Aiyura; and four (or five) figures for Hol. Between March and November 1979, 10 bundles were weighed from 10 sellers per survey; thereafter 20 bundles from 20 sellers were weighed each survey.

(2) During the survey period, people began selling sweet potato in larger lots for K1 or K2 in Kainantu market. As the price per kilogram is generally greater than for smaller lots, prices were also recorded for 20 of the larger lots per survey. Sweet potato was sold in 10 or 20 toea lots in Aiyura and Hol markets during the survey period, although in late 1984 K1 lots were being sold in Hol market.

(3) In Aiyura market prices were recorded separately for Asiranka sellers and the rest of the sellers. In general prices were similar for Asiranka and non-Asiranka sellers. The price given here is a mean of the two prices.

Table A6.6 Number of bundles of food crops on display per market, Friday morning, Kainantu market, by commodity group, May 1979 to May 1982

Year	Month	Sweet potato	Staples, except sweet potato(1)	Vegetables (2)	Beans (3)	All food crops, except sweet potato
1979	May	787	628	1148	31	3328
	Jun	420	641	698	1	3855
	Jul	187	336	551	39	3246
	Aug	295	420	1099	31	4906
	Sep	156	482	628	61	4572
	Oct	172	541	1026	55	5841
	Nov	380	665	942	30	7466
	Dec	277	368	756	31	4920
1980	Jan	486	588	662	36	4079
	Feb	390	679	618	55	3924
	Mar	462	488	732	19	3121
	Apr	620	372	727	27	2326
	May	768	614	474	15	3377
	Jun	337	358	666	16	1867
	Jul	380	391	895	19	2833
	Aug	656	705	1151	26	3725
	Sep	732	460	982	36	2909
	Oct	173	544	1021	45	4557
	Nov	549	459	926	31	4517
	Dec	873	338	719	15	4309
1981	Jan	727	579	676	67	3604
	Feb	766	1066	803	75	4206
	Mar	1309	1080	1101	29	4133
	Apr	1120	388	786	25	2399
	May	770	823	829	26	3229
	Jun	899	682	1369	55	3718
	Jul	674	917	1104	63	5437
	Aug	551	451	795	14	2033
	Sep	795	851	949	48	3897
	Oct	809	698	958	36	4629
	Nov	876	522	1143	30	5034
	Dec	709	189	483	3	1667
1982	Jan	787	436	787	26	3246
	Feb	454	311	409	24	2323
	Mar	627	703	707	28	3714
	Apr	859	599	1095	10	3512
	May	1788	648	1414	20	4007

Notes

(1) Bananas, *Xanthosoma* taro, corn, taro, winged bean tubers and cassava. Potato and peanuts are not included as they are overrepresented in market sales relative to village consumption.

(2) Oenanthe, Chinese cabbage, spring onion, rungia, choko tips, pumpkin tips, ferns, pak choi, aibika, *Nasturtium schlechteri*, watercress, *Ficus dammaropsis* leaves, *Amaranthus* spp, *Solanum nodiflorum*, *Cyanotis moluccana*, *Ficus copiosa* leaves, winged bean leaves, lowland pitpit, highland pitpit, mushrooms. Cabbage is not included as it is overrepresented in market sales.

(3) Common bean, winged bean, hyacinth bean

Table A6.7 Number of bundles of food crops on display per market, Saturday morning, Hol market, by commodity group, September 1979 to September 1981

Year	Month	Sweet potato	Staples, except sweet potato(1)	Vegetables (2)	Beans (3)	All food crops, except sweet potato
1979	Sep	252	335	262	8	928
	Oct	275	387	249	7	852
	Nov	275	396	249	24	858
	Dec	429	660	307	52	1375
1980	Jan	232	737	407	67	1572
	Feb	299	1026	331	122	2217
	Mar	336	857	280	122	2081
	Apr	317	822	275	116	2105
	May	272	755	247	10	2095
	Jun	199	563	135	1	1342
	Jul	241	361	123	2	956
	Aug	189	326	102	2	850
	Sep	171	231	196	2	874
	Oct	114	294	91	4	685
	Nov	78	309	177	5	879
	Dec	195	384	309	28	955
1981	Jan	102	415	347	78	1384
	Feb	116	573	378	107	1803
	Mar	98	732	311	85	1830
	Apr	180	497	437	260	1575
	May	173	727	266	40	1193
	Jun	301	803	208	11	1248
	Jul	128	581	131	3	923
	Aug	81	367	99	2	612
	Sep	200	316	170	0	696

Notes

(1) Banana, pumpkin fruit, corn, taro, *Xanthosoma* taro, yams, winged bean tubers. Pumpkin fruit were included in this group because they are an important calorie source on the Nembi Plateau (Baines, 1983:57), as they are in the nearby Wage Valley (Sillitoe, 1983:241). At Kainantu, as in most other highland locations, pumpkin fruit are a very minor food source.

(2) Rungia, highland pitpit, cabbage, *Nasturtium schlechteri*, *Amaranthus* spp, pumpkin tips, pak choi, aibika, *Ficus copiosa*, oenanthe, spring onion, watercress, choko tips, mushrooms, tomatoes

(3) Common bean, hyacinth bean, winged bean

Table A6.8 Number of bundles of marita pandanus, cooking banana, corn and common bean on display per market, Friday morning, Kainantu market, May 1979 to May 1982

Year	Month	Marita pandanus	Cooking banana	Corn	Common bean
1979	May	68	73	89	23
	Jun	3	352	34	1
	Jul	0	70	18	39
	Aug	0	133	7	31
	Sep	0	241	11	61
	Oct	2	138	12	55
	Nov	12	350	46	30
	Dec	35	125	52	31
1980	Jan	154	140	202	33
	Feb	261	47	320	49
	Mar	1511	81	201	14
	Apr	95	165	43	1
	May	42	349	14	14
	Jun	7	65	20	16
	Jul	0	65	3	19
	Aug	0	268	8	26
	Sep	0	110	17	36
	Oct	0	76	59	45
	Nov	30	229	31	31
	Dec	141	9	149	15
1981	Jan	184	166	202	65
	Feb	606	117	593	45
	Mar	44	193	375	23
	Apr	82	48	62	1
	May	50	280	18	25
	Jun	0	41	14	55
	Jul	0	163	36	63
	Aug	0	81	41	14
	Sep	0	66	37	48
	Oct	0	83	58	36
	Nov	112	87	111	30
	Dec	57	41	26	3
1982	Jan	160	54	81	26
	Feb	14	53	56	24
	Mar	12	116	76	23
	Apr	32	140	51	2
	May	0	212	17	18

Table A6.9 Number of bundles of marita pandanus, cooking banana, corn and common bean on display per market, Saturday morning, Hol market, September 1979 to September 1981

Year	Month	Marita pandanus	Cooking banana	Corn	Common bean
1979	Sep	0	106	53	7
	Oct	0	163	38	7
	Nov	0	164	43	24
	Dec	0	251	154	50
1980	Jan	18	211	187	30
	Feb	183	335	378	41
	Mar	320	316	266	17
	Apr	288	345	227	11
	May	558	433	112	1
	Jun	153	389	32	0
	Jul	43	213	19	2
	Aug	50	189	6	2
	Sep	16	129	8	2
	Oct	0	182	4	4
	Nov	0	157	17	5
	Dec	0	195	17	28
1981	Jan	132	122	83	77
	Feb	193	132	206	87
	Mar	283	161	284	33
	Apr	173	126	160	14
	May	18	146	139	10
	Jun	3	332	77	3
	Jul	15	269	34	3
	Aug	2	148	22	1
	Sep	0	89	14	0

APPENDIX 7

DATA SOURCES ON REPORTED PERIODS OF FOOD SHORTAGES AND ABUNDANT FOOD SUPPLY, EASTERN HIGHLANDS (1932 to 1971) AND SOUTHERN HIGHLANDS (1949 to 1974)

Table A7.1 Reported periods of food shortages and abundant food supply, Eastern Highlands, 1932 to 1971(1)

Period(2)	Location(3)	Sources(4)
REPORTED FOOD SHORTAGES		
Kainantu District(5)		
Jan37	Kainantu area	Finintegu B of 1936/37
Aug38-Jan39	Widespread	DPI Aiyura Monthly Reports August, September, 1938 Upper Ramu M of 1938/39
Feb-Mar41	N and W of Ramu PP (slight shortages)	Upper Ramu M of 1940/41
Aug-Nov(?)41	Widespread	Aiyura MR August 1941
Oct52	Kainantu local area only	Kainantu 6 of 1952/53
Aug-Sep58	South Lamari area	Kainantu 4 of 1958/59
Oct-Dec62	Gadsup, Tairora CDs	Kainantu 6,8 of 1962/63
Jul64-Mar65	Agarabi, Gadsup, Kamano, Tairora CDs	Kainantu 1,4,6, of 1964/65 Obura 2,5 of 1964/65
Sep-Oct72	Few villages in Iturua and Dogara CDs	Obura 3,4 of 1972/73
Late72	Agarabi and Gadsup CDs	Young (1973:9)
Aug82-Mar83	Widespread	(Fieldwork R. M. Bourke (Reports DPI Kainantu
Jul84-Feb85	Widespread	(and Aiyura (Kainantu market prices
Wonenara District		
Sep-Oct53	Aziana area only	Kainantu 4 of 1953/54
Jun-Sep60	Aziana CD	Kainantu 2,4,5, of 1960/61
Apr-Jun62	Aziana, Kuwepu, Yelia CDs	Kainantu 17 of 1961/62 Wonenara 6,11 of 1962/63

Jan-Feb64	Wugamwa CD	Wonenara 13 of 1963/64
Aug64	Wugamwa CD	Wonenara 3 of 1964/65
Oct67-Mar68	Aziana, Kuwepu CDs	Wonenara 3,6,10 of 1967/68 Wonenara 2 of 1968/69

Henganofi District

Jan37	Furai people	Finintegu B of 1936/37
Oct-Nov(?)49	N and E of Henganofi	Bena 3,6 of 1949/50
Oct54-Mar55	Widespread (Dunantina, Faiyantina, Kafetina CDs)	Goroka 6,8,15,17 of 1954/55
Dec64-Feb65	Kafetina, Faiyantina CDs	Henganofi 3,4 of 1964/65

Okapa District

Jul-Dec62	South Fore, Auyana CDs	Okapa 2 of 1963/64 Kainantu 8 of 1962/63
1967	Okapa area	Mathews (1971:AppenIV)
Jan68	Keigana-Kanite CD	Okapa 9 of 1967/68

Goroka District

Nov-Dec45	Benabena (slight shortage)	Bena 12,19 of 1944/45
Jan-Feb50	Lower areas, Asaro V (slight shortage)	Bena 5 of 1949/50
Nov-Dec52	Asaro CD	Goroka 8 of 1952/53
Nov-Dec53	S and E section only of Asaro CD	Goroka 9 of 1953/54
Sep-Nov54	Lower areas of Benabena CD only	Goroka 5 of 1954/55
Aug-Sep56	Watabung, Benabena CDs	Goroka 1,2 of 1956/57
Sep-Dec58	Benabena CD	Goroka 4 of 1957/58
Sep-Nov59	Benabena CD	Goroka 4 of 1959/60
Feb-May61	Upper Asaro CD	Goroka 10 of 1960/61
Feb-Mar63	Lowa CD	Goroka 11 of 1962/63
Sep-Nov63	Bena CD (some areas only)	Goroka 4 of 1963/64
Nov-Dec66	Bena CD	Goroka 6 of 1966/67
Jan68	Parts of Watabung and Asaro CDs	Goroka 15 of 1967/68

Oct70-Jan71	Goroka area	Shannon (1973) Goroka market prices

Lufa District

Jan-Feb65	Parts of Yagaria CD	Henganofi 4 of 1964/65
Jan-Feb71	Yagaria, Labogai CDs	Lufa 8 of 1970/71
Nov71-Jan72	Labogai, Unavi CDs	Lufa 9,12 of 1971/72

REPORTED ABUNDANT FOOD SUPPLY

Kainantu District

Jun37	Gadsup CD	Upper Ramu B of 1936/37
May-Jul45	Agarabi, Gadsup, Tairora CDs	Bena 31, 32 of 1944/45 Bena 2 of 1945/46
Jan-Feb53	Widespread	Kainantu 8 of 1952/53
Sep-Nov58	Kamano CD	Kainantu 3 of 1958/59
Nov63-Jan64	Kamano, Piora, Tairora CDs	Kainantu 13, 16 of 1963/64 Wonenara 10 of 1963/64
Mar-Apr65	Tairora CD	Obura 9 of 1964/65
Mar-Apr66	Kamano CD	Kainantu 10 of 1965/66

Wonenara District

Aug-Nov62	Wugamwa, Yelia CDs	Wonenara 5,6 of 1962/63
May-Jun63	Wugamwa CD	Wonenara 18 of 1962/63
May-Jun64	Yelia CD	Wonenara 16 of 1963/64

Henganofi District

Jun-Oct45	Dunantina V; Finintegu PP	Bena 4,8,9, of 1945/46
Nov-Dec51	Dunantina CD	Goroka 7 of 1951/52
Oct53	Dunantina CD	Goroka 6 of 1953/54
Jun55	Kamanuntina, Dunantina Vs	Goroka 17 of 1954/55

Okapa District

Jan-Mar55	S of Mt Michael	Kainantu 11 of 1954/55
May-Aug56	Gimi, South Fore CDs	Kainantu 3,5 of 1956/57
Nov-Dec63	Keiagana-Kanite CD	Okapa 6 of 1963/64
Feb-Aug66	Auyana, North Fore CDs	Okapa 5A,8 of 1965/66

		Okapa 3 of 1966/67
Feb-Mar67	Auyana, South Fore, North Fore CDs	Okapa 16 of 1966/67
Feb-Mar68	Auyana, South Fore CDs	Okapa 13 of 1967/68

Goroka District

Nov51-Jan52	Goroka, Benabena, Watabung areas	Goroka 6,7,8 of 1951/52
May53	Western Goroka SD	Goroka 18 of 1952/53
Jan-Feb55	Goroka SD	Goroka 13 of 1954/55
May59	Unggai CD	Goroka 10 of 1957/58
Sep-Oct64	Unggai CD	Goroka 12 of 1964/65
Dec66	Unggai CD	Goroka 8 of 1966/67

Lufa District

No reports of very abundant food supply

Notes

(1) This data set includes reports of food shortages or especially abundant supply. It does not cover reports of normal or adequate supply. The frequency of these is indicated in Figures 3.1 to 3.4.

(2) "Period" refers to the period covered by the report. The actual period of inadequate or abundant food supply is likely to be longer in many cases.

