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4

The Intercropping of Smallholder Coconuts in Western Samoa

An analysis using multi-stage linear programming

RJ Burgess

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ABSTRACT

The village agricultural sector of Western Samoa holds a key position in the country's economy, commanding the majority of the productive resources and providing a large proportion of export earnings. Present trends however show declining export earnings and an exodus of younger males from village agriculture into wage employment in Apia and through migration to New Zealand. Trends are seen to reflect declining returns per manday in traditional production systems. A modern systematic intercropping system is investigated as to its technical and economic feasibility as a means of providing rural family cash income requirements in competition with alternative sources.

The technical basis of intercropping is established prior to detailing individual crop yield, price and input parameters. Cash flows obtained were compared on returns to labour. To obtain an optimal combination of coconuts and intercrops from an economic standpoint, alternative programming techniques were considered and multi-stage linear programming adopted. This permitted adequate modelling of the intercropping system's inter-relationships and optimisation of the system over the life-cycle of the coconut stand.

The model maximised the present value of cash surpluses, which represented the return to labour. It allowed a portion of family labour to be allocated competitively between wage and on-farm employment. Financing of the cash deficits during perennial crop establishment was through loans or cash transfers.

Medium to high planting densities for coconut were optimal for the intercropping system adopted. Pineapple and cocoa were the dominant intercrops. An increasing portion of family labour in wage employment was drawn on for land resource increments above four hectares up to full utilisation at approximately eight hectares. Higher rates of time preference reduced the total area established. Cash surpluses above a basic family living requirement barely met the level obtainable in alternative employment in the first half of the coconut life cycle but were substantially higher thereafter. Attention needs to be directed to the present non-intercropping phase to improve the economic attractiveness of the system. Further analysis is required of shorter segments of the system to establish within-period cash flow financing requirements.

The intercropping system is regarded as capable of making a valuable contribution to rural family livelihood and of having a substantial impact on the overall economy.

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ACKNOWLEDGEMENTS

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To my family and wife Feaua'i, for endless encouragement, Fa'afetai tele lava.

R.J. Burgess

August 1977

Canberra

GLOSSARY OF TERMS

aiga	extended family
fono	in the village context, the council of titleholders who exercise authority in village affairs
matai	a title holder, and as such the head of an extended family
pule	the authority exercised by a titleholder over family members and family land
Talā	unit of Samoan currency for which the symbol adopted in the study is 'T'. Exchange rate T1.00 = N.Z.$1.25 (1971) 1 Talā = 100 sene

CHAPTER 1

INTRODUCTION

The economy of the Independent State of Western Samoa has evolved from something approaching pure self-subsistence in the pre-European era, to a position today where a degree of cash cropping has been added to subsistence garden agriculture as the basis for the majority of the country's export earnings.

While in the early post-World War II period, this cash cropping provided rural families with their cash needs, the earnings from coconuts, cocoa and bananas have in recent times been increasingly supplemented by cash from members of the family engaged in wage employment in the capital city of Apia and in New Zealand. The growth of these external cash resources has also been accompanied by an increase in demand by families for purchased food, permanent building materials and means of private transport. Earnings from coconuts, cocoa and bananas per manday have declined due to a combination of diseases, lowered soil fertility and aged stands in the case of the perennial crops. This has further encouraged the movement of labour away from the family land and into wage employment.

The macro-economic effects of the above situation are an increasing deficit on the trading account, with the major backstop for that deficit, and personal transfers from Samoans working in New Zealand being extremely susceptible to small changes in the economic and political balance in New Zealand.

In this context, the study is concerned with the need and the possibility, technically and economically, of effecting the conversion of a substantial proportion of the agricultural sector of Western Samoa to a viable commercial agriculture capable of providing rural families with incomes competitive with urban alternatives. With reference to the whole economy, the agricultural sector needs to be capable of providing expanding levels of export earnings, stable supplies of staple foods at reasonable prices and surpluses of produce suitable for the development of processing industries.

Potential to effect such a substantial commercialisation of smallholder agriculture is seen in the developments taking place, principally in South India and Sri Lanka, involving the systematic intercropping of coconut stands. In these countries, coconut intercropping has been researched along technical lines, but little work appears to have been done on the economics of the intercropping system.

In the following sections of this introductory chapter it is therefore proposed to consider in some detail the relevant resources and plans as they apply to the agricultural sector in Western Samoa, as background to considerations of the introduction of a systematic intercropping system under coconuts, and then to summarise those technical aspects of intercropping, and specifically of the intercropping system developed by the Central Plantation Crops Research Institute at Kasaragod in South India, which are essential considerations in the economic modelling of the system. The chapter will conclude with an outline of the study plan.

The Agricultural Sector in Western Samoa

The resources of land, labour and capital available to the agricultural sector in Western Samoa indicate the sector's potential and importance to the country's economy.

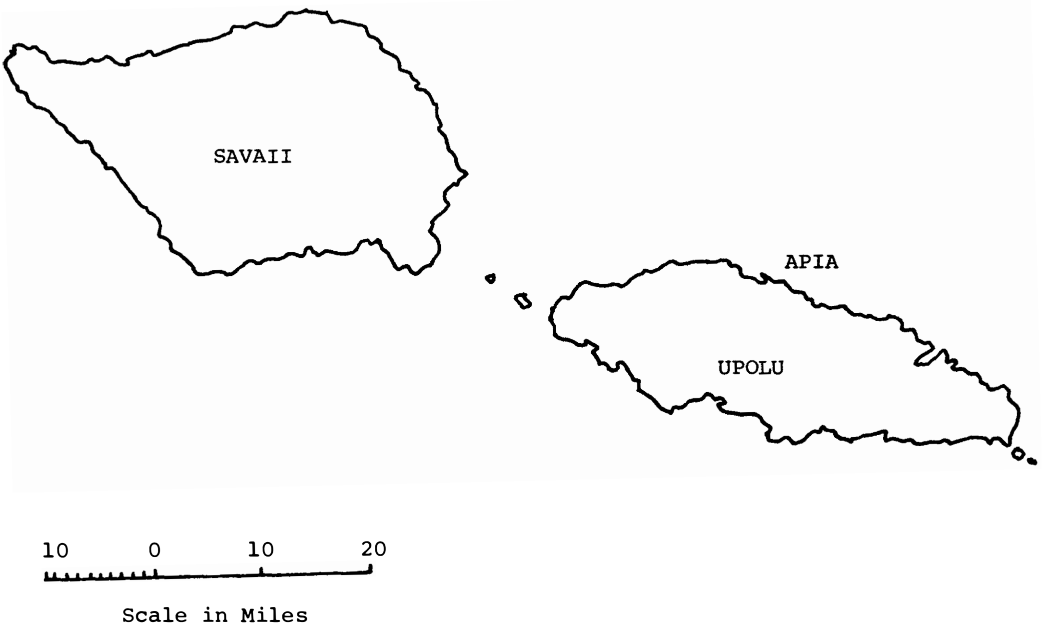
Western Samoa is located 14° south of the equator and between the longitudes 168° and 173° west. It is volcanic in origin and has most of its 2930 square kilometres concentrated in the two main islands of Upolu and Savaii (Figure 1.1). The volcanic rocks are mainly basalt dating from the Pliocene era through to historic eruptions in 1760 and 1905-6. The volcanic fissures have formed the west-north-west axes of the two main islands, rising to approximately 900 m in Upolu and 1800 m in Savaii. The climatic patterns combine with the different ages of parent rock to provide the main variations in soil types.

The climate is hot and wet. Temperatures vary little from the annual average of 26°C. Seasonal range is small and daily range averages 5.5C°. Change with altitude is such, that annual average temperature moves to 21°C on the tops of Upolu and 15°C on the tops of Savaii. Annual rainfall lies between 2000 mm and 5000 mm increasing from west to east and from north to south while in the main coconut areas the maximum is approximately 3800 mm. There is a marked increase in rainfall with altitude. Seasonal variation is more apparent in the lower rainfall areas with June, July and August being dry months.

Soils are classified from moderately high to very low subsoil nutrient status. Higher rainfall areas have greater weathering

FIGURE 1.1

MAP OF WESTERN SAMOA



and soils of lower nutrient status. Cropping soils on steeper slopes and alluvial soils maintain their nutrient status through soil movement but are only a small proportion of the area being cropped. The major cropping areas undergo normal depletion, and on such soils a bush fallow rotation varying from three to ten years is practised in the production of traditional food crops.

The proportion of the land being cultivated appears low (see Table 1.1) suggesting that there is no shortage of land to support an expanding population. This is tempered however by the lower fertility of much of the remaining forest areas and the need to maintain them for water conservation and climate control. Thus a case exists for advocating the intensification of present land use patterns based on the intercropping of coconut stands.

TABLE 1.1

LAND DISPOSITION IN HECTARES

	Village Land (Ha's)	Commercial Plantation (Ha's)	Planned Settle-ments (Ha's)	Urban (Ha's)	Other (Ha's)	Total Occupied (Ha's)	Forests and Lava Fields (Ha's)	Total Area (Ha's)
Upolu	27,530	8,890	420	1,915	750	30,505	72,300	111,805
Savaii	22,760	650			235	23,645	147,600	171,245
Western Samoa	50,290	9,540	420	1,915	985	63,150	219,900	283,050

Source: Farrell and Ward 1962, p.186.

Consideration of the agricultural sector's labour resources will indicate that employment potential in alternative areas is limited but that agriculture must be able to effectively compete with those alternatives to ensure a viable sector.

The population of Western Samoa was estimated at 151,630 in mid-1975. Population characteristics include a high though slowly declining birth rate, a low death rate, a high out-migration rate and a high dependancy ratio (see Table 1.2). Significant changes occurred during the 1966-1971 intercensal period. The proportion of the economically active population in agriculture declined from 71.6 per cent to 66.3 per cent. At the same time the total potential labour force increased by 14 per cent, the number of economically active increased 17 per cent and those in wage employment increased 32 per cent. In balance there was a slight reduction in the inactive portion of the labour force and a significant movement into wage employment. A comparison of age structure indicates that 66 per cent of those employed in wage employment were between 15 and 35 years while in village agriculture less than half were in that category. It is this group which makes up the bulk of those migrating to New Zealand, suggesting that the family head (matai), in allocating family labour, perceives the return from migration of family members to be presently greater than the return in agriculture.

Trends following the 1971 census suggest a continuation of the drain on labour out of agriculture. Wage employment has expanded with the impetus of a number of government infra-structure development projects and the establishment of a large forestry operation in Savaii. Data on recent out-migration is dramatic: levels have

TABLE 1.2

DEMOGRAPHIC VARIABLES: WESTERN SAMOA

(Rates per thousand of Population)

	Inter-Censal Periods		Estimates		
	1961-66	1966-71	1972	1973	1974
Crude Birth Rate	44.3	41.6	37.1	36.9	36.7
Crude Death Rate	8.2	6.5*	6.5	6.8	6.6
Natural Increase	36.1	35.1	30.6	30.1	30.1
Net Out-Migration	9.4	12.9	7.7	25.1	28.1
Population Growth	26.7	22.2	22.9	5.0	2.0

* Incomplete data makes apparent decline suspect.

Source: Western Samoa. Department of Economic Development, 1975, Table 1, p.17.

continued to increase, from 2950 in 1971 to 4240 in 1974. However, recent political developments have seen a severe cutback in out-migration possibilities, and have created considerable uncertainty in the ability of remittances to provide a reliable source of foreign exchange earnings for the country, and cash income for families. It is therefore clear that agriculture will have to remain the country's chief source of foreign exchange and employment.

The ability of the government to generate wage employment opportunities to substitute for present levels of out-migration is limited. Supply of capital is restricted, as are the opportunities to develop an industrial sector. Further, as the major potential for industrial development lies in the processing of agricultural products, the agricultural sector will be required to improve productivity and output to ensure the raw material supply for such a development. Finally the continuation of present trends into wage employment and out of agriculture will put considerable pressure on those remaining in the agricultural sector to meet the demands for food supplies by the non-agricultural sectors and the 53 per cent of the population which remain economically dependent. Thus the agricultural sector, while presently facing declining labour input, is presented with the challenge of leading economic development and providing employment opportunities competitive with other sectors of the economy.

Capital resources important to the development of a viable commercial agriculture include the infrastructural services of transport and market outlets, education, research and extension, as well as the supply of credit and purchased inputs.

Infrastructural resources servicing the agricultural sector have expanded considerably since Independence. Communications and marketing opportunities have expanded with the construction of roads, wharves and the operation of a vehicular inter-island ferry. Agricultural education received considerable impetus with the establishment of the Regional College of Tropical Agriculture in 1966. Diploma holders from the college now staff a number of technical and extension positions in the Department of Agriculture.

An important advance in the financial market was the establishment of the Development Bank of Western Samoa in 1974. The bank has offices in both Upolu and Savaii and lends to small-scale traditional agriculture to facilitate such developments as land clearing for food crops, outboard motors and fishing gear for village fishermen and small utility trucks for transporting produce to the Apia market. Much of its financing is short-term running finance to permit the use of purchased inputs.

The Agricultural Store Corporation is the most recent development providing a wide range of inputs for farmers. The government finances the store to allow many of the major inputs to be sold at subsidised prices, especially those lines, such as fertiliser and pesticides which increased sharply in price following the 1972 oil crisis.

In summary, the land resources available to agriculture are adequate, the capital and infrastructural services are developing, while the labour resource depends to a large extent on agriculture providing returns to labour inputs competitive with the other sectors of the economy.

An indication of the size of the agricultural sector is given by the areas cultivated. Precise information on areas planted to the major crops is limited. Estimates vary considerably. A Department of Agriculture estimate using coconut project planting records plus a pre-project area of 28,300 hectares comes to 65,000 hectares. The study of the Institut de Recherches pur les Huites de Palme et Oleagineaux (1975) investigating the development of hybrid coconuts puts the area at 60,700 hectares while the Third Five Year Development Plan (Western Samoa. Department of Economic Development 1975) uses a "harvested" area of 31,000 hectares (see Table 1.3). Table 1.3 builds, from average exports for 1972-74 of the major crops, estimates of local consumption and conservative

TABLE 1.3

THE MAJOR CROPS: AREAS, PRODUCTION AND YIELDS

Item	Coconuts	Cocoa	Bananas	Taro - Ta'amu
Average Exports 1972-74	83 m. nuts (16,000 tonnes)	1,660 tonnes	2 m. kg	2 m. kg
Consumption Per Capita	365 nuts	small	136 kg	166 kg
Total Consumption	55 m. nuts	140 tonnes	20 m. kg	25 m. kg
Aggregate Production	138 m. nuts	1,800 tonnes	22 m. kg	27 m. kg
Harvested Area	31,000 ha	4,900 ha	1,300 ha	2,000 ha
Yield per Hectare	4,450 nuts	367 kg	17 tonnes	14 tonnes

Source: Western Samoa. Department of Economic Development 1975, p.121.

harvested areas to indicate the order of average yields. The overall picture is one of low yields and low returns to the farmer's management and labour.

The performance of the agricultural sector is investigated briefly from the viewpoints of 'share in Gross Domestic Product' and of 'the proportion of the national food requirements supplied'.

In evaluating the share of agriculture in Gross Domestic Product in Western Samoa one is confronted with the difficulty of how to include the subsistence component of output. A study of gross domestic product for 1952, 1958 and 1970 including only the export output of agriculture is summarised in Table 1.4. The major slump in the agricultural share from 35 per cent to 16 per cent during 1958 to 1970 represents a combination of increased local consumption, declining productivity from old stands of perennial crops, reduced fertility of the soil in many growing areas and major diseases in banana and copra production.

Food production and consumption data are needed in order to consider the locally utilised component of agricultural output. A summary of local sales of agricultural produce made by Fairbairn (1973) covers the range of cash sales of food items (see Table 1.5). A steady rate of expansion is indicated. Enright (1976) investigating the Apia market located at Savalalo found that the numbers of sellers, based on license receipts had increased by 134 per cent over the period 1968 to 1975. In addition to food transacted through the market and some commercial outlets, supplies include imports and subsistence food output. Table 1.6 giving imports of commodities for

1970 and 1973 indicates that food and agricultural produce imports were between 30 and 33 per cent of total imports, costing in 1971 some T2,730,000.

TABLE 1.4

GROSS DOMESTIC PRODUCT FOR WESTERN SAMOA - SELECTED YEARS AT CONSTANT PRICES (BASE YEAR: 1952) ('000 Tālā)

Sector	1952		1958		1970		Annual Growth (%)	
	T	%	T	%	T	%	1952-58	1958-70
Agriculture	2121	34	2779	35	1552	16	5	-6
Manufacturing	86	2	59	1	351	4	-5	16
Commercial Services	3147	51	3934	50	4905	53	4	2
Tourism	0	0	0	0	141	2	-	-
Government	565	9	891	11	1799	19	10	6
Missions	241	4	284	3	599	6	3	6
Total	6160	100	7947	100	9347	100	4.8	1.3

Source: Fairbairn 1973, p.154, using a conversion rate of T1 = NZ$1.16.

TABLE 1.5

LOCAL SALES OF AGRICULTURAL PRODUCE ('000 Tālā)

Sector	1952	1958	1970
Local Consumers	305.2	395.4	497.0
Government	31.4	39.0	42.0
Total	336.6	434.4	539.0

Source: Fairbairn 1973.

