AGROFORESTRY FARMING SYSTEMS
IN BULOLO VALLEY,
MOROBE PROVINCE, PAPUA NEW GUINEA

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by

Vida Sonoling

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Environment and Policy Institute
East-West Center
1777 East-West Road
Honolulu, Hawaii 96848

The United Nations University
Toho Seimei Building
15-1, Shibuya 2-chome, Shibuya-ku
Tokyo 150, Japan

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VIDA SONOLING was one of three researchers from the South Pacific who served as professional associates in the East-West Center-United Nations University Agroforestry Systems Inventory Project in the Pacific.

Related studies, which are available from the East-West Center, are:

Traditional Agroforestry System in Iriqila, Vella La Vella Island, Western Province, Solomon Islands, by Thornley Hite

and

Introduction of Industrial Agroforestry System in the East Sepik Province of Papua New Guinea, by Peter Tom.

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FOREWORD

Over the past few years, there has been a worldwide effort to identify and characterize traditional land-use systems where woody perennials (mainly trees) are used in spatial or temporal combination with annual crops or pasture. This effort is part of a burgeoning interest in agroforestry as a major land-use option for tropical lands where current cropping and grazing practices were leading to economic and ecologic decline. Many of these traditional systems have been developed over centuries of trial and error and have become sustainable. It was also hypothesized that these systems might be improved in productivity and protective function by using some of the new research on improved or new trees and crops.

The Pacific Islands are a rich source of traditional knowledge about land husbandry. An inventory has been underway in this region to correspond with similar efforts in Asia, Africa, and Latin America. It was thought that a few detailed case study analyses in the Pacific might make a significant contribution to this important activity. Consequently, the United Nations University funded a small case study workshop for three Pacific Island forestry professionals at the East-West Center. The workshop had training, field research, literature research, and writing components. The three participants, who were selected by the United Nations University, benefited greatly under the supervision of and close association with EAPI Research Associate Napoleon Vergara.

This paper by Mr. Sonoling of Papua New Guinea is one of the products of this activity. It forms a part of the ongoing project entitled Forests and Farms in EAPI's Program in Land, Air, and Water Management.

Lawrence S. Hamilton
Program Coordinator

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INTRODUCTION

The traditional agroforestry system (otherwise known as swiddening or shifting cultivation) plays an important daily occupational role in the lives of people in Papua New Guinea (PNG). More than 90 percent of the country's population of 3.5 million depend entirely on agroforestry. In Morobe Province alone, 238,138 (76.7 percent of the province's population of 310,622) live in rural areas and only 72,484 in urban or semiurban areas. Only about 10 percent of the people in the Wau District (population 29,217) claim no involvement in agroforestry activities (PNG National Statistical Office 1985).

Through years of practice, PNG farmers have developed unique agricultural skills and systems guided by sociocultural, traditional, and environmental influences. These are seen in most of the highlands of the country where sweet potato (Ipomoea batatas) is the staple food and is therefore intensively cultivated, and in Morobe Province where there are extensive banana (Musa sp.) plantations. These patterns are also distinct in Bulolo Valley, Morobe Province, where this study was conducted.

From September 1985 to August 1986, the nature, the problems, and the practices of traditional agroforestry system in Bulolo Valley were observed. Crops, methods of cultivation, and farm management techniques were closely monitored, and their variations, effectivity, and limitations were noted.

Shifting cultivation in Bulolo has limitations due to dwindling land areas and increasing population pressures. Landowners, farmers,

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Vida Sonoling was formerly District Forestry Officer of the Bulolo District, Morobe Province, Papua New Guinea.

gold miners, and settlers are becoming apprehensive. Most suitable lands had been planted with semipermanent crops such as coffee, coconuts, and other fruit trees. Others are used for cattle grazing or leased out to private entrepreneurs or to government forestry and agricultural agencies. Landowners have thus been cultivating the poorer hilly sites, which, after abandonment, usually become dominated by grasses and other weeds. Landowners have also initiated short fallow periods of 2 to 3 years or less. On the other hand, illegal food gardening practices have occurred in forest lease lands. Protective forest strips are cleared and burned for cultivation, and records show that many wild forest fires emanated from such clearing and burning practices. All this caused shifting cultivation to be regarded in a negative light in the area.

Land tenure systems had been the main setback for major development projects in Bulolo. Between 1975 and 1985, more than 7000 ha of logged-over areas degenerated into grasslands (Imperata cylindrica and bamboo) or into unproductive forests (secondary regrowth; see Figure 1). Some became a haven for continuous shifting cultivation. Attempts by the national and provincial governments to acquire these lands for permanent forest plantations and rehabilitation have been unsuccessful because tribal landowners refuse to part with their land (Yauieb and Gardner 1982; Howcroft 1983).

OBJECTIVES

This research was conducted to identify and analyze current problems in Bulolo Valley's long-existing, widely practiced traditional agroforestry farming system and to develop means to improve the system. A further goal has been to identify the research needs involving the major crops now extensively used and the implementation of modified forms of agroforestry systems to enhance forestry and rural development. Specifically, the study aimed to:

- Identify and classify the existing and most widely practiced swidden agroforestry system in the area.

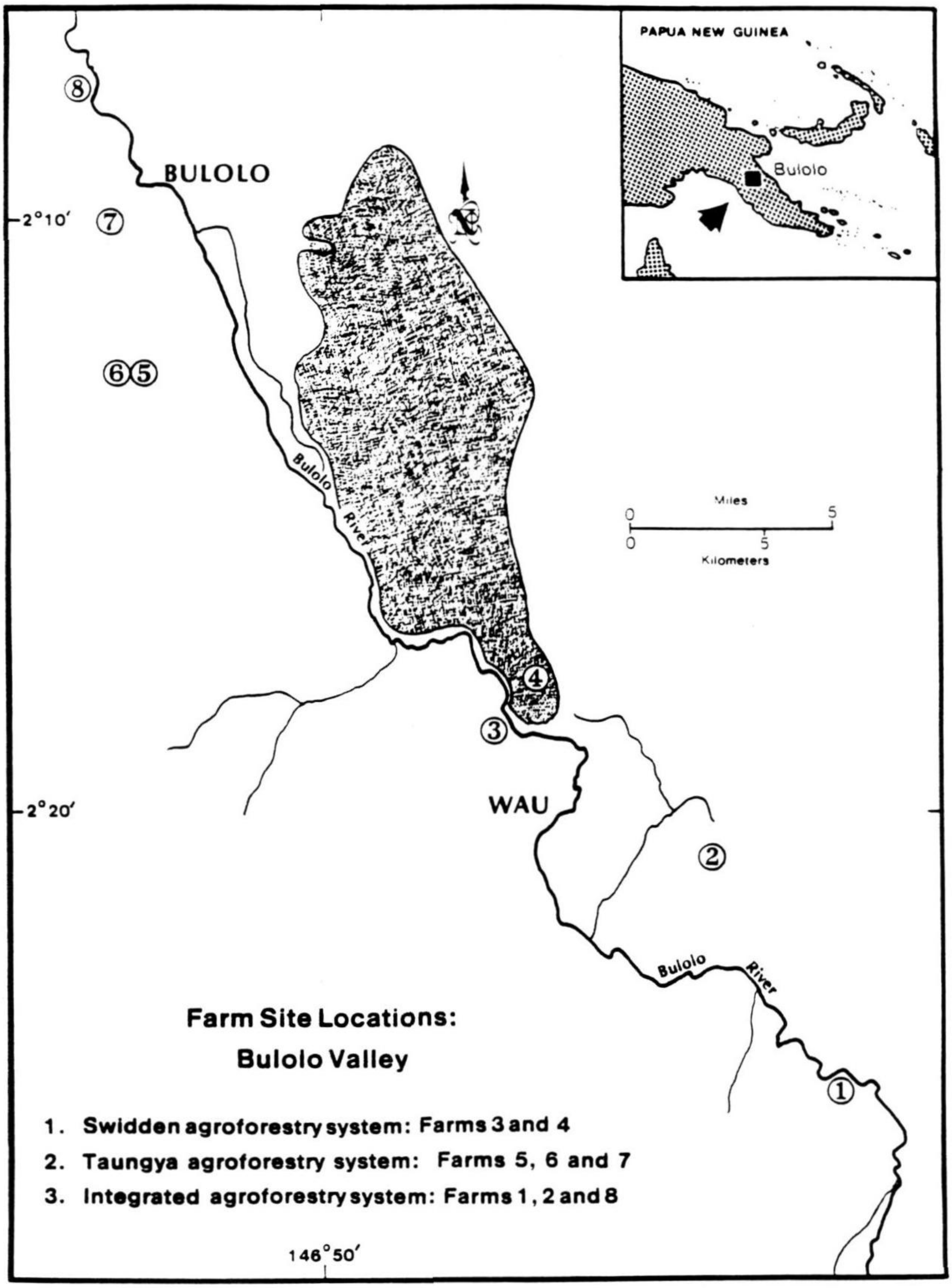


Figure 1. Approximate location of the 1975-85 logged-over areas undergoing rapid invasion of grasslands and becoming degraded through continuous shifting cultivation and annual burning. (Note: Area involved more than 7000 ha.) Figure also shows location of farm sites.

- Carry out an inventory of the area's crop composition and combinations, and to examine crop interrelations in the area's systems.
- Analyze the productivity and sustainability of the present agroforestry system by assessing the input and output components.
- Identify problems and opportunities in the existing agroforestry production system to develop a modified model for use toward improvements in sustainability, productivity, and adoptability.