(3) "Location" refers to portions of a District. Abbreviations used are CD for Census Division, SD for Sub District (an earlier administrative unit), PP for Patrol Post, LGC for Local Government Council and V for Valley. Reports of food shortages for single villages only are not included. There are a number of these in patrol reports.

(4) "Sources" are mostly patrol reports of the Department of District Administration. Thus "Kainantu 6 of 1952/53" is Kainantu Station Patrol Report No. 6 of 1952/53. Numbers are not available for some earlier reports from Finintegu and Upper Ramu on the copies consulted, and these are numbered as B or M only. MR stands for monthly report.

(5) The Kainantu data continue until early 1985. Sources consulted are patrol reports (1932 to 1984); monthly reports for DPI Aiyura (1936 onwards); personal communications with A. J. Kimber for the period 1966 to 1977; field observations and regular surveys of Kainantu market by R. M. Bourke for 1978 to 1984; and DPI files in Goroka.

Table A7.2 Reported periods of food shortages and abundant food supply, Southern Highlands, 1949 to 1971(1)

Period(2)	Location(3)	Sources(4)
REPORTED FOOD SHORTAGES		
Pangia District(5)		
May-Jun62	Part Wiru CD only	Pangia 3 of 1961/62
Aug65	Wiru CD	Pangia 3 of 1965/66
Jun-Dec67	Wiru CD	A. Strathern, pers.comm. (April,1985)
Oct-Nov69	Wiru CD	Pangia 5 of 1969/70
Jul70-Mar71	Wiru CD	Pangia 1,4,5,6,7 of 1970/71
Ialibu District		
Oct-Dec52	Mt Ialibu area	Mendi 5 of 1952/53
Jul-Sep53	Widespread	Mendi 9 of 1952/53 Mendi 10 of 1953/54
Aug-Nov55	Ialibu Basin only	Ialibu 1,2 of 1955/56 Mendi 3 of 1955/56
Aug60	Some parts of Imbong'gu CD	Ialibu 4 of 1960/61
Mar-May62	Ialibu-Mendi road route/ Ialibu area	Mendi 16 of 1961/62
Jun65-Feb66	Widespread	Ialibu 1,5 of 1965/66
Aug67-Mar68	Widespread	Ialibu 2,3,5,9,10 of 1967/68
Dec69-Mar70	Widespread	Ialibu 9,10,12 of 1969/70
Mar-May71	Widespread	Ialibu 10,12 of 1970/71
Kagua District		
Sep-Dec52	Erave R area	Mendi 5 of 1952/53
May-Oct55	Widespread	Erave 4 of 1954/55 Mendi 3 of 1955/56
Jul-Dec58	Widespread	Kagua 1,3,4 of 1958/59 Erave 4 of 1958/59
Jul-Nov61	Widespread	Erave 1 of 1961/62 Kagua 5 of 1961/62

Aug62	Kuare CD	Kagua 2 of 1962/63
Sep-Nov65	Widespread	Erave 2 of 1967/68 Kagua 2,3,4 of 1965/66
Sep-Oct67	Widespread	Erave 2 of 1967/68
Mendi District		
Apr52	Some groups only, Upper Mendi V	Mendi 3 of 1951/52
Jun-Dec53	Widespread	Mendi 9 of 1952/53 Mendi 1,9 of 1953/54
Feb-Oct55	Widespread	Mendi 7 of 1954/55 Erave 4 of 1954/55 Mendi 2,3,7 of 1955/56
Oct-Nov58	Anga Gorge only	Mendi 4 of 1958/59
Mar-Aug60	Widespread	Mendi 7,9 of 1959/60 Mendi 2,7 of 1960/61
Mar-May62	Mendi-Ialibu road route	Mendi 16 of 1961/62
Aug-Nov65	Widespread	Mendi 2,3,4 of 1965/66
Apr-Oct67	Widespread	Mendi 19 of 1966/67 Mendi 4,9 of 1967/68
Oct-Dec70	Widespread	Mendi 1,4 of 1970/71
Nipa District		
Jul-Aug55	Nembi Valley	Mendi 2 of 1955/56
May-Dec62	Angu and Nipa CDs	Kutubu 6 of 1961/62 Nipa 4 of 1962/63
Feb-May65	Nipa Basin	Nipa 7,9 of 1964/65
Aug65-Jan66	Widespread	Nipa 1,2,5,6 of 1965/66
Apr-Nov67	Widespread	Mendi 19 of 1966/67 Nipa 1,6 of 1967/68
Aug67-Mar68	Margarima, Upper Wage CDs	Nipa 3,7A of 1967/68 Margarima 2 of 1967/68
Jan71	Margarima CD	Margarima 5 of 1970/71
Tari District		
Nov52-Feb53	Benaria, Tari Basin, South East Tari SD	Kutubu 5 of 1952/53 Tari 2 of 1952/53
Oct-Nov54	Tari-Lake Kutubu road route	Tari 3,4 of 1954/55
May56	Haibuga Marsh, Tagari R	Tari 6 of 1955/56

Jul-Nov57	Tari Basin, Tagari R	Tari 1 of 1957/58 Koroba 2 of 1957/58
Sep-Nov60	North Basin; W of Tari	Tari 6,8,11 of 1960/61
Aug61-Jan62	Komo; Haibuga Swamp; Iumu CD; Lower Tari CD	Komo 1 of 1961/62 Tari 2,7 of 1961/62 Kutubu 4 of 1961/62
May-Oct62	East Basin, Lower Tari CDs	Tari 7 of 1962/63 Kutubu 6 of 1961/62 Kutubu 2 of 1962/63
May-Jul63	Mananda CD	Komo 5 of 1962/63 Komo 2 of 1963/64
Aug65-Feb66	Widespread	Tari 2,6,7,10 of 1965/66 Komo 2,6 of 1965/66
Oct-Dec70	South Basin CD	Tari 6 of 1970/71

Koroba District

May-Jul55	Widespread	Tari 7 of 1954/55 Tari 1 of 1955/56
Jun-Dec57	Widespread	Koroba 8 of 1956/57 Tari 1 of 1957/58 Koroba 1,2,4,6 of 1957/58
Aug62-Jan63	Widespread	L Kopiago 2,4 of 1962/63 Koroba 12,14 of 1962/63
Jun-Aug63	Logaiyu CD	L Kopiago 1 of 1963/64
Sep-Dec65	Widespread	L Kopiago 2,3,4 of 1965/66 L Kopiago 2 of 1966/67
Jun-Aug67	Widespread	L Kopiago 1 of 1967/68 Koroba 12 of 1966/67 Koroba 1 of 1967/68 Loh (1967)

REPORTED ABUNDANT FOOD SUPPLY

Pangia District

Jul-Aug60	Wiru CD	Ialibu 3 of 1960/61
Jan66	Wiru CD	Pangia 8 of 1965/66

Ialibu District

Aug-Oct66	Kewabi CD	Kagua 3 of 1966/67
Oct-Nov69	Kewabi, Imbong'gu CDs	Ialibu 8 of 1969/70

Kagua District

Nov56-Feb57	Widespread	Erave 6,7,8 of 1956/57
Jun58	Kari Tiburu CD, Kagua Valley	Erave 8 of 1957/58
Aug-Oct66	West Kagua CD	Kagua 3 of 1966/67

Mendi District

Aug-Oct64	Lai Valley, Undiri CDs	Mendi 4 of 1964/65
Jun-Aug66	Lai Valley, Karint CDs	Mendi 14 of 1965/66
Late66-early67	Kambiri CD	Mendi 4 of 1967/68

Nipa District

No reports of very abundant food supply

Tari District

Jun54	Tari Station area	Tari 7 of 1953/54
Feb-Jul55	Haibuga Marsh; SE Huri Basin	Tari 6,8 of 1954/55
Nov56	W and NW of Tari	Tari 5 of 1956/57
Jul-Aug58	Haibuga Marsh	Tari 1 of 1958/59
Jun61	East of Tari	Tari 14 of 1960/61
Oct-Nov63	Haibuga/Munima CD	Tari 10 of 1963/64
Feb-Mar65	Tari LGC area	Tari 7 of 1964/65
Apr66-Feb67	Widespread	Tari 15,17 of 1965/66 Komo 10 of 1965/66 Tari 6,8 of 1966/67

Koroba District

Jan-Jul58	Koroba-Tagari road	Koroba 5,8,9,11 of 1957/58

Notes

(1 to 4) See notes for Table A7.1.

(5) There is only one census division (Wiru CD) in Pangia District.

Table A7.3 Available information on food shortages in the Southern Highlands, 1972 to 1974(1)

Period	Information and source
Pangia District	
1972-73	No food aid given or other reports of food shortages
1974	Sweet potato very scarce in November and December 1974 (A. Strathern, pers.comm. November 1983)
Ialibu District	
1972-73	Frost damage to food gardens in October 1972 (Brown and Powell, 1974) Food aid given in October, November and December 1972 (Waddell, 1973a; Table 8.3)
Kagua District	
1972-73	Frost damage to food gardens in October 1972 (Brown and Powell, 1974) Virtually no food aid given in 1972 (Table 8.3) The following patrol reports refer to food shortages: Kagua 4,7,18,20,21,22 of 1972/73; Erave 10 of 1972/73
Mendi District	
1972-73	Frost damage to food gardens in Upper Mendi Valley from about June 1972 (Brown and Powell, 1974) Food situation in Upper Mendi and Lai Valleys becoming serious, September 1972 (*PNG Post Courier*, 21 Sep, 1972,p1) Food aid given in Mendi area and Lai Valley in October, November and December 1972 (Table 8.3) The following patrol reports refer to food shortage: Mendi 5,6 of 1972/73
Nipa District	
1972-73	**Margarima area.** Frost damaged gardens from about June 1972 (Brown and Powell, 1974) "Famine" reported in Margarima area in September 1972 (*PNG Post Courier*, 21 Sep, 1972,p1) Relief operation in Upper Wage Valley (Margarima) in August 1972 (Margarima PR 4A of 1972/73) The following patrol reports refer to food shortage: Margarima 1,2,3,4,5,6,7,8,13 of 1972/73 **Other parts of Nipa District.** Frost damage in Nipa and Poroma areas from October 1972 (Brown and Powell, 1974) Food aid given in October, November, December 1972 (Table 8.3) The following patrol reports refer to food shortage: Nipa 1,3,4,5,6,7,8 of 1972/73; Poroma 2,3,5,6 of 1972/73

1974	Mid to late 1974. Food scarce in one community in the Wage Valley (Sillitoe, 1979:257,300)

Tari District

1972-73	Frost damaged food gardens in October 1972 (Brown and Powell, 1974) Very little food aid given in the Tari District in November and December 1972 (Table 8.3) The following patrol reports refer to food shortages: Tari 1,4,5,6,7,8,9,10,12,13,14,15,16,19,22 of 1972/73 (October 1972 to January 1973); Komo 3,5,6,8 of 1972/73

Koroba District

1972-73	Frost damaged food gardens in October 1972 (Brown and Powell, 1974) Food aid provided in October, November, December 1972 (Table 8.3) The following patrol reports refer to food shortage: Koroba 4,11 of 1972/73
1974	Food shortages reported in Koroba area in August 1974 (*PNG Post Courier*, 26 Aug, 1974p4)

Note

(1) The three year period 1972 to 1974 has to be treated separately from the period up to 1971 because the nature of the sources changed in 1972. From early 1972 onwards only the covers for patrol reports are lodged in the National Archives in Port Moresby and food shortages are covered in situation reports, rather than in the body of the patrol reports. Some of these are available in provincial files and have been consulted but for most patrol reports only an indication of content (such as "famine relief") is available. Further information on the 1972-73 food shortages is located in government files in the Southern Highlands Archives and Resource Centre (Allott and Morgan, 1982).

APPENDIX 8

NEMBI CHILD MALNUTRITION AND BIRTHWEIGHT DATA

Table A8.1 Number and percentage of malnourished children aged 1 to 5 years, Central Nembi Plateau, October 1978 to December 1984(1)

Year	Month	Number of Children 60-80% wfa(2)	<60% wfa	Attendance	Percent of Children 60-80% wfa	<60% wfa	<80% wfa
1978	Oct	119	7	352	33.8	2.0	35.8
	Nov	116	7	304	38.2	2.3	40.5
	Dec	139	8	328	42.4	2.4	44.8
1979	Jan	150	9	326	46.0	2.8	48.8
	Feb	141	10	316	44.6	3.2	47.8
	Mar	97	8	197	49.2	4.1	53.3
	Apr	30	5	83	36.1	6.0	42.2
	May	154	8	337	45.7	2.4	48.1
	Jun	132	7	318	41.5	2.2	43.7
	Jul	145	4	284	51.1	1.4	52.5
	Aug	145	7	317	45.7	2.2	47.9
	Sep	137	7	302	45.4	2.3	47.7
	Oct	146	5	311	46.9	1.6	48.6
	Nov	120	8	296	40.5	2.7	43.2
	Dec	101	3	223	45.3	1.3	46.6
1980	Jan	-	-	-	-	-	-
	Feb	165	3	329	50.2	0.9	51.1
	Mar	124	3	299	41.5	1.0	42.5
	Apr	130	5	328	39.6	1.5	41.2
	May	145	8	315	46.0	2.5	48.6
	Jun	179	8	324	55.2	2.5	57.7
	Jul	71	3	146	48.6	2.1	50.7
	Aug	136	8	319	42.6	2.5	45.1
	Sep	153	6	324	47.2	1.9	49.1
	Oct	-	-	-	-	-	-
	Nov	142	6	341	41.6	1.8	43.4
	Dec	140	12	305	45.9	3.9	49.8
1981	Jan	140	8	329	42.6	2.4	45.0
	Feb	166	5	328	50.6	1.5	52.1
	Mar	162	10	349	46.4	2.9	49.3
	Apr	159	11	327	48.6	3.4	52.0
	May	162	8	345	47.0	2.3	49.3
	Jun	146	4	351	41.6	1.1	42.7
	Jul	153	5	326	46.9	1.5	48.5
	Aug	145	1	325	44.6	0.3	44.9
	Sep	124	5	314	39.5	1.6	41.1
	Oct	145	5	353	41.1	1.4	42.5
	Nov	142	2	323	44.0	0.6	44.6
	Dec	121	3	351	34.5	0.9	35.3
1982	Jan	146	5	348	42.0	1.4	43.4
	Feb	150	5	336	44.6	1.5	46.1
	Mar	148	4	348	42.5	1.1	43.7
	Apr	152	4	338	45.0	1.2	46.2
	May	157	9	324	48.5	2.8	51.2
	Jun	151	4	329	45.9	1.2	47.1

	Jul	168	7	334	50.3	2.1	52.4
	Aug	140	3	300	46.7	1.0	47.7
	Sep	159	3	333	47.7	0.9	48.6
	Oct	132	2	317	41.6	0.6	42.3
	Nov	155	5	334	46.4	1.5	47.9
	Dec	163	3	336	48.5	0.9	49.4
1983	Jan	174	2	340	51.2	0.6	51.8
	Feb	176	5	326	54.0	1.5	55.5
	Mar	153	4	308	49.7	1.3	51.0
	Apr	136	6	309	44.0	1.9	46.0
	May	116	7	231	50.2	3.0	53.2
	Jun	138	2	291	47.4	0.7	48.1
	Jul	99	0	268	36.9	0.0	36.9
	Aug	102	7	228	44.7	3.1	47.8
	Sep	159	3	338	47.0	0.9	47.9
	Oct	89	5	236	37.7	2.1	39.8
	Nov	39	1	94	41.5	1.1	42.6
	Dec	125	3	251	49.8	1.2	51.0
1984	Jan	68	2	308	22.1	0.6	22.7
	Feb	87	11	290	30.0	3.8	33.8
	Mar	47	2	218	21.6	0.9	22.5
	Apr	119	3	319	37.3	0.9	38.2
	May	122	10	267	45.7	3.7	49.4
	Jun	92	5	199	46.2	2.5	48.7
	Jul	61	7	144	42.4	4.9	47.2
	Aug	99	10	195	50.8	5.1	55.9
	Sep	78	6	142	54.9	4.2	59.2
	Oct	142	8	272	52.2	2.9	55.1
	Nov	103	5	238	43.3	2.1	45.4
	Dec	103	7	240	42.9	2.9	45.8

Notes

(1) Figures were extracted from the records of the Pumberel Health Centre where summaries by clinic are held. Data from Embi/Enip, Upa/Kum and Pumberel clinics have been combined.