TABLE 1.6

IMPORTS BY COMMODITY GROUPS

('000 Tālā)

Standard International Group Classification	1970		1971		1972		1973	
	T	%	T	%	T	%	T	%
0 Food and Live Animals	2438	25	2709	28	3504	27	3969	27
1 Beverages/Tobacco	437	5	529	5	694	5	868	6
2 Crude Materials	124	1	140	2	183	1	116	1
3 Fuels Lubricants	371	4	398	4	450	4	700	5
4 Fats and Oils	22	0	21	0	15	0	32	0
5 Chemicals	567	6	557	6	758	6	738	5
6 Manufactured Goods	2464	25	2498	26	2990	23	3214	22
7 Machinery/Equipment	2488	25	1834	19	3301	25	3253	23
8 Misc. Manufactures	880	9	925	10	1151	9	1544	11
9 Other	-	-	3	0	1	0	-	-
Total Imports	9791	100	9614	100	13,047	100	14,434	100

Source: Western Samoa. Department of Economic Development 1975, Appendix Table 14.

A valuation of village subsistence food production for 1970 by Fairbairn (1973) is T7,390,000 indicating that it is still the major source of the country's food supply.

In total however, the declining levels of agricultural exports, the substantial imports of food items and the requirements of agricultural raw material for industrial expansion, provide a major challenge to policy makers and the agricultural sector in the decade ahead.

The Western Samoa Third Five Year Development Plan sets out the need for economic growth in the context of the observed aspirations of the population for a range of consumer goods, together with government aims to increase welfare through improved availability of such public services as health and education.

Using a 15-20 year perspective for the agricultural sector, the plan looks to a five-fold increase in the output of the major perennial crops, coconut and cocoa, with moderate gains in a variety of other crops for processing and/or exporting, realised through measures which will permit full participation by village agriculture in improved productivity.

With regard to the participation of village agriculture, the plan notes that there is no single method available for inducing higher output but suggests that the universal desire for enhancing family and village prestige, prosperity and security is likely to be the source of motivation and that plans should be formulated from this perspective. Thus plans for development are expected to depend on, and to strengthen, the traditional source of authority, the matai and the village fono.

Thus while present performance of the agricultural sector has not made agriculture the 'leading edge' of development in the past, the expressed aspirations of the government as indicated in the Third Five Year Development Plan, together with the country's available resource base, suggest that it should and could be, given the availability of suitably adapted technology and production systems together with their effective extension. In the next section consideration is given to intercropping as one production system fulfilling these needs.

Intercropping

Having established the context in which intercropping might be considered as an important strategy in the development of the village rural sector, it is now necessary to examine intercropping itself. Firstly, intercropping as presently practised in Western Samoa is looked at, and its potential is considered, on the basis of agricultural regions.[1] This leads to a discussion of the importance of the technical and agronomic aspects of intercropping and how they will impinge on an economic analysis, thus establishing the need for a detailed consideration of the agronomic technology of individual crops. The section is completed by then examining modern intercropping as an agronomic system with particular emphasis on those technical aspects which will influence the economic analysis.

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1 Agricultural 'region' is adopted from Ward (1962). While this term is usually used for political entities, it is used here to define areas analysed on the basis of physical, social and economic factors, as opposed to the use of 'zone' in the context of climate and village cropping areas.

Traditional Intercropping

Intercropping in Western Samoa, while appearing to the casual observer to be commonly practised, has received little formal attention.

Of the studies of agriculture in Western Samoa, that which analyses the degree of intercropping in some detail is the survey done in 1955-56 and reported by Farrell and Ward (1962). The common patterns of village agriculture are described, based on surveys in twenty Samoan villages in the non-urban areas of the country. Three typical zones were defined on the basis of land use. The coconut zone lies immediately behind the coastal village dwelling area and is the most extensive, occupying on average some 55-60 per cent of village land. Densities of palms are noted to vary significantly, with over 250 per hectare common due to volunteer palms. Even in 1956 the age of many stands was described as 40-60 years and well past peak production. Pure stands accounted for 45 per cent of the coconut zone, while 30 per cent was interplanted with one crop, usually cocoa or bananas, and 10 per cent with two crops. Fertility of many soils in the coconut zone was said to be an important constraint on successful intercropping without fertiliser. Inland the coconut zone gives way to the mixed-crop zone. Here cocoa, bananas, taro and other minor crops are produced on irregular plots interspersed with patches of scrub, grass and creepers. The introduction of cocoa and the Cavendish banana as cash crops has reduced the food producing role of this zone. Traditional bush fallow is severely reduced and the cover is more commonly by creepers such as 'mile-a-minute' (Mikamia micrantha). Some 34 per cent of the mixed-crop zone was reported under cocoa of which only

6 per cent was in pure stands. The rest is intercultivated with bananas, coconut and taro. Intercropping is not practised in the taro zone which lies between the mixed-crop zone and the inland forests. Taro (Colocasia) is produced on small plots recently cleared from forest or bush fallow on a rotation which may run between 3 and 10 years, depending on land reserves and soil fertility. Farrell and Ward (1962) have quantified the degree of intercropping over village cropland as a whole by means of a coefficient of intercultivation (C.I.)[2]. The crops considered were coconut, cocoa and bananas. The average values were 21 for Upolu villages and 23 for Savaii villages (see Table 1.7). The range was from 4 to 40 compared with 49 for the planned settlement area at Tanumalala. Here on poor soils with no bush fallow, higher production was obtained through careful weeding, spacing and provision of shade. This suggests that the potential for improved methods of intercropping may be considerable.

More recent surveys pay little attention to the extent or importance of intercropping. Lockwood (1971) showed land use for three of his four villages to be monocropped, while the fourth had approximately 4 per cent of land with coconuts and cocoa intercropping. In his description mention was made of some areas of food crops under coconuts in two other villages. The 'Survey of Household Living Conditions' conducted by the Department of Statistics (1972) gave

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2 Coefficient of Intercultivation:

$$CI = \frac{100(X_2 + 2X_3 + 3X_4 + \ldots)}{Y(N-1)}$$

where X_2 is the area in two crops, X_3 is the area in three crops etc, Y is total crop area, N is number of individual crops, taken as constant to allow inter-village comparison. The CI is zero for all land under monocropping and is 100 for all three crops completely intercultivated.

TABLE 1.7

LAND UTILISATION IN SAMOAN VILLAGES

Village	Occupied Village Land in Acres*	Cropland in Acres†	Cropland as a Percentage of Occupied Land	Population 1956	Occupied Land per capita in Acres	Cropland per capita in Acres	Coefficient of Intercultivation
Amaile	942	582	62	284	3.3	2.0	22
Satalo	1042	681	65	234	4.5	2.9	7
Siuniu	451	334	74	89	5.1	3.8	9
Sa'anapu	1180	1005	85	633	1.9	1.6	32
Samatau	901	631	70	666	1.4	1.0	16
Tufulele	414	310	75	414	1.0	0.8	10
Fusi (Saluafata)	366	325	89	254	1.4	1.3	35
Falevao	623	466	75	280	2.2	1.7	36
Salimu	188	137	73	76	2.5	1.8	16
Uafato	240	206	86	186	1.3	1.1	25
Upolu: 10 Sample Villages	6347	4677	74	3116	2.0	1.5	21
Asaga	698	433	62	166	4.2	2.6	4
Safotulafai[1]	1292	1104	85	248	5.2	4.5	20
Satufia	691	547	79	313	2.2	1.8	30
Taga	624	427	68	386	1.6	1.1	27
Vaipua	270	254	94	258	1.1	1.0	26
Falealupo[2]	1297	1132	89	712	1.8	1.6	40
Vaisala	571	492	86	392	1.5	1.3	17
Matavai	240	235	98	146	1.7	1.6	10
Sato'alepai	1441	759	53	345	4.2	2.2	29
Savaii: 9 Sample Villages	7124	5383	76	2966	2.4	1.8	23
Western Samoa: 19 Sample Villages	13,471	10,060	75	6082	2.2	1.7	22

1 Subvillages of Fusi and Fuifata only.
2 Subvillages of Vaotupua and Avata only.
* That part of the land that has been cleared. This does not include forest.
† That part of the cleared land actually in crops.

Source: Farrell and Ward 1962, p.187.

no recognition to interplanting in its land use analysis. The Village Benchmark Survey conducted by the Department of Agriculture in 1976 obtained data on crop areas and outputs. There is insufficient data however to derive an indication of the degree of intercropping except for the urban village of Fagalii. Individual crop areas were 113 per cent of the total crop area, which, given that 32 per cent of the crop area is in coconuts, does not appear to be a high level of intercropping. Three of the other five villages surveyed are reported however as having cattle grazing under coconuts.

It is difficult to draw any conclusions on present intercropping practice in Western Samoa from the information available. However, given the relatively stable nature of village agriculture, it would seem reasonable to use the observations of Farrell and Ward and to conclude that while some intercropping is presently undertaken in the coconut zone, there is no formal pattern and the potential for expansion of intercropping would appear to be considerable.

Reynolds (1977) listed a number of advantages favouring intercropping in the coconut zone. Much of the main coconut areas lies between 0-305 m on land of easy contour and moderate-to-good fertility. Being adjacent to the village dwelling area, the coconut zone requires much less walking time by farmers than that involved for crops in the mixed and taro zones. In much of the coconut area a circular pattern of declining yield with age has reduced labour returns from copra, and hence labour inputs, with the resulting overgrown stands declining further in output and being more difficult to harvest. Thus intercropping would benefit the farmer indirectly through improvements in coconut production resulting from the husbandry of the intercrop, as well as directly from income from the intercrop itself.

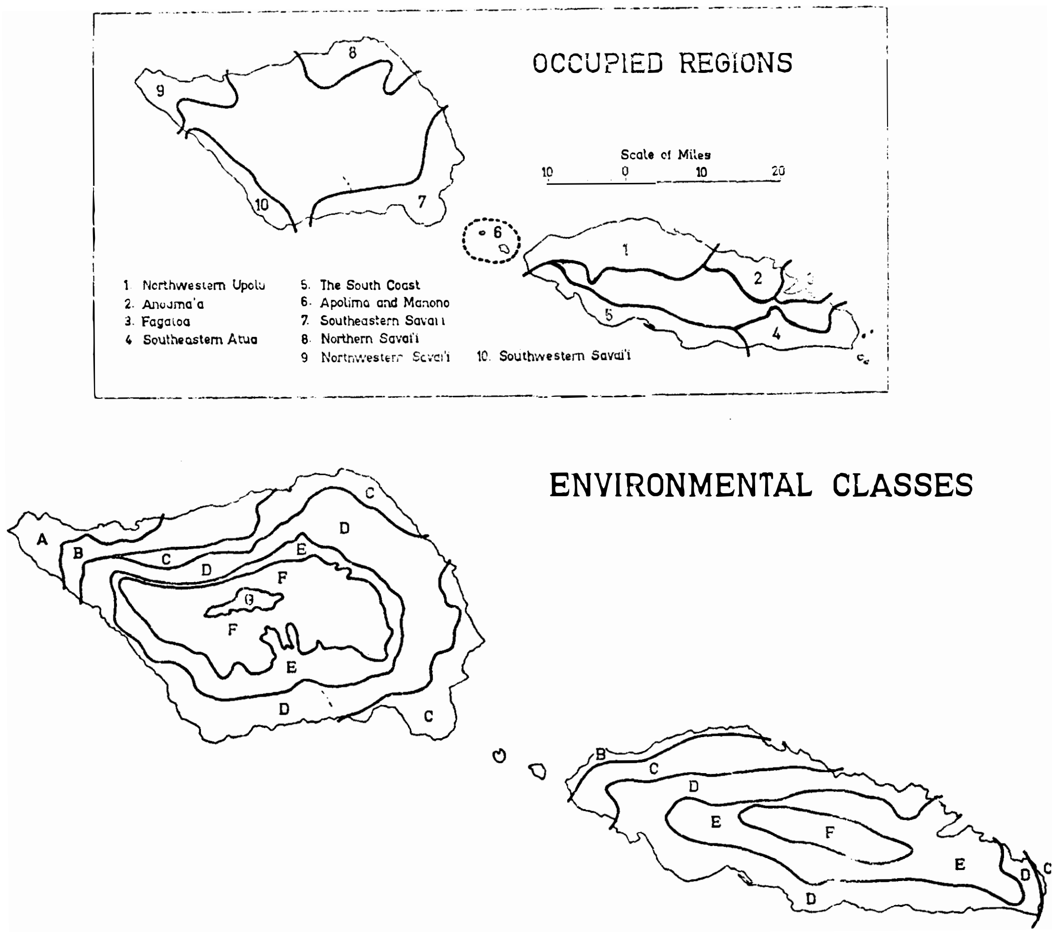
A detailed consideration of intercropping potential can be made using the regional analysis of Ward (1962). Ten regions (see Figure 1.2) were defined from an amalgam of physical and social factors of which rainfall, soils, cropland per capita and their interaction were the main factors used. These same factors have important influences on intercropping itself. For example the rocky soils limit potential intercrops to those not requiring cultivation. High rainfall areas are unsuited to cocoa production until more black-pod resistant strains are available, while at the other extreme coconut establishment is difficult in areas subject to drought, though present cocoa losses from leaf fall point to possible benefits from shading the cocoa with coconut. Low cropland per capita is seen as providing an incentive to intensify by intercropping. These factors are described in more detail by region in Appendix E and are summarised in Table 1.8.

Having examined the need, the potential, and the existing pattern of intercropping in Western Samoa, it is now possible to move on to establishing the technical basis for the economic analysis of modern intercropping systems.

The interplanting of crops results in a complex biological system, with many competitive relationships involving the resources of light, water, nutrients and space. The system is further

FIGURE 1.2

AGRICULTURAL REGIONS IN WESTERN SAMOA
IN RELATION TO ENVIRONMENTAL CLASSES



LOWLAND
(Mean annual temperature 78° F.)

A MODERATE TO STRONG DRY SEASON
3 months very dry
4-6 months moderately dry
Mean annual rainfall 85-90 inches

B MODERATE DRY SEASON
2 months very dry
3-4 months moderately dry
Mean annual rainfall 90-100 inches

LOWLAND AND FOOTHILL
(Mean annual temperature 78°-71°F.)

C. WEAK DRY SEASON
1 month very dry
3 months moderately dry
Mean annual rainfall 100-130 inches

D VERY WEAK DRY SEASON
No very dry months
1-2 months moderately dry
Mean annual rainfall 130-175 inches

E NO DRY SEASON
Mean annual rainfall 130-175 inches

UPLAND
(Mean annual temperature 71°-67° F.)

F. NO DRY SEASON
Mean annual rainfall 175-200 inches

HIGHLAND
(Mean annual temperature 66°-60° F.)

G. NO DRY SEASON
Mean annual rainfall c. 200 inches

Source: Fox and Cumberland 1962, p.85, p.293.

TABLE 1.8

AGRICULTURAL REGIONS AND INTERCROPPING POTENTIAL

	Region	Environmental Class[1]	Soil Fertility	Cropland (Ha) per Capital	Crops Grown[2]	Intercropping Potential[3]
1	N.W. Upolu	B/C	Moderate/High	0.4	Coconut, Cocoa, Taro Bananas (Pineapple)	High
2	Anoama'a	D	Moderate, pockets of deep soil	0.53	Coconuts, Taro Bananas (Resistant Cocoa, Pineapple)	High
3	S.E. Atua	D	Low, deep stone-free soils	1.0	Coconuts, Bananas (Cattle)	Low
5	South Coast Upolu	D	Moderate-Mod./Low deep soils	0.65-1.2	Coconut/Cocoa- Coconut/Taro (Cattle)	Medium
7	S.E. Savaii	C/D	Moderate, stony	1.6-2.0	Coconut, Banana Taro (Cattle)	Low
8	N. Savaii	C/D	Moderate, stony some boulders	1.0	Coconut, Cocoa, Taro (Pineapple)	Medium
9	N.W. Savaii	A/B	Moderate/High stony/bouldery	0.65	Cocoa, Pineapple Ta'amu, Citrus (Coconut)	High
10	S.W. Savaii	D	Mod./Low, shallow bouldery soils	0.48	Coconut, Cocoa Banana, Taro	High

1 Environmental class - refer Figure 1.2.

2 Crops grown - present patterns with potential crops in brackets.

3 Intercrop potential - technically and economically for model in this study - excludes cattle intercrop suited to regions classed low.

Source: Appendix E.

complicated by the long-term nature of some of the crops and in particular of the principal crop, coconuts. Here the relationships which apply at one point in time may be expected to change, resulting in changes to the system's output. Thus, in order to define the input-output coefficients of the system it will be necessary to examine the agronomic characteristics of the individual crops and in addition to consider the spatial and time relationships when those crops are incorporated into an intercropping system.

This complex of inter-relationships determining the economics of the intercropping system is the likely reason for some of the divergence of opinion as to the merits of intercropping. For example, intercropping of coconuts during the establishment phase has been condemned as retarding the development of the palm (Sampson 1923, pp.149-53). Others, observing traditional intercropping patterns in smallholder agriculture, have regarded its role as largely concerned with risk reduction and have seen such a system as limiting the application of new technology and the achievement of higher levels of output for the individual crops (Ruthenberg 1971, pp.244-247).