METHODOLOGY

Selection of Field Sites

Bulolo Valley has faced the pressures of increasing population brought about by in-migration because of earlier gold mining, wood harvesting and wood processing operations, and other economic activities. These have led to increased pressures on adjoining hilly areas to raise sufficient food for subsistence. Thus, Bulolo Valley seems a suitable location for a study of agroforestry systems and their effects on sustainability and stability of the natural environment.

This research was conducted from September 1985 to August 1986 at Bulolo Valley ($7^{\circ}30'$ S, $146^{\circ}46.5'$ E), Morobe Province, approximately 65 km from Lae (Figure 2). The valley extends over the Bulolo River catchment, covering an estimated land area of more than 80,000 ha and situated between Kupers Range on the east and the Bulolo Watut divide on the west. Altitude variation of the selected farms ranges from 500 to 1200 m.

Topographical features range from steep (more than 20 percent slopes) to moderate and flat areas. Areas in steeper slopes are either under grasslands or forests and are not suitable for cultivation. Soils had been classified in broad terms: brown forest soils and regosolic brown soils co-dominant in lowland hills, some red

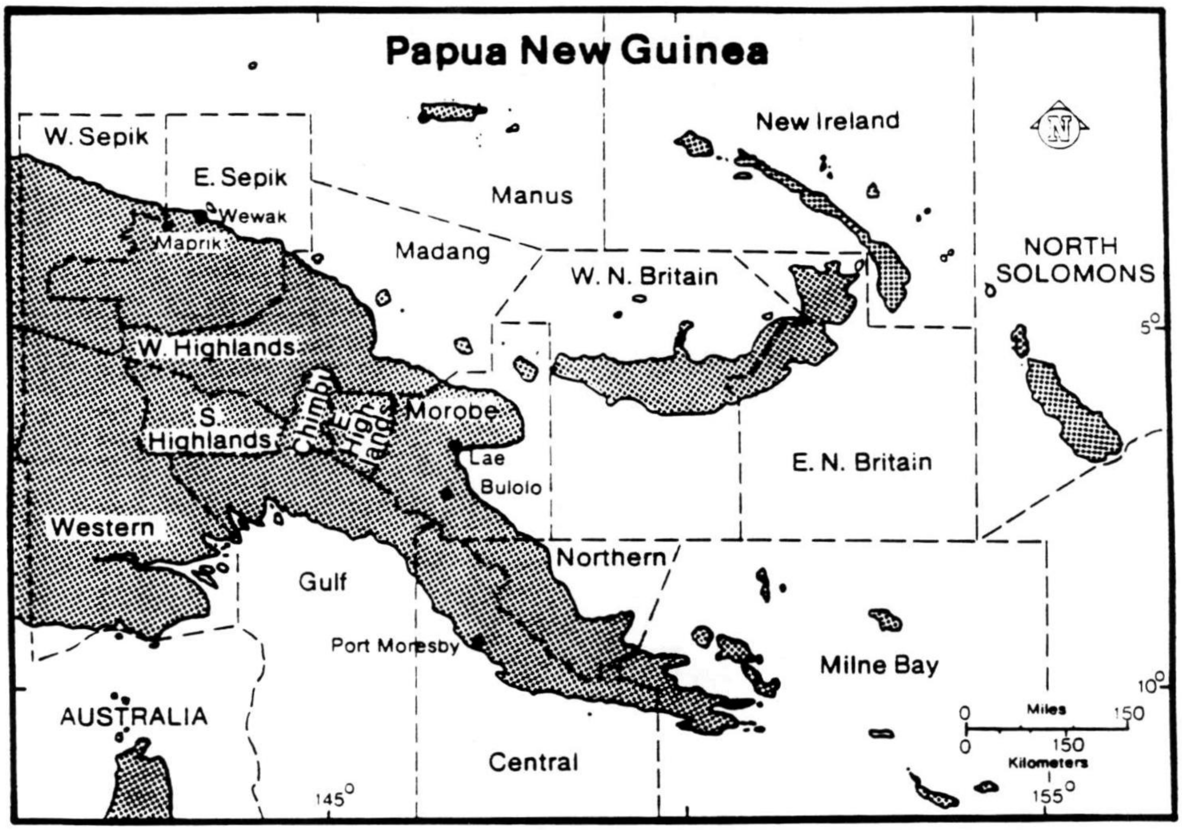


Figure 2. Location map of Bulolo.

and yellow latosols on stable crests and lower slopes, and gleyed pelosols on impervious sedimentary rocks.

The predominant vegetation are grass on hilly areas where fires are frequent, secondary regrowth on disturbed forest sites, natural forest stands, and man-made forest plantations. Climate records show only minor temperature variations. Mean maximum temperature readings of 23°C to 34°C and mean minimum readings of 20°C to 25°C are usual with daily fluctuations of about 7°C. Rainfall records for Bulolo show a mean annual of less than 1600 mm, which is considered dry compared to other parts of PNG with more than 4000 mm (Bleeker 1983).

Selection of Farmers

Farmers in the study were selected to represent the type of distribution of resources among the population. These include:

- Landowners farming their hilly lands (Farmers 1 and 2);
- A landless farmer permitted to farm through arrangements with the landowners (Farmer 4); and
- Settlers farming on customary tribal or government land (Farmers 3, 5, 6, 7, and 8).

Eight farmers were selected and their farming techniques, farm produce over time, labor inputs, and costs were monitored. The farms were further categorized into three farming systems:

- Traditional swidden or shifting cultivation system, where "slash and burn" is widely practiced and where sites are cultivated, then abandoned after the harvest of food crops, with no physical soil and site improvement practices (Farmers 3 and 4).
- Integrated agroforestry system, where much of the traditional food crops are cultivated with some site improvement practices such as compost making, soil erosion control, crop rotation, and planting of valuable tree species--mostly *Leucaena leucocephala* (Farmers 1, 2, and 8).
- *Taungya* agroforestry system where the farmers start with food crop cultivation, followed with tree plantings (Farmers 5, 6, and 7).

(See Figure 1 for farm site locations in each category.)

During the research, tree seedlings were distributed to farmers. The performance of the seedlings will be observed for the next 2 to 3 years before any conclusion is made.

Some farmers did not want to plant trees mainly because of their lack of secure landownership. They did not wish to plant trees that they thought would not benefit them. This situation requires much extension groundwork, possibly with the aid of demonstration plots, run and managed by government officers on government lands, or run by individual farmers on their customary lands. This would be a major undertaking if agroforestry is to be a success in Bulolo.

Garden sites had been selected based on many considerations (i.e., newly planted gardens where adequate information was to be gathered within the 12-month research period). Most gardens selected were relatively new (2 to 3 months old), with few at the ready-for-burning-off stage.

Almost all the garden sites were in well-drained secondary forest with few exceptions of regrowth (bush fallows) and grasslands. The forested areas cleared for gardens contained mixed species, including bamboo (Bambusa sp.), candlenut tree (Aleurites moluccana), women's tongue (Albizzia lebbek), Garuga floribunda, Glochidion concolor, Grewia crenata, Pipturus argenteus, Pisonia umbelliflorum, Rhus taitensis, Spondias dulcis, and Trema orientalis. The undergrowth was thick with Alpinia sp., Angiopteris opaca, Cyathea sp., Heliconia indica, and numerous vines and small shrubs.

Soil protective measures had been minimal in all of the farms studied. Unintentional practices of felling logs across the slopes or planting of food crops in rows across slopes minimized soil wash out. Forest clearings in patches with remaining forested areas were used as filtration zones and, to some extent, erosion control was the traditional management practice. Some food crops such as sweet potatoes, pumpkins, choko, and other cover crops were good minimizers of soil erosion.

Soil improvement measures such as tillage and adding ash and crop or weed leftovers were common. Use of expensive artificial fertilizer was not encouraged; the economics of the practice would probably be unfavorable. Pest control measures are not intentionally practiced but the Bianggai people occasionally build small spot fires to drive away insect pests with heat and smoke from their yams. The whole setup, polyculture and polyvarieties among the crop species, has a natural insect and pest repellent nature.

RESULTS

Description of Agroforestry Systems

Only the following three agroforestry systems were employed by the farmers in the study site: (1) swidden or slash-and-burn system (also known as traditional agroforestry), (2) the taungya system, and (3) the integrated agroforestry system.

Swidden System. The swidden system is the most prevalent of the three systems. The farmers cut either the primary forest or the fallow forest at the onset of the dry season (May to June), leave the biomass to dry in the sun, burn them about July, and plant the crops at the start of the rainy period (about August). After 2 to 4 years of cropping, soil fertility is either severely depleted or the noxious weeds take over the site and make further cultivation extremely difficult. The farmers then transfer to another site and leave the first area to fallow for about 20 years. After that period of fallow, the farmers say they can return to that site, repeat the slash-and-burn cycle, and expect similar productivity as the first cycle.

The farmers' activities in the swidden system follow a certain year-round pattern based on the seasons (Figure 3). Crops planted in the swidden farm are predominantly annual root crops (sweet potato, taro, yam, Chinese taro, cassava), pumpkin, choko, beans, maize, cucumber, onion, and watermelon. Other biannual or semiperennial crops, such as pawpaw, banana, Highlands pitpit, and betelnut are also planted (Figure 4). (See Appendix A for a list of food crops.)

The crop diversity pattern in a traditional swidden farm is usually intense, including other crops such as banana, sweet potato, and minor food crops. The pattern would also be a mozaic of irregular patches, which is normal in mixed cropping.