(2) wfa is weight for age based on the Harvard standard.

Table A8.2 Mean birthweight (kg) of children, Pumberel Health Centre, January 1979 to March 1986(1)

Year	Month	Mean birthweight	Standard deviation	Number
1979	Jan	2.878	0.130	9
	Feb	3.100	0.376	13
	Mar	2.857	0.374	7
	Apr	2.645	0.317	11
	May	2.700	0.249	11
	Jun	2.900	0.400	3
	Jul	2.850	0.337	12
	Aug	2.892	0.406	12
	Sep	2.844	0.321	9
	Oct	2.808	0.371	13
	Nov	2.761	0.259	18
	Dec	2.917	0.409	12
1980	Jan	2.914	0.422	21
	Feb	2.617	0.330	12
	Mar	2.838	0.302	8
	Apr	2.550	0.353	12
	May	3.033	0.462	12
	Jun	3.031	0.335	13
	Jul	2.832	0.386	19
	Aug	3.058	0.394	12
	Sep	2.757	0.467	14
	Oct	2.753	0.339	17
	Nov	2.808	0.440	24
	Dec	2.831	0.352	16
1981	Jan	2.764	0.391	11
	Feb	2.756	0.371	9
	Mar	2.822	0.370	9
	Apr	2.831	0.357	16
	May	2.657	0.336	7
	Jun	2.900	0.404	7
	Jul	2.713	0.285	8
	Aug	2.860	0.313	5
	Sep	2.778	0.409	9
	Oct	2.680	0.205	5
	Nov	3.010	0.335	10
	Dec	3.000	0.300	7
1982	Jan	2.767	0.274	18
	Feb	2.873	0.420	15
	Mar	3.033	0.314	6
	Apr	2.930	0.818	10
	May	2.863	0.416	16
	Jun	2.920	0.374	10
	Jul	2.809	0.316	22
	Aug	2.808	0.444	13
	Sep	2.694	0.498	17
	Oct	2.755	0.415	22
	Nov	2.533	0.476	6
	Dec	3.031	0.210	13
1983	Jan	2.686	0.540	7
	Feb	2.925	0.150	4
	Mar	2.833	0.352	12
	Apr	2.729	0.457	7

	May	3.014	0.491	7
	Jun	2.600	0.408	7
	Jul	2.640	0.310	10
	Aug	3.033	0.513	3
	Sep	2.888	0.461	8
	Oct	2.725	0.320	4
	Nov	2.900	0.177	8
	Dec	2.660	0.321	5
1984	Jan	2.767	0.423	6
	Feb	2.970	0.386	10
	Mar	-	-	0
	Apr	3.025	0.473	16
	May	-	-	0
	Jun	2.843	0.257	7
	Jul	2.914	0.279	7
	Aug	3.100	0.306	7
	Sep	2.975	0.499	4
	Oct	2.841	0.352	17
	Nov	2.954	0.320	13
	Dec	2.711	0.289	9
1985	Jan	2.850	0.399	12
	Feb	2.930	0.430	10
	Mar	2.740	0.288	10
	Apr	2.720	0.390	5
	May	-	-	0
	Jun(2)	3.000	-	1
	Jul	3.057	0.493	7
	Aug	2.800	0.346	3
	Sep	2.467	0.503	3
	Oct	2.920	0.311	5
	Nov	2.800	0.283	6
	Dec	-	-	0
1986	Jan	3.067	0.058	3
	Feb	2.900	0.552	5
	Mar	2.975	0.206	4

Notes

(1) Data was extracted from the birth register of the Pumberel Health Centre by B. J. Allen and J. Baines. It includes babies delivered at the Health Centre and babies brought to clinic within 24 hours of delivery. Births recorded as stillborn and premature have been excluded.

(2) In compiling the running mean, June 1985 was treated as missing data as there was only one birth in this month.

APPENDIX 9

DATA ON COFFEE HARVESTS, BEER/FOOD SALES, AND AGREEMENT WORKERS

Table A9.1 Monthly village coffee production, Kainantu, 1978 to 1984; beer sales, Eastern Highlands, 1978 to 1984; retail sales tax, Eastern Highlands, 1982 to 1984; food sales, Store A and liquor sales, Store B, Kainantu, 1982 to 1984

Year	Month	Coffee (kg) (1)	Beer (litres) (x1000) (2)	Retail tax (kina) (3)	Food Store A (kina) (4)	Liquor Store B (kina) (5)
1978	Jan	18660				
	Feb	11768				
	Mar	11735				
	Apr	29452				
	May	84246	352			
	Jun	162147	406			
	Jul	134046	446			
	Aug	160123	490			
	Sep	109573	448			
	Oct	119436	350			
	Nov	41760	451			
	Dec	102600	187			
1979	Jan	20804	236			
	Feb	27426	157			
	Mar	59352	256			
	Apr	102267	245			
	May	167686	410			
	Jun	251151	629			
	Jul	205612	740			
	Aug	214938	517			
	Sep	158668	428			
	Oct	121720	452			
	Nov	58200	334			
	Dec	55260	336			
1980	Jan	34082	299			
	Feb	32700	186			
	Mar	36180	86			
	Apr	84955	215			
	May	193647	287			
	Jun	426559	430			
	Jul	419670	167			
	Aug	268178	368			
	Sep	208291	403			
	Oct	182100	397			
	Nov	22980	400			
	Dec	29178	392			
1981	Jan	24175	137			
	Feb	15918	128			
	Mar	38433	176			
	Apr	58830	198			
	May	98887	327			
	Jun	166953	439			
	Jul	250290	538			
	Aug	324539	505			

	Sep	201965	423			
	Oct	82146	392			
	Nov	50274	253			
	Dec	41333	422			
1982	Jan	49858	231		106212	27100
	Feb	48370	146		105920	25700
	Mar	106291	233		126825	32042
	Apr	81079	433		147651	35250
	May	173445	318	89517	151206	55282
	Jun	265978	101	95108	159907	0(6)
	Jul	403910	680	106000	179024	55533
	Aug	234187	533	84783	144523	41403
	Sep	264431	424	85402	142569	52659
	Oct	151522	328	94099	138096	44378
	Nov	64778	325	78594	121477	35447
	Dec	56474	182	54964	145721	36885
1983	Jan	30660	174	64083	99914	24950
	Feb	28560	161	62584	94492	24062
	Mar	37563	247	68695	127663	30828
	Apr	53929	197	85607	106130	31682
	May	71001	320	85598	122341	35904
	Jun	235020	309	99703	143138	34598
	Jul	442754	444	106871	162982	62740
	Aug	449110	541	83546	159086	57949
	Sep	275422	408	101479	159470	58365
	Oct	196560	355	81922	130161	32576
	Nov	87540	244	66891	120534	30178
	Dec	59400	303	89167	142417	38552
1984	Jan	13260	198	70280	101176	16150
	Feb	4500	226	65901	102300	11610
	Mar	15120	213	83920	140405	14295
	Apr	14580	237	73896	104146	18373
	May	48360	322	87543	114380	22614
	Jun	151020	487	103548	154088	41455
	Jul	178860	486	51989		54760
	Aug	144600	424	149808		58379
	Sep	97920	363	86337		48464
	Oct	87240	321	137019		44508
	Nov	112740	333	50926		47198
	Dec	29580	374	66528		36957

Notes

(1) Coffee production is the monthly output of smallholder coffee from the two factories in Kainantu (as green bean). In 1984 only one factory processed smallholder coffee. Part of this is from Okapa and Henganofi Districts.

(2) Beer sales are calculated from the liquor tax paid to the EHP government by the two beer breweries in Lae based on wholesale sales in the Eastern Highlands.

(3) Retail sales tax is a provincial government tax on all goods except beer. The rate is 3% of retail value and figures are unadjusted.

(4) Food sales of store A are the unadjusted value of all food lines sold by four stores of one retail group in Kainantu.

(5) Liquor sales of store B are the unadjusted value of all liquor (mostly beer) sold by stores of another retail group in Kainantu.

(6) Liquor sales prohibited during the 1982 national election.

Table A9.2 Monthly sales of bulk petrol, Mendi, 1980 to 1984; beer sales, Southern Highlands, 1982 to 1984; rice, tinned fish and beer sales, Store A, Mendi, 1982 to 1984

Year	Month	Petrol SHP(1) (litres)	Beer SHP(2) (litres)	Store A, Mendi Rice (kg)	Fish (kg)	Beer (litres)
1980	Sep	63077				
	Oct	46870				
	Nov	65507				
	Dec	12957				
1981	Jan	87436				
	Feb	50218				
	Mar	55780				
	Apr	-				
	May	63417				
	Jun	13638				
	Jul	48256				
	Aug	42960				
	Sep	25003				
	Oct	26821				
	Nov	15684				
	Dec	39055				
1982	Jan	60000				
	Feb	51800				
	Mar	15229				
	Apr	26958	126464			
	May	17065	92400			
	Jun	52279	1952			
	Jul	67434	97920	3000	1000	15792
	Aug	36841	111856	4100	1500	12000
	Sep	52538	105664	2700	900	16592
	Oct	50006	104864	2100	1200	12880
	Nov	72226	110144	1900	1100	11384
	Dec	40368	46928	2400	1300	18112
1983	Jan	52279	65600	1600	900	11168
	Feb	41666	46800	1900	1100	7616
	Mar	55041	68128	2100	1100	11360
	Apr	41403	66800	2300	1300	10688
	May	91920	66800	2250	1200	11720
	Jun	51352	62464	2100	1150	0
	Jul	58578	30016	2700	0	7616
	Aug	83553	35968	1900	900	9088
	Sep	33743	49232	2700	700	13120
	Oct	55241	43104	3100	900	14728
	Nov	24630	50272	2700	1000	11384
	Dec	93463	61712	2100	900	12000
1984	Jan	34095	74176	2000	800	8064
	Feb	41687	75472	1600	600	6008
	Mar	53499	54064	2100	500	12920
	Apr	53524	39728	2100	1200	7616
	May	27912	97632	2250	1200	7656
	Jun	62754	76528	2300	1100	6944
	Jul	55951	38048			
	Aug	41278	48032			

Notes

(1) Bulk sales of petrol are from the only wholesale fuel supplier in the SHP.

(2) Calculated from the provincial liquor sales tax of 50 toea per 8 litre beer carton.

Table A9.3 Quantity and value of Papua New Guinea coffee exports, 1965 to 1985; Eastern Highlands smallholder production, 1975 to 1985; and mean price Y grade beans, 1965 to 1985(1)

Year	PNG coffee exports (tonnes) (2)	EHP smallholder production (tonnes)	Export value (kina)		Price (toea/kg)	
			Actual	Constant 1984 currency	Actual (3)	Constant 1984 currency
1965	11,237		9,064,284	31,007,715	76.1	260.3
1966	12,037		9,391,001	30,652,059	73.5	239.9
1967	16,793		12,857,139	40,912,903	69.7	221.8
1968	17,546		13,542,549	42,583,144	69.3	217.9
1969	24,696		18,503,679	58,371,606	66.0	208.2
1970	23,527		20,184,811	62,725,536	90.0	279.7
1971	27,725		21,827,293	63,692,041	77.0	224.7
1972	29,968		20,647,095	56,784,376	73.7	202.7
1973	36,998		31,448,149	79,865,708	88.0	223.5
1974	35,895		33,386,134	68,799,957	91.5	188.6
1975	35,735	6,532	34,802,900	64,932,776	98.1	183.0
1976	47,953	8,725	100,160,016	173,555,182	211.3	366.1
1977	37,565	6,068	143,707,728	238,260,881	347.8	576.6
1978	46,162	7,703	107,341,703	168,218,630	229.8	360.1
1979	49,587	8,954	124,999,827	185,246,062	250.2	370.7
1980	51,000	9,948	118,646,193	156,868,868	226.3	299.2
1981	46,981	10,560	69,325,071	84,817,844	146.3	179.0
1982	40,845	8,452	77,878,442	90,285,774	181.4	210.3
1983	52,689	17,340	95,054,832	102,124,448	174.7	187.7
1984	49,444	12,893	109,683,285	109,683,285	215.3	215.3
1985	40,104	9,250	117,238,040	113,091,108	286.1	276.0

Notes

(1) Sources are the PNG Coffee Industry Board, Goroka; DPI (1984); and Munnull and Densley (1978).

(2) Figures are tonnes of green bean. Production differs from exports in some years because of stocks held in anticipation of price rises. This occurred in 1983 and the 1983 export figures are an underestimate of production.

(3) Price is FOB for Y grade. Most village coffee is sold as Y grade.