In is the writer's contention that the divergence of opinions on the merits of intercropping derive from applying intercropping in an informal manner. This study recognises explicitly the complex interrelationships involved in intercropping, carefully defining the technical basis of modern intercropping systems which have placed limitations on the crops considered for intercropping as well as on the time sequence during which these crops can be grown. It is now proposed to briefly review the technical basis for modern intercropping using the concept of 'multi-storey' cropping developed at the Central Plantation Crops Research Institute (CPCRI) of South India. Terms have been precisely defined by CPCRI workers so that 'intercropping' refers to interplanting with annual crops; 'mixed cropping' refers to interplanting with perennials and 'multi-storey' cropping is a system of interplanting with both perennial and annual crops. In all cases the central crop considered is coconut. This study however will continue to use 'intercropping' as a general term referring to the interplanting of any crop under coconuts unless otherwise indicated.

Modern Intercropping Systems

The development of multi-storeyed cropping at the CPCRI arose from considerations of biological efficiency in the process whereby crops use the resources of solar energy and land mass for the production of economic output.

Theoretical considerations of biological efficiency point to a potential of 286.7 tonnes per hectare of dry matter (Loomis and Williams 1973), while at 175 palms per hectare and 100 nuts per palm, coconut monoculture produces 17.4 tonnes per hectare per annum of dry matter. Thus it is suggested that there is a considerable under-utilisation of biological resources in coconut monoculture.

Multiple cropping in the production of annual crops has been one of the major advances in production per unit area per unit of time. Greater biological efficiency in the utilisation of solar energy and land mass has been attained through maintaining the 'photosynthetic factory', or cropping system, operative for a longer duration within the relevant unit of time.

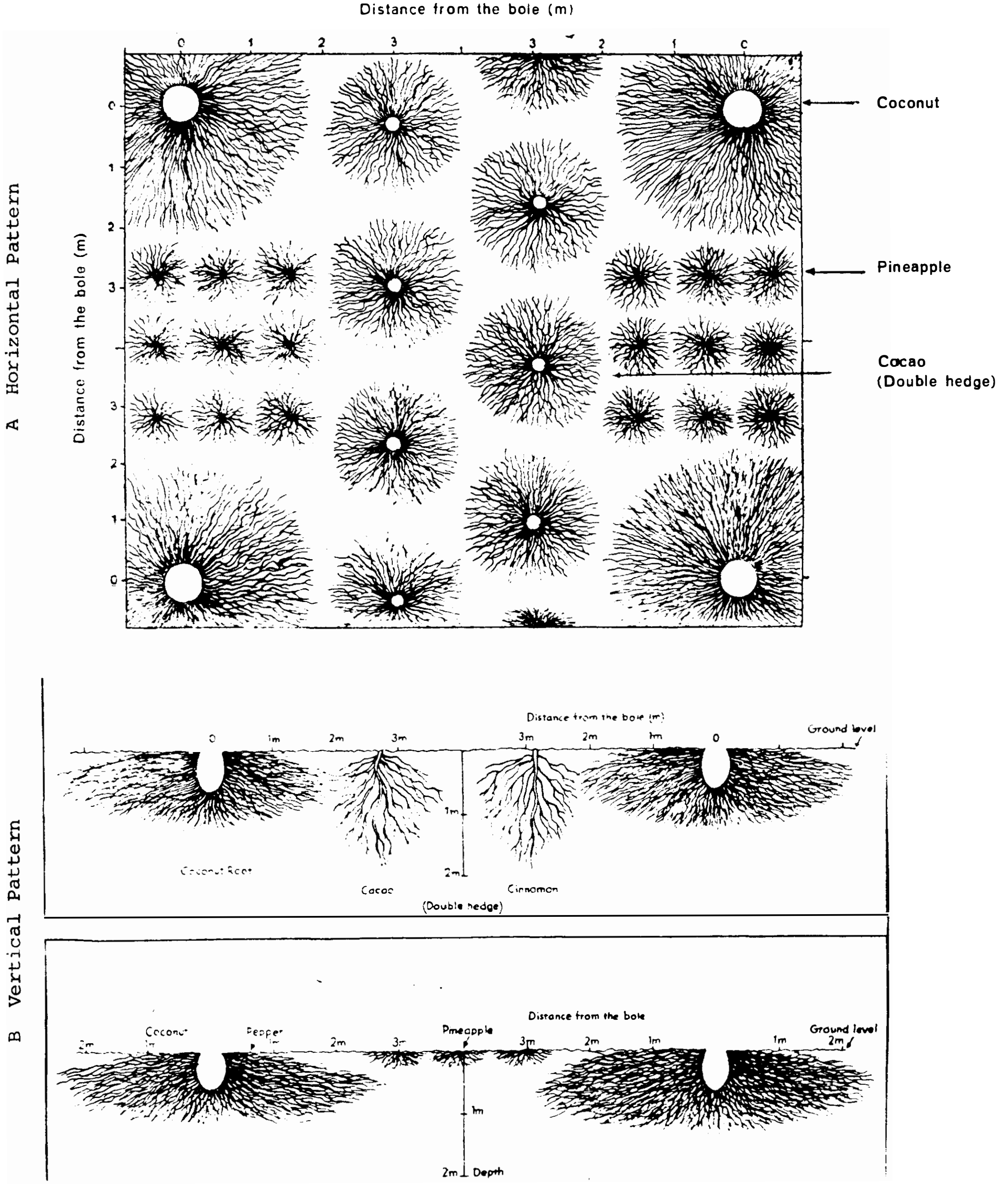
In perennial cropping the land is committed to that crop over a number of years. Hence the approach at the CPCRI was to look to a combination of 'mutually compatible' crops which efficiently utilise the environmental resources (Nelliat et al. 1974).

The study began by considering the utilisation of resources by the coconut. Firstly, in determining planting density for coconuts, the meeting of the leaf canopy of adjacent trees rather than their overlapping is considered an important determinant of tree productivity. For tall coconut varieties, this gives a density of 175 palms per hectare or a square spacing of 7.5 m. However, the zone of effective utilisation by the coconut roots is a circle of radius two metres from the base of the palm or a 23 per cent utilisation of the surface area. Vertically the zone of efficient utilisation by the coconut roots is from 30 cm down to 120 cm (see Figure 1.3).

Solar energy utilisation is a dynamic factor varying with the age of the coconut stand. Light utilisation increases as the leaf canopy of the newly established trees extends to its mature size at six to eight years. This high level of utilisation (around 80 per cent) continues to 25-30 years at which stage the increasing height of the palms increases light transmission from slant rays (see Figure 1.4). In addition to the height effect, the venetian structure and orientation of the leaves themselves allows a portion of radiation to percolate through the canopy to lower levels.

FIGURE 1.3

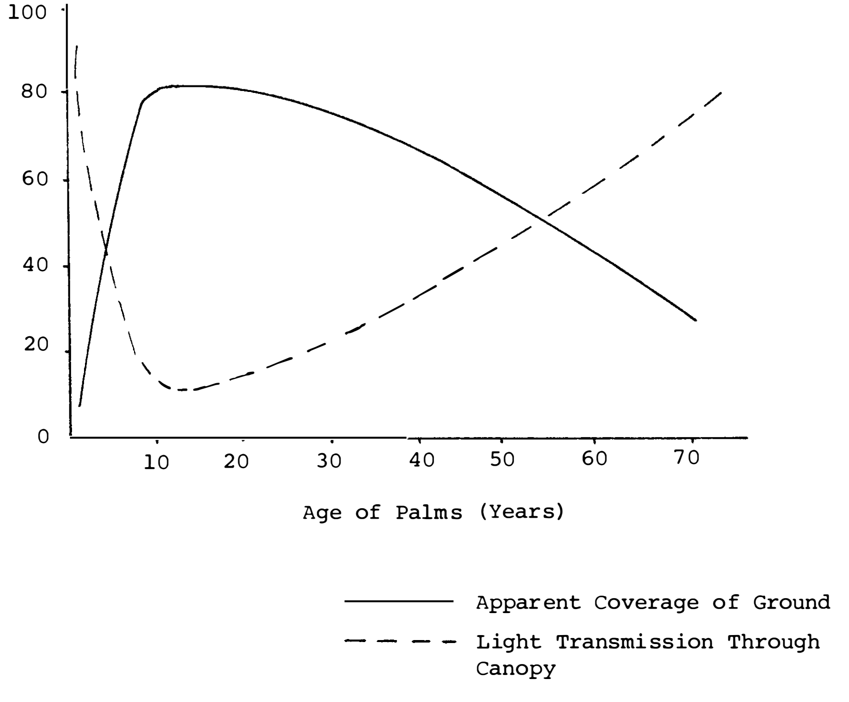
SCHEMATIC REPRESENTATIONS OF THE ROOT DISTRIBUTION PATTERN IN A MULTI-STOREY CROP COMBINATION



Source: Nelliat et al. 1974.

FIGURE 1.4

LIGHT UTILISATION AND PENETRATION
IN A COCONUT STAND OVER TIME



Source: Nelliat et al. 1974.

Thus at different stages of the coconut stand's life-cycle, light availability for other crops will first decrease and then increase and the potential for intercropping will change accordingly. Given the changing potential for other crops, it is likely that a flexible combination of intercropping with annual and perennial crops is likely to fit the biological constraints best.

The CPCRI multi-storeyed cropping formulation is static to the extent that it provides for a fixed crop combination being interplanted in a coconut stand at about 30 years. The combination of cocoa or cinnamon plus black pepper and pineapples is one which efficiently utilises the land mass resource and the light profile. The efficiency of light utilisation is increased by the complementary heights of the crops: coconuts, 10-30 m; black pepper trained on the coconut trunks, 6-8 m; cocoa or cinnamon, 1.5-2.5 m; and pineapple or tubers, 1 m. The root systems form a mutually exclusive pattern (see Figure 1.3). Cocoa and cinnamon have a tap root with limited lateral spread and pineapples are surface feeders. Hence competition for soil space is minimised, while utilisation of applied nutrients is maximised, as is soil water. Further, evapo-transpiration is reduced by maintaining a humid micro-climate, while below ground level a greater development of micro-organisms in the rhizosphere[3] has been noted. These include organisms responsible for nitrogen fixation and phosphate solubilising, producing higher levels of available soil nitrogen and phosphate. Thus Nair et al. (1975) were able to explain the greater coconut yield responses of coconuts

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3 Area in the vicinity of plants' feeding roots.

intercropped with cocoa over control coconuts where both stands received improved management. Responses over pre-experimental yields were 64 per cent in control coconuts and 116 per cent in the mixed cropped coconuts. Thus the advantage of the designed system over a random pattern of intercropping relates to the competition for light, soil nutrients and water being minimised in the former with corresponding yield benefits.

Nelliat et al. (1974) however have not looked at the period of establishment of the coconut when, for up to six to eight years, light penetration is sufficient for the production of intercrops. Intercropping of perennials is not considered for this period due to the shortness of its duration. The technical requirements for potential intercrops for this period are again that competitive effects should be minimised. Smith (1967) points to a number of technical benefits accruing to the establishing coconut, deriving from the cultivation, weeding and manuring of the intercrop. He suggests a careful choice of such 'catch' crops to minimise competition for light, water and nutrients. A wide range of tubers, grains and pulses are commonly grown as catch crops. Of the species which may produce problems by competition, creeping legumes require regular weeding to prevent them from growing up and over young palms, while bananas can be light competitive inducing etiolation and weakening of the palm stem. All crops should be considered competitive for nutrients and both the establishing palm and the intercrop are likely to need separate provision for fertiliser application.

Modern intercropping appears to have considerable scope for application in a number of the agricultural regions in Western

Samoa where it is well suited to the present resource constraints on soil fertility and man-land ratios.

However, the complexity of intercropping makes the data requirement for economic analysis an onerous one. No long-term research defining input-output relationships under an intercropping regime is presently available to the knowledge of the writer. The study has therefore had to make use of derived data from a number of different countries and situations. This material is explicitly mentioned in the text so that the strengths and weaknesses of the information available can be assessed by the reader. An assessment is also made in the conclusion as to what additional data would be necessary to derive results which could be reliably applied in extension work.

Plan of the Study

It has been previously indicated that Western Samoa is faced with important decisions in economic development: to either continue to press for the right for migrant workers to enter New Zealand; or to urgently organise for a substantial adoption, by the village agricultural sector of economically efficient forms of commercial production capable of supplying the foreign exchange, food and raw materials needed by the economy. As indicated, the former policy faces political uncertainty and strains family relationships and traditional social patterns, while the latter is seen to be based on, and to strengthen, traditional Samoan values.

The Third Five Year Development Plan sets agricultural targets for the existing crops, principally coconuts and cocoa, assuming the adoption of new varieties and new technology to improve their economic viability. However, considerable doubts must remain as to the economic competitiveness of monocrops, especially in the case of coconut. In this context the economic advantages of intercropping given by Nelliat and Krishna (1976), that is, increased incomes, improved income distribution over time, increased returns on investment, risk reduction, family employment generation and cost economies in weeding coconut stands, indicate the economic superiority of intercropping over coconut monoculture.

The objective set for the study then is to examine the economic potential of planned intercropping of coconuts. Economic potential is confined in the main however to financial aspects of the system, and to evaluating the cash earning potential in competition with local wage employment opportunities presently available to rural families. Further consideration is given to this objective in discussing the objective function to be adopted by the model in the context of Samoan society and its value system.

The introduction has made explicit the essential link between the technical assumptions and the economic analysis, and set the technical framework of the intercropping system. The next chapter examines those technical and agronomic details of the individual crops relevant to establishing a cash flow analysis. The cash flows obtained are examined and the need for further analysis established. This is followed by an appraisal of the economic techniques that were considered for further analysis and an elaboration of the technique chosen, multi-stage linear programming. The remaining chapters cover the development of the model, empirical results and policy implications.

CHAPTER 2

THE CROPS AND THEIR CASH FLOWS

Introduction

The purpose of this chapter is to examine the individual crops that will be considered for inclusion in the intercropping model. The basic aim is to establish the technical details which will be important in determining the input-output relationships adopted for the analysis, initially the cash flows. In arriving at such a position the relevant literature was reviewed. This was necessary as it was the only basis on which reasonable reliability could be claimed for the data ultimately adopted. The material reviewed was broadly categorised into the following areas: world trading position, crop production, the crop in Western Samoa, crop yield, price and cost information. The summarising of material on the world trade enabled the writer to obtain a feeling of each crop's future as a foreign exchange earner in the Western Samoan economy. It also provided a background for choosing suitable future prices for the crops. Crop production material indicated those areas in which new technology was reliably established, and was thus pertinent to assessing costs and yields. Describing the crop's place in the Western Samoan agricultural sector was done in order that the reader could appreciate its position and importance and assess the potential impact from adoption of intercropping.

However, given the volume of material involved, that on world trade, crop production and the crop in Western Samoa is placed in technical appendices. Only the information directly relevant to the establishment of the cash flows for the crops is presented in this chapter. The information available from the cash flow analysis, however, does not answer all the economic questions posed by the study. The lack of clear answers sets the stage for taking the economic analysis a step further and concludes the chapter.

The crops considered (coconuts, cocoa, pineapple, taro and bananas) are those regarded as fitting the economic requirements as defined by the CPCRI intercropping system, and as crops of present or potential economic significance in Western Samoan agriculture. The opportunity is taken here to briefly outline some of the constraints on intercropping implied in the preceding chapter, to provide a context in which to consider the individual crops and to analyse the cash flow results. Ten intercropping periods are defined over the total production cycle of 65 years. The first period, years one to six, allows taro and pineapple intercrops, as they in no way compete for sunlight with the developing palm. Bananas are excluded on these grounds and cocoa, as a perennial, is obviously not feasible over such a short period. Between the seventh and twenty-fifth years, or period two, no intercrops can be planted due to the light constraint. This is followed by eight five-year periods over the years twenty-six to sixty-five. Period three allows the most shade tolerant crops (cocoa and taro) to be established while from period four all intercrops can be considered competitively. We now need to turn to the individual crop's production and cash flows.

Coconuts

The Coconut Yield Stream

No data are available for yield streams of coconut over time from Western Samoa. Information from other sources provides data for limited spans of the coconut life cycle. Frémond and Ouvrier (1972) and Von Uexhüll (1972) give yield streams for the period from commencement of bearing (8 years old in both these cases) to 16 and 13 years respectively in relation to fertiliser experiments. While this provides more data than commonly available, the analysis establishes statistical significance between the control and the fertiliser treatments independently at each age without considering that the observations are also observations on a particular yield stream over time. Without deriving the underlying yield streams it is not possible to establish overall statistical significance or even stochastic dominance for the treatments. Frémond and de Lamothe (1972) present comparative yield streams for tall and hybrid varieties of coconut. Here observations are more limited; seven years on the 'tall' variety (West African tall) from year 7 to year 13 and four and five years observations on three hybrid varieties (West Africa Tall by Malayan Yellow Dwarf) from year 4 to year 8. The yield stream used by Recter et al. (1972) for palms 36 to 60 years old appears to have a somewhat arbitrary basis. Given an average yield of 1500 kg/ha per year for palms of around 35 years, Recter et al. (1972) assume a decline due to natural age effects of 150 kg/ha every five years over the period. De Silva's data (1976) are the most extensive for studies not aimed specifically at predicting yield streams by age.