Taungya System. Under this system, the farmers occupy a previously cleared area and plant traditional food crops similar to

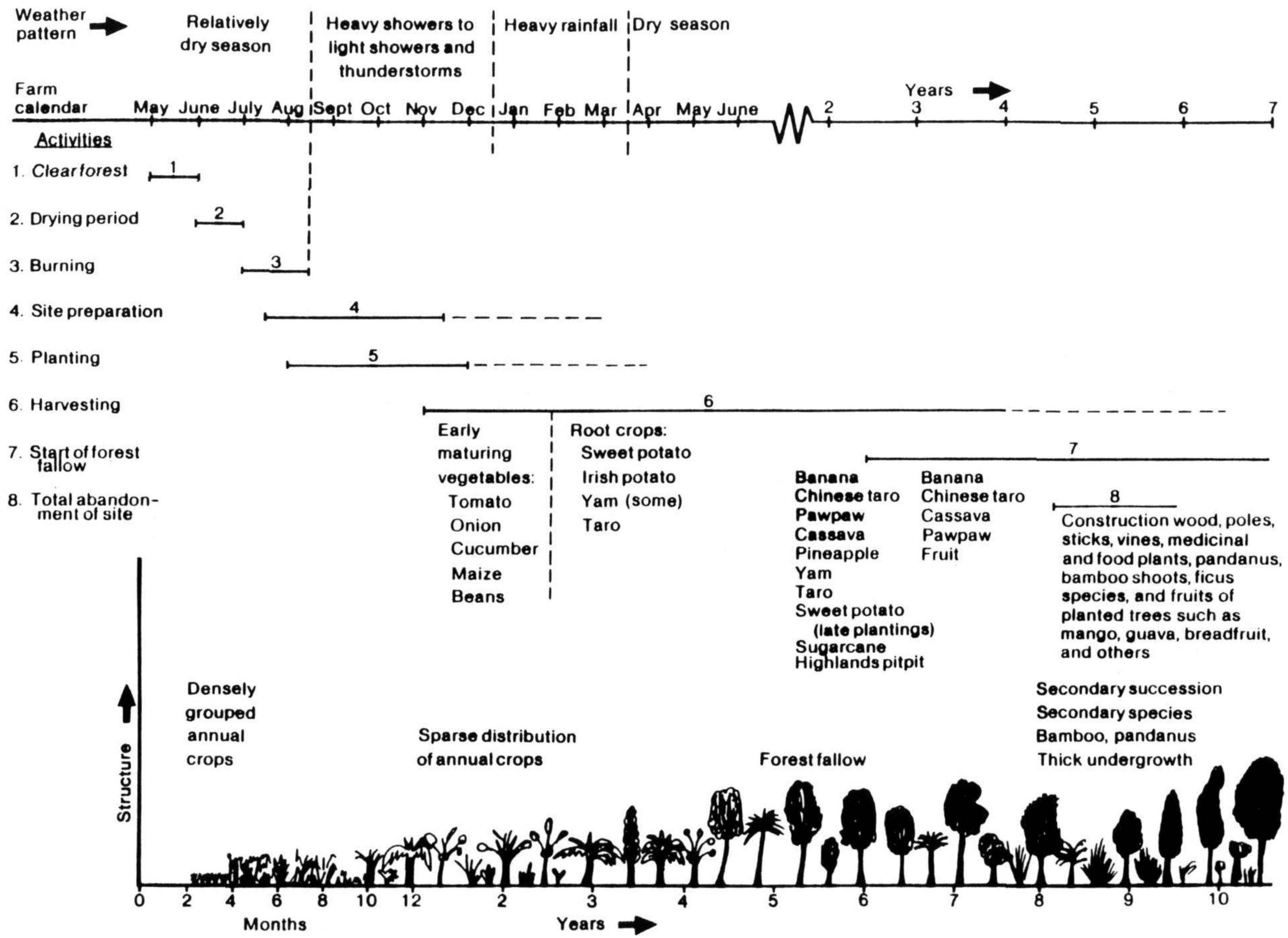
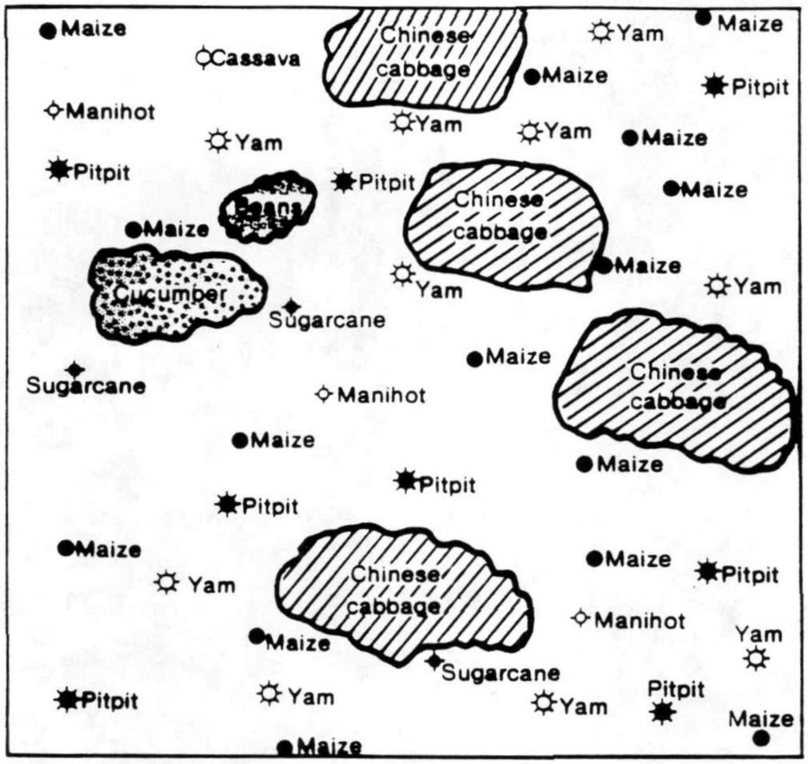


Figure 3. A calendar year of activities in swidden systems in relation to seasons and the successional transitions.



Crop density and diversity

Cucumber	6
Maize	15
Yam	11
Manihot	3
Sugarcane	2
Pitpit	8
Cassava	1
Long beans	1
Pawpaw	0
Chinese cabbage	abundant

Figure 4. Diagram of mixed-crop swidden. (Note: This diagram was based on Farmer no. 4's 2-month-old 0.0025 ha swidden in September 1985.)

those cultivated under the swidden system. Simultaneously, they plant government-provided tree seedlings at prescribed spacing. They are presently using 7 m x 4 m and 5 m x 4 m since the normal 4 m x 3.5 m spacing used in pure forest plantation establishments would be too close and not favorable for intercropping. These wider spacings allow farmers needing longer periods to grow their food crops and to maintain the trees planted.

The objective of taungya is to establish a forest plantation and a food farm at the same time on the same site, and for the farmers to leave the sites and move to another area in need of reforestation as soon as the tree crowns close and provide too much shade for undercropping. The expected time period would be up to 8 years as shown by a few sample garden sites near Bulolo. The government agency involved in this project is the Department of Forests, and the seedlings distributed to the farmers are the important timber-bearing species common to the area, such as Klinkii pine (Araucaria hunstenii), Hoop pine (A. cunninghamii), Pinus sp., Leucaena sp., Acacia sp., Eucalyptus sp., and other minor fruit trees of commercial value.

The multiple aims of this system are (1) to enable the farmers to produce their own food, (2) to ensure that there are woody perennials to serve as slope stabilizers and minimizers of erosion and revegetate the forest cover removed by the farmers, (3) to produce timber for local use or for local industries, and (4) to provide employment opportunities to local inhabitants in the Bulolo Valley.

The spatial arrangement of the taungya system (Figure 5) initially appears as a random mixture when the trees are planted between the food crops. When the trees grow larger, the alternate row patterns appear and the farmers use the spaces between the rows of trees for food cultivation until the crowns close. The cropping period is 4 years. It is expected that farmers would replant the areas after harvesting the root crops and would still maintain the harvest from banana, pawpaw, Chinese taro, and other fruits for the next 4 years. The small portion of forestland managed through the taungya system since September 1982 would be a good example for other farmers.

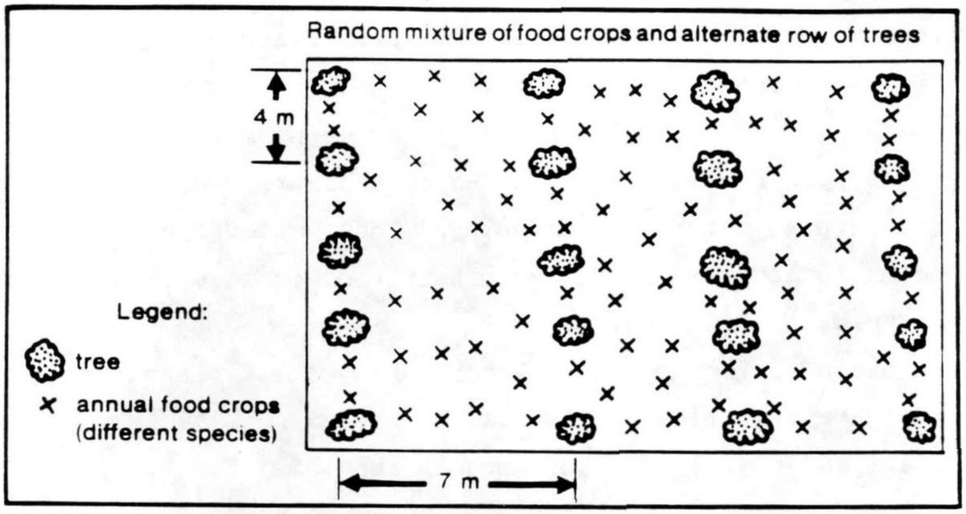


Figure 5. Spatial arrangement in a taungya swidden.