Table A9.4 Number of agreement workers leaving their district, Eastern and Southern Highlands, 1951 to 1971(1)

Year	Eastern Highlands						Southern Highlands(2)					
	Ktu	Won	Hen	Oka	Gor (3)	Luf	Ial (4)	Kag	Men	Nip	Tar	Kor
1951					1239							
1952					294							
1953	20				394				13		34	
1954	129		1		339				0		0	
1955	189		277		617				28		0	
1956	153		290		373	222			17		0	
1957	321		94		375	114			21		0	
1958	463		171	119	19	600			0		0	
1959	247		29	116	190	97		4	71		0	
1960	886		461	0	548	229		0	241		0	
1961	345		366	21	223	508	-	-	-	-	-	-
1962	549		171	2	514	227	-	-	-	-	-	-
1963	431	26	194	273	148	530	405	1	293	16	386	130
1964	381	43	287	341	230	208	265	383	668	144	450	218
1965	380	46	200	257	302	439	325	285	535	109	392	113
1966	467	86	83	749	151	496	827	507	529	65	433	525
1967	498	284	208	354	372	360	384	324	359	68	456	386
1968	496	138	356	503	308	300	895	368	259	157	475	597
1969	537	299	218	419	420	418	408	144	232	177	437	611
1970	558	165	216	188	125	86	666	355	274	390	1215	499
1971	332	162	150	225	262	193	519	356	197	403	618	809

Notes

(1) The source is Department of Labour records, Goroka and Mt Hagen. Figures were extracted by R. G. Ward, who kindly made them available. Districts are Kainantu, Wonenara, Henganofi, Okapa, Goroka, Lufa, Ialibu, Kagua, Mendi, Nipa, Tari and Koroba. Lake Kopiago Sub-district was administered from the Western Highlands during this period, but figures are included with Koroba District as the original sub-district is now part of the Koroba District.

(2) There is a gap in the data between October 1960 and January 1963 in the figures from the Southern Highlands. Otherwise no entry indicates that no workers were recruited.

(3) The 1951 figure for Goroka District probably includes all recruits from the Eastern Highlands and Chimbu.

(4) Figures for Ialibu District also include Pangia District. Separate data are available for 1966, 1969, 1970 and 1971. In 1966, 255 men were recruited from Pangia District (Harris, 1972:129). There were 243, 490 and 204 agreement workers from Pangia in 1969, 1970 and 1971 respectively. Thus during these four years, there were about equal numbers of workers recruited from Pangia and Ialibu Districts.

APPENDIX 10

DATA ON NUT PANDANUS HARVESTS

Table A10.1 Harvesting periods of karuka nut pandanus at six highland locations, 1976 to 1985(1)

1. Kainantu

Regular observations commenced: February 1979

Method of observation: Fortnightly count of value of nuts offered for sale in Kainantu market

Observers: R. M. Bourke and K. Nema (assisted by W. Akus, C. Tumana and A. Nigel)

Harvesting period: February-May 1979; February-March 1980; March-April 1981; November 1981; January-April 1982; January-May 1983; November 1983; February to May 1985. (See Table A10.2 for market counts). Note that market surveys include both recently harvested and stored nuts and thus tends to overestimate the length of the harvesting season. Karuka pandanus were in season in the nearby Okapa area in January-February 1978 (Jeffries, 1978:129fn), and were probably also bearing in the Kainantu area at about the same time.

2. Goroka

Regular observations commenced: October 1979

Method of observation: Fortnightly counts of value of nuts offered for sale in Goroka market until September 1982, and then casual observations of market and village production

Observers: T. Tarepe (1979 to 1985) and B. Carrad (1983, 1984)

Harvesting periods: January-March 1980; August 1980; March-May 1981; November 1981; March-April 1982; January-March 1983 (very big); July-August 1984 (small); January -mid May 1985 (see Table A10.3)

3. Wabag

Regular observations commenced: August 1978

Method of observation: Casual observations of sales in Wabag market and village production in Middle Lai Valley

Observers: M. Meggitt (1976), B. Carrad (1978 to 1980), E. Paugari (1981, 1982), L. Baldwin (1983), P. Wohlt (1984, 1985)

Harvesting periods: June-July 1976 (big); August-September 1978; February-March 1980 (some in December 1979 and January 1980 also); August-September 1981 (small); late December 1982-April 1983 (very big); June-mid July 1985 (small)

4. Mendi

Regular observations commenced: January 1979

Method of observation: Casual observation of sales in Mendi market and village production in Mendi Valley

Observers: J. Tompkins (1979, 1980), R. M. Bourke (1978 to 1981), M. Anders (1981 to 1983), R. Crittenden (1984, 1985), C. Floyd (1984)

Harvesting periods: September 1978; late June-September 1979; February-early May 1980; late December 1980-January 1981 (small); February-March 1982 (big); mid December 1982-March 1983 (very big); April 1984 (small); mid February-April 1985 (big); late June-July 1985. (Sillitoe (1983:108) gives data on bearing seasons for the Wage Valley near Nipa in 1977 and 1978)

5. Tari

Regular observations commenced: January 1976

Method of observation: Regular observations of village production in North Tari Basin (1976 to 1980) (Rose, 1982); casual observations in Tari market and village production in Tari Basin (1981 to 1985)

Observers: C. Rose (1976 to 1980), E. D'Souza (1981 to 1985)

Harvesting periods: January-February 1976 (small); December 1976-March 1977 (big); May-July 1978 (average); January-February 1979 (small); May-July 1979 (small); December 1979-March 1980 (big); September-October 1980 (small); February 1981 (small); February-early March 1982 (small); July-early August 1982 (small); February-early March 1983 (very big); February-March 1984 (small); February-mid March 1985 (average); June-early July 1985

6. Oksapmin

Regular observations commenced: September 1978

Method of observation: Casual and systematic observations of village production (Cape, 1981:156)

Observers: N. Cape (1978 to 1980), J. Darby (1981 to 1984), I. Davis (1984, 1985), J. O'Sullivan (1985, 1986)

Harvesting periods: February-March 1978 (big); July-August 1979 (small); February-March 1980 (big); December 1980-February 1981 (small); mid December 1981-March 1982; June 1982 (very small); December 1982-March 1983 (very big); July-August 1983 (very small); February 1984 (very small); February-April 1985 (very big); June 1985; mid December 1985-early April 1986 (big)

Note

(1) These data are for the cultivated species only (*P. julianettii*). Recordings ceased at all locations during 1986. The quality of the data varies because of the number of observers and the unavoidable subjectivity of assessment of crop size. The most consistent methods were used at Kainantu and Tari. Based on comments provided, I have classed crop size as: very big, big, average, small and very small.

Table A10.2 Number of bundles of karuka nut pandanus on display per market, Kainantu market, March 1979 to December 1985(1)

Month	1979	1980	1981	1982	1983	1984	1985
Jan	-	7	7	223	281	0	0
Feb	-	92	19	326	861	0	712
Mar	186	191	46	295	193	0	402
Apr	99	16	53	219	113	0	301
May	237	0	7	54	134	0	208
Jun	52	0	0	22	-	0	0
Jul	52	0	0	7	37	0	0
Aug	43	0	0	0	1	0	0
Sep	25	0	0	2	1	0	0
Oct	11	2	4	0	3	0	0
Nov	9	0	43	2	37	0	0
Dec	3	0	0	2	0	0	0
Total	717	308	179	1152	1661	0	1623

Note

(1) Counts of karuka nuts (*Pandanus julianettii*) offered for sale were made as part of regular fortnightly surveys of Kainantu market between March 1979 and May 1983 by the author and others (Table A6.1). Thereafter these were made weekly or bi-weekly by K. Nema until the end of 1985. Figures presented are the mean from two to four surveys.

The value of karuka nut pandanus offered for sale was recorded and converted into "number of bundles of 10 toea value". Thus recordings are the value of nuts offered for sale at a certain time of day. (For example: 186 "bundles" is equivalent to K18.60).

Generally no distinction was made between newly harvested nuts and stored nuts. Hence this technique tends to prolong the apparent harvesting period. For example in 1985 fresh nuts were available between early February and mid-March only. Stored nuts dominated sales from early March and continued until the end of May.

Table A10.3 Number of bundles of karuka nut pandanus on display per market, Goroka market, October 1979 to September 1982(1)

Month	1979	1980	1981	1982
Jan		31	0	4
Feb		39	0	14
Mar		347	1110	56
Apr		4	94	79
May		45	122	0
Jun		57	48	1
Jul		49	16	0
Aug		114	6	0
Sep		0	3	0
Oct	0	0	5	
Nov	6	0	24	
Dec	0	0	0	

Note

(1) Counts of karuka nut pandanus (*Pandanus julianettii*) offered for sale were made as part of a regular fortnightly survey of Goroka market (Table A6.1) by T. Tarepe, who kindly made his data available. Techniques used were the same as for the Kainantu market survey (see note, Table A10.2).

Table A10.4 Harvesting periods of karuka nut pandanus noted in patrol reports, Southern Highlands, 1949 to 1971(1)

Period	Location	Source
Jun-Jul 1955	Tari	Tari 8 of 1954/55
Aug-Sep 1957	Koroba	Koroba 1 of 1957/58
Jan-Mar 1958	Koroba	Koroba 5,6,8 of 1957/58
Jan-Feb 1958	Erave, Kagua, Nembi Nipa, Tari(2)	Erave 5 of 1957/58
Mar-Apr 1960	Tari	Tari 5 of 1959/60
Feb-Mar 1961	Ialibu	Ialibu 8 of 1960/61
May-Jun 1961	Margarima	Nipa 5 of 1960/61
Feb 62	Tari	Kutubu 4 of 1961/62
Jan 63	Lake Kopiago	Kopiago 5 of 1962/63
Jan-Feb 64	Tari	Tari 15 of 1963/64
Feb 65	Nipa Basin	Nipa 7 of 1964/65
Nov 65-Mar 66	Upper Mendi	Mendi 3,7 of 1965/66
Dec 65-Feb 66	Ialibu	Ialibu 5 of 1965/66
Early 66	Tari	Tari 2 of 1965/66
Jan 66	Margarima	Nipa 6 of 1965/66
Feb 68	Ialibu	Ialibu 10,14 of 1967/68
Mar 68	Nipa Basin	Nipa 15 of 1967/68
Feb 70	Ialibu	Ialibu 14 of 1969/70
Feb-Mar 70	Upper Mendi	Mendi 17 of 1969/70

Notes

(1) The source is incidental comments made in patrol reports. This is not a systematic source of information on pandanus harvests, but some patterns are apparent.

(2) Reported as the "best season for many years".

Table A10.5 Wild karuka nut pandanus (*Pandanus brosimos*) harvesting periods, Iumbisa Village, Kandep area, Enga (1972 to 1975, 1983 to 1986) and Tari Basin (1983 to 1986)

1. Iumbisa Village

Regular observations: April 1972 to April 1975; January 1983 to December 1986

Method of observation: Systematic observation of village production

Observer: P. Wohlt (The observations for the period 1972 to 1975 were published in Wohlt, 1978:126-127)

Harvesting periods: January-February 1973 (large); January-February 1975 (large); January-February 1983 (average); late April-beginning May 1984 (small); August 1984 (very small); June-mid July 1985 (large); February 1986

2. Fringe of Tari Basin

Regular observations: 1983 to 1986

Method of observation: Casual observations on migration by villagers to high altitude locations (Tari Gap) to harvest nuts

Observer: E. D'Souza

Harvesting periods: late January 1983-early March 1983 (large); early June-early July 1985

APPENDIX 11

SWEET POTATO TIME-OF-PLANTING TRIAL DATA

Table A11.1 Global data sources on optimum time of planting for sweet potato

Location	Latitude	Best months for planting	Source	Nature of source(1)
Keravat, PNG	4° S	Oct-Mar	Bourke (unpubl. data)	Trial(2)
Chimbu, PNG	6° S	Jun-Sep	Goodbody (in press)	Trial(3)
Aiyura, PNG	6° S	Aug-Nov	Bourke (1985a)	Trial(4)
Ukiriguru, Tanzania	7° S	Dec-Jan	Billington (1970)	Trial
East Africa	4-11° S	Any time(5)	Jana (1982)	General
Malaita, Solomon Islands	9° S	May-Oct	Gollifer (1980)	Trials (m)
Laloki, PNG	9° S	May-Jul	King (1985)	Trial
Trinidad	10° N	Oct-Jan	Kennard (1944)	General(6)
Tamil Nadu, India	11° N	Sep-Oct	Shanmugavelu *et al.* (1972)	Trial(7)
Puerto Rico	18° N	Sep-Jan	Badillo-Feliciano (1979)	Trial
Puerto Rico	18° N	Sep-Dec	Moscoso (1955)(8)	Trials (m)
Tongatapu Is, Tonga	21° S	Apr-Aug	Anders (1977)	Trials (m)
Taiwan	22-25° N	Aug-Nov	Tsou and Villareal (1982)	General(9)
South Taiwan	23° N	Aug-Oct	Lin (1983)	General
South Africa	24-34° S	Sep-Nov	Dept. Agric. (1980)	General
Mymensingh, Bangladesh	25° N	Nov-Dec	Toib and Rashid (1978)	Trial
Tucuman, Argentina	27° S	Sep	Folquer and Brucher (1950)	Trial
Northern NSW, Australia	28-30° S	Oct-Jan	Buggie (1979)	General
Georgia, Miss., South Carolina, Texas, USA	32-33° N	Apr-early May	Anderson *et al.* (1945)	Trials (m)

SW of Western Australia	32-34° S	Sep-Jan	Hawson (1986)	General
Japan	32-35° N	May	H. Takagi (pers. comm.)	General
South Carolina, USA	34° N	mid-May	Beattie *et al.* (1934)	Trials (m)
North Island, New Zealand	35-39° S	mid-Oct-mid Dec	Coleman (1972)	General

Notes

(1) Nature of source: Trial - Single trial only
Trials (m) - More than one trial or year's data
General - A general recommendation or statement

(2) The data from Keravat, New Britain is based on an unpublished analysis by the author of 32 plantings of a crop rotation trial between 1954 and 1974 (Bourke, 1977). Crops planted between October and March (or November to April) yielded twice as well as those planted between April and September (or May to October). (12.5 t/ha cf 6.7 t/ha for October-March and April-September plantings respectively). However, the indication from this preliminary analysis that higher sweet potato yields are obtained from plantings made in the wetter months of the year is questionable. This is because the price of sweet potato in the nearby Rabaul market for the period 1971 to 1984 did not fluctuate on an annual seasonal basis.

(3) Goodbody (in press) did not conclude that planting during these months will always result in high sweet potato yields. This result may apply to that year only.

(4) It is later concluded that this finding is not valid, but it is included here for consistency as the results are published.

(5) In Kenya, Tanzania and Uganda, growers plant at any time of the year provided soil moisture is sufficient (Jana, 1982:68-69).

(6) Kennard's (1944) statement is based on experimental results obtained between 1927 and 1943. Haynes (1970) quotes Kennard in giving the best planting time as September to March, and other authors have followed Haynes. Kennard further states that within the October to January season, crops planted in October outyielded those planted in November or December.