Curves are presented for coconut from 30 to 60 years of age with a distinctive U shape. Figures however are uncertain and appear to represent output per plot so that yields cannot be reliably ascertained. The above data are presented for comparison in Figure 2.1.

Western Samoan data are in the nature of average yield estimations on existing stands of coconuts, many of which are 60-80 years old. The Third Five Year Development Plan makes an estimate of 4446 nuts/hectare.[1] Using a conversion rate of 5133 nuts per ton of copra the yield estimate is equivalent to 882 kg per hectare of copra. An earlier estimate comes from Lockwood (1971) based on his 1966 survey of four Samoan villages.[2]

Production information was collected from visits to villages from February to July. A major hurricane occurred on the 29th January 1966. The data is extrapolated and presented as annual production and disposal of nuts. Data was also collected on coconut area, palm density and proportion of productive to non-productive palms. Total production in tonnes per hectare ranged over 0.6-1.29, averaging 0.96. The proportion of the village coconut stand in productive palms varied

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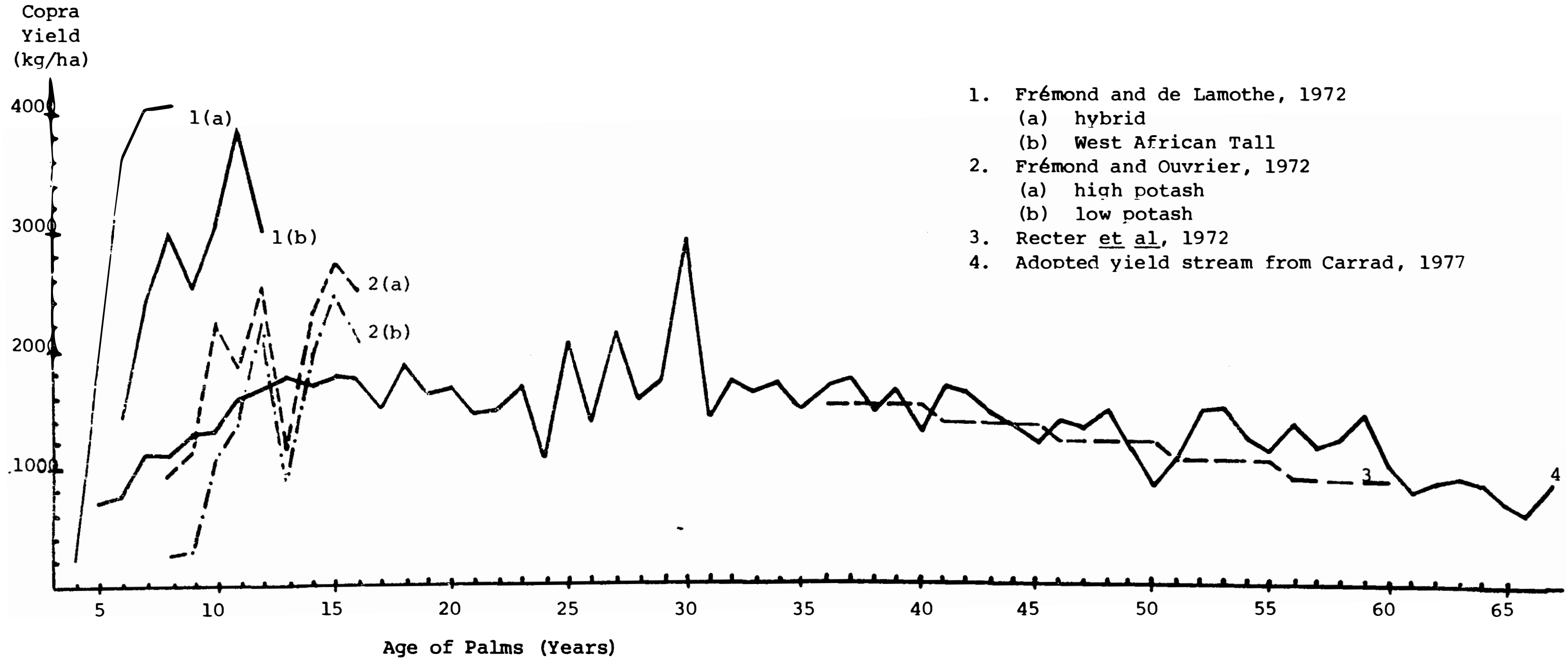
1 Based on an estimated area in coconuts of 29,555 hectares (73,000 acres) and average export of copra of 15,000 tons, (equivalent to 77m nuts) plus consumption of 1 nut per person per day (58m nuts) (Western Samoa. Department of Economic Development 1975).

2 The villages were surveyed in a rotation of one to two weeks per visit and five visits so that each village received a total of at least seven weeks of detailed daily questions in the sample households (aiga). The daily questionnaire, with regard to coconuts, covered nuts gathered, nuts husked, copra sold, nuts sold, nuts used by the household, by chickens and by pigs. Also reported is a wastage factor used as a balancing item. The method of estimating total production is not clear.

FIGURE 2.1

COMPARATIVE COPRA YIELD CURVES



from 54-84 per cent with an average of 70 per cent. Converting yields above to yield per unit of productive area gave an average result of 1.37 tonnes/ha. Average subsistence use (livestock plus human food) was 22 per cent. Assuming that under an intercropping regime wastage is eliminated, then some 78 per cent of yield or 1.07 tonnes per hectare can be allocated to cash producing output (see Table 2.1). The data suggest a high degree of variation between villages (standard deviation of 0.32 tonnes/ha and coefficient of variation of 29 per cent). This would reflect soil and climatic differences and also the wide range in planting density reported (99-198 palms/ hectare even though management practice is commonly considered uniform throughout the country). The most recent data come from the Village Benchmark Surveys of the Department of Agriculture (1977) which record yields for five villages ranging from 0.7 tonnes per hectare to 1.35 tonnes per hectare averaging 1.0 tonnes per hectare (standard deviation = 0.27 and coefficient of variation = 27 per cent). This is a total yield figure not adjusted for proportion of productive area or subsistence requirements. It is concluded that a coconut yield stream adopted to represent Western Samoan conditions could reasonably be expected to approach 1.1 tonnes per hectare of dry copra (equivalent to 7.7 kg per tree) during the 40-60 year phase of production having already made an allowance for 22 per cent utilisation in subsistence. Better management has been assumed to reflect the production methodology implicit in intercropping together with probability of hybrid planting material being available under a new coconut project (Technical Appendix 1).

TABLE 2.1

COCONUT OUTPUT AND UTILISATION IN FOUR SAMOAN VILLAGES, 1966

	Uafato	Taga	Poutasi	Utualii	Average
Coconut Plantation Area (Hectares)	70.4	131.6	210.5	34.4	
Palm Density (Palms per Hectare)	124	198	99	148	142
Palm Assessment					
% Less Than 7 Years	6	8	29	5	
% Aged	10	23	17	15	
% Productive	84	69	54	80	72
Total Output (000's Nuts)	323	717	670	229	
Utilisation					
% Subsistence	17	19	11	20	22
% Livestock	6	11	3	2	
% Copra	39	60	77	56	
% Sale of Nuts	-	-	-	24	
% Wastage	38	10	9	-2	
Yield					
Nuts per Hectare	4588	5448	3183	6657	
Nuts per Productive Hectare	5462	7896	5894	8321	6900
Tonnes Copra per Productive Hectare	1.060	1.533	1.144	1.615	1.339
Tonnes Copra per Productive Hectare in Cash Earning					1.045

Source: Adapted from Lockwood 1971; Appendix Table 3.

The most valuable data on coconut yield streams are from the Lever Plantations Pacific Pty Ltd (LPPPL) in the Solomon Islands. Green and Foale (1961) present estate yield curves based on an average planting data, covering a period of 30 years, for two estates planted in 1907-8, and a period of 17 years for one of the above estates planted 1907, one planted 1917 and one planted 1923. The 17 year curves show production peaking at 14-16 years while the 30 year curve implies a second peak at around 30 years. No statistical information is provided on the fitting of these curves. The estates include plantings at different densities as well as environmental differences due to location. Carrad (1977) overcomes a number of the above problems by adopting the methodology of Etherington (1973) whereby output and yield are predicted on the basis of the cohort structure of the stand in cases where planting has been spread over several seasons.[3] The LPPPL estates were planted over periods varying from five to twelve years making them well suited to cohort structure analysis. The period of output observations also varied from 13 to 31 years during the period 1911-41 which was interrupted by World War II. Plantings in each year and planting densities were recorded so that the age distribution of the stock of trees could be projected

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3 The general planting-output relationship for a perennial crop is:

$$Q^*_t = \sum_{i=1}^{\infty} b_i X_{t-i}$$

where Q^*_t = the potential output of the crop in year t

b_i = potential yield per tree in year t of the crop planted in year t-i

X_{t-i} = number of trees in year t of age t-i

k = age at which the crop commences bearing over the period. Estate differences, including climate, soils and topography, were accumulated in estate dummy variables. Estate output was recorded as tons of dry copra so that constant technologies of nut collection and copra processing must be assumed for the period. In the latter case, a conversion rate of 55 per cent was maintained even though new drying facilities were installed. Nut collection though was expected to be influenced by the development of cattle herds and the maintenance of a low vegetation facilitating nut pick-up. However, the lack of data in this area is felt not to appreciably detract from the age-output relationship obtained. Price was introduced into the relationship as an annual figure, as a different from trend and as a lagged difference from trend without being significant in explaining output or yield.

Results were very encouraging with a high explanatory power ($R^2 = 0.87$) and significant coefficients for 'estate effects' and for ages from year 5 to year 33 (see Table 2.2). Adjusting the age coefficients by the constant (0.53 kg/tree) and for the average estate effect (0.92 kg/tree) gave the yield per tree at each age (see Table 2.3 and Figure 2.2).

Yields show a steady increase to 13 years after which annual fluctuations from trend become greater and the often observed biennial bearing tendency of perennials is clearly shown. The sequence is seen to reverse itself twice during the period (at years 22 and 29) due possibly to climatic influences. The 15 year sequence of peak yields suggested by Green and Foale (1961) cannot be completely discounted on the basis of the above, though the removal of the density effect in establishing the age relationship to yield

TABLE 2.2

COCONUT COHORT YIELD ANALYSIS:

AGE AND ESTATE COEFFICIENTS

Variable Name	Coefficient	t Ratio	Number of Observations	D.W.	R^2
Banika Estate	-0.00166	5.0710	178	0.86	.87
Lingatu Estate	-0.00120	2.8660			
Somata Estate	0.00132	3.7458			
Pepesala Estate	0.00183	5.5287			
Faiami Estate	0.00344	10.3241			
Ufa Estate	0.00178	5.2342			
Price	-0.00001	1.1713			
Age 5	0.00227	1.8995			
Age 6	0.00275	2.4150			
Age 7	0.00552	4.0895			
Age 8	0.00513	3.4691			
Age 9	0.00640	4.1976			
Age 10	0.00662	4.2481			
Age 11	0.00864	5.4351			
Age 12	0.00939	5.8176			
Age 13	0.00991	6.0685			
Age 14	0.00942	5.5801			
Age 15	0.00993	5.7998			
Age 16	0.00980	5.4948			
Age 17	0.00801	4.2746			
Age 18	0.01060	5.4800			
Age 19	0.00886	4.4989			
Age 20	0.00926	4.6492			
Age 21	0.00855	3.7288			
Age 22	0.00795	3.9818			
Age 23	0.00928	4.4090			
Age 24	0.00485	2.2140			
Age 25	0.01201	4.7248			
Age 26	0.00702	2.3221			
Age 27	0.01253	3.4144			
Age 28	0.00835	2.2291			
Age 29	0.00957	2.5405			
Age 30	0.01829	4.6536			
Age 31	0.00734	1.5511			
Age 32	0.00957	1.6143			
Age 33	0.00981	1.2578			
Age 34	0.00356	0.3924			
Age 35	0.02122	1.6894			
Constant	-0.0053				

Source: Carrad 1977.

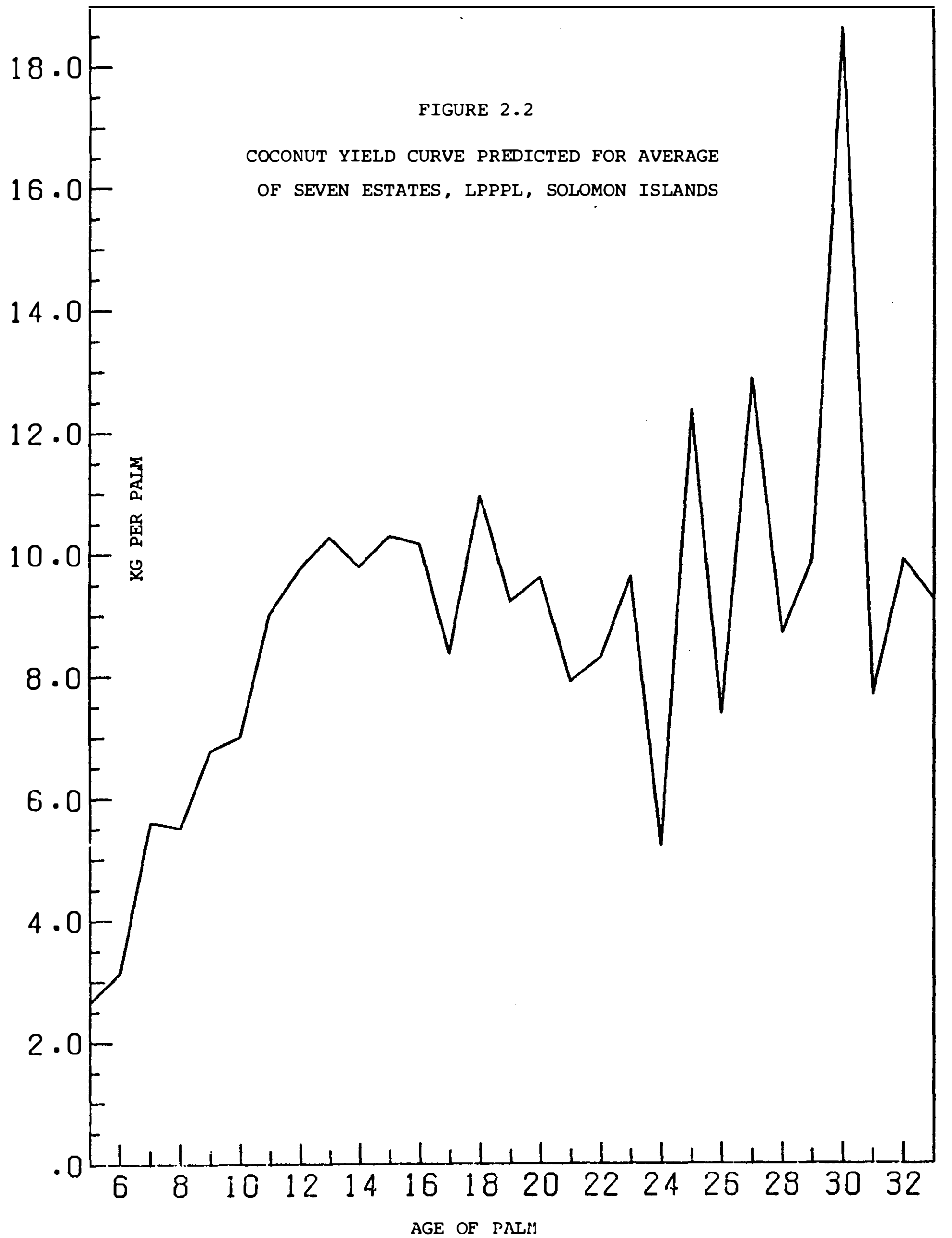
TABLE 2.3

COCONUT AGE COEFFICIENTS FOR YIELD PER PALM (KG)
ADJUSTED FOR AVERAGE ESTATE EFFECT

Variable	Yield	Yield Adjusted*
Age 5	1.74	2.66
Age 6	2.22	3.14
Age 7	4.69	5.61
Age 8	4.60	5.52
Age 9	5.87	6.79
Age 10	6.09	7.01
Age 11	8.11	9.03
Age 12	8.86	9.78
Age 13	9.38	10.30
Age 14	8.89	9.81
Age 15	9.40	10.32
Age 16	9.27	10.19
Age 17	7.48	8.40
Age 18	10.07	10.99
Age 19	8.33	9.25
Age 20	8.73	9.65
Age 21	7.02	7.94
Age 22	7.42	8.34
Age 23	8.75	9.67
Age 24	4.32	5.24
Age 25	11.48	12.40
Age 26	6.49	7.41
Age 27	12.00	12.92
Age 28	7.82	8.74
Age 29	9.04	9.96
Age 30	17.76	18.68
Age 31	6.81	7.73
Age 32	9.04	9.96
Age 33	8.38	9.30
Age 34	3.03	3.95
Age 35	20.69	21.61

* Average 'estate effect' was 0.92 kg copra.

Source: Carrad 1977.



Source: Carrad 1977.

per tree indicates that the Green and Foale results were possibly biassed by combining outputs of estates planted at different densities.