Integrated System. This system has been found among the landowners cultivating their own lands. In the initial stages, food crops are cultivated as in the swidden system, then the desired tree species (Leucaena and Casuarina oligodon) are planted among food crops. When most of the root crops are harvested, coffee seedlings are planted between the Leucaena rows and the areas are finally converted to coffee plots. Other perennial combinations in the integrated system are Leucaena/Cardamum, banana/bird's eye chili, banana/betelnut, coconut/coffee, and Casuarina/coffee. These combinations are common in Bulolo Valley. (See Table 1 for the different tree species found in the farming units studied to get an idea of how trees are related to the farms.)

Crop Interrelationship in the Farming Systems

In the three systems studied, crop interrelationship varied among the farmers because of the types of preferred food crops. The cropping arrangements were mixed plantings. Polycultures and polyvarieties were commonly practiced among the farmers (see Appendix B). Simultaneous plantings of all crops were carried out

Table 1. Record of fruit trees and other trees of value found in the farming units studied

Farmer no.	Fruit trees	Other valued trees	Comments
1	3	3	Landowner willing to plant trees
2	6	3	Landowner willing to plant trees
3	3	-	Gold miner with shorter fallow (2-3 years)
4	-	-	Refuses to plant trees; landownership problems; land under dispute
5	2	2	Government land; farmers given
6	2	2	tree seedlings to plant; field
7	-	4	performance of trees to be
8	5	3	determined in 2 years

Note: The number of trees shown in columns 2 and 3 refer to tree species and not to individual trees. Fruit trees planted around houses are also included apart from the trees and fruit trees found in the garden areas. (See Appendix A for a list of fruit trees.)

after the cleaned forest sites were burned, but the crop maturity dates were different (e.g., sweet potato matures at 6 months; banana, at 12 to 18 months, depending on the variety). Thus, there was continuity of production and harvest.

Among the newly established areas 2 to 4 months old, food crop composition and intensity per unit area were high. Even the farmers find it difficult to walk through the garden. The density is less in 5- to 8-month-old gardens where most of the leafy vegetables (Chinese cabbage, Amaranthus, beans, maize, and cucumber) have been harvested. The sites of 8-month-old gardens would be covered with dense masses of sweet potatoes and pumpkins, patches of taros and yams. Sugarcane, banana, Highlands pitpit, pawpaw, and cassava seem to form the top storied layers. In some cases, shade-tolerant species such as Chinese taro, Seratia palmaefolia, and choko thrive under the storied layers of bananas and pawpaw. Under extreme monoculture or semimonoculture farms, crops are seen in monoculture patches occupying certain

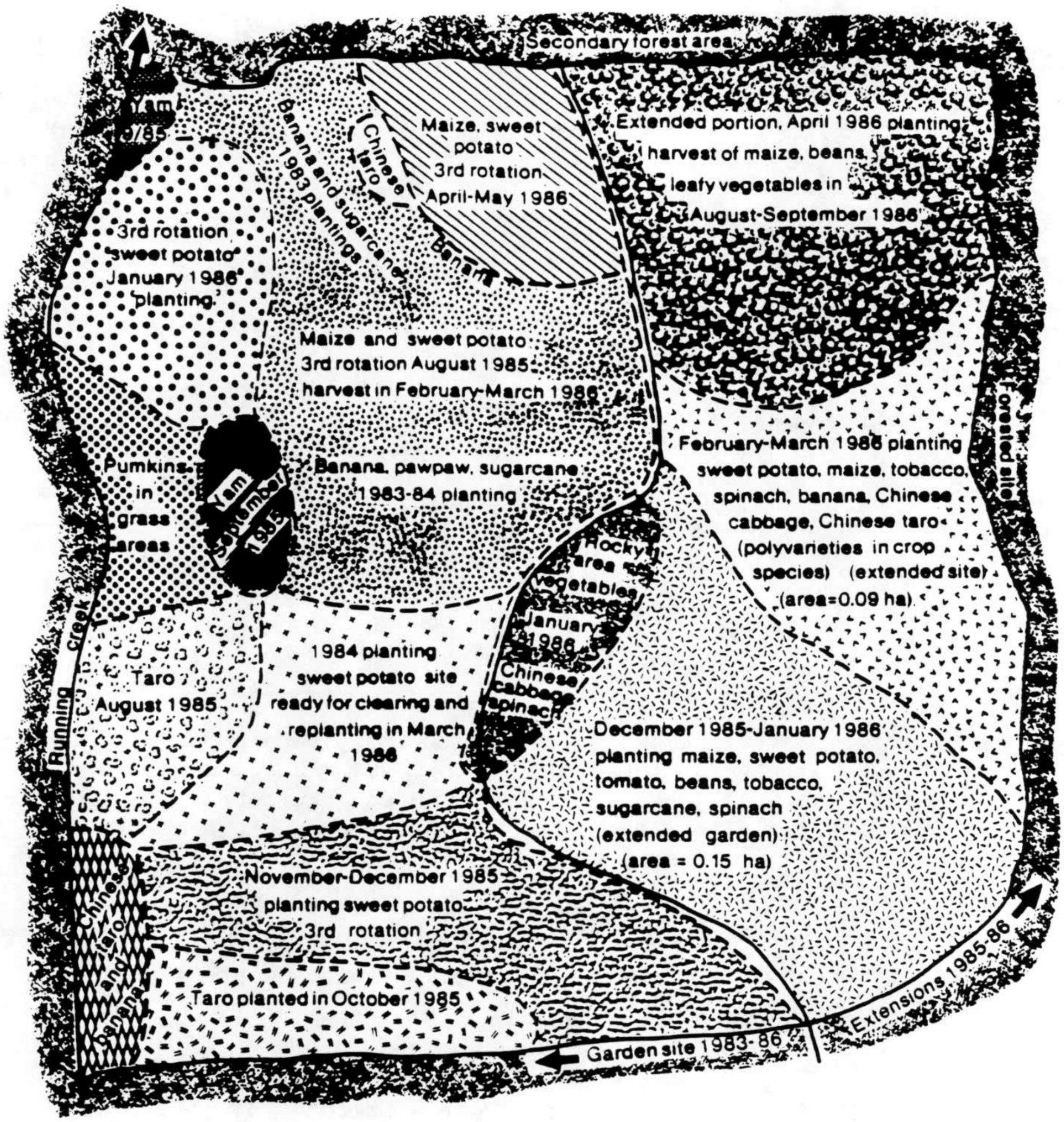


Figure 6. Crop dynamics, Farm no. 5 (not drawn to scale).

sections of the farm. A detailed layout of the crop dynamics is presented in Figure 6. Another presentation of food crop composition is shown in Table 2. Quadrats laid out in the fields were helpful indicators of the crop combinations in the farming areas studied.

The cropping patterns were almost identical for the three systems in the first 2 years. Variability was expected where tree components were involved or in areas invaded by weeds. The cropping areas were

Table 2. Food crops cultivated per 5 m x 5 m quadrat at Bulolo Valley, 1985-86

Garden age	1-3 months					4-7 months				8-12 months				12+ months		
Quadrat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Latin names (common names)																
Abelmoschus manihot (hibiscus spinach)			1				3	3							2	3
Amaranthus sp. (Amaranthus)		D					D	D								
Ananas comosus (pineapple)												1				
Brassica chinensis (Chinese cabbage)	D	D											D			
Colocasia esculenta (taro)					31		8	6		8			10		9	8
Capsicum frutescens (chili)								1								
Carica papaya (pawpaw)			2			3										
Citrullus lanatus (watermelon)		3	1													
Cucumis sativus (cucumber)	8		6	6					D	D						
Dioscorea alata (greater yam)		20	6	2			12	14	18						11	14
D. esculenta (lesser yam)		5	9	8			3	2	4							
Ipomoea batatas (sweet potato)	6M							2M		D	D	D			D	D
Lycopersicon esculentum (tomato)			1										6	36		
Manihot utilissima (cassava)				1							1	2				
Musa sp. (banana)	2														4	3
Saccharum edules (pitpit)	2		1	2	3		3M	3M	3M	4M					2M	1M
S. officinarum (sugarcane)	1	4		2		4	4M	6M	5M						4M	5M
Seratia palmaefolia (highlands pitpit)			5	9												
Vigna unguiculata var. sesquipedalis				1		3										
Xanthosoma sagittifolium (Chinese taro)						16	1			25						
Zea mays (maize)	11		15	15	6	2				13M						
Total number of individuals	31	36	47	46	40	28	35	38	31	52	2	3	16	1	33	35
Number of species	6	6	10	9	3	5	8	9	5	6	2	2	3	1	7	7

Notes: D = Dominant
M = Mounds (e.g., 3M = 3 Mounds)

either left to grow into forest fallow in swidden systems, or cleared and maintained at regular intervals and planted with root crops as long as possible in the taungya system. Harvesting from other perennial crops such as banana and pawpaw would continue, as would maintaining the forest trees planted.