(7) Shanmugavelu *et al.* (1972) quote other studies from India that are not reproduced in Figure 6.2 because the original reports have not been seen. However for the studies where the location is given, these findings are consistent with the data in Figure 6.2. A summary follows:

At Coimbature (Tamil Nadu, 11° N), an earlier study also found that October was the optimum time of planting for sweet potato. Trials in Bihar (24° N), Assam (26° N) and Uttar Pradesh (27° N) indicated that June or May-June was the optimum period.

(8) Cited by Badillo-Feliciano (1979).

(9) Crops harvested in February to April in Taiwan outyield those planted in July to September (Tsou and Villareal, 1982:40). For a 5-6 month crop (Wan, 1982), this suggests that the highest yields are obtained from August to November plantings.

Table A11.2 Aiyura soil exhaustion trial: soil moisture storage (SMS) data and growing period rainfall index (GPRI)(1)

Planting number	SMS at planting	No of weeks when SMS = 100 mm			No of weeks when SMS < 20 mm			GPRI
		during first 30 weeks	dur. first 13 weeks	dur. final 13 weeks	during first 30 weeks	dur. first 13 weeks	dur. final 13 weeks	
1	88	17	11	4	4	0	5	0.2
2	72	12	0	9	3	3	0	4.7
3	100	8	4	5	1	0	0	1.2
4	100	16	1	1	2	0	4	0.5
5	44	10	1	9	0	0	0	3.0
6	100	9	7	1	0	0	0	0.7
7	63	22	11	7	0	0	0	3.7
8	71	8	0	6	7	6	0	4.9
9	100	14	8	5	0	0	0	2.9
10	-	13	6	4	0	0	0	-
11	100	10	4	4	0	0	0	-
12	-	3	0	1	7	3	4	-
13	-	20	7	13	0	0	0	-
14	-	2	1	3	14	2	4	-
15	100	10	9	0	6	0	6	0.6
16	3	12	0	8	6	6	0	56.9
17	32	2	0	6	9	5	0	6.7
18	100	11	8	3	0	0	0	1.0
19	100	9	8	1	1	0	1	0.5
20	17	17	3	6	1	1	0	9.3
21	12	8	2	5	0	0	0	5.1
22	42	13	0	11	2	2	0	5.9
23	100	5	5	10	12	1	0	0.7
24	100	15	10	10	0	0	0	0.8

Note

(1) The soil moisture storage was calculated for an assumed soil available water capacity of 100 mm. Growing period rainfall index (GPRI) was devised by Goodbody (in press) as the total rainfall between 90 and 120 days after planting divided by the total rainfall during the 30 days before planting. Because the growing period of the three trials at Aiyura was longer than for the one reported by Goodbody, a longer and later period was selected as the numerator to preserve Goodbody's concept. GPRI as used here is the rainfall between 22 and 29 weeks after planting (inclusive) divided by the rainfall during the 30 days before planting.

Table A11.3 Aiyura sweet potato time-of-planting trial 1: dates of planting and harvesting and yield data

Treatment number	Date of planting	Date of harvest	Tuber yield (kg/ha)(1) Marketable	Stockfeed	Total	Top growth yield	Plant density at one month (2)
1	1/8/79	4/3/80	26,806	3528	30,333	31,056	32,500
2	3/9/79	1/4/80	25,611	4889	30,500	23,139	49,900
3	1/10/79	1/5/80	24,528	7444	31,972	26,806	49,900
4	1/11/79	2/6/80	22,667	7806	30,472	14,222	50,000
5	3/12/79	1/7/80	12,167	7306	19,472	11,472	50,000
6	2/1/80	1/8/80	8,639	7833	16,472	13,306	50,000
7	1/2/80	1/9/80	11,861	4111	15,972	18,250	50,000
8	3/3/80	1/10/80	1,694	6472	8,167	32,694	50,000
9	1/4/80	1/12/80	15,778	6417	22,194	25,472	50,000
10	1/5/80	6/1/81	16,889	5375	22,264	28,472	47,200
11	2/6/80	2/2/81	9,472	4667	14,139	28,333	47,200
12	1/7/80	2/3/81	26,431	4667	31,097	25,306	48,200
13	1/8/80	6/4/81	9,333	4250	13,583	20,500	49,900
14	1/9/80	4/5/81	9,750	3722	13,472	19,306	50,000
15	8/10/80	1/6/81	9,333	4583	13,917	23,722	48,600
16	10/11/80	6/7/81	11,861	5528	17,389	24,333	50,000
17	8/12/80	3/8/81	13,583	6292	19,875	21,278	50,000
18	13/1/81	7/9/81	10,153	4653	14,806	21,319	50,000
19	9/2/81	5/10/81	12,583	4778	17,361	15,667	50,000
20	9/3/81	9/11/81	11,778	4250	16,028	16,986	48,600
21	13/4/81	7/12/81	9,306	5139	14,444	20,694	50,000
22	11/5/81	4/1/82	11,944	4306	16,250	17,250	47,200
23	8/6/81	1/2/82	9,333	6000	15,333	21,833	50,000
24	13/7/81	1/3/82	8,431	5319	13,750	26,819	50,000
Level of significance, treatments 1-12(3)			***	**	***	***	***
Standard error of difference			3,200	962	3,247	3533	1,860
Level of significance, treatments 13-24			NS	*	NS	NS	***
Standard error of difference			-	731	-	-	602

Notes

(1) Tubers heavier than 100 g were classed as marketable, less than 100 g as stockfeed.

(2) Planting density was 50,000 cuttings per hectare.

(3) Statistical analysis was done by ANOVA. Because of the blocking system used, it was analysed as two trials: treatments 1-12 in one group and treatments 13-24 in the other.

Table A11.4 Aiyura sweet potato time-of-planting trial 1: soil moisture storage (SMS) data and growing period rainfall index (GPRI)

Treatment number	SMS at planting	Number of weeks when SMS = 100 mm			Number of weeks when SMS < 20 mm			GPRI
		during first 30 weeks	dur. first 13 weeks	dur. final 13 weeks	during first 30 weeks	dur. first 13 weeks	dur. final 13 weeks	
1	24	12	0	10	7	8	0	10.1
2	15	17	2	12	4	4	0	5.5
3	0	19	5	10	0	1	0	8.8
4	5	21	9	8	0	0	0	3.5
5	87	19	11	4	2	0	2	0.6
6	100	16	12	2	6	0	6	0.6
7	100	12	10	0	8	0	8	0.6
8	100	9	9	0	8	0	6	1.6
9	100	4	4	1	11	2	5	0.7
10	100	2	2	6	13	6	5	0.7
11	49	4	0	9	13	8	2	5.1
12	7	9	0	11	11	6	0	28.1
13	6	11	0	7	7	5	0	7.2
14	54	12	1	7	5	5	0	3.2
15	25	16	5	4	5	5	0	4.7
16	9	16	9	4	1	2	0	8.0
17	100	15	10	1	0	0	0	0.9
18	100	11	7	3	0	0	0	0.9
19	90	10	7	3	0	0	0	1.1
20	78	7	4	3	0	0	0	0.7
21	100	8	3	4	0	0	0	1.4
22	64	6	2	6	0	0	0	1.8
23	80	10	3	9	0	0	0	7.4
24	91	14	2	12	0	0	0	4.9

Table A11.5 Aiyura sweet potato time-of-planting trial 1: mean maximum and minimum temperatures, bright sunshine and solar radiation

Treatment number	Mean max. temp. (oC) during crop life (1)	dur. first 90 days	dur. final 90 days	Mean min. temp. (oC) during crop life	dur. first 90 days	dur. final 90 days	Bright sunshine during crop life (hrs)(2)	Solar radiation during crop life (3)
1	23.4	22.5	24.0	14.3	13.9	14.7	4.1	6.6
2	23.3	23.8	22.9	14.5	14.6	14.9	3.9	6.4
3	23.6	23.9	22.7	14.8	14.3	15.0	3.6	6.3
4	23.3	24.1	22.9	14.7	14.4	14.6	3.7	6.3
5	23.1	24.6	23.3	14.7	15.0	14.8	3.6	6.4
6	22.9	22.9	22.7	14.6	15.0	14.0	3.5	5.9
7	22.5	22.7	22.1	14.5	15.0	13.9	3.5	6.2
8	22.3	23.0	22.6	14.3	15.2	14.1	3.9	5.9
9	22.9	23.0	23.5	14.1	14.6	13.7	4.3	6.3
10	23.0	22.7	23.2	14.1	14.1	13.5	4.3	6.3
11	23.0	22.1	23.8	14.1	13.9	14.5	3.9	6.1
12	23.1	22.1	23.8	14.2	13.8	14.9	3.8	5.8
13	23.2	22.5	23.4	14.2	14.0	14.2	4.2	6.4
14	23.7	23.4	24.0	14.3	13.7	14.4	4.3	6.5
15	23.8	24.0	23.8	14.4	14.0	14.3	4.3	6.4
16	23.6	23.8	22.9	14.5	14.7	14.5	3.7	6.0
17	23.2	22.4	22.1	14.5	14.1	14.4	3.4	5.9
18	22.9	23.9	21.5	14.3	14.5	14.0	3.7	5.9
19	22.8	24.0	21.7	14.2	14.3	14.0	3.9	6.1
20	22.7	23.6	22.2	14.2	14.2	14.0	3.9	6.1
21	22.5	22.4	22.9	14.4	14.5	14.7	3.5	6.2
22	22.6	22.0	23.6	14.4	14.4	14.7	3.3	5.7
23	22.7	21.6	23.7	14.4	14.0	14.7	3.1	5.6
24	23.0	21.8	23.9	14.5	13.9	14.8	3.3	5.7

Notes

(1) Temperatures were recorded in a standard Stephenson screen at the Aiyura meteorological station which is located some 800 metres from the site of this trial.

(2) Bright sunshine was measured by a Campbell-Stoke Sunshine Recorder.

(3) Solar radiation was measured with a Rimco Solarimeter in units of ampere-hours.

Table A11.6 Aiyura sweet potato time-of-planting trial 2: dates of planting and harvesting and yield data

Treatment	Date of planting	Date of harvest	Tuber yield (kg/ha)(1) Marketable	Tuber yield (kg/ha)(1) Stockfeed	Total	Top growth yield (kg/ha)	Plant density at one month (2)
1	8/10/80	27/5/81	20,000	6222	26,222	20,400	75,600
2	5/11/80	24/6/81	18,978	5378	24,356	25,422	73,300
3	3/12/80	29/7/81	13,133	8178	21,311	20,444	80,000
4	30/12/80	26/8/81	13,244	4311	17,556	25,200	80,000
5	4/2/81	30/9/81	10,178	6400	16,578	24,422	78,900
6	4/3/81	28/10/81	14,333	5111	19,444	12,556	76,700
7	8/4/81	25/11/81	11,333	6111	17,444	13,222	78,900
8	6/5/81	23/12/81	12,000	5244	17,244	15,422	76,700
9	3/6/81	27/1/82	15,156	6444	21,600	14,489	78,900
10	1/7/81	24/2/82	13,178	5867	19,044	16,022	80,000
11	5/8/81	31/3/82	16,578	7089	23,667	12,111	78,900
12	2/9/81	28/4/82	18,267	6733	25,000	10,400	80,000
Level of significance			**	**	*	**	**
Standard error of difference			2,660	875	2,938	3,784	1,690

Notes

(1) Tubers heavier than 100 g were classed as marketable and those less than 100 g as stockfeed.

(2) Planting density was 80,000 cuttings per hectare.

Table A11.7 Aiyura sweet potato time-of-planting trial 2: soil moisture storage (SMS) data and growing period rainfall index (GPRI)

Treatment number	SMS at planting	Number of weeks when SMS = 100 mm			Number of weeks when SMS = 20 mm			GPRI
		during first 33 weeks	dur. first 13 weeks	dur. final 13 weeks	during first 33 weeks	dur. first 13 weeks	dur. final 13 weeks	
1	25	16	6	5	5	5	0	4.9
2	0	16	9	4	1	1	0	9.0
3	100	16	11	1	0	0	0	0.9
4	100	12	7	2	0	0	0	0.7
5	90	11	7	4	0	0	0	0.9
6	100	9	4	2	0	0	0	0.8
7	100	8	4	3	0	0	0	1.5
8	79	8	1	4	0	0	0	1.1
9	31	11	3	9	0	0	0	10.6
10	91	16	3	12	0	0	0	4.7
11	77	20	3	13	0	0	0	6.6
12	100	21	3	12	0	0	0	3.4

Table A11.8 Aiyura sweet potato time-of-planting trial 2: mean maximum and minimum temperatures, bright sunshine and solar radiation

Treatment number	Mean max. temp. (oC) (1)			Mean min. temp. (oC)			Bright sunshine	Solar radiation
	during crop life	during first 90 days	during final 90 days	during crop life	during first 90 days	during final 90 days	during crop life (hrs)(2)	during crop life (3)
1	23.8	24.0	23.8	14.4	14.0	14.3	4.3	6.4
2	23.7	23.2	23.6	14.5	14.3	14.6	3.9	6.2
3	23.2	23.7	22.2	14.5	14.9	14.4	3.4	5.6
4	22.9	23.9	21.8	14.3	14.4	14.0	3.7	5.9
5	22.8	24.0	21.7	14.3	14.3	14.0	4.0	6.1
6	22.6	23.7	22.2	14.2	14.3	14.1	3.8	5.8
7	22.5	22.9	22.8	14.3	14.5	14.5	3.6	6.3
8	22.5	22.1	23.4	14.4	14.4	14.7	3.3	6.1
9	22.7	21.8	24.0	14.4	14.0	14.9	3.1	5.3
10	22.8	21.5	24.0	14.4	13.9	14.8	3.2	5.7
11	23.3	22.3	23.9	14.5	14.1	14.8	3.3	5.7
12	23.4	22.9	23.9	14.6	14.6	14.6	3.2	5.7

Notes

(1) Temperatures were recorded in a standard Stephenson screen at the Aiyura meteorological station which is located some 600 metres from the site of this trial.

(2) Bright sunshine was measured by a Campbell-Stoke Sunshine Recorder.

(3) Solar radiation was measured with a Rimco Solarimeter in units of ampere-hours.