Further data were available from the LPPPL estates for the period 1961-74. Carrad (1977) summarised the main influences on estate output during this period which confounded attempts to derive a similar age-productivity relationship to that for the pre-World War II periods.[4] The only conclusions possible then from the attempted regression analysis were to confirm the major significance of palm age, number and location (estate effect) in explaining output (Carrad 1977).

It was still possible however, to derive yield per tree information for each estate and to group these yields in an age sequence (see Table 2.4) bearing in mind the positive influences of introduced management practices which would tend to maintain yields against the expected decline with age. A yield stream was then selected arbitrarily for ages 35 to 65 years on the basis that it continued from the average pre-war yield stream in a reasonably logical progression.

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4 The estates planted prior to the war were in declining yield phases with mean age varying from 48 to 65 years. The war had changed areas and numbers of palms. From the early 1960s significant changes to management practices were introduced. Old palms were fertilised with potash. Cattle herds were completely rehabilitated with numbers growing from 900 in 1961 to some 5,840 in 1972 at which point full brushing strength was achieved. This reduced labour costs in weeding and mandays required to harvest the nuts. The replanting of areas in the old estates commenced in the 1960s. More recent plantings used hybrid palms developed on the estates. By 1966 replanting had occurred on approximately 20 per cent of the area in selected estates.

TABLE 2.4

YIELD PER PALM FOR SOME LPPPL ESTATES, 1961-74 (KG)

Average Age Palm	Lingatu	Somata	Sifola	West Bay	Banika	Pepesala	Adopted Yield Coefficient
35	7.7						7.7
36	7.8						7.8
37	7.8						7.8
38	8.1						8.1
39	7.0						7.0
40	6.1						6.4
41	6.6	8.0					6.6
42	7.2	7.3					7.2
43	6.8	7.5					6.8
44	8.1	7.1					8.1
45	8.7	6.8					8.7
46	6.9	5.1					6.9
47	4.5	6.1					6.1
48	5.0	5.9					5.9
49		10.0	8.4				10.0
50		6.8	6.1	4.9	4.0		6.8
51		7.8	7.8	4.6	3.9		7.8
52		5.4	10.7	6.4	4.9	5.9	5.4
53		3.6	10.8	6.9	4.6	6.5	3.6
54		6.2	8.9	7.2	6.7	5.7	6.2
55			8.1	6.6	5.6	6.2	6.2
56			7.8	7.3	5.0	5.6	5.6
57			8.4	7.4	5.2	4.6	4.6
58			8.9	8.1	6.1	5.4	5.4
59			10.4	8.6	6.5	5.1	5.1
60			7.3	10.1	6.1	5.4	5.4
61			5.5	9.6	4.9	5.7	5.7
62			8.3	7.6	4.3	5.5	5.5
63				7.8	6.3	4.7	4.7
64						4.5	4.5
65						4.7	4.7

Source: Carrad 1977.

The combined yield stream (65 years) is presented in Table 2.5 together with the per hectare yields for alternative palm densities, as the basis for establishing the coconut cash flows. The 40 to 60 year component of the yield stream suggests than an

TABLE 2.5

COCONUT YIELD STREAMS

Year	Yield Kg/Tree	Alternative A 178 palms/ha	Alternative B 156 palms/ha	Alternative C 123 palms/ha
		Yield Kg/Ha	Yield Kg/Ha	Yield Kg/Ha
5	2.7	481	421	332
6	3.1	552	484	381
7	5.6	997	874	689
8	5.5	979	858	677
9	6.8	1210	1061	836
10	7.0	1246	1092	861
11	9.0	1602	1404	1107
12	9.8	1744	1529	1205
13	10.3	1833	1607	1267
14	9.8	1744	1529	1205
15	10.3	1833	1607	1267
16	10.2	1816	1591	1205
17	8.4	1495	1310	1267
18	11.0	1958	1716	1255
19	9.3	1655	1451	1033
20	9.7	1727	1513	1353
21	7.9	1406	1232	1144
22	8.3	1477	1295	1193
23	9.7	1727	1513	972
24	5.2	926	811	1021
25	12.4	2207	1934	1193
26	7.4	1317	1154	640
27	12.9	2296	2012	1525
28	8.7	1549	1357	910
29	10.0	1780	1560	1587
30	18.7	3327	2917	1070
31	7.7	1371	1201	1230
32	10.0	1780	1560	2300
33	9.3	1655	1451	947
34	4.0	712	624	1230
35	7.7	1371	1201	1144
36	7.8	1388	1217	492
37	7.8	1388	1217	947
38	8.1	1442	1264	959
39	7.0	1246	1092	959
40	6.4	1139	998	996
41	6.6	1175	1030	861
42	7.2	1282	1123	787
43	6.8	1210	1061	812
44	8.1	1442	1264	886
45	8.7	1549	1357	836
46	6.9	1228	1076	996
47	6.1	1086	952	1070

(Contd. over/)

TABLE 2.5

(Contd.)

Year	Yield Kg/Tree	Alternative A 178 palms/ha	Alternative B 156 palms/ha	Alternative C 123 palms/ha
		Yield Kg/Ha	Yield Kg/Ha	Yield Kg/Ha
48	5.9	1050	920	726
49	10.0	1780	1560	1230
50	6.8	1210	1061	836
51	7.8	1388	1217	959
52	5.4	961	842	664
53	3.6	641	562	443
54	6.2	1104	967	763
55	6.2	1104	967	763
56	5.6	997	874	689
57	4.6	819	718	566
58	5.4	961	842	664
59	5.1	908	796	627
60	5.4	961	842	664
61	5.7	1015	889	701
62	5.5	979	858	677
63	4.7	837	733	578
64	4.5	801	702	554
65	4.7	837	733	578

Source: Carrad 1977.

approximation to Western Samoan conditions can be made. However this must be done cautiously, given that when discounting the net revenue stream to a present value, it is the production levels early in the time stream that are most critical to the final result.

Copra Prices

Recter et al. (1972) present price projections for 1971-95. They analysed 17 years of prices but were unable to establish a significant relationship for price over time. Their prices are f.o.b. Kuala Lumpur in Malaysian dollars. The coefficient of variation for the seventeen years' data is 13 per cent. The projection assumes the mean price for the previous seventeen years to apply to 1971-75 with a decline of 0.25 of a standard deviation per live year interval thereafter. The projected decline is based on the assumption of increasing competition from oil palm. This is questionable to the extent that coconut oil is the major lauric oil with special properties for use in soap manufacturing so that palm oil, one of the 'hard oils', is only a potential substitute for coconut oil in edible and other industrial products. This is further suggested by an analysis deriving the correlation coefficients for price movements between the 'hard' and 'lauric' oil groups (FAO 1971). Non-significant coefficients were obtained (less than 0.4) implying a low potential for substitution. The FAO report showed however that the average price for fats and oils for 1950-65 had declined in real terms[5] by approximately 1 per cent per annum. More recent price trends are given in Table 2.6. Coconut oil supplies are dominated by the Philippines to the extent that the high 1974 prices reflected short supplies due to the 1973 drought in that country, while in 1975 exports again expanded rapidly (a 70 per cent increase). Prices were also influenced in 1975 by the world recession and by consumer reaction to the high prices of 1974. Continued rapid expansion of supplies of coconut oil is expected to drop in 1977 while palm oil is forecast to continue its steady increase in supply. However it appears reasonable to hope for a stabilising of coconut product returns through the efforts of the EEC Lomé Convention and the UNCTAD Buffer Stock proposals.

5 Deflated by the FAO Index of Manufactured Products.

TABLE 2.6

PRICE TRENDS: FAO PRICE INDEX[1]

Year:	Average 1969-71	1972	1973	1974	1975
All Fats and Oils	108	102	182	325	217
Lauric Oils	112	77	170	339	139
Other Edible/Soap Fats and Oils	98	89	168	255	173

1 1964-66 = 100

Source: Fao 1971.

Producer price is set by the Western Samoan Copra Board by the announcing of price levels from time to time that apply at various levels in the marketing channel. It is assumed that the producer in the model would sell his copra to the first level dealer, usually the village storekeeper. Taking announced prices for November 1973 and May 1975 as examples, price per ton of copra at the first level dealer was 74 per cent and 66 per cent of the f.o.b. price. An average therefore of 70 per cent of the f.o.b. price is taken as the producer price. The 1969-71 FAO Price Index average for lauric oils of 112 corresponds to an f.o.b. Apia price of T126.57 which is adopted as a conservative long-run average price for the purposes of this study. Producer price is therefore set at T90.00 per tonne.

Costs in Smallholder Production

Establishment costs for replanted coconut will involve, at some early stage, the removal of old palms if intercropping is being considered. Hung (1976) has pointed out the high costs of removal as a deterrent to clean felling. Costs estimated included truck and chainsaw hire totalling approximately T240 per hectare including 60 mandays for loading and carrying. The costing provides for transport to the Forestry Post treatment plant. As each hectare of old coconuts will provide approximately 3000 fence posts, a charge of T0.12 per post has been incurred. It is felt that this cost should be borne by the Post Treatment operation so that a farmer could have old coconut logs removed free of charge. This would leave stump disposal and other light clearing work to be met by the farmer. Hung (1976) discusses the development of <u>Metarrhizium</u>, a fungus parasitic on rhinoceros beetle lavae, which if applied to the coconut stumps would permit them to be left to rot without becoming a breeding site for the beetle. This would eliminate the labour intensive alternative of stump removal while reducing effective intercropping area during the first five years by 390 square metres per hectare or some 4 per cent.

Establishment clearing then requires the removal of small trees and bushes commonly found in old coconut stands. An input of 20 mandays per hectare is estimated for the purpose. Removal of ground cover is effected by spraying a non-selective herbicide (Paraquat at 17 litres/ha) requiring three mandays per hectare and costing T50.50 for materials. Each tree requires the spraying of a circle of 2 m radius; thus the area to be treated is 2240 m^2, 1960 m^2 and 1550 m^2 for palm densities of 178, 156 and 123 palms per hectare respectively (densities A, B and C of Table 2.5). Weed control during the establishment year is expected to require a further four light applications of Paraquat (12 litres/ha) costing T0.045 per spray per palm. For this ring spraying, one manday per hectare of coconuts is required per spray for all palm densities.

Other establishment costs include seednuts, lining and hole digging, planting and fertilising. Seednuts under the former Coconut Project were available at T3.00 per 100. It is suggested that the hybrid seednuts will be sold at T12.00 per 100 to ensure greater economy in their use. Lining and hole digging are reported at 30 mandays per hectare in Papua New Guinea (Oisher 1970) and $A44 per hectare for LPPPL estates (Carrad 1977). From Western Samoa, McConnell (1972) reports 60 holes per manday for planting banana corms, so that 30 holes per manday is estimated for the lining and digging of coconut holes using the maximum hole size as recommended by Liyanage (Technical Appendix 1). Planting of seednuts is given as 18 mandays per hectare (Oisher 1970) and $A7 per hectare (Carrad 1977). An estimate of 60 seedlings planted per manday is adopted. Fertiliser application at planting has in the past in Western Samoa been recommended as 0.23 kg per palm of NPK 10.5.20. The application rate equivalent to that under the coconut Fertilizer Demonstration Scheme in India is 3 kg of 10.5.20 per palm. Leach et al. (1976) noted severe potash deficiency in old palms being intercropped and evidence of sulphur deficiency. In lieu of better information an application of 1 kg of 10.5.20 per palm is proposed.

Maintenance costs in the coconut stand include weeding, fertilising and pest control, plus harvesting after bearing commences. In year two vacancies in the stand due tc dead or poor seedlings should occur. The seednut cost is put at 5 per cent of the original stand and 1 manday per hectare is allocated for the replanting.

Maintenance weed control diminishes as the coconut canopy develops: the application rate remains at 12 litres per hectare while the number of applications is reduced to four in year two, and three in the subsequent years of the early intercropping phase. The Pueraria phaseloides cover established between the intercropping phases is estimated to require two ring spray applications plus light slashing four times per annum at three mandays per hectare to aid nut collection.

Pest control work includes sanitation and checking young palms for rhinoceros beetle and stick insect. One manday per two months is the expected labour input.

Maintenance fertiliser is estimated to continue at 1 kg per palm per annum until bearing in year 5 when application is increased to 1.5 kg. This rate is continued until year 40 when the rate is reduced back to 1 kg per palm for the remaining years of the palm's economic life.

Harvesting and processing commences in year 5. A survey of Papua New Guinea smallholders quotes an average of 52 mandays per ton of copra, but a mode of between 20 and 30 mandays (PNG. Department of Agriculture, Stock and Fisheries 1973). Oisher (1970) reports 30 mandays per acre for yields from one to seven hundred-weight and 32 mandays per acre for eight hundred-weight of copra. The latter is equivalent to 82 mandays per tonne. Harvesting, but not processing on the LPPPL estates, is done on contract at $A11.73 per tonne of dry copra (Carrad 1977). Lockwood (1971) made a detailed study of the labour input in nut collection and copra processing for the four Western Samoan villages surveyed. Results were very similar in all four villages, reported at 8-9 manhours per 100 lb of copra or 22 mandays per tonne. This latter value is adopted for the purpose of this study.

Fixed costs are dominated by the provision to construct and maintain a small hot-air drier. The drier, of standard Samoan design, is constructed in year 5 for T200. General maintenance of the drier requires replacement of the drums and wire every five years at a cost of T5.00. Tools required and their replacement are given in Appendix B, Table 1.

Coconut Cash Flows

As can be seen in Table 2.7, gross margins for the 65 year yield stream are derived for the three palm density alternatives based on the adopted prices and costs. For all alternatives there are four years of negative flows which are balanced by cumulative positive flows to year 10. Gross margins varied with yield fluctuations and with the assumed prices; no year during the bearing period of the palms had a negative margin. In practice however, with the level of price fluctuation normally experienced, it is quite conceivable that zero or negative margins could result. Further, as the derived yield curve has randomised weather effects so that the age coefficients are based on some average climatic situation, yield fluctuations in practice are likely to be greater than shown. The adoption of improved technology (fertiliser and herbicide) has probably made the enterprise more risk-prone to the extent that the farmer is assumed to commit funds for purchased inputs irrespective of income fluctuations. In practice, years of low returns are likely to result

TABLE 2.7

COCONUT CASH FLOWS AND LABOUR INPUTS AT THREE PLANTING DENSITIES

Year	Period	Density A (178 palms/ha)			Density B (156 palms/ha)			Density C (123 palms/ha)		
		Labour (Mandays)	Income (T)	Return (T/MD)	Labour (Mandays)	Income (T)	Return (T/MD)	Labour (Mandays)	Income (T)	Return (T/MD)
1	1	41	-79.10		40	-68.70		38	-54.40	
2		12	-47.40		12	-41.50		12	-32.70	
3		10	-38.30		10	-33.50		10	-26.50	
4		10	-38.30		10	-33.50		10	-26.50	
5		32	5.89		30	5.09		28	4.08	
6		33	12.28		32	10.76		29	8.49	
7	2	43	52.33	1.86	40	45.86	1.77	36	36.21	1.69
8		43	50.71		40	44.42		36	35.13	
9		47	71.50		44	62.69		39	49.44	
10		49	74.74		45	65.48		40	51.69	
11		56	106.78		52	93.56		45	73.83	
12		59	119.56		55	104.81		48	82.65	
13		61	127.57		56	111.83		49	88.23	
14		59	119.56		55	104.81		48	82.65	
15		61	127.57		56	111.83		49	88.23	
16		61	126.04		56	110.39		49	87.15	
17		54	97.15		48	85.10		44	67.17	
18		64	138.82		59	121.64		51	95.97	
19		57	111.55		53	97.79		46	77.16	
20		59	118.03		54	103.37		47	81.57	
21		52	89.14		48	78.08		42	61.68	
22		54	95.53		50	83.75		43	66.09	
23		59	118.03		54	103.37		46	81.57	
24		41	45.94		39	40.19		35	31.80	
25		69	161.23		63	141.26		55	111.45	
26	3	50	81.13	2.23	46	71.06	2.14	41	56.10	1.94
27		71	169.24		65	148.28		56	117.03	
28		55	102.01		51	89.33		45	70.50	
29		60	122.80		55	107.60		48	84.90	
30		94	262.03		85	229.73		72	181.20	
31	4	51	85.99	1.69	47	75.29	1.60	42	59.43	1.43
32		60	122.80		55	107.60		48	84.90	
33		57	111.55		53	97.79		46	77.16	
34		36	26.68		35	23.36		32	18.48	
35		52	85.99		47	75.29		42	59.43	
36	5	52	87.52	1.62	48	76.73	1.53	42	60.51	1.37
37		52	87.52		48	76.73		42	60.51	
38		53	92.38		49	80.96		43	63.84	
39		49	74.74		45	65.48		40	51.69	
40		46	65.11		43	57.02		38	45.03	
41	6	47	68.35	1.64	44	59.90	1.54	39	47.28	1.38
42		49	77.98		46	68.27		40	53.94	
43		47	71.50		44	62.69		39	49.44	
44		53	92.38		49	80.96		43	63.84	
45		55	102.01		51	89.33		45	70.50	
46	7	48	73.12	1.57	45	64.04	1.49	40	50.61	1.32
47		45	60.34		42	52.88		38	41.70	
48		44	57.10		41	50.00		37	39.54	
49		60	122.80		55	107.60		48	84.90	
50		47	71.50		44	62.69		39	49.44	
51	8	52	87.52	1.28	48	76.73	1.21	42	60.51	1.05
52		42	49.09		39	42.98		36	33.96	
53		35	20.29		33	17.78		31	14.07	
54		45	61.96		42	54.23		38	42.87	
55		45	61.96		42	54.23		38	42.87	
56	9	43	52.33	1.12	40	45.86	1.04	36	36.21	0.91
57		39	36.31		37	31.82		33	25.14	
58		42	49.09		39	42.98		36	33.96	
59		41	44.32		39	38.84		35	30.63	
60		42	49.09		39	42.98		36	33.96	
61	10	43	53.95	1.06	41	47.21	0.99	36	37.29	0.86
62		43	50.71		40	44.42		36	35.13	
63		39	37.93		37	33.17		34	26.22	
64		39	34.69		36	30.38		33	24.06	
65		39	37.93		37	33.17		34	26.22	

in the farmer substantially reducing the use of purchased inputs in subsequent years. The effect on the estimated yield stream of irregular levels of inputs is not known. Alternatively the farmer could substitute labour for capital in weeding but only at the expense of returns to labour.