Only a slight difference in food crop mixture was noticed. For example, when yam is cultivated by the Bianggai people (e.g., Farmer 1), no other crops except for a few gingers are planted between the yam mounds until the yam vines are climbing up the support poles, a period that takes as long as 3 months. The Bianggai people observe this, believing that competition from other crops would result in poor yam harvest. After that period, other food crops are allowed to be planted between the yam mounds. However, the Buang people, who also cultivate yam as a staple root crop, mix yam with other crops such as maize, *Amaranthus*, cucumber, beans, and Chinese cabbage without observing separation of cropping times between yam and other crops.

When bananas are harvested after 2 years, shading is reduced and farmers reintroduce root crops such as sweet potato and taro, or even maize and beans. In most instances, the old sites are partially maintained only for harvesting what is harvestable and for obtaining planting materials such as taro tubers or banana suckers for new cultivation. The total abandonment of garden sites is determined by a number of considerations:

- Decline in soil fertility shown by poor crop performance and noted by farmers who, through experience, can determine whether soil is fertile from crop harvests;
- Poor quality of crops planted in succeeding rotation; and soil appearances (e.g., emergence of rocks);
- Follow up of land use, such as forest fallows, integrated system, and taungya system as perceived by the farmers.

The longest time farmers had been cultivating the same portion of land under the study area was 3 years (1983-86). Although gardens were extended into adjacent areas, the older sites were replanted with sweet potato, maize, yam, and taro for the last 3 years with good harvests.

The crop interrelationships among the three systems were similar, at least during the first 3 years; therefore, a detailed separate description by system would not be necessary.

Estimates were made of areas occupied by individual crops. Sweet potato covered 0.72 ha; yam, 0.016 ha; taro, 0.045 ha; and Chinese taro, 0.033 ha. The mixed-cropping nature of the farm and its irregular crop arrangements made it difficult to estimate the areas occupied by each of the crops. Total area of this particular farm was 0.814 ha. The older site (1983-86) was 0.62 ha and the extended sites (1985-86) covered 0.194 ha.

Analysis of Productivity and Sustainability of Agroforestry Systems

Although all the food crops in the study area were planted simultaneously, there were variations in their maturity times. The leafy vegetables such as *Amaranthus*, Chinese cabbage, lettuce, pumpkin tips, and choko tips were ready for harvest within 2 to 3 months. The next lot of crops--beans, maize, cucumbers, rock melons, and watermelons--were ready after 3 to 5 months. Sweet potato was ready at 4 months, taro at 7 months, and yam at 6 to 12 months or more. Some crops needed a longer time for maturity (e.g., Chinese taro took 10 months; banana and pawpaw bore fruit after 1 year or more). The crop maturity times could be altered in unfavorable weather conditions, as in 1985-86, when the expected wet season from November to March turned out dry.

Farms studied were productive from 2 months to more than 4 years. Second and third rotations are usual for some crops (e.g., sweet potato planted in mounds left after harvesting yam and taro), while crops such as sugarcane, banana, and pawpaw are in the process of production (Figure 6). In older farms, 1-year-old bananas, combined with sugarcane and pawpaw, overcrowd the crops underneath. Only the shade-tolerant crops (e.g., Chinese taro, hibiscus spinach, *Seratia* palmaefloia, choko), pumpkin, and Highlands pitpit (Saccharum edules) continue to be productive.

The products of agroforestry systems are geared to meet the social, economic, and cultural needs of the farmers in their respective environmental settings. Household farming units not only produce crops to meet their domestic needs, but in many instances take extra harvests for distribution to relatives and friends as a social investment. The farmers can also sell their surplus harvest in local open markets, government-established markets (such as Niugini Produce marketing agents), and to institutions such as high schools and colleges. A higher demand for a particular crop encourages the farmer to produce more of that crop in succeeding plantings.

Although the sociocultural motives are not clear, it is common for farmers to compare their harvests in intervillage contests. In the 1985-86 yam season, a young Bianggai farmer was declared a champion grower of yam for growing the biggest and longest yam, which stimulated yam-growing in the area to some extent.

Most of Bulolo's agroforestry systems are year-round. If crops are raised in monoculture, they are seasonal. For example, yam cultivation starts in August/September, and the first harvest comes 6 months later (March/April). This is followed by other harvests in regular succession for up to 1 year, or even more, as in the yam varieties that take longer to mature. Without intercrops, the farmers would be unoccupied between seasonal yam-related activities.

When asked how their 1983-84 harvests fared compared to those of the latest planting season (September 1985 to August 1986), most farmers said they recall no difference in harvests. Nevertheless, respondents who said there was an increase in their sweet potato, yam, taro, and banana harvests were asked to validate their answers. Findings revealed that some gardens in 1985-86 were larger than those of 1983-84; thus, more food was produced. Another reason was the introduction of some additional root crops. Farmer no. 4 only had a crop of sweet potatoes in 1983-84; then in 1985-86, he had patches of taro and yam in the same garden. The farmer did not produce more sweet potatoes in 1985-86, but instead had taro and yam in his harvest. Farmer no. 5, on the other hand, extended his garden in

1985-86, and in the process produced much more than from his small garden in 1983-84. The farmer sold his produce at the local market and gave the extra harvest to his relatives and friends. (Production per farmer is presented in Table 3.)

Most of the farmers involved in the study produced food from their farms mainly to feed their households. About 70 percent of each of the crop species produced is meant for household consumption, 20 percent goes to the market, and 10 percent is reserved for planting stocks and for animal feed. The exception was Farmer no. 2 who was mostly growing vegetables for the Niugini Produce Market and only had a few taro planted in her farm for personal consumption.

Of the six most common staple food crops seen in the area, sweet potato, taro, and yam had the highest frequency in the farms studied. Maize, though common, was a short-term grain crop compared to the root crops. The production figures in Table 3 were calculated from the actual field measurements of the crop yields. Comparative quantity and the frequency of occurrence of crops in the farms could mean (1) farmers favor one crop over another; (2) farmers feel compelled to grow these crops to meet their household needs; or (3) farmers endeavor to produce extra food crops for sale to markets or for distribution to relatives and friends.

The major reasons some common food crops do not appear in Table 3 include poor soil fertility and crop performance. For example, Farmer no. 7 is unable to produce Chinese taro, banana, and maize because these crops are unsuitable for his farmland, which was formerly a degraded grassland.

Crop harvests were generally very frequent--a maximum of three times a week of between 10 and 15 kg for household use and more than 20 kg for the market during peak harvest periods.

The swidden farming system in the area appears to be a sustainable system in that it obviously produces sufficient crops to meet the present farming units' social, economic, and cultural needs. Though the production per unit area per unit time will gradually decline during each cycle, this system could be sustainable if the fallows are allowed over long periods, as indicated by the long-term viability of traditional swiddens in the area.

Table 3. Production record of common staple food crops, Bulolo Valley (1985-86)

Farmer no.	Family unit size	Farm area (ha)	Sweet potato		Taro		Yam species		Chinese taro		Banana species		Maize		Other crops		Total farmer/ ha/yr
			kg/farm	kg/ha	kg/farm	kg/ha	kg/farm	kg/ha	kg/farm	kg/ha	kg/farm	kg/ha	kg/farm	kg/ha	kg/farm	kg/ha	
1	6	0.097	20	206	20	206	40	412	--	--	--	--	15	155	25	258	1237
2	4	0.050	--	--	26	520	--	--							224	4480	5000
3	3	0.320	45	141	18	56	25	78	10	31	5	16	25	78	84	263	663
4	7	0.256	265	1035	120	469	150	586	--	--	--	--	15	59	56	217	2366
5	6	0.814	280	344	30	37	23	28	70	86	35	43	40	49	150	184	771
6	4	0.250	60	240	250	1000	150	600	200	800			45	180	90	360	3180
7	3	0.274	75	274	--	--	20	73							70	255	602
8	6	0.330	43	130	55	167	71	214	75	227	11	33	91	275	254	1073	2119

Note: 1 ha = 2.47 acres

Farm areas were calculated from field measurements. Areas of Farmers 1 and 2 were regarded too small for the normal size garden. The normal garden size is 0.188 ha (75 m x 25 m on flat areas).

The average farming household of six consumes 35 kg of food produced each week, or 1.6 to 1.8 t/yr. This quantity of food can easily be produced from the farms; but when farmers prefer food substitutes such as canned food and rice that they cannot produce, they need to sell their excess produce to buy these substitutes. The total food crop production per farmer per hectare per year in the area would easily meet the household requirements for 1 year. Farmers who do not produce enough could easily depend on food substitutes, which are either stored or bought from other farmers at the local markets. Most farmers have other out-of-farm employment and occupation, such as gold mining. Others are regular wage earners, self-employed, or owners of coffee plots from which they earn cash income.

Identification of Problems and Opportunities

Figure 7 and Table 4 both show that labor in farming was very intensive only during the peak periods and that during the off season farmers were engaged in other occupations. The farmers' behavior is based on several determinants.

- Farmers view gardening as a seasonal or "once-only" annual engagement, particularly during peak periods of planting and harvesting.
- The production is sufficient to feed the household; farmers do not necessarily spend extra time and effort to produce extra output.
- Most farmers have other out-of-farm occupations; therefore, they cannot afford to do much more farming than they do during the weekends.
- Other activities such as coffee picking and gold mining provide income that enable farmers to buy farm produce substitutes. Farmers therefore view these activities as important as farming and would spend equal time as they would do in farming.