APPENDIX 12

SOIL MOISTURE STORAGE AND SURPLUS, AND REPORTED FROSTS, EASTERN HIGHLANDS AND SOUTHERN HIGHLANDS

Table A12.1 Monthly mean soil moisture storage (mm), Aiyura, 1952 to 1984(1)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1952	100	100	100	96	58	94	75	69	86	93	92	98	88
1953	100	100	99	99	72	42	94	81	98	82	86	99	88
1954	99	100	97	100	96	78	81	89	77	37	65	100	85
1955	100	98	100	100	80	58	30	50	17	29	56	100	68
1956	96	100	100	89	24	4	4	59	30	18	74	100	58
1957	85	99	100	100	76	54	28	76	70	90	96	100	81
1958	99	100	99	94	51	19	28	46	66	61	76	96	70
1959	85	100	100	100	94	78	83	55	45	71	79	96	82
1960	100	100	99	100	79	75	41	16	3	76	86	100	73
1961	95	99	96	90	98	95	87	89	79	88	93	87	91
1962	81	75	89	91	91	51	77	86	91	83	81	100	83
1963	77	22	42	98	43	34	72	80	100	94	92	94	71
1964	100	100	100	96	87	49	8	10	20	26	54	80	61
1965	99	100	98	93	87	49	38	13	11	32	20	83	60
1966	95	100	100	50	44	45	21	16	19	82	76	97	62
1967	94	100	92	80	62	87	94	54	35	97	91	100	82
1968	100	96	84	85	73	56	21	59	66	89	97	97	77
1969	100	100	96	93	66	24	21	67	95	89	88	100	78
1970	84	85	100	71	57	44	50	46	36	92	77	100	70
1971	97	100	100	100	93	92	62	27	24	69	76	96	78
1972	99	100	100	100	95	47	28	4	7	14	79	89	64
1973	100	96	100	94	92	87	81	97	62	97	99	100	92
1974	92	100	93	84	54	85	69	53	30	69	97	82	76
1975	92	100	100	94	98	65	20	33	25	50	51	92	68
1976	100	97	90	91	81	53	38	33	28	84	91	100	74
1977	100	99	95	100	92	73	79	59	42	97	68	78	82
1978	100	94	96	97	95	59	53	72	59	62	57	94	78
1979	98	100	100	100	92	78	47	12	5	32	83	99	71
1980	100	97	100	96	80	20	13	29	50	15	41	100	62
1981	100	73	83	100	55	82	89	91	93	79	91	96	86
1982	100	100	100	98	84	65	54	34	3	15	22	96	64
1983	100	98	98	77	84	96	69	75	40	83	96	99	85
1984	71	33	91	94	100	77	80	61	32	69	81	100	74
Mean	95	93	95	92	77	61	53	53	47	66	76	95	75

Note

(1) Soil moisture storage and water surplus were calculated on a weekly basis from daily rainfall records for an assumed soil available water capacity of 100 mm. Monthly figures are means for four or five week periods.

Table A12.2 Monthly mean soil moisture storage (mm), Goroka, 1952 to 1984(1)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1952	100	100	100	100	61	61	32	11	9	20	29	25	54
1953	83	100	98	100	66	20	18	8	17	41	67	91	59
1954	100	100	100	100	94	67	7	5	7	7	21	47	55
1955	71	88	89	99	94	52	3	0	0	46	51	92	57
1956	99	100	100	93	27	0	8	4	5	2	59	100	50
1957	86	96	100	98	56	56	33	52	67	61	47	100	71
1958	97	100	100	95	46	3	3	8	57	76	87	97	64
1959	66	100	100	100	58	19	11	3	12	32	11	90	50
1960	100	100	94	95	31	49	7	2	1	28	88	100	58
1961	86	98	85	98	99	79	31	61	67	83	81	63	78
1962	62	84	97	100	95	65	33	50	23	46	84	100	70
1963	53	3	44	94	38	15	17	14	100	98	50	50	48
1964	94	100	97	97	80	16	2	1	9	2	54	80	53
1965	94	92	99	94	85	50	8	12	54	33	6	75	59
1966	100	100	100	57	56	32	4	1	22	96	95	94	63
1967	94	91	100	94	80	64	13	5	52	97	88	100	73
1968	99	98	88	77	39	3	3	6	14	55	80	100	55
1969	97	98	100	97	67	12	6	7	25	95	94	100	67
1970	73	69	100	81	67	10	15	18	7	62	96	99	58
1971	100	100	100	96	90	53	33	6	13	34	23	66	60
1972	97	89	100	100	88	16	7	4	2	19	21	43	49
1973	77	98	98	98	79	26	31	17	6	55	100	100	65
1974	87	100	96	90	39	29	6	1	0	19	76	89	53
1975	91	100	97	90	100	64	6	12	2	1	19	91	56
1976	100	85	47	83	33	12	12	7	14	54	59	58	47
1977	97	96	75	95	80	41	43	33	9	48	74	71	64
1978	68	93	91	89	58	40	3	7	6	37	43	93	52
1979	92	95	100	99	-	60	17	1	1	64	92	97	65
1980	100	94	99	98	85	26	39	33	25	35	67	100	67
1981	100	96	83	97	70	69	59	5	23	85	88	100	73
1982	100	100	100	91	66	85	36	26	30	5	37	73	62
1983	93	92	100	83	94	81	46	6	7	100	97	99	75
1984	54	57	100	99	90	93	75	64	12	79	92	100	76
Mean	88	91	93	93	69	41	20	15	21	49	63	84	61

Note

(1) Daily rainfall figures were not available for Goroka after 1977. For the period January 1978 to April 1983, rainfall figures used are from Magia Farm, which is just south of Goroka. From May 1983 until December 1984, figures used are from the nearby station at Orobiga.

Table A12.3 Monthly mean soil moisture storage (mm), Mendi, 1956 to 1984

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1956	40	100	98	100	94	93	100	100	99	98	96	100	93
1957	66	89	100	100	70	85	100	98	88	67	60	96	85
1958	89	97	98	99	95	79	88	95	100	98	92	90	93
1959	63	90	100	100	95	99	100	96	100	96	90	78	92
1960	97	98	87	100	92	100	94	99	99	96	91	97	96
1961	94	100	82	98	99	99	100	99	98	90	92	96	96
1962	94	100	100	100	95	95	100	97	100	100	73	94	96
1963	97	91	97	94	78	88	86	88	100	94	41	66	85
1964	89	97	100	100	99	90	100	100	97	100	100	67	95
1965	99	95	100	82	99	89	47	6	15	35	92	93	71
1966	97	100	100	85	100	100	75	97	99	100	96	95	95
1967	95	100	96	98	92	94	100	99	94	98	82	92	95
1968	97	85	93	90	99	97	100	90	90	100	97	100	95
1969	100	97	100	95	90	96	94	100	96	100	94	95	96
1970	94	100	100	87	100	97	100	100	100	100	100	98	98
1971	96	98	99	100	-	-	-	97	100	100	98	99	99
1972	92	100	98	98	95	57	83	18	3	38	82	88	71
1973	94	100	100	100	97	99	97	100	100	100	98	97	99
1974	100	100	96	95	63	83	98	79	99	100	88	99	92
1975	94	100	100	100	95	98	97	99	99	99	98	100	98
1976	100	94	100	92	93	98	94	65	60	100	97	100	91
1977	100	100	75	100	95	100	100	97	97	91	92	96	95
1978	-	-	-	-	96	97	100	97	100	96	96	100	98
1979	69	50	96	87	97	99	80	63	94	80	99	86	83
1980	100	100	98	100	100	89	100	100	93	79	88	100	96
1981	100	98	84	97	98	100	100	79	100	100	100	100	96
1982	100	96	87	84	92	87	39	47	31	3	13	95	65
1983	100	100	98	100	100	100	100	98	100	100	100	100	100
1984	100	100	100	100	100	100	90	97	100	100	73	99	97
Mean	91	96	96	96	94	93	92	86	88	88	87	94	92

Table A12.4 Monthly mean water surplus (mm/week), Aiyura, 1952 to 1984

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1952	40	48	66	34	0	6	0	0	0	12	8	17	19
1953	30	46	22	19	3	0	7	8	21	3	35	27	18
1954	25	52	27	56	11	30	6	2	4	0	10	22	20
1955	37	43	35	55	18	0	0	0	0	0	0	30	18
1956	25	28	34	24	0	0	0	0	0	0	4	49	14
1957	7	32	73	12	8	0	0	26	18	13	18	57	22
1958	9	29	34	2	0	0	0	0	0	0	0	38	9
1959	3	38	44	58	0	0	0	0	0	16	9	46	18
1960	30	69	29	31	0	0	0	0	0	8	23	8	17
1961	21	19	25	19	21	12	0	47	3	26	21	24	20
1962	3	8	32	16	21	0	0	7	13	0	11	22	11
1963	0	0	0	4	0	10	0	2	9	15	4	16	5
1964	56	23	27	26	1	0	0	0	0	0	9	3	12
1965	21	42	42	17	3	0	0	0	0	0	0	13	12
1966	11	67	76	0	0	0	0	0	0	1	4	7	14
1967	38	54	13	11	0	4	11	0	0	23	15	35	17
1968	29	19	10	12	0	0	0	4	0	12	21	23	11
1969	27	48	28	15	0	0	0	0	14	14	14	35	16
1970	0	0	41	7	0	0	0	0	0	41	37	56	15
1971	13	34	31	23	8	2	0	0	0	0	0	16	11
1972	22	38	36	26	33	0	0	0	0	0	7	35	16
1973	55	46	130	18	6	3	0	5	0	8	29	28	27
1974	0	83	8	6	0	0	4	0	0	0	17	25	12
1975	10	67	21	21	11	0	0	0	0	0	0	36	14
1976	42	39	1	24	4	0	0	0	0	3	15	36	14
1977	41	32	14	15	15	0	0	0	0	30	6	11	14
1978	17	18	28	25	2	0	0	0	0	0	5	10	9
1979	9	58	53	12	13	0	0	0	0	0	3	11	13
1980	57	12	20	34	13	0	0	0	0	0	6	49	16
1981	44	44	12	39	0	0	3	12	1	0	16	45	18
1982	73	40	45	29	19	5	0	0	0	0	0	10	18
1983	44	37	18	8	21	15	0	0	0	6	26	26	17
1984	8	0	21	17	19	0	0	0	0	18	16	53	13
Mean	26	37	33	22	8	3	1	3	3	8	12	28	15

Table A12.5 Monthly mean water surplus (mm/week), Goroka, 1952 to 1984

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1952	49	47	59	30	0	0	0	0	0	0	0	0	15
1953	1	33	8	28	16	0	0	0	0	0	24	11	10
1954	42	68	19	25	15	0	0	0	0	0	0	0	14
1955	10	6	20	18	2	0	0	0	0	0	0	23	7
1956	34	25	35	15	0	0	0	0	0	0	0	49	13
1957	13	3	53	30	11	0	0	4	0	5	0	53	14
1958	7	52	41	13	0	0	0	0	0	17	17	36	15
1959	0	49	44	41	0	0	0	0	0	0	0	2	11
1960	53	75	28	45	0	0	0	0	0	0	18	43	22
1961	25	13	13	12	16	0	0	0	19	32	10	0	12
1962	0	14	13	22	51	0	0	0	0	0	8	54	14
1963	0	0	5	3	0	0	0	0	21	11	0	0	3
1964	49	31	33	10	2	0	0	0	0	0	5	0	11
1965	18	21	32	2	3	0	0	0	0	0	0	24	8
1966	27	48	44	0	0	0	0	0	0	31	15	8	14
1967	62	47	17	14	12	0	0	0	0	4	3	26	15
1968	50	28	33	1	0	0	0	0	0	0	2	35	12
1969	13	13	53	15	0	0	0	0	0	6	20	44	14
1970	0	0	34	15	5	0	0	0	0	5	19	35	9
1971	30	46	27	15	12	0	0	0	0	0	0	0	11
1972	15	22	32	39	13	0	0	0	0	0	0	0	10
1973	12	63	65	39	0	0	0	0	0	0	47	45	23
1974	3	84	21	13	0	0	0	0	0	0	0	3	10
1975	19	63	29	28	25	0	0	0	0	0	0	21	15
1976	12	40	0	7	0	0	0	0	0	0	0	0	5
1977	39	32	1	17	3	0	0	0	0	5	10	1	9
1978	0	1	22	24	0	0	0	0	0	0	0	13	5
1979	17	26	23	8	-	0	0	0	0	0	20	32	11
1980	56	21	5	15	3	0	0	0	0	0	4	36	12
1981	49	25	17	9	0	0	0	0	0	0	28	48	15
1982	53	47	39	1	6	3	0	0	0	0	0	0	12
1983	33	35	56	25	9	6	0	0	0	30	18	19	19
1984	0	0	22	29	10	2	3	0	0	20	10	49	12
Mean	24	33	29	18	7	0	0	0	1	5	8	22	12

Table A12.6 Monthly mean water surplus (mm/week), Mendi, 1956 to 1984

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1956	0	28	22	29	9	19	46	37	22	34	38	30	26
1957	0	17	52	43	1	7	49	35	23	0	6	42	23
1958	8	24	29	9	14	0	2	30	62	40	13	6	20
1959	0	5	37	35	15	14	46	13	32	41	4	2	20
1960	31	38	8	34	13	34	45	33	49	16	18	10	27
1961	25	49	10	28	19	20	60	70	47	69	0	35	36
1962	29	36	39	31	22	7	30	69	47	69	0	35	35
1963	44	12	42	11	24	17	26	18	36	20	0	0	21
1964	40	11	48	44	28	2	33	38	24	46	45	0	30
1965	23	23	59	0	27	2	0	0	0	0	9	49	16
1966	33	94	35	2	41	37	0	15	5	54	9	15	28
1967	18	42	30	9	20	25	62	42	30	29	1	3	26
1968	34	9	58	4	24	6	53	15	13	24	24	42	26
1969	43	33	27	24	10	3	8	23	20	13	20	15	20
1970	25	33	71	10	59	37	45	30	50	75	46	18	42
1971	33	14	41	17	-	-	-	46	47	37	53	18	34
1972	4	52	59	21	21	0	1	0	0	0	34	2	16
1973	27	23	65	65	39	16	61	58	83	44	15	40	45
1974	61	40	50	49	0	5	27	5	32	14	4	16	25
1975	16	96	121	45	18	2	13	17	17	22	36	62	39
1976	10	25	52	35	8	9	15	11	0	52	32	27	23
1977	38	70	17	58	33	70	40	87	17	31	6	15	40
1978	-	-	-	-	15	12	18	27	78	17	33	60	33
1979	0	0	47	11	21	38	-	11	12	4	11	1	14
1980	36	14	38	32	18	18	77	68	14	0	12	45	31
1981	39	34	0	49	21	49	38	8	39	42	56	31	34
1982	56	16	26	9	9	11	0	0	0	0	0	2	11
1983	29	22	47	21	50	25	15	15	33	24	6	33	27
1984	54	36	61	46	50	47	10	15	33	24	6	33	35
Mean	27	32	43	28	22	19	30	29	30	29	19	24	28

Table A12.7 Reported frosts in the Eastern Highlands, 1932 to 1984 (1)

Period (2)(3)	Location	Severity of damage	Food shortage resulting	Source
1972	Aiyura Basin	Slight	No	M. Binabina (pers.comm., 1982)
Nov 81	Lafayufa and Koko area (Lufa/Chimbu border)	Slight	No	DPI files, Goroka
Jul 82	Offafina area (Okapa District)	Slight	No	DPI files, Goroka
Jul 82	Henganofi area	Slight	No	DPI files, Goroka
Jul-Nov 82	Aiyura Basin	Slight	No	Author's observations

Notes

(1) Sources consulted are patrol reports (1932 to 1984) (Figures 3.1, 3.2); and files of national and provincial DPI, provincial Public Health and Department of the Eastern Highlands (1972 onwards).