Net revenue per manday during the second period (years 7 to 25) averaged between T1.86 for 178 palms per hectare to T1.69 for 123 palms per hectare. This period is important as it is the time during which potential for increasing income through intercropping is extremely limited. The returns to labour are higher in the third period (years 26 to 30) during which time they are above the present minimum wage of T2.00 for the two higher densities. Thereafter returns drop steadily so that by period 10 (years 61-65), labour is getting T0.86 and T1.06 per manday for 123 and 178 palms per hectare respectively. The need for supplementing income through intercropping even at the higher palm density is dramatically illustrated.

Cocoa

Cocoa is the only truly perennial intercrop considered in the model. It can be established from period three and is a crop especially suited to intercropping from an agronomic standpoint.

Cocoa Yield Streams Over Time

No data were available for this study for cocoa output or yields by age of tree or age of the stand of cocoa from Western Samoa. It has therefore been necessary to survey statistics available from other producing regions. Few such studies present yield streams over time and even fewer give the analytical basis on which these yield streams are constructed.

As most of the data available represent 'isolated-in-time', average production levels, for districts, regions or countries, it has been summarised in an endeavour to allow individual results to be compared with each other and with data to be presented on cocoa yield streams. Where applicable the data are presented as ranges to allow for seasonal variation. Age and cocoa variety are important in determining output, so that such information is given when available. As yields per unit area are sensitive to planting density, the latter information is used to present yield per tree for comparison (see Table 2.8).

Yield streams for cocoa are derived most reliably from the basic planting-output model, summarised under coconuts. The model has been investigated by Bateman (1965), Behrman (1968) and Ady (1968) in studies aimed at deriving cocoa supply functions for the regions and countries in West Africa. The planting output model served to supplement the planting decision relationship when data on acreage planted was not available (Lim 1975).

Both Bateman and Behrman adapt the basic planting output model to the two phase yield curve assumed in earlier cocoa studies (Beckett 1921). Thus the yield curve is defined simply by estimating two yield coefficients and the corresponding two ages at which the yield increments occur. While these coefficients are contained in the supply equations estimated by the aforementioned, solution of

TABLE 2.8

COCOA PRODUCTION: OUTPUT AND YIELD DATA
AT A POINT IN THE LIFE CYCLE (DRY BEANS)

Source	Yield (Kg/Ha)	Trees/Ha	Yield (Kg/Tree)	Age Information
Urquhart 1955, p.199 Gold Coast 1930s	393-674	(1.5 m spacing)	0.09-0.16	Average for 1st 20 years of production
Smallholder Survey, Gazelle Peninsula, PNG 1973	(a) 296-494	570	0.52-0.87	82% mature trees in the stand
	(b)		0.63-1.06	Mature equivalent
Smallholder Survey, Bougainville, PNG	(a)	600	0.55	65% mature trees in a stand
	(b)		0.84	Mature equibalent
Nair et al. 1970, Cocoa under Coconuts (Forastero seedings)	(a)(i) 143.5 (ii) 308.0	350	(i) 0.41 (ii) 0.88	Year 3 Year 4 } Single Row
	(b)(i) 266.5 (ii) 448.5	650	(i) 0.41 (ii) 0.69	Year 3 Year 4 } Double Row
WSTEC, Western Samoa (Trinitario) Murray 1971	276-439	494 (4.6 m spacing)		35-45 years
Vaoi Brothers, Western Samoa (Trinitario) Murray 1971	674-786	494	1.36-1.59	20-30 years

their absolute values was not possible due to under-identification of the simultaneous expressions derived for the coefficients (see Appendix C). Ady in her review (1968) questions the validity of the two phase yield curve.

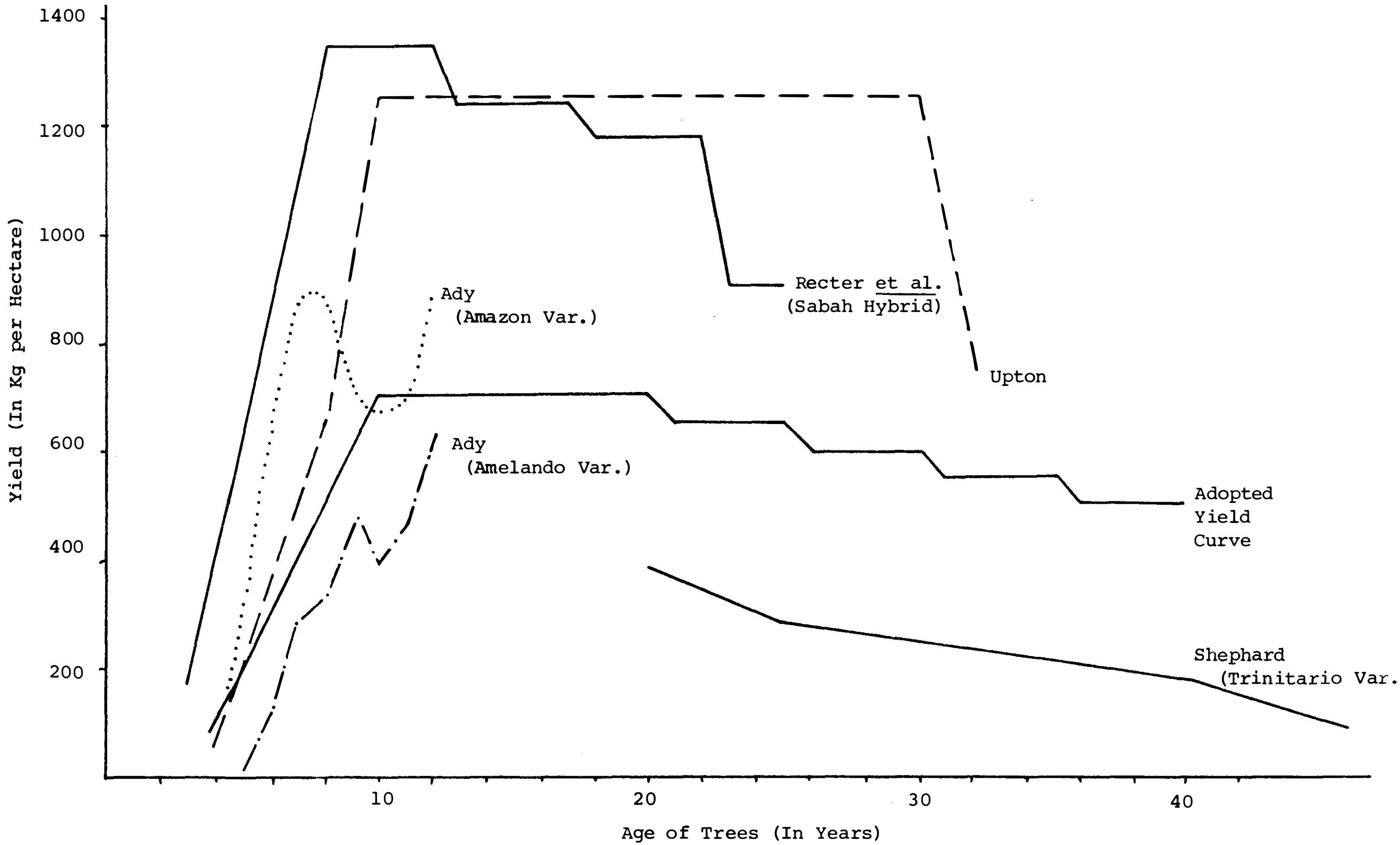
The yield curves presented by Ady (Figure 2.3) including imported varieties (new 'Amazon' material) are interesting, showing substantially different curves for the different cocoa varieties. The variability in the curves for the introductions makes it difficult to discern any general pattern except that bearing commences as early as year 3 and rises rapidly to full bearing at around years 6 to 8. This suggests unfortunately that generalising from the Forastero yield curves to the Western Samoan Trinitario type is highly questionable.

Upton (1966), considering the problem of optimal replacement in cocoa, presents a yield stream for years 1 to 32 (see Figure 2.3). In comparison with other curves available, the rate of increase in production at commencement of bearing is of the same order, while the level of production at maturity (years 10 to 30) is high. A sudden decline from year 30 is assumed. No empirical basis for the data is given.

Shephard (Urquhart 1955, p.107-119), discussing the rehabilitation of cocoa plantations in Trinidad confirms the observation of Bateman that individual healthy cocoa tress may continue to improve in yield or at least maintain it for as long as 100 years on a good soil. However few attain such an age. The tree casualty rate is such that by 40 years Shephard found that less than half the

FIGURE 2.3

COMPARATIVE COCOA YIELD CURVES



original trees would have survived and only 10 per cent remained at 60 years. Thus even under plantation conditions with replacement of individual dead trees[7], yield per acre was found, over a 15 year period (1935-1950) to fall from 625 kg/ha to 337 kg/ha. From Bateman's discussion (1965), the yield per unit area is expected to decline approximately 30 years after planting. Shephard's data for yields on poor cocoa soils points to an earlier decline from around year 20 (see Figure 2.3).

In coming to a decision on the adoption of a suitable yield stream it is pertinent to note present proposals by the Samoan Department of Agriculture regarding breeding and selection work in cocoa.[8] It will be assumed that at least Phase 3 or provision of selected planting will be reached by the time establishment of cocoa enters the intercropping model. Thus the upper levels of present yields being achieved could be assumed to represent an average position for use in the model. Referring to Table 2.8, the productivity achieved at Vaisala Savaii on the Vaai plantation is selected as representing present high yields and future average

7 The system of individual replacement often fails to establish a new thriving tree and was shown by Shephard to be incapable of sustaining yields. Thus a system of complete replanting of sections is advocated.

8 Under the new scheme (Friend 1975) farmers are to be supplied with unselected Trinitario seedlings in Phase 1 and seedlings from imported selected Trinitario seed from Papua New Guinea in Phase 2. Phase 3 will replace imported seed with selected Samoan Trinitario material and Phase 4 will involve long-term hybridisation and production of high yielding, disease resistant hybrid seedlings from locally established seed gardens. Murray (1972) describes in detail the requirements for Phase 4 and suggests it will be 10 years from initiation of the project until seedlings will be ready for farmers.

production with improved husbandry. For convenience in analysis a constant rate of production increase is assumed to year 10 followed by a step function over the declining phase to year 40. Each step level determines a constant annuity value over the range of that step. The shape of the curve is approximated relative to the yield streams available and to a maximum yield at maturity of 1.4 kg of dry beans per tree. The spacing adopted relates to that used in the multi-storeyed cropping models (Nelliat et al. 1974), of 2.5 m square or 1600 trees per hectare. Given the synergistic effects of the coconut-cocoa combination found by Nair et al. (1975), it is not felt necessary to adjust cocoa yields to the intercropping situation. Table 2.9 gives details of the adopted yield stream.

TABLE 2.9

COCOA YIELD STREAM: VALUES ADOPTED FOR THE MODEL
(KG DRY BEANS)

Year	Yield per Tree (Kg)	Yield per Hectare (Kg)
4	0.2	320
5	0.4	640
6	0.6	960
7	0.8	1280
8	1.0	1600
9	1.2	1920
10-20	1.4	2240
21-25	1.3	2080
25-30	1.2	1920
31-35	1.1	1760
36-40	1.0	1600

Cocoa Prices

Recter et al. (1972) have presented an analysis of London market spot prices for cocoa for 1954-70, which demonstrated a highly significant cyclical pattern of four phases, the first two phases of 3 years each and the last two of five years each. The regression fitted was a polynomial of degree six. A general declining trend was also predicted. However it is a matter for concern that the authors have produced a 16 year cyclical pattern based on 17 years' data. Further difficulties relate to the market situation that has developed in the 1970s, with prices returning to the levels of the 1950s and reaching record levels in 1974 and 1976. From the discussion of FAO demand and supply projections and the International Cocoa Agreement (Technical Appendix 2), the price of US 50c/lb (T825/tonne) used for demand projections will be assumed as the f.o.b. price received by the Western Samoan Cocoa Board. Further, it is assumed that the Cocoa Board, following the recommendations of Murray (1972), will reduce reconditioning and make other cost savings and, by effecting improvements in overall crop quality from central fermentaries, be in a position to pay out 70 per cent of the f.o.b. price for dry beans, i.e. T619 per tonne. While the model will assume marketing of wet beans and therefore no processing costs, the cash flow is based on yield, price and input data in terms of dry beans, as this is the form in which the data are available and no satisfactory basis is available for conversion to a wet bean basis.

Costs of Production for Cocoa

Activities in establishment are lining, hole digging, seedling cost, light clearing or weeding, planting and fertilising in year one with weeding and fertilising in the two subsequent years prior to commencement of production.

Urquhart (1955: Appendix II) presents costs and returns from smallholder production in West Africa. Different establishment methods limit their potential for application to Western Samoa. Other studies with cost information are derived from estate production systems so that similar limitations apply (Urquhart 1955, Upton 1966, Bulder 1972 and Recter et al. 1972). From Western Samoa, surveyed costs of production have been conducted for banana production (McConnell 1972, Rhee 1974a, Hiemstra 1977) and for certain operations in common, information is applicable.

The cost of planting material, rooted clonal cuttings, under the previous Cocoa Project of the Western Samoa Department of Agriculture was T3.00 per 100. As Planting will take place under the assumption that stage 5 of the new selection and breeding program is achieved (Technical Appendix 2), the value imputed to planting material is T15.00 per 100.

Lining and holing, adapating the recommended 10 inch cube hole, is estimated to require one manday per 60 holes. This is supported by banana cost data (McConnell 1972) where a similar hole is required for a banana corm. Planting is estimated at 60 seedlings per manday. The clearing of the cover crop will be effected by a light spray of paraquat (12 litres/hectare). The sprayed cover will provide useful mulch and little regrowth is expected. Spraying requires three mandays per hectare. Weed control in the remainder of the establishment year is expected to require four further treatments, requiring spot spraying of 30 per cent of the original area. In subsequent years the cocoa canopy develops rapidly and control is effected by spot spraying 20 per cent, 15 per cent and 10 per cent of the original area in years 2, 3 and 4 onwards, respectively four times per annum at the rate of 17 litres per hectare.

Fertilising recommendations for cocoa vary widely. No work is available from Western Samoa giving fertiliser requirements over the life cycle of the tree. Many of the problems noted by de Silva (1976) in coconuts will also apply in cocoa. The recommendations of Murray (1972) are adopted after consideration of the levels in comparison with those of other workers (Technical Appendix 2). A modification is felt reasonable however to the extent that the rate of application build-up is delayed to fall into phase with the yield and income build-up. Given that the area was in a legume cover crop prior to establishing cocoa, this is not expected to reduce the assumed yield stream which is still regarded as suitably conservative. Further, as 10.5.10 is the NPK fertiliser supplied through the agricultural store and not 15.15.21, the levels are approximated by amounts of 10.5.20 (see Appendix B, Table 2). Fertiliser is applied using three mandays per hectare.

From year four when trees start bearing, black pod will be controlled by two sprayings of a zinc based fungicide (Manzate D at 500 gm/hectare) during November and December plus removal by hand of infected pods. Rat damage will be controlled again from year 4 by laying Warfarin bait at a cost of T10 per hectare per annum.

Pruning[9] of new plants should start two years from establishment. Urquhart (1955 p.193) reports pruning labour requirements as approximately 0.5 mandays per annum from year 2: another case where pruning and supplying in year 2 required three mandays, with four mandays per hectare in subsequent years prior to yield for 'care of trees'. A further example required 17 mandays in year 2 for 'care of trees', pruning and supplying and 8 mandays in years 3 and 4 for 'care of trees'.

Supplying or replacing of dead seedlings is recommended during the first year after planting; later than this, competition from neighbouring healthy trees prevents the likelihood of successfully establishing a replacement (Shephard 1955).

Pruning is budgeted at two mandays per 500 trees in year 2 and one manday per 500 trees in subsequent years. Assuming the need to supply 15 per cent of trees, costs will include seedlings at T15/100, redigging the hole and planting at 50 trees per manday.

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9 At closer spacings the aim is to encourage 3-4 vigorous non-competitive branches from the jorquette (point of branching). Chupons or sucker growths are also removed. Excessive pruning stagnates growth, reduces yield, causes excessive flushing and makes the tree more susceptible to insect attack.