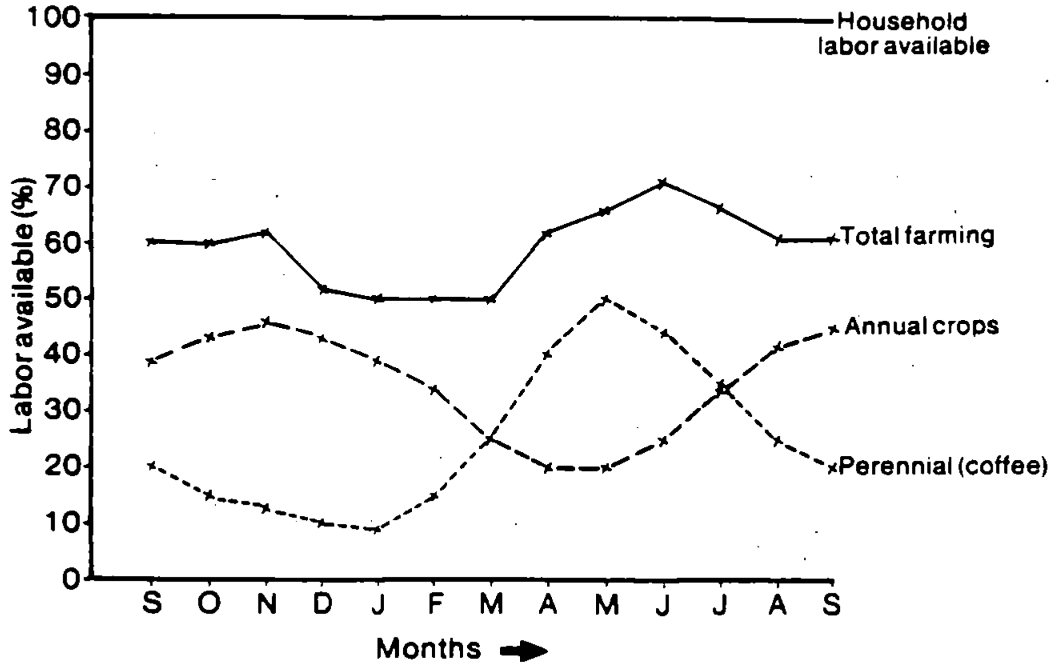


Figure 7. Household labor force distribution pattern in integrated agroforestry system (coffee and annual food crop production), September 1985 to August 1986, Bulolo.

- The social and economic status of farming households are low compared to other advanced groups such as gold miners, coffee growers, and regular wage earners. Most farmers will tend to spend time in activities where they could obtain higher incomes to boost the status of their households.
- Markets for the farm produce are such that farmers are not motivated to produce in larger quantities. Much of the farm produce sold at the local markets are from extra harvests that the household cannot consume at one time, or the need for money to purchase farm substitutes forces farmers to sell some of their produce.

Other environmental and social constraints play major roles in creating the present systems in Bulolo, and most of the farmers are conscious about them. They are identified as:

Table 4. Division by sexes in different farm activities

Activities performed	Average worker-day (WD)[1]		Total costs/WD[2]	
	Male	Female	US$	PNGK
Clearing forests[3]	5	5	39.20	35.00
Burning/site preparation	3	3	23.52	21.00
Planting annual crops	10	10	78.40	70.00
Planting perennials	5	2	27.44	24.50
Maintenance (weeding)	2	5	27.44	24.50
Harvesting annual crops	2	6	31.36	28.00
			227.36	203.00

[1]One WD = 8 hours of work

[2]Cost/WD calculated from the present rural rates of K35.00/fortnight, K17.50/week (exchange rate September 1985 to June 1986 PNG Kina = US$1.12).

[3]Average garden area = 0.188 ha (0.464 acres)

- Rising population pressures from an influx of rural people in search of employment into urban/semiurban areas of the Wau District. There is also an increase in the local population due to good medical care, improved diets, and social services in the communities, which have further increased the pressure on land available for gardening. Settlers who fail to obtain gainful employment situate gardens on whatever suitable site they find, mostly in lands that are either customarily owned or under government lease. Other people, such as the gold miners who have mining leases along the Bulolo River, need land to grow their food crops. Some regular wage earners at the Bulolo and Wau townships do gardening activities as a form of leisure or for "passing-weekends." Although most of these gardeners are illegally occupying the lands, evicting them would lead to social and political problems.
- Fast degradation of productive forested lands due to expansion of swidden farming practices and burning of grasslands and

forests. Burning of grassland is consciously done every year during dry periods to renew the grass, drive away insects, and clear the site for planting. This is a scene common in Wau, Bulolo, Mumeng, and Markham Valley.

- Traditional land tenure systems. About 97 percent of the land in Bulolo Valley, as well as other parts of PNG, is under the traditional or customary clan and tribal ownership. Therefore, land is a commodity difficult to obtain or lease to carry out any form of development project. In Bulolo, landowning tribes are a minority; most of the population are migrants. The illegal gardeners and settlers are tolerated by the customary landowners for fear that ejecting them would create social unrest. Local government agencies are somewhat powerless in resolving this squatting issue because of its strong political implications. Still, many landowners are not willing to lease their lands to the government for forestry development.
- Fund shortages faced by the Morobe Provincial Government. The entire workforce was laid off for 1 month to 6 months each year since 1978. Since most of the laid-off employees have lived in Bulolo-Wau for as long as 15 years, gardening was the only means of supporting their families during the lay-off period. Although gardening is prohibited in government leased lands, many workers were allowed to make gardens to avoid trouble.
- Mass lay-offs in the private sector. About 400 workers at PNG Forest Products, the local timber company, and another 200 employees of the Forestry Division have been placed on and off payrolls since 1980 due to funding problems. Since further employment opportunities are virtually nil, most have survived through farming activities and self-employment. Most of these workers come from other parts of PNG, such as East and West Sepik provinces, Madang Province, and the Highlands regions. Relocating these workers back to their provinces is financially and culturally difficult. With no employment opportunities, they engage in swidden farming.

The development opportunities available to the farmers based on the findings of this research, general observations, and understanding of existing constraints will be summed up under three major categories: (1) economic motives, (2) sociocultural influences, and (3) environmental effects.

Economic Motives. The farmers in Bulolo are normally not motivated to be productive beyond their subsistence needs. This is mainly because there are no consumers to absorb excess farm produce that may arise from more productive agroforestry systems. It would be easier for farmers to accept new techniques and methods of farming that could lead to low-level but sustainable yields rather than increased yields.

Marketability is another problem. The government market, which was supposed to purchase farm products directly from the farmers, has not come up to expectations. Farmer no. 2 complains that her good grade vegetables had been either downgraded or rejected by the government. Most farmers are unable to sell all their produce even at the local markets. They thus end up giving away for free their unsold products rather than carrying them back home over long distances.

Sociocultural Influences. Improved farming technologies such as mulching, making and adding composts, planting nitrogen-fixing trees, controlling soil erosion and sedimentation are readily available in Bulolo through various extension agencies. However, the farmers usually have a negative attitude toward these new systems partly because of a lack of economic rewards as discussed earlier. In other cases, a major limiting factor is the presence of customary taboos such as those prohibiting open discussions between male government extension workers and the women in households performing gardening chores. A probable remedy is to have female extension workers visit and explain new methodologies to the female farmers, while male extensionists do the same for the male farmers. Generally more consultative approaches are needed before new methods and crop species are introduced. This is to overcome the farmer's traditional reluctance to accept something new and untried. To solve illegal gardening and settlements, a compromise should be reached between the landowners and the settlers, bearing in mind that the settlers are there to stay no matter what the costs are. In this case, permissive occupancy may be allowed with the occupants paying land rental to the owners. This will establish a clear relationship between the landowners and the settlers, and also indicate the real ownership of the land.

Another option would be to establish corporations between landowners and settlers in joint projects, such as cattle raising, agroforestry farming, and reforestation projects, with the government's assistance in terms of technical advice and credit.

Environmental Influences. Most farmers are quite conscious about the changes taking place around them, such as expanding grasslands, loss of soil fertility, increasing land scarcity, worsening population pressures, and shortening forest fallow periods. Some farmers have tried to remedy the situation by making the planting of trees a part of their farming system, but more tasks need to be done. The government agroforestry institutions should carry out more awareness campaigns and organize farmers' visits to successful land rehabilitation projects and agroforestry farms with settings similar to the farmers' environment. Many farmers also need to be educated not to set fires on grasslands unnecessarily. They should be made responsible for damage inflicted upon the environment by enlisting them to rehabilitate grasslands or to plant trees in the garden sites before abandoning them.

Due to fast degradation of their farm sites, some farmers have been induced by the government to plant such trees as *Leucaena leucocephala*, *Acacia auriculiformis*, *Casuarina oligodon*, and *Pinus caribbaea*. They were informed that their continued production from and occupancy of the land will depend largely on how well they can plant these trees to minimize site degradation. The long-term impacts of this approach will be known in 2 to 3 years.

There is a greater need to institutionalize agroforestry planning and implementation involving the customary landowners and land users. This participatory step would be a breakthrough in advancing agroforestry development in the area. The present opportunity of planting tree species is mainly on an ad hoc basis and does not provide strong fundamentals of any agroforestry systems in the area.

ANALYSIS AND DISCUSSION OF RESULTS

Farm Sizes

The size of individual household gardens studied varied from 0.016 to 0.814 ha, whereas community or collective farms varied from 0.097 to 2 ha. The latter farms are large garden areas farmed by more than one household and are formed when farmers initially clear small pieces of forested lands to make food gardens, then gradually expand and extend into the adjacent forest to make the garden larger. This chain of events occurs if there are available adjacent forested lands to be cleared; otherwise, the farmers shift to new sites elsewhere. The cropping pattern on extended gardens forms a mozaic of patches of old crops, newly planted areas, and newly cleared forest areas all in one farming unit.