(2) Giddings (1966) reported snowfalls and consequent food shortages in the Goroka area about 1916. The descriptions that Giddings obtained are more likely to have been frost than snow (pers.comm. between R. J. Giddings and B. J. Allen, 1982)

(3) The frosts at Lafayufa and Koko occurred on 6th November 1981. Those at Aiyura in 1982 were on the mornings of 19th July and 18th November.

Table A12.8 Reported frosts in the Southern Highlands, 1949 to 1984(1)

Period (2)	Location	Severity of damage(3)	Food shortage resulting	Source (4)
Mid 53	Upper Mendi V	Severe	Yes(5)	Mendi 9 of 1953/54
Oct 58	Lai V	Severe	?	Mendi 2 of 1958/59
Mar-Apr 60	Ialibu Basin	Severe	No	Ialibu 8 of 1959/60
Mar-Apr 60	Upper Mendi V	?	Yes	Mendi 7 of 1959/60
Sep 61	Ialibu Basin	Severe	?	Ialibu 2 of 1961/62
Sep 61	Ialibu area	Severe	No	Ialibu 4 of 1961/62 *South Pacific Post* Sep 19, 1961:3
Sep 61	Nipa Basin	Severe	No	Nipa 2 of 1961/62
Sep 61	Wage V, Nipa Basin	Severe	?	Lake Kutubu 1 of 1960/61
Sep 61	Upper Mendi V	?	?	Mendi 9 of 1961/62
Sep 65	Upper Mendi V	Severe	?	Mendi 2,3 of 1965/66
Oct-Dec 65	Upper Mendi V	"Repeated"	?	Mendi 11 of 1965/66
Jun-Oct 72	Margarima	Severe	Yes	Brown & Powell (1974)
Jun-Oct 72	Upper Mendi V	Severe	Yes	Brown & Powell (1974) Simpson (1978:103)
Sep 72	Ialibu area	?	?	*PNG Post Courier* Sep 21, 1972:1
Oct 72	Ialibu Basin, Kagua, Nipa, Poroma, Tari, Koroba	Severe	Yes	Brown & Powell (1974)
Oct 72	Tari Basin (Haibuga-Munima, South Basin, Benaria, North Basin,Paijera)	Moderate	?	Tari 5,6,7 of 1972/73
Oct 72	Paijera area, Tari Basin	Slight	Yes	Tari 10 of 1972/73
Aug 74	Upper Mendi, Ialibu, Margarima areas	Moderate	No	*PNG Post Courier* Aug 26, 1974:4
? 74	Upper Mendi V	Slight	No	Simpson (1978:104)

Oct-Nov 80	Lavani V	Severe	?	Wohlt *et al.* (1982:17-28)
Oct-Nov 80	Upper Mendi, Margarima, Ialibu, Lai V, Koroba areas	Moderate	Yes	DPI files, Mendi Wohlt *et al.* (1982) Author's observations (Upper Mendi)
Oct-Nov 80	Kongip Village, Nembi Plateau	Slight	No	Crittenden (1982:421)
Jul-Nov 82	Upper Mendi	Severe	Yes	M. Anders (pers. comm., 1982, 1983) DPI files. Mendi
Sep-Nov 82	Upper Mendi	Severe	?	Radcliffe (1985a: 9-12)
Jul 82	Lavani V	Severe	Yes	E. D'Souza (pers. comm., 1983)
Jul 82	Ialibu, Margarima	Severe	Yes	M. Anders (pers. comm., 1982) Various newspaper reports(6) DPI files, Mendi
Oct 84	Margarima area	Slight	No	Author's observations

Notes

(1) This data set is based on all available sources from the Southern Highlands. Between 1949 and 1971, these are mostly patrol reports. For this period, the quality of the data sources is fairly uniform, and the frequency of reports by outsiders increased over time (Figures 3.3, 3.4). Between 1972 and 1974, sources are some patrol reports, published papers, newspaper reports and government files, but not all archival material has been consulted. There is a gap in data between 1975 and 1977 (inclusive) although there is no indication that severe frosts occurred in these years. From 1978 onwards sources are provincial and national government files, personal communication with various government staff and the author's observations. Thus the data set is based on information of uneven quality and quantity. The frosts of late 1980 are best documented and the series of extended and very severe ones in 1972 are not well documented in the sources consulted.

(2) Some reports refer to single frosts, others to repeated ones, but the number of frosts is generally not stated.

(3) Damage is classed as slight, moderate and severe. The classification is approximate only because of the subjectivity of the various sources used.

(4) Sources such as Mendi 9 of 1953/54 refer to unpublished patrol reports.

(5) Other unspecified reasons were also given by villagers for this food shortage.

(6) Newspaper reports on frost and drought in 1982 include: *Times of PNG*, July 22:1; July 30:1; August 27; *PNG Post Courier* July 28:1; August 24:3; August 25; September 17; October 1:7; October 18:1; October 28; *Niugini News*, November 27:1.

APPENDIX 13

DATA FROM CROP PLANTING SURVEYS

Table A13.1 Asiranka crop planting survey: mean area of various classes of garden planted per month, October 1979 to December 1982 (m^2/woman/week); sweet potato, mixed and all food crops(1)

Month		Sweet potato					Mixed	All food crops
		Grassland fallow		Forest fallow				
		ex fallow	ex crop	ex fallow	ex crop	Total		
1979	Oct	16	24	-	-	40	15	63
	Nov	34	39	-	-	74	54	217
	Dec	95	30	33	0	157	13	177
1980	Jan	84	82	0	0	166	3	206
	Feb	58	24	23	0	105	8	174
	Mar	27	30	33	0	89	6	122
	Apr	0	53	0	0	53	5	66
	May	0	24	4	0	28	0	116
	Jun	0	0	6	0	6	0	45
	Jul	0	33	9	0	42	15	104
	Aug	0	2	0	0	2	5	37
	Sep	18	37	1	0	56	19	96
	Oct	1	19	0	0	20	25	54
	Nov	0	19	12	0	31	46	79
	Dec	14	26	25	0	65	2	76
1981	Jan	3	21	0	0	24	0	48
	Feb	9	25	0	0	34	0	50
	Mar	19	32	0	0	51	6	67
	Apr	0	12	0	0	12	13	42
	May	26	29	0	0	55	2	83
	Jun	8	31	11	0	50	7	103
	Jul	0	6	0	0	6	2	19
	Aug	14	20	6	0	40	5	65
	Sep	0	7	0	0	7	20	30
	Oct	6	16	3	0	25	12	45
	Nov	4	6	0	0	10	13	40
	Dec	9	14	0	0	23	0	27
1982	Jan	0	36	0	12	48	13	62
	Feb	0	4	0	0	4	4	14
	Mar	0	13	0	3	16	1	25
	Apr	4	9	0	0	13	10	29
	May	9	13	0	0	22	18	81
	Jun	27	33	0	0	61	14	136
	Jul	0	9	0	0	9	0	10
	Aug	9	25	8	7	49	10	77
	Sep	8	14	74	0	97	36	150
	Oct	24	33	58	0	115	41	159
	Nov	8	9	23	0	39	4	43
	Dec	28	31	30	0	89	67	163

Note

(1) See note 1, Table A13.2

Table A13.2 Asiranka crop planting survey: mean area of various classes of garden planted per month, October 1979 to December 1982 (m^2/woman/week); peanuts, winged bean, introduced vegetables, coffee, *Xanthosoma* taro and taro(1)

Month		Peanuts	Winged bean(2)	Introduced vegetables (3)	Potato	Coffee (4)	*Xanthosoma* taro	Taro (5)
1979	Oct	8	0	0	0	10	0	0
	Nov	87	0	0	3	-	0	0
	Dec	0	0	0	7	-	0	0
1980	Jan	29	0	1	6	-	0	0
	Feb	61	0	0	0	-	0	0
	Mar	25	0	2	0	-	0	0
	Apr	9	0	0	0	-	0	0
	May	68	19	0	0	-	0	0
	Jun	25	14	0	0	-	0	0
	Jul	37	0	1	9	-	0	0
	Aug	18	9	1	0	0	0	0
	Sep	12	2	3	3	1	0	1
	Oct	3	0	2	4	83	1	0
	Nov	0	0	1	0	0	0	0
	Dec	8	0	1	1	0	0	0
1981	Jan	21	0	3	0	0	0	0
	Feb	13	0	2	1	0	0	0
	Mar	10	0	0	0	0	0	0
	Apr	13	0	0	4	0	0	0
	May	14	0	8	0	2	2	2
	Jun	11	28	5	2	1	0	0
	Jul	11	0	0	0	0	0	0
	Aug	8	10	0	2	0	0	0
	Sep	3	0	1	0	0	0	0
	Oct	0	0	7	0	0	0	0
	Nov	9	0	0	7	0	0	0
	Dec	2	0	0	2	0	0	0
1982	Jan	0	0	1	0	0	0	0
	Feb	3	0	0	3	0	0	0
	Mar	8	0	0	0	0	0	0
	Apr	4	0	0	1	0	0	0
	May	31	6	3	1	0	0	0
	Jun	10	24	6	0	0	19	2
	Jul	0	0	0	1	0	0	0
	Aug	12	0	1	2	2	2	0
	Sep	13	0	0	0	0	0	5
	Oct	0	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0
	Dec	7	0	0	0	0	0	0

Notes

(1) The data are measurements of garden area planted by 10 women recorded at monthly intervals by the author. The survey commenced in August 1979. For August and September 1979, the survey period was one week only and the data are not reliable. Between October 1979 and July 1980, the survey period was two weeks. These data are likely to be reasonably reliable, although for this period the figures may be an overestimate of the area planted. Between August 1980 and December 1982, the survey period was a month (4 or 5 weeks) and there are no known problems with the data collected.

No recordings were made on plantings of tree crops, unless they were interplanted with arable crops, but areas planted per month are very small. The classes of garden refer to the dominant crop. Other species are commonly mixed planted with the main species, for example, common beans, corn and amaranthus are often planted in sweet potato gardens. Mixed gardens contain numerous species in a mixed planting pattern. The most common species planted in this garden type are listed in Table A2.6 and all crop species used are given in Table A2.7.

(2) These recordings are of winged beans grown as a monoculture in better drained sites for tuber and bean production. Some winged bean are also planted in mixed gardens where they produce mainly beans.

(3) Introduced vegetables are recently introduced species, such as lettuce and broccoli, grown in monospecific plots for sale to expatriates. Introduced vegetables are also grown in mixed gardens.

(4) Regular recordings of area of coffee planted commenced in August 1980. Almost all the new coffee plantings were mixed planted with food crops. The coffee planted in October 1980 followed an old mixed garden rather than being planted with the food crops.

(5) *Colocasia* taro is an important component of mixed gardens (Table A13.1), and the figures here are for plots of *Colocasia* taro only.

Table A13.3 Asiranka crop planting survey: mean area of various classes of garden, fallow type and previous history, January 1980 to December 1982 (m^2/woman/year)

Garden type(1)	Fallow type(2)	Previous history(3)	Area planted
Sweet potato	Grassland	Fallow	563
Sweet potato	Grassland	Crop	1070
Sweet potato	Forest	Fallow	464
Sweet potato	Forest	Crop	38
Mixed	Grassland	Fallow	347
Mixed	Grassland	Crop	60
Mixed	Forest	Fallow	249
Mixed	Forest	Crop	0
Peanuts	Grassland	Fallow	24
Peanuts	Grassland	Crop	557
Winged bean	Grassland	Fallow	16
Winged bean	Grassland	Crop	93
Winged bean	Forest	Fallow	11
Winged bean	Forest	Crop	47
Introduced vegetables	Grassland	Fallow	13
Introduced vegetables	Grassland	Crop	65
Potato	Grassland	Fallow	14
Potato	Grassland	Crop	51
Potato	Forest	Fallow	2
Potato	Forest	Crop	0
Coffee(4)	Grassland	Fallow	(10)
Coffee	Grassland	Crop	(50)
Xanthosoma taro	Grassland	Fallow	8
Xanthosoma taro	Grassland	Crop	0
Xanthosoma taro	Forest	Fallow	38
Xanthosoma taro	Forest	Crop	0
Taro	Grassland	Fallow	10
Taro	Grassland	Crop	5
Taro	Forest	Fallow	1
Taro	Forest	Crop	0
Yams	Grassland	Fallow	1
Yams	Grassland	Crop	3
Others(5)	Grassland	Fallow	1
Others	Grassland	Crop	3
TOTAL	-	-	3755

Notes

(1) Garden type refers to the dominant species in a planting. Other species were also commonly planted at low densities with the main species. Mixed gardens contained numerous species (see Table A2.6).

(2) Almost all of the plantings in grasslands were located on the grassland flats in the Aiyura Basin (Figure A2.2, A2.3), but some planting (1-2%) followed tall grass fallows on the sides of the Basin. A more detailed classification of fallow types is given in Table A2.5. Plots of peanuts, introduced vegetables, coffee and yams were planted only in grassland sites, although some yams and introduced vegetables were planted in mixed gardens in forest sites.

(3) Previous history refers to the land use immediately prior to the planting. Plantings were classed as following a fallow or another arable planting. The latter may have been of the same species (for example, sweet potato preceded by sweet potato) or a different species (for example, sweet potato preceded by peanuts). When short fallows of up to several months separated plantings, the previous history was classed as crop rather than fallow.

(4) Recordings of area of coffee planted commenced in August 1980. Almost all new coffee plantings were mixed with food crops, and the area of coffee is thus not counted in the total.

(5) Other refers to pure stands of stawberry, pineapple and corn.