Harvesting of pods from the tree, breaking them open and removal of wet beans is one of the major demands on labour occurring seasonally. The main crop in Western Samoa is harvested during July-August while the secondary crop comes in during December. Size of the latter crop varies considerably, with the biennial beaning tendency of cocoa being very small in 'off' years and vice versa. However with no specific data available, such effects have had to be averaged out in the assumed yield stream.

Data on labour for the harvesting process varies from 15 mandays per acre (Beckett 1921), 18 mandays per acre in Lukolela Estates, Zaire (formerly Belgium Congo) with a yield of 600 lb per acre (Urquhart 1955) while Recter et al. (1972) costs harvesting at $M0.07/lb. These estimates are compared on the basis of labour input per tonne of dry beans (Appendix B, Table 3) and a requirement of 30 mandays per tonne is adopted as being appropriate to the Western Samoa situation.

The fixed costs for smallholder cocoa production in the situation where wet beans are marketed are relatively small. A knapsack sprayer is purchased in year one for weed control and later black pod control work. Replacement is expected every 10 years. One spade is also needed in year one and two for hole digging in establishing seedlings. One pruning saw is purchased in year two for major pruning work in shaping the tree. Secateurs are used for minor pruning and for harvesting. Three are purchased in year 4 and one replaced every two years. Prices are shown in Appendix B, Table 4.

Cocoa Cash Flows

Three years of negative flows occur prior to the commencement of bearing in year four. Cumulative positive flows equal cumulative negative flows by year six. The assumed step yield function for cocoa, adopted in lieu of other more reliable information, has provided stable income flows. In practice, yield and price fluctuations would be expected to cause fluctuation in income, though the extent of such fluctuations is not able to be estimated with present data. Net revenues in the case of cocoa however suggest sufficient margin to reduce the amount of disruption caused to farmers by such fluctuation. However, in comparison to coconut which produces a steady cash flow through the year, cocoa has a seasonal harvest and cash flow. In this situation income fluctuation may have a greater impact on expenditure on maintenance inputs, which for cocoa is expected to have some detrimental effect on future yield flows.

Net revenue per manday in cocoa is considerably more substantial than for copra. Following the establishment phase during which time and investment of capital and labour is made, the net revenue per manday in each year is much greater than the current minimum wage (see Table 2.10).

Pineapple

Pineapple is the 'new' crop being investigated for the model, in the sense that it is not a traditional crop in Western Samoa. It is part however of the CPCRI intercropping system and potentially a useful smallholder crop in the Western Samoan context.

TABLE 2.10

COCOA CASH FLOWS AND LABOUR INPUTS

Year:		1	2	3	4	5	6	7	8	9	10-20	21-25	26-30	31-35	36-40
Gross Revenue	(T)				198.08	396.16	594.24	792.32	990.40	1188.48	1386.56	1287.52	1188.48	1089.44	990.40
Variable Costs	(T)														
Planting Material		240.00	36.00												
Clearing		42.00													
Weeding		50.40	47.60	37.70	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80
Fertilising		40.00	40.00	40.00	40.00	80.00	160.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00	320.00
Pest Control					15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Total		387.40	138.60	92.70	78.80	118.80	198.80	358.80	358.80	358.80	358.80	358.80	358.80	358.80	358.80
Net Revenue	(T)	-387.40	-138.60	-92.70	119.28	227.36	395.44	433.52	631.60	829.68	1027.76	928.72	829.68	730.64	631.60
Labour Input	(MD)														
Lining and Holing		27	4												
Planting		27													
Clearing		2													
Weeding		4	4	4	4	4	4	4	4	4	4	4	4	4	4
Fertilising		1	1	1	1	2	2	3	3	3	3	3	3	3	3
Pest Control					5	5	5	5	5	5	5	5	5	5	5
Pruning				3	3	3	3	3	3	3	3	3	3	3	3
Harvesting			6		10	19	29	38	48	58	67	62	58	53	48
Total		61	15	8	23	33	43	53	63	73	82	77	73	68	63
Net Revenue/Manday					5.19	8.40	9.20	8.18	10.03	11.37	12.53	12.06	11.37	10.74	10.03

It is brought in as a possible first period crop and then reintroduced from period four when shading is reduced again.

Pineapple Yields

Major influences on pineapple yields are planting density and crop number, be it main crop, or first or second ratoon. Yields at traditional planting densities (10,000 plants per hectare) give large fruit (6 kg) but these involve more wastage in processing and lower yields on a per unit area basis. At higher planting densities and input levels fruit size lies in the range 1.2 to 1.8 kg. Variations in yield between crops are reported for 36,000 plants per hectare. Main crop averages are 50 tonnes per hectare, first ratoon crops fall to around 37 tonnes while the second ratoon crop produces 25 tonnes per hectare (Collins 1960). Nair's (1976) production figures are 5000 kg from 3500 plants or an estimate of 80 per cent bearing for plants producing 1.8 kg fruit. The Collins data for 36,000 plants is broken down as 80 per cent bearing and 1.8 kg fruit at the main crop, 60 per cent bearing and 1.8 kg fruit at the first ratoon crop and 50 per cent bearing and 1.4 kg fruit for the second ratoon crop. Adapting the Nair and Collins figures to pineapple yields at average densities under coconuts, a yield stream of 1.2 kg fruit and 80 per cent bearing, 1.0 kg fruit and 60 per cent bearing and 1.0 kg fruit and 50 per cent bearing at 25,000 plants per hectare is adopted for the model. The time component is 20 months for the main crop after planting, a first ratoon crop 14 months later at 34 months and the second ratoon crop at 48 months followed by a 12 month period of working chopped plant residues back into the soil prior to replanting. In total this is a 5 year cycle.

Pineapple Prices

Given the lack of specific projects for export development of pineapple products in the Third Five Year Plan, the existing price offered by the Government Food Processing Laboratory appears a reasonable one to adopt in calculating cash flows. While this price, 2.5 sene[10]/lb is greater than that recommended by Martin (1971) it is supported by prices attainable for fresh fruit on the local and New Zealand markets.

Costs in Pineapple Production

The only data available for pineapple costs of production are those presented by Nair (1976). Comparison with the Western Samoa situation was attempted using an exchange rate of 10 rupees = T1.00 and a labour cost of 8 rupees per manday.

Preparatory cultivation required 17 mandays per hectare (Nair 1976) in the intercropping system investigated. Work required is the construction of beds between coconut rows running at right angles to the cocoa hedges. Preparation would be done in most cases with hand tools due to the rocky nature of many Samoan soils. Hence labour input is increased to 100 mandays per hectare. Land preparation in year five requiring 20 mandays per hectare is to mulch the old pineapple crop in order to maintain soil organic matter. The one year of fallow between pineapple cycles will allow the mulch to break down, so that together with the fertiliser application, production levels are expected to be maintained in successive crops.

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10 1 Tālā = 100 sene.

Planting material costs are presently limited to the costs of collection from the Agricultural College at Alafua. However an amount of T2.00 per 100 pieces is budgeted, anticipating increased demand and to ensure good material.

Planting manday input was imputed from information on taro planting. This was 400 plants per manday including work required in mulching with dry coconut leaves around the plants.

Fertiliser application adopted is 0.05 kg per plant of NPK 10.5.20 as the amount providing the recommended level of nutrients per plant (see Technical Appendix 3, Table 1). Fertiliser is costed at the unsubsidised value of T0.20 per kilogram. Application is divided into four amounts during the year requiring one manday per application.

Weed control requirements are based on data available from McConnell (1972). In year one an initial spray of 17 litres per hectare of paraquat is applied to give suitable control at planting. This is expected to be maintained by quarterly applications of paraquat at the rate of 11 litres per hectare. Each application requires two mandays. Under pest and disease control, provision is made during the bearing years for rat control and spraying of pesticides.

Harvesting input reported by Nair (1976) was R220 or the equivalent of 5.4 mandays per tonne. Data on taro harvesting suggests however that 500 kg of fruit can be harvested per manday which is the input used in the model.

Pineapple Cash Flow

Cash flows are derived for the yield and cost information available over the five year cycle of one pineapple planting. Table 2.11 summarises the data including the labour input. Present lack of significant pest or disease problems together with the moderate weed control required under coconuts make pineapple an attractive proposition. Cumulated figures without discounting show a net revenue per manday value at T6.64.

TABLE 2.11

PINEAPPLE CASH FLOW AND LABOUR INPUTS

Year:	1	2	3	4	5	Total
Crop		1	2	3		
Yield per Plant (Kg)		1.2	1.0	1.0		
Percent Bearing		80	60	50		
Yield per Hectare (Tonnes)		24	15	12.5		
Gross Revenue (T)		2712	1695	1412.5		
Costs (T)						
Planting Material	500					
Fertiliser	360	360	360	360		
Herbicides	175	154	154	154		
Pesticides		20	20	20		
Total	1035	534	534	534		
Net Revenue (T)	-1035	2178	1161	878.5		3182.5
Mandays						
Land Preparation	100				20	
Planting	62					
Fertilising	4	4	4	4		
Spraying	8	8	8	8		
Hand Weeding	30	30	40	40		
Pest Control		2	2	2		
Harvesting		48	30	25		
Total	204	92	84	79	20	479

Taro

Taro is also a potential intercrop during both intercropping phases and, as a very shade tolerant species, it is reintroduced at period three. It is the shortest term crop considered so that each period involves three or four crop cycles.

Taro Yields

The early intercropping phase, period one, of six years assumes two taro cycles of three crops each. With a crop interval of eight months from planting to harvesting each cycle occupies the land for two years permitting a two year legume fallow between the two cycles. A traditional spacing pattern is adopted of 90 cm x 90 cm or 12,000 plants per hectare. Based on the average yield of 11.3 tonnes per hectare, a conservative yield stream is adopted assuming run-down fertility for the land at the beginning of the program, but some response to the inputs of fertiliser and weed control. Actual yields are given in Table 2.12 (p.76).

The later intercropping phase, periods three to ten, involves five year intervals. Given that the model may choose to intercrop with taro continuously over that period a conservative yield stream was adopted in spite of a likely improvement in soil fertility, the input of fertiliser and research results for individual crops using closer spacing. The five year interval is cropped four times which leaves, with a nine month crop interval, a twenty-four month fallow period for a legume crop. Yields adopted are given in Table 2.13 (p.77).

Taro Prices

Due to the present level of fluctuations in taro prices,[11] caution is needed in allocating a particular price over the period of the model. However, given policy initiative to stabilise the New Zealand market, together with growth in the market resulting from Polynesian migrants to New Zealand, the net producer price given by Rhee (1974c) of T2.67 per 32 kg case or 8.3 sene per kilogram is adopted.

Cost of Production in Taro

As taro is being introduced in the intercropping model solely in the role of a cash crop, a number of changes to traditional practices are assumed. While a portion of the required planting material could be obtained from shoots produced in subsistence taro stands, for the purposes of simplifying the model and also to ensure sufficient availability of material when required, the current price for purchased planting material of T3.00 per 100 is budgeted.

Clearing costs for trees and scrub prior to early phase intercropping have been accounted for under coconut replanting. In both phases however the ground cover has to be sprayed prior to planting. This is achieved using 17 litres/hectare of Paraquat at a cost of T50.50 and three mandays per hectare. Planting is one of the major labour costs in taro production. Lockwood (1971) found, that

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11 Rhee (1974c) prices for the export market (Technical Appendix 4): Enright (1976) records price at 15c/kg in 1974 increasing to 59c/kg in 1975 and reducing to 15c/kg in 1976 in the local market.

on average, 35 man hours were required for clearing and planting 1000 taro. An allocation for planting alone of 15 man hours or 3 mandays per 1000 taro is made.[12] While up to six hand weeding operations may be carried out prior to harvesting, three such operations are assumed to represent the average requirement. In the model it is proposed that weeding be effected by two applications of 11 litres per hectare of Paraquat and one hand weeding at 20 mandays per hectare.

Harvesting involves lifting the tuber, removing dirt, tops and roots and packing in 32 kilogram cases supplied by the marketing authority, assuming the output is being sold for export. It is estimated that 13 cases or 416 kilograms of taro can be harvested and packed per manday.

Fertiliser is applied according to the recommendations of Leach et al. (1976). This requires application of 18 kg per 1000 plants of NPK 10.5.20 and the spraying of 1.4 kg per 1000 plants of urea. Cost is T3.88 per 1000 plants plus a labour input of seven mandays per hectare of taro.

Following a crop cycle of three crops in the early phase and five crops in the late phase, a cover crop is established to rebuild fertility and smother the weeds. Pueraria phaseloides is established by broadcasting seed after the last harvest at a cost of T10.00 per hectare.

The fixed costs of taro production are limited to basic tools and are given in Appendix B, Table 6.

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12 Confirmed by personal communication with Mr T. Neru, Extension Division, Department of Agriculture, Western Samoa.

TABLE 2.12

TARO CASH FLOW: EARLY INTERCROPPING PHASE

Cycle:	1			2			Total
Crop No:	1	2	3	4	5	6	
Yield (Tonnes/Ha)	14	12	10	12	10	8	
Gross Revenue (T)	1162	996	830	996	830	664	
Costs (T)							
Planting Material	360	360	360	360	360	360	
Clearing	60	60	60	60	60	60	
Weeding	77	77	77	77	77	77	
Fertilizer	150	159	150	150	150	150	
Cover Crop							
Total	647	647	657	647	647	657	
Net Revenue (t)	515	349	173	349	183	17	1586
Labour Input (MD)							
Clearing	2	2	2	2	2	2	
Weeding	24	24	24	24	24	24	
Fertiliser Application	7	7	7	7	7	7	
Cover Crop			1			1	
Planting	36	36	36	36	36	36	
Harvesting	34	29	24	29	24	19	
Total Mandays	103	98	94	98	93	89	575
Net Revenue per Manday							2.76

TABLE 2.13

TARO CASH FLOW: LATE INTERCROPPING PHASE

Crop No:	1	2	3	4	Total
Yield (Tonnes/Ha)	16	14	12	10	
Gross Revenue (T)	1328	1162	996	830	
Cash Costs (T)					
Planting Material	360	360	360	360	
Clearing	60	60	60	60	
Weeding	77	77	77	77	
Fertiliser	200	200	200	200	
Cover Crop					
Total	697	697	697	707	
Net Revenue (T)	613	465	299	123	1500
Labour Inputs (MD)					
Clearing	2	2	2	2	
Weeding	24	24	24	24	
Fertiliser Application	7	7	7	7	
Cover Crop				1	
Planting	36	36	36	36	
Harvesting	39	34	29	24	
Total Mandays	108	103	98	93	402
Net Revenue per Manday					3.73

Taro Cash Flows

Tables 2.12 and 2.13 summarise the costs and returns information for the early and late intercropping phases respectively. Technology assumed has reduced the labour input over traditional practice. However with full costing of all inputs and a conservative yield stream the returns to labour are moderate. The particular advantage of taro is in its early generation of income and low fixed costs.

Bananas

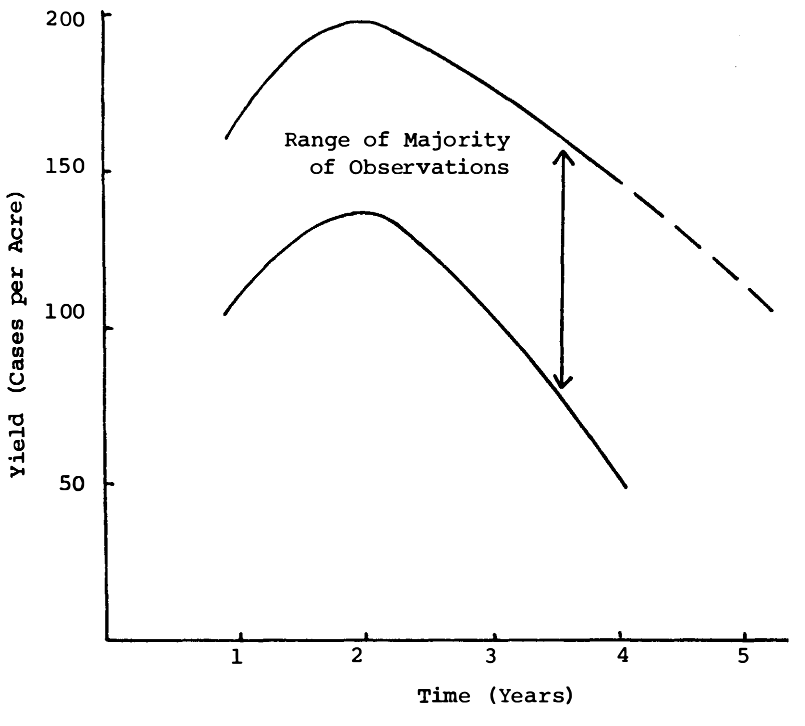
Due to lack of data on such alternatives as production for the local market or production from the disease resistant local varieties of banana, the cash flows are based on the production of export quality bananas using the Cavendish variety and assuming the continued availability of presently subsidised inputs.

Banana Yields

McConnell (1972) surveyed twelve commercial banana plantations. In defining yield he noted difficulties such as the lack of records or records for export only and considerable variability between farms and within farms over time. He defined a range between which the majority of plantations fell, and was able to show a yield trend over time (Figure 2.4). In addition to the exported portion of output, McConnell found on average that 15 per cent of production was rejected for export and was sold at the Apia market.