The number of cultivated species of crops decreases with the increasing age of gardens. The main staple food crops that usually remain are sweet potato, taro, yam, and banana. Dominance of one crop species over the others is explained by the farmers' favoring certain food crops as influenced or guided by market conditions. In some instances, the choice of crop species is affected by the ready availability of planting materials of a particular crop species.

Increasing length of the gardening period is usually accompanied by a succession of crops (e.g., from vegetables through root crops, bananas, papayas, sugarcane, and Highlands pitpit). Many cultivars, such as tubers and suckers in the old garden sites, are used as planting materials for new planting sites. Banana, sugarcane, Highlands pitpit, hibiscus spinach, cassava, and papaya are the dominant residual crops in 1-year-old gardens.

Despite the polyculture and polyvariety nature of cultivation in the three identified agroforestry systems, farmers commonly rearrange and segregate crop species but do not separate species varieties. For instance, taro patches were seen with 8 to 10 varieties of the species all planted together; the same goes for sweet potatoes, yams, and bananas. Biologically, such crop arrangements are advantageous, as they keep insect pests to a minimum. In fact, only the Bianggai people's traditional use of spot-fires to drive the insect pests with heat and smoke from their yam cultivation can be considered an exception to the use of polyculture as a pest-control measure in the study area.

Polycultural and polyvarietal cropping yields other ecological and economic advantages to the farmers. Crops mature and become harvestable from the same patch and garden sites at different ages so that there is a continuous stream of harvests. In addition, garden crops that yield tubers rather than fruits, even if matured, can be left unharvested till they are needed.

The succession of cultivars present in a 12-month period is presented in Table 2. The information was gathered from 16 established 5 m x 5 m quadrats, two per selected farm and located in representative portions of each of the gardens. These sample plots yielded little information on crop productivity and succession mainly because (1) the farmers favored certain crop species that were intensively cultivated, (2) the farmers were motivated by market forces, in which case shorter rotations of up to 3 months were used with similar crops, and (3) the quadrats had all been in the relatively new garden sites less than 12 months old.

Productivity of the Agroforestry Systems

Since all the farm sites studied were within close proximity of the household unit, not much time was wasted in walking; 10 minutes walking-time was the maximum. This meant that the farmer spent more time in actual farming activities. This did have some influence on the farm productivity per hectare per year but not in terms of yield per unit of labor input.

Division of labor by sexes was often necessary because of the various tasks performed. The male farmers' actual worker-days varied because most had out-of-farm occupations. The female records of farm activities per day were more consistent because farming was the main daily occupation of the women (Table 4).

Productivity records showed the produce of farmers per hectare per year to be generally stable and consistent throughout the 12-month study, September 1985 to August 1986. Long-term productivity changes could not be firmly established during the brief duration of this study, and farmers' recollection of past trends are not very reliable. Monitoring of the eight farms over at least 2 years would be desirable.

There were variations in levels of input, and therefore in output per person per year. Some household labor capabilities were overestimated (e.g., some children included as household labor had little or no contribution to farm activities since they were either in school or baby-sitting their young kin). Despite this, the levels of farm produce per hectare per year had been stable. This was based on an average household of six (two parents and four children), consuming 5.83 kg of farm produce/person/week.

Based on the foregoing, the total household consumption of food was estimated to be 1.82 t/yr. No accurate measurement was taken of the substitutes for farm produce, which amounted to 40 percent of the households' daily meals, as observed at the villages in the Wau-Bulolo areas. However, this observation on food patterns was also highlighted by a report (Thaman 1982) that excessive consumption of tinned and processed food has become a major problem in Pacific urban areas and is likewise becoming common in all community levels among the Pacific nations.

The household's daily needs were sufficiently met with farm produce. Yet, there was enough left for sale in the markets and for giving away to friends and relatives. Most of the farmers interviewed were quite satisfied with the level of production from their farms. However, there were unpredictable catastrophes such as prolonged dry seasons that inhibit crop productivity, cause farmers to harvest barely enough to maintain their family needs, and cause the local market prices to rise substantially.

In some cases, farm work forces were diverted to priority projects such as picking coffee, mining gold, and performing community activities. These diversions had little effect on the productivity of the agroforestry systems thus far because farming activities were continued by the women, especially in tending, weeding, and harvesting the food crops.

Economic Evaluation of the Farming Systems

Most of the farmers studied did not evaluate their production in financial terms. Their interests are defined by their households' social welfare (i.e., their farms' productive capacity in meeting their domestic needs). Needs are defined to include food and cash to buy food substitutes, tools, clothes, and to meet other expenses.

The noncash inputs or costs are of minor importance in the daily lives of the farmers. In most cases the costs are minimum and are expressed in terms of reciprocal activities, barter systems, and exchange of food produce for labor.

Cost-and-benefit evaluation is of higher priority in this research, however, in order to serve as a basis for policy decisions, recommendations, and suggestions to be made by planners and policymakers. The costs considered in the research were labor inputs, capital investments, rental payments, and material costs. Benefits included the annual food yields, cash income from produce sales, and, if duly monetized, the positive residuals such as soil erosion control, sedimentation prevention, wood and fuel production, nitrogen fixation through tree planting, and rehabilitation of degraded sites. These additional environmental benefits boost the ecological stability and continuity of the agroforestry systems' cycles.

Local inhabitants, however, prefer to hang on to their age-old swidden practices and view introduced agroforestry systems as a foreign concept. Yet, unconsciously, many farmers who originally started with food crop cultivation have shifted to mixed

Leucaena/coffee cropping, which was viewed differently by them from the integrated agroforestry that uses food crop and commercial forest tree combinations. The economics and the time factors involved are the main deciding elements in this strategy. Coffee provides returns in a short time and markets are readily available, whereas commercial forest trees have long rotations (35 to 40 years) and unstable markets.

Each activity, input or output, was physically measured, then monetized as costs or benefits per hectare per year. The research project under the three systems can thus be assessed as follows:

Swidden Agroforestry Systems

Costs: Wage rate: PNGK35/2 weeks, US$39.20
Exchange rate: PNGK1 = RS$1.12

	Activity and cost/ha/yr	
Site preparation	85.11 WD x US$3.92/d = US$333.63	
Planting food crops	106.38 WD x 3.92/d = 417.01	
Maintenance (weeding)	37.23 WD x 3.92/d = 145.94	
Harvesting food crops	42.55 WD x 3.92/d = 166.80	
Total cost/ha/yr		1,063.38
Land rentals K25/mo[1] (K300/yr)		336.00
Total cost/ha/yr		1,339.38

Benefits

Crop yield/ha (September 1985 to August 1986)

Sweet potato	1.68 ton x US$95 =	US$159.60
Taro species	1.10 ton x 80 =	88.00
Yam species	1.02 ton x 80 =	81.60
Chinese taro	0.755 ton x 75 =	56.63
Banana species	0.109 ton x 50 =	5.45
Maize	0.491 ton x 45 =	22.10
Other crops	2.24 ton x 50 =	112.00
	Livestock avg. K200/yr	224.00
	Others, trade store goods	500.00
Total revenue from farm produce/yr		1,249.38

[1]Suggested rental rate for squatters to establish squatter-owner relationship related to use of clan lands.

With a total cost of $1,399.38/ha/yr and a total revenue of only $1,249.38, the swidden farm appears to be a noneconomic undertaking. One possible reason for this evaluation is that the value of labor input is placed at US$3.92, the legal minimum daily wage for PNG rural workers, whereas the women and some of the men have few skills that can be offered to alternative employment and may therefore be worth less than the legal minimum wage. Using a daily wage of $3 instead of $3.92, for example, would make the farm economic.

Another possible reason for the swidden farm's "unprofitability" is the overestimation of the activities' worker-days per hectare where the children's labor input is tallied as those of the adults when, in reality, such input should be counted as lesser work-day input because of their lesser output.

The fortunate situation where Bulolo farmers can engage in gold panning during nonpeak farm periods and can earn an average of $2,420/yr is an added boost to the family income.

Taungya Agroforestry System

Costs: The costs are similar to the swidden system except with the addition of tree planting: 21.28 WD x US$3.92 = US$83.42.

Benefits: The benefits are the same for crop yields since the trees are too young (1-year old) to yield any product. Income from out-of-farm activities (wages) is US$1,962/yr.

Integrated Agroforestry System. Although additional income is derived from coffee yields and fodder production, the costs are still the same as those in swidden and taungya systems, minus the land rentals since the farmers use their own land. The average coffee production is 0.38 to 0.5 kg/tree/yr; a farmer with 100 coffee trees/ha would thus expect to get 38 to 50 kg dry weight of coffee per year. Expected average revenue would be K55 per year. Most of the farmer-owned coffee plots were small (0.023 to 0.09 ha), so estimates were made from field observations of the larger areas. Expected fodder production usually would be about 300 to 900 kg/ha green

Table 5. Costs and benefits for first year of operation

Value/ha/yr	Swidden	Taungya	Integrated AF
Input	$1,399.38	$1,482.80[a]	$1,146.80[b]
Output	1,249.38	1,249.38	1,249.38
Net revenue	(150.00)	(233.42)	102.58
Off-farm income	2,420.00	1,962.00	2,688.00

[a]With additional cost of tree planting

[b]With additional planting but minus land rentals

weight. Most landowners have gold minings from which they make an average income of K200 (US$224) per month.

Table 5 summarizes the costs and benefits of the three agroforestry systems for the first year of operation.