Table A13.4 Upa crop planting survey: mean area of various classes of gardens planted per month, December 1979 to June 1982 (m^2/woman/week)(1)

Month		Sweet potato			Mixed	Other	All food crops
		Ex fallow	Ex crop	Total			
1979	Dec	51	20	71	48	0	119
1980	Jan	23	47	70	33	0	102
	Feb	23	37	60	8	0	68
	Mar	5	26	30	10	0	40
	Apr	3	28	31	1	0	32
	May	8	12	20	2	1	23
	Jun	0	22	22	9	0	31
	Jul	0	9	9	0	1	10
	Aug	3	34	36	0	0	36
	Sep	1	26	28	7	0	35
	Oct	6	37	43	3	0	46
	Nov	13	36	50	17	0	66
	Dec	12	55	67	23	0	90
1981	Jan	5	91	95	18	0	113
	Feb	18	62	80	13	0	93
	Mar	9	64	73	10	0	83
	Apr	3	37	40	10	2	52
	May	14	50	64	3	0	67
	Jun	10	60	70	2	0	72
	Jul	12	52	64	11	0	75
	Aug	9	23	31	0	1	32
	Sep	6	38	44	0	0	44
	Oct	7	24	31	59	0	90
	Nov	3	56	59	19	3	81
	Dec	0	44	44	23	0	67
1982	Jan	20	23	43	4	0	47
	Feb	3	60	63	14	0	77
	Mar	3	32	36	9	0	45
	Apr	3	13	16	7	0	23
	May	0	30	30	7	2	39
	Jun	1	26	27	2	0	29

Note

(1) These data are derived from a monthly survey conducted by E. D'Souza of 10 women from 3 clans of Upa Village, Nembi Plateau, between November 1979 and June 1982. The survey period was one week only for November 1979 and the data are not reliable. Between December 1979 and March 1980, the survey period was 2 weeks and these figures are likely to be reasonably reliable, although these figures may be an overestimate of area planted. From April 1980 onwards the survey period was a month (4 or 5 weeks) and there are no known problems with the data collected.

Table A13.5 Upa crop planting survey: mean area of various classes of garden and previous history, July 1980 to June 1982 (m^2/woman/year)(1)

Garden type(2)	Previous history	Area planted	Percentage
Sweet potato	Fallow(3)	352	11.4
Sweet potato	Crop(4)	2,147	69.6
Mixed	Fallow	548	17.8
Mixed	Crop	18	0.6
Household	Fallow	11	0.4
Peanuts	Crop	8	0.3
TOTAL	-	3,085	100.1

Notes

(1) The annual means presented here are derived from the final 24 months of the survey period.

(2) No recordings were made of tree crops, but areas planted per month are very small. The garden type refers to the dominant crop. A limited number of other species are planted into sweet potato gardens. Mixed gardens contain numerous species. Household gardens are small plantings located adjacent to dwellings. (See Appendix 4 and Table A4.1).

(3) Sweet potato plantings preceded by short grass fallows .

(4) Virtually all sweet potato plantings in this category followed sweet potato crops, although one planting followed a mixed garden (mean: 5 m^2/woman/year).

Table A13.6 Upa garden area survey: mean area of various classes of garden and previous history, November 1984 (m^2/woman)(1)

Garden type	Previous history	Area planted
Sweet potato - not harvested(2)	Fallow	959
Sweet potato - not harvested	Crop	1022
Sweet potato - harvested(3)	Fallow	521
Sweet potato - harvested	Crop	1974
Mixed - 1984 plantings(4)	Fallow	183
Mixed - 1984 plantings	Crop	15
Mixed - 1983 plantings(5)	Fallow	299
Mixed - 1983 plantings	Crop	0
Household	Fallow	8
TOTAL	-	4981

Notes

(1) This survey is a cross-sectional one and results are not directly comparable with the longitudinal study of 1979 to 1982 (Table A13.5). All gardens planted by the 12 women who had participated in the 1979 to 1982 study, including the two replacements, were measured by the author in early to mid-November 1984. The survey, which also included a detailed household census and a count of economic tree crops, required a day per woman. Significant areas had been cleared of fallow vegetation by November 1984 and were still to be planted. The 12 women provided food for 62 people (including themselves).

(2) The class "sweet potato - not harvested" refers to recently planted crops which had been planted during the previous 5 months or so.

(3) Some of the class "sweet potato - harvested" was crop that had been harvested a long time ago and the land was, in effect, under a sweet potato cover crop.

(4) This class refers to recently planted mixed gardens. Large plantings of mixed gardens were due to be planted in the two months following the survey.

(5) "Mixed -1983 plantings" refers to plantings made in late 1983-early 1984.

Table A13.7 Tari, Upper Mendi and Pangia crop planting survey: mean area of food gardens planted per month, September 1981 to October 1982(1) (m^2/family/month)

Month		Tari		Upper Mendi		Pangia	
		Number(2)	Mean	Number	Mean	Number	Mean
1981	Sep	16	429	-	-		
	Oct	17	390	9	493		
	Nov	17	392	9	340		
	Dec	17	597	9	159		
1982	Jan	17	419	9	124		
	Feb	17	280	9	225		
	Mar	17	502	9	344		
	Apr	17	401	10	69		
	May	17	378	10	284		
	Jun	17	446	10	299		
	Jul	17	383	10	18		
	Aug	17	462	10	121		
	Sep	17	349	10	210	14	425
	Oct	17	389	15	321	14	477
	Nov	17	338	19	131	15	467
	Dec	17	492	19	155	15	529
1983	Jan	17	535	19	224	15	484
	Feb	17	452	19	217	16	676
	Mar	17	279	19	191	18	431
	Apr	17	286	19	269	18	251
	May	17	198	19	309	18	175
	Jun	17	318	19	160	17	72
	Jul	17	272	19	194	17	30
	Aug	17	300	19	257	17	170
	Sep	17	328	19	227	17	71
	Oct	17	270	-	-	-	-

Notes

(1) Recordings were made by members of the Southern Highlands Agricultural Field Trials, Studies, Extension and Monitoring Unit (AFTSEMU). The data were kindly made available by the AFTSEMU team leader, R. Crittenden. Results of the surveys were published in a slightly different format in Crittenden *et al.* (1985).

(2) Number refers to the number of "families" whose gardens were surveyed. Further information on survey techniques and the geographic spread of families within each study area is given by Crittenden *et al.* (1985). The survey commenced on the first Monday of each month, so the monthly means refer to 4 or 5 weekly periods. The mean number of people per family varied between locations (and presumably within each study area as the number of families surveyed changed). Mean number of persons per family was 5.8, 5.1 and 5.2 for Tari, Upper Mendi and Pangia respectively (R. Crittenden, pers.comm., 1986).

APPENDIX 14

DATA ON SALES OF IMPORTED FOOD

Table A14.1 Monthly purchases (kina) for 10 trade stores, Central Nembi Plateau, November 1983 to December 1984(1)

Year	Month	Upa trade stores(2)		Hol/Kongip trade stores(3)	
		Rice	All commodities	Rice	All commodities
1983	Nov	79	403	-	-
	Dec	104	218	70	177
1984	Jan	48	210	0	99
	Feb	65	132	22	171
	Mar	114	309	0	14
	Apr	59	397	138	716
	May	0	0	25	87
	Jun	204	690	0	0
	Jul	762	1265	137	744
	Aug	559	1219	265	422
	Sep	71	264	0	0
	Oct	385	809	492	1952
	Nov	-	105 (4)	241	404
	Dec	-	80	107	293

Notes

(1) The data source is receipts from wholesale suppliers retained by the store owners.

(2) There were 10 trade stores operating in Upa in 1984. Receipts were available for 8 of these.

(3) The Hol/Kongip data are from two stores that have a high turnover and where the owners had apparently retained receipts for all of 1984. The store at Hol caters for visitors and patients of the Pumberel Health Centre.

(4) Figures for November and December were kindly forwarded by Yako Pei of Upa.

Table A14.2 Annual rice sales (tonnes) from Mt. Hagen and Goroka wholesale terminals, 1977 to 1985(1)

Year	Mt. Hagen(2)	Goroka	Mt. Hagen plus Goroka
1977	9,826	5,919	15,745
1978	11,262	6,838	18,100
1979	11,594	6,865	18,459
1980	12,216	7,060	19,276
1981	12,703	6,545	19,248
1982	12,862	7,421	20,283
1983	10,662	6,651	17,313
1984	13,762	9,253	23,015
1985	14,513	8,525	23,038

Notes

(1) Figures were kindly provided by Rice Industries Ltd, who had a monopoly on rice imports into PNG until late 1986.

(2) Mt. Hagen and Goroka are the only wholesale terminals in the highlands. The Mt. Hagen terminal serves the Western Highlands, Southern Highlands and Enga and possibily part of Chimbu. The Goroka terminal serves the Eastern Highlands and Chimbu. Some sales are also made to highland buyers from the Lae terminal. Over this period 19-23 per cent of PNG sales were through the two highland terminals.

Table A14.3 Monthly rice sales (tonnes per week) from Mt. Hagen and Goroka wholesale terminals, July 1976 to December, 1985(1)

Mt. Hagen

Mth	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Jan		133	157	203	235	176	183	214	181	225
Feb		133	185	189	250	264	228	204	156	237
Mar		162	169	207	207	250	171	200	202	243
Apr		200	220	244	250	267	286	217	190	286
May		218	296	266	235	281	266	230	239	312
Jun		249	211	265	192	294	234	248	334	302
Jul	186	210	222	295	230	222	250	227	275	318
Aug	189	209	247	284	259	297	249	200	305	308
Sep	190	160	222	152	250	234	280	170	332	274
Oct	163	213	234	192	244	228	297	204	355	360
Nov	166	177	239	148	225	203	284	168	325	302
Dec	126	194	210	228	230	232	253	181	283	249

Goroka

Mth	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Jan		75	101	129	112	88	101	148	105	177
Feb		70	108	98	136	99	121	152	95	146
Mar		95	100	112	127	130	93	123	118	146
Apr		105	136	159	165	143	174	113	129	178
May		123	177	160	172	150	136	132	179	199
Jun		159	121	171	135	136	156	166	209	193
Jul	124	141	139	180	122	115	129	143	183	187
Aug	127	120	157	128	139	146	132	145	185	155
Sep	106	117	135	134	134	123	153	116	226	144
Oct	85	119	138	121	120	118	171	104	234	130
Nov	89	102	131	101	111	125	190	99	245	143
Dec	81	135	130	96	151	146	160	89	234	162

Note

(1) Source is Rice Industries Ltd, Lae.

Table A14.4 Imports (tonnes per year) of wheat, flour and rice into Papua New Guinea, 1961 to 1985(1)

Year	Flour	Wheat (2)	Flour equivalent(3)	Rice	Rice plus flour equivalent
1961-62	7,027		7,027	21,676	28,703
1962-63	7,111		7,111	23,275	30,386
1963-64	8,308		8,308	24,021	32,329
1964-65	9,521		9,521	28,119	37,640
1965-66	12,008		12,008	33,781	45,789
1966-67	13,225		13,225	32,816	46,041
1967-68	14,372		14,372	38,678	53,050
1968-69	16,226		16,226	38,260	54,486
1969-70	23,350		23,350	45,188	68,538
1970-71	25,164		25,164	47,069	72,233
1971-72	24,482		24,482	48,552	73,034
1972-73	22,912	22	22,929	61,648	84,577
1973-74	21,201	23	21,219	41,659	62,878
1974-75	26,171	0	26,171	54,906	81,077
1975-76	23,834	0	23,834	54,847	78,681
1977	21,799	7,367	27,466	72,449	99,915
1978	13,788	22,393	31,013	77,642	108,655
1979	16,300	19,349	31,184	81,277	112,461
1980	16,832	28,099	38,447	88,924	127,371
1981	4,729	40,427	35,827	88,099	123,926
1982	337	48,948	37,989	93,524	131,513
1983	303	32,957	25,655	92,633	118,288
1984	83	60,933	46,955	102,774	149,729
1985	9	45,604	35,089	111,223	146,312

Notes

(1) Figures were provided by the National Statistics Office and DPI Rural Statistics Section, Port Moresby, apart from rice imports for 1977 to 1985 which are from Rice Industries Ltd, Lae.

(2) Unmilled wheat was not imported into PNG in any quantity until 1977. Since then, unmilled wheat has replaced imports of milled wheat flour.

(3) Flour equivalent is flour plus wheat converted to flour equivalent using a factor of 1.3 tonnes wheat = 1 tonne flour.

APPENDIX 15

DATA SOURCES USED FOR MODEL OF FOOD SUPPLY

Soil moisture storage and surplus are derived from soil water balances calculated for Aiyura and Mendi. Monthly mean soil moisture storage and water surplus for Aiyura and Mendi are given in Tables A12.1, A12.3, A12.4 and A12.6; the timing of extended droughts, extended water surpluses and extreme water surpluses in Tables 7.1, 7.2 and 7.3. An extended drought is defined as a continuous period when the calculated soil moisture storage was less than 20 mm for 8 weeks or longer (Mendi) or 10 weeks (Goroka); an extended water surplus as a continuous period of water surplus of 20 weeks or longer. An extreme water surplus is defined as a calculated surplus of greater than 170 mm per week.

The price of sweet potato is derived from recordings in Kainantu and Hol markets for 10 toea bundles and converted into constant 1984 currency. The Kainantu data extend until May 1983. Thereafter prices are estimated (except for November 1983 and September 1984). The Nembi price data extend until July 1982 and are estimated thereafter (except for October/November 1984). Price estimates are derived by extrapolating from recorded prices and villagers' reports of the timing of the 1984 food shortage. Unadjusted data are given in Table A6.5.

The area of sweet potato planted is based on measurements of area planted by a sample of 10 women in Asiranka Village (until December 1982) and in Upa Village (until June 1982)(Tables A13.1, A13.4). Thereafter the figures are estimated. The 1984 figures were estimated from cross sectional recordings made in late 1984.

Rice sales are monthly sales from the wholesale rice terminal in Goroka. Figures are given in Table A14.3. **Reported food shortages** in the Kainantu area and on the Nembi Plateau are based on reports by villagers that food was scarce (Chapter 3).

The child malnutrition rate is the percentage of children aged 1 to 5 years attending monthly MCH clinics who weighed less than 80% of their weight for age (Harvard Standard). It is based on data held by the Pumberel Health Centre for three MCH clinics that serve the central Nembi Plateau (Table A8.1).

The calculated sweet potato supply indices for the Kainantu area and the Nembi Plateau have been derived using the following formula:

Supply index = Area planted (6/8 months previous) x yield index

The yield index is based on the following calculations and assumptions: Extended periods of soil moisture surplus or extreme water surpluses depress yield to 80% of the long term average eight months later (Kainantu area) or six months later (Nembi Plateau). Droughts depress yield to 80% of the long term average during the drought and in the following month. The combined effects of extended water surplus and drought result in a yield of 60% of the long term average. This model assumes that the major detrimental effect of an extended water surplus occurs during the period of tuber initiation soon after planting; and the major effect of a drought occurs immediately because of a cessation of tuber bulking. The high and extended soil moisture surpluses between January and May 1984 in the Southern Highlands are assumed to have depressed yields to 70% rather than 80% of the long term average. Lag periods of eight months for the Kainantu area and six months for the Nembi Plateau were used.

Above average yields (125%) were assumed for three periods because of the higher than normal proportion of gardens that followed a fallow. No estimates have been made for higher than average yields induced by favourable soil moisture conditions because there is insufficient information on the positive relationship between climatic conditions and sweet potato tuber yield.