The net revenue of the swidden system is not expected to improve; it will probably worsen as the productivity of the site declines from the impacts of erosion. However, net revenue from the taungya and integrated systems will most likely improve over the years as the yield of perennial components becomes available. It is not possible to arrive at discounted values of future improved yields since those future yields cannot be accurately determined. Thus, comparison of net revenues is limited to first-year benefit/cost data without any discounting. The input and output of these study farms will continue to be monitored for future economic evaluation.

CONCLUSION

In general, the farms had been productive throughout the 12 months, but the sustainability of the existing swidden, taungya, and integrated agroforestry systems studied cannot be determined. There were indications of weakness in the systems, such as ecological instability, declining soil fertility, and environmental deterioration resulting from poor land management techniques.

Moreover, the farmers' leisurely work attitudes did not contribute much to improving the systems. The farmers were also dissatisfied because farm income alone would not support their needs and wants. Therefore, most of the farmers sought out-of-farm activities that gave them more returns than farming. This would not be so if the markets for farm produce were such that the farmers could earn enough to make a living out of farming alone.

Other associated and existing constraints that affected this research were the land tenure systems, the population pressures resulting from the entry of more people into the study areas, and the economic instabilities of Papua New Guinea as a whole.

Although land is abundant in Bulolo, current ownership problems may limit the development of agroforestry projects. Nevertheless, the agroforestry systems studied in the area had given the researcher enough knowledge to be able to recommend their adoption in development programs. The systems may not solve all existing land problems in the area, but they can be used as a tool by the policy- and decision-makers. The most promising among the widely practiced swidden agroforestry systems in Bulolo is the taungya system. Its acceptability and sustainability will have to be proven in the long run.

Strategies must be implemented for containing illegal farming on government leased lands by the laid-off workers. Either the government will let the workers go back to their paid jobs or let them continue to garden if their return to work is not possible. The latter option would necessitate that the gardens be semipermanent, using either taungya or integrated agroforestry as cropping systems. Farmers may be allowed to practice swidden cultivation on government lands as population densities increase and restorative fallows are shortened, despite its detrimental effects on the site.

APPENDICES

APPENDIX A

INVENTORY OF FOOD CROPS AND FRUIT TREES IN THE STUDY FARMS

Latin name	Common name	Occurrence in farms							
		1	2	3	4	5	6	7	8
FOOD CROPS									
Abelmoschus manihot	Hibiscus spinach (Aibica)	VA	A	A	A	VA	VA	R	VA
Allium cepa	Spring onion	A	VA	C	C	VA	VA	C	VA
Amaranthus hybridus	Spinach	A	A	VA	A	VA	VA	S	VA
Ananas comosus	Pineapple	S	S	S	R	R	R	C	S
Arachis hypogaea	Peanut/ground nut	A	A	VA	C	VA	C	VA	S
Brassica chinensis	Chinese cabbage	C	A	C	C	C	C	R	C
Capsicum frutescens	Bird's eye chili	R	S	R	R	C	R	R	C
Citrullus lanatus	Watermelon	C	R	C	C	S	S	R	C
Colocasia esculenta	Taro	C	A	S	S	C	VA	R	A
Cucumis melo	Rock melon	C	R	A	A	C	C	R	C
C. sativus	Cucumber	A	S	VA	VA	VA	VA	R	VA
Cucurbita pepo	Pumpkin	S	S	VA	VA	VA	VA	R	VA
Dioscorea alata	Greater yam	VA	R	C	R	R	R	R	A
D. esculenta	Lesser yam	A	C	C	C	S	S	S	A
D. rotundata	Guinea yam	A	R	R	R	R	R	R	R
D. trifida	Cush-cush yam	VA	R	C	R	R	R	R	A
Ipomoea batatas	Sweet potato	A	R	A	VA	VA	S	VA	VA
Lycopersicon esculentum	Tomato	C	A	A	C	A	A	R	A
Manihot utilissima	Cassava/tapioca	C	R	S	S	S	S	C	S
Musa sp.	Banana	R	R	R	S	C	C	R	VA
Passiflora edulis	Passion fruit	R	VA	R	R	R	R	R	R
Phaseolus aureus	Mung bean	C	C	R	R	R	R	R	C

Frequency of food crops:
- VA = very abundant
- A = abundant
- C = common
- S = scarce (only few seen)
- R = rare (could also mean none)

Appendix A (continued)

Latin name	Common name	Occurrence in farms							
		1	2	3	4	5	6	7	8
FOOD CROPS									
Phaseolus vulgaris	Green bean	C	C	A	A	A	A	R	A
Psophocarpus tetragonolobus	Winged bean	A	C	C	C	R	VA	R	VA
Saccharum edules	Pitpit	VA	C	VA	VA	VA	VA	C	VA
S. officinarum	Sugarcane	VA	C	VA	VA	VA	VA	C	VA
Seratia palmaefolia	Highlands pitpit	A	C	VA	VA	VA	VA	R	VA
Solanum tuberosum	Irish potato	A	A	S	C	R	R	R	S
Vigna sinensis	Cowpea	C	C	C	C	C	C	R	A
V. unguiculata var. sesquipedalis	Long bean	A	A	A	A	A	A	R	A
Xanthosoma sagittifolium	Chinese taro	R	R	R	R	A	A	R	A
Zea mays	Maize/corn	VA	A	VA	VA	VA	VA	C	VA
	Lettuce	C	C	R	R	R	R	R	R
	Choko	VA	VA	A	A	A	A	R	VA
	Silver beet	A	VA	R	R	R	R	R	R
	Pahchoi	R	A	R	R	R	R	R	R
	Broccoli	R	A	R	R	R	R	R	R

Frequency of food crops:
VA = very abundant
A = abundant
C = common
S = scarce (only few seen)
R = rare (could also mean none)

Appendix A (continued)

Latin name	Common name	Occurrence in farms							
		1	2	3	4	5	6	7	8
FRUIT TREES									
Annona muricata	Soursop	R	C	C	R	R	R	R	C
Areca catechu	Betel nut	A	VA	A	A	A	R	R	A
Artocarpus altilis	Breadfruit	C	C	R	R	R	R	R	A
Carica papaya	Pawpaw	C	A	C	A	A	A	R	A
Citrus aurantifolia	Lime	-	R	-	-	-	-	-	-
C. reticulata	Mandarin orange	A	VA	VA	C	-	-	-	C
C. sinensis	Sweet orange	VA	VA	VA	C	-	-	-	A
Cocos nucifera	Coconut	A	VA	VA	A	-	-	-	A
Cyphomandra betacea	Tree tomato	R	C	R	-	-	-	-	-
Mangifera indica	Mango	-	C	C	-	-	-	-	R
Persea americana	Avocado	C	A	A	-	-	-	-	C
Psidium guajava	Guava	R	R	R	-	-	-	-	R

Frequency of fruit trees:
VA = very abundant (more than 20)
A = abundant (10 to 20)
C = common (5 to 10)
R = rare (less than 5)

APPENDIX B

IDENTIFIED POLYVARIETIES AMONG POLYCULTURES

Latin name	Common name	Number of varieties	Distinguishable features
Abelmoschus manihot	Hibiscus spinach	4	Leaf shape, color
Amaranthus sp.	*Amaranthus*	2	Leaf color and growth
Ananas comosus	Pineapple	2	Leaf (prickly and smooth), taste, growth pattern
Arachis hypogaea	Peanut	2	Color of stalk and nuts
Brassica chinensis	Chinese cabbage	3	Color of leaves
Capsicum annuum	Pepper	1	
C. frutescens	Bird's eye chili	2	Size of fruits
Citrullus lanatus	Watermelon	2	Color and size of fruits, shape of leaves
Colocasia esculenta	Taro	10	Color of stalks and corn
Cucumis melo	Rock melon	1	
C. sativus	Cucumber	4	Shape, color of fruits
Cucurbita pepo	Pumpkin	4	Shape of leaf and fruits, taste
Dioscorea alata	Greater yam	5	Shape, color of leaf and vines, color of yam tubers, shapes and sizes
D. esculenta	Lesser yam	5	
D. rotundata	Guinea yam	4	
D. trifida	Cush-cush yam	2	
Ipomoea batatas	Sweet potato	6	Shape of leaves, color of vines, size, shape, and color of tubers, taste
Lycopersicon esculentum	Tomato	4	Shape of fruits
Manihot utilissima	Cassava/tapioca	2	Color of leaves and tubers, taste
Musa paradisiaca	Plantains	4	Color variations, growth patterns, size of fruits, taste
Musa sapientum	Banana	6	Color, growth patterns and maturity times, shape of fruits

Appendix B (continued)

Latin name	Common name	Number of varieties	Distinguishable features
Passiflora edulis	Passion fruit	2	Leaf color, fruit color, and coat variation
Phaseolus vulgaris	Green bean	1(?)	
Psophocarpus tetragonolobus	Winged bean	3	Color of leaf and stalks
Saccharum edules	Pitpit	3	Growth pattern, shape of inflorescence, color of stems
S. officinarum	Sugarcane	8	Color variation, growth pattern, taste
Seratia palmaefolia	Highlands pitpit	4	Color, shape, and size
Solanum tuberosum	Irish potato	2	Color of leaves and stalk
Vigna unguiculata var. sesquipedalis	Long bean	3	Color, size, and shape of bean pods
	Choko	2	Color of vines and fruits
Xanthosoma sagittifolium	Chinese taro	2	Color of leaves and stalk
Zea mays	Maize/corn	3	Color and size of cobs

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