FIGURE 2.4

BANANA YIELD STREAM



Source: McConnell, 1972.

Rhee (1974b) surveyed 59 plantations throughout the country and obtained production estimates derived from plants per unit area, number of bunches per plant per year and bunch weights. As this information was gained through questioning farmers at one point in time, the higher yields obtained compared with McConnell are viewed with caution (see Table 2.14).

Hiemstra (1977) provides the latest review of data, updating McConnell's estimates for prices, presenting a case study of a plantation with high inputs and production and suggesting an intermediate level operation as being 'typical' of present plantation practice by accounting for the increased problems of disease control since the McConnell study. This level of costs and returns is adopted for the purposes of the study, as representing the technology necessary for the intensive intercropping program being modelled.

Banana Prices

Price is fixed, for export bananas f.o.b. Apia, through negotiation between the New Zealand importer and the Western Samoa Banana Board. On the basis of the negotiated f.o.b. price, the Banana Board deducts its costs calculated on a per case breakdown and fixes a price paid to the grower. At present, this includes a T0.80 per case subsidy to the grower in a total price of T2.40 per case (22.7 kg). This total price is assumed for the purposes of the model, as Hiemstra's study (1977) indicates that profitability of production is dependent on such a subsidy at present.

TABLE 2.14

COMPARISON OF BANANA YIELD DATA

McConnell (1972)		
Year	High Yield (Cases)	Low Yield (Cases)
1	160	100
2	200	140
3	170	100
4	150	50
5	120	0

Rhee (1974)	
District	Yield (Cases)
I	308.8
II	325.4
III	391.1
IV	220.9
Size of Plantation (Acres)	
<1	240.6
1-2	287.3
2-4	296.1
>4	385.2

Costs of Production

The following inputs are designated by Hiemstra as required for the production stream for bananas assumed. The input of 37 mandays per hectare to slash and clear medium bush allowed by Hiemstra is not required in the intercropping model. Instead a blanket spray at 17 litres per hectare of Paraquat is allowed to kill off the cover crop prior to planting. This costs T50.50 and two mandays to apply. Lining and hole digging (1750 per hectare) requires an input of 16 mandays. Planting involves 10 mandays while planting material at T3.00 per 100 costs T52.50. Corms are trimmed and dipped in Dieldrin to combat nematodes at T7.40 and 3 mandays. Weeding requirements are reduced from that recommended by the shading effect of the coconuts and by the use of a cover crop prior to inter-cropping. Weed control is effected by two hand weedings totalling 20 mandays, plus four inter-row sprays at 5 litres per hectare costing T17.50 plus two mandays. Further nematode control after planting requires the application of 2.5 litres per hectare of Fumazon and weevil control, 1.2 litres per hectare of dieldrin. Cost is T11.10 and three mandays. While Department of Agriculture services are available for leafspot control, the regularity of treatment required together with some difficulties in the supply of the service make it advisable to budget for a mist blower (see fixed costs) and the application of 140 gm per hectare of Benlate at two week intervals from three months after planting. Misting oil is applied simultaneously at 11 litres per hectare plus 70 gm per hectare of sticker. Costs total T65.00 and labour for application and removing infected leaves is 36 mandays per hectare. Scabmoth control in the fruit requires puffing with DDT at 250 gm per case or T0.17 per case. Forty-eight cases can be treated per manday.

Costs in years two to five require adjustment from the levels in year one. Weeding is reduced to two applications of Paraquat at 5 litres per hectare (T8.80 and four mandays). Fertiliser application is constant over the five years at 1 kg per plant of NPK 10.5.20 or 1.75 tonnes per hectare costing T70.00 at the subsidised price of T0.04 per kg. Application involves two mandays. Nematode and weevil control application rates are doubled to T22.20 per hectare applied by three mandays of labour. Leaf spot control is increased 33 per cent to extend over the full 12 months being T86.50 and 48 mandays. Provision is needed for bunchytop control, to dig out and cut up infested plants for spraying by the Department of Agriculture control program. This input is 60 mandays per hectare. Desuckering is necessary from year two to maintain strong following plants and is carried out each month needing 24 mandays per year. Harvesting requirement is 17 mandays per 100 cases.

Banana Cash Flows and Fixed Costs

While bananas provide a regular flow of income over time, gross revenues are constrained at present export price and net revenues are reduced by the high cost component (see Table 2.15). This comparison with other crops is less marked in the data given, as banana costings involve subsidised inputs in line with government policy. Other crops have used unsubsidised costs. Net revenue per manday compares unfavourably with the other intercrops and is only slightly better than coconut. Fixed costs (Appendix B, Table 7) are also greater than for the other intercrops due to the need for a misting machine.

A Comparison of Cash Flows

Having defined the crop cash flows and the intercropping patterns permitted under the system adopted, it is possible to examine the results comparatively to see what conclusions can be drawn. The

TABLE 2.15

BANANA CASH FLOW AND LABOUR INPUTS

Year:	1	2	3	4	5
Yield Cases/Hectare	400	550	450	350	250
Gross Revenue	960.00	1320.00	1080.00	840.00	600.00
Variable Costs					
Clearing	50.50				
Planting Material	52.50				
Corm Treatment	7.40				
Weeding	17.50	8.80	8.80	8.80	8.80
Fertiliser	70.00	70.00	70.00	70.00	70.00
Nematode and Weevil Control	11.10	22.20	22.20	22.20	22.20
Leafspot	65.00	86.50	86.50	86.50	86.50
Scabmoth	68.00	93.50	76.50	59.50	42.50
Total	342.00	281.00	264.00	247.00	230.00
Net Revenue	618.00	1039.00	816.00	593.00	370.00
Labour (MD)					
Lining and Digging	16				
Clearing	2				
Planting	10				
Corm Treatment	3				
Weeding	28	4	4	4	4
Fertilising	2	2	2	2	2
Nematode Control	3	3	3	3	3
Leafspot Control	36	48	48	48	48
Scabmoth Control	20	28	23	18	13
Desuckering		24	24	24	24
Harvesting	163	224	184	143	102
Bunchytop Control		60	60	60	60
Total	283	393	348	302	256
Net Revenue/Manday	2.18	2.64	2.34	1.96	1.45

intercropping constraints are recalled as follows: taro and pineapple in period one, no intercrops in period two, cocoa and taro in period three and all intercrops from period four.

A first method of easy comparison is to consider the returns per manday of labour input.

TABLE 2.16

NET REVENUE PER MANDAY

(T)

Coconuts			Cocoa	Pineapple	Taro		Banana
A	B	C			Early	Late	
1.86-1.06	1.77-0.99	1.69-0.86	5.19-12.53	4.16	2.76	3.73	2.17

Table 2.16 demonstrates dramatically the low profitability of coconuts and the potential to provide, through intercropping, a return to labour competitive with the basic minimum wage of T2.00.

In period one, pineapple has the advantage over early taro on the basis of return per manday. In period three comparison between cocoa and taro favours the former. However the effect of time preference may be important here in determining the balance between early income from taro as opposed to a higher income stream from cocoa after an interval of four years. This becomes even more apparent when a comparison is made in period four between taro and pineapple, the latter having a slightly higher return per manday but with negative income in year one compared with a positive income for taro. Thus it is going to be necessary to consider discounted cash flows to improve the comparison between alternative crops.

Differences between crops in the year that income flows become positive implies different establishment or investment costs, requiring the producer to have sources of capital available. This now means that crops should also be considered on the basis of their return to capital, especially where that capital is in limited supply. Thus the problem of evaluating crop alternatives involves two limiting resources for which it is necessary to define resource availability. It is now evident that a programming algorithm may well be more efficient in such an evaluation than a visual appraisal of sets of returns to labour and capital.

This is reinforced when we increase the range of questions asked: to consider the potential of the farm enterprise under intercropping, to utilise additional family labour presently deployed in wage employment, or to utilise loan funds under alternative repayment conditions. The transfer of cash from one period to the next to provide development capital is another consideration which will influence when a crop can most profitably be introduced. The cash surplus available to family consumption, following allowance for fixed costs and the other cash using and providing activities, could conceivably be derived from the cash flow comparison, but would be optimal only if the earlier decisions on the most profitable crop combination had been answered correctly. A final question to answer, and perhaps the most significant in terms of the farmers decision making is at what density to initially establish the coconut stand so as to optimise the overall intercropping system's generation of cash surpluses. This decision using a suitable programming algorithm can also be considered at different resource levels, in particular for land, and at different time preference rates.

The next chapter will therefore set out to investigate alternative programming approaches within the context of the system being studied and of the environment in which it is proposed that it should operate.

CHAPTER 3

APPROACHES TO MODELLING THE FARM FIRM OVER TIME

Of the possible approaches to the economic analysis of intercropping of coconuts, those which provide decision rules to optimise the farmer's criterion or objective function will be examined in this chapter.[1] While modelling in all cases must be an abstraction from the real world, the model chosen should be able to specify, with a degree of realism, a number of technical and economic interrelationships over time. For this reason, the budgeting approach used in the cash flow analysis, with its limited capacity to consider interdependent relationships of variables, was found wanting and was rejected in favour of programming approaches where simultaneous endogenous solution of such variables are possible. Following a discussion of some of the difficulties that time brings to the analysis, this chapter goes on to consider alternative programming techniques in order to focus in the last section on a technique considered appropriate to smallholder coconut production in Western Samoa.

Time

The incorporation of time into mathematical models is approached in a variety of ways. Those models where time itself is treated as a continuous independent variable are not relevant to the present problem and are disregarded. Further, time enters the analysis

1 Non-optimising approaches such as simulation are considered beyond the scope of this study and are not considered.

in the Hicksian sense, as compared with the Frisch-Samuelson concept involving uncertainty of prices and technology over time. In "Value and Capital", Hicks writes:

> "The definition of economic dynamics ... (are) those parts (of economic theory) where every quantity must be dated.
>
> In economic statics we think of any entrepreneur employing such and such quantities of factors and producing by their aid such and such quantities of products, but we do not ask when the factors are employed and when the products come to be ready. In economic dynamics we ask such questions; and we even pay special attention to the way changes in those dates affect the relations between factors and products." (Hicks 1948, p.115)

Hicks notes that output produced in time t is a different output from that produced in time t+1 and hence, just as in the multi-product case, we have a choice of alternative outputs. Furthermore, evaluating the preferred production plan, Hicks states that where different streams of net revenue result from alternative input strategies, the criterion for comparisons is the capitalised or present value of the surplus stream.

To determine present value, prices and price expectations, and interest and interest rate expectations, must be known. The interest rate, under perfect competition, is the cost of borrowing one unit of money for one period. More significantly, the equilibrium interest rate will equal the rate of time preference for each consumer and the marginal rate of return on investments for each producer.

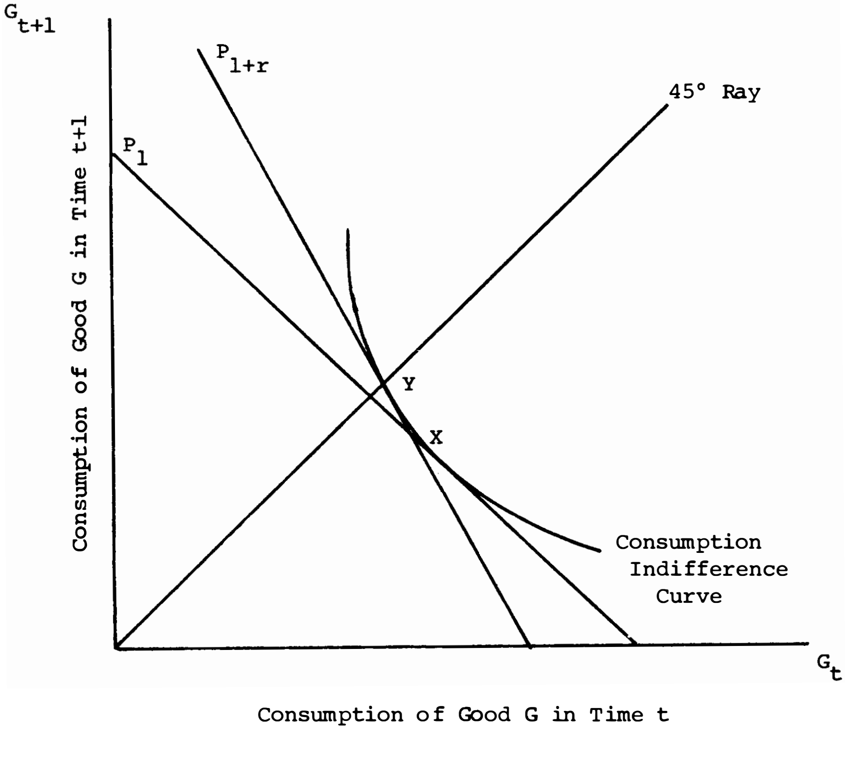
Consumer time preference, according to Böhm-Bawerk, exists where there is an anticipation of rising future wealth permitting an increase in present consumption. It may also arise from an underestimation of future needs resulting in high present marginal propensity to consume. Thirdly, he asserts that present goods will be preferred where they can be traded for future goods.

Consumption indifference curves can be used to represent time preference where the two goods are G_t, in time t on the horizontal axis, and good G_{t+1}, consumed in time t+1 on the vertical axis (see Figure 3.1). Positive time preference is shown by equilibrium consumption points below the 45° ray (X), given that the price line (P_1) represents equal prices in both periods, i.e. interest rate is equal to zero. The effect of a positive interest is to increase the slope of the price line (P_{1+r}) and the cost of present consumption. In equilibrium, the interest rate will equal the consumer's rate of time preference implying indifference between consumption in either period (Y). The level of time preference is generally found to be inversely related to income level and possibly influenced by such factors as short life expectancy and fatalistic philosophies.

Consider the producer, who is said to balance investment opportunities in the bond market and on his production unit. In the production unit the producer evaluates the marginal internal rates of return from investments in different periods and compares them with the market rates of interest for comparable periods. Higher marginal internal rates of return would induce the producer to borrow funds (supply bonds) for investment until the marginal internal rates of return on remaining investments equal the interest rate.

FIGURE 3.1

CONSUMER TIME PREFERENCE



In practice however, the marginal rate of return for on-farm investment and interest rate are not necessarily in equilibrium. Upton (1976) describes this problem of disequilibrium with reference to a simplified tree crop production model as representative of many farm investment processes. There is an initial 'construction period' using inputs but producing no output, followed by a 'running in' period as output increases and inputs reduce to a maintenance level. Then follows the period of normal utilisation with outputs shown to exceed inputs by a constant amount, terminated in the simplified representation at the point of replacement. To assume a steady state situation required for equilibrium either constant growth or zero growth must hold. In both cases a proportion of trees, appropriate to the replacement age must be replanted each year and this must have been in progress for at least a period equal to the replacement age.

Given a market rate of interest, the flow of inputs and outputs are discounted to give the sum of net present value (SNPV). A series of SNPVs derived for a series of time periods within the flow provides a profile of SNPVs or capitalised values. This profile will be zero in year 0 for a unique interest rate in the simplified model assumed, being the internal rate of return (IRR), while at higher interest rates there will be a period for which the capitalised value is negative. Given that the investment was mistakenly made and that the period of negative capitalised values has passed, it will pay to continue the process to the end of its life as capital value is now positive.

In a situation of technological change a new variety of the tree crop will have an IRR greater than the old variety. It is likely that finance for investment will be scarce so that the opportunity cost of using such finance is equal to the IRR of the new variety. The capital value profile of the old variety discounted at the new opportunity cost for investment finance will be negative in its initial years. But while it will no longer pay to invest in the old variety, existing stands of the old variety which have passed the period of negative capital value would be maintained as profitable. As the enterprise was assumed to be in steady state equilibrium prior to technological change, it will require planting with the new variety for the number of years equal to the replacement age before the enterprise regains equilibrium. During the period of disequilibrium different rates of return will be produced by the old and new varieties making it difficult to define a single rate of return on capital. Further, as other farmers adopt the new variety, aggregate supply functions will change, shifting prices and inducing further technological change.

Thus, given the time to reach a new equilibrium plus the likelihood of continued technological change, it is not possible to assume equilibrium between the rate of return on investment opportunities and the market rate of interest. Hence it may be necessary to make some arbitrary assumption as to the discount rate which represents the decision maker's time preference rate. This problem may be overcome by alternative formulations of the objective function which is to be maximised, and in practise is overcome where the Development Bank is able to set a specific rate of interest for specific programmes and allocate such credit through some rationing process.

Alternative Programming Techniques

In the following sections, alternative dynamic programming approaches are examined as potential models to represent the system under examination in this study.

Recursive Programming

Recursive programming is one of the approaches to programming over time.[2] Weinschenk (1971) defines recursive programming as:

> "a sequence of mathematical programming in which the parameters of a given problem are functionally related to the optimal variables of the preceding problems of the sequence."

In the multi-period case, this sequence is over time with the parameters related to values of variables in the previous time period.

Day (1963) describes the procedure as synthesising linear programming with difference equations. The difference equations specify the implicit time relationship between a variable and its value in the previous time period. The explicit solution of a difference equation gives a time path for the growth of a variable so defined. In recursive programming the specific time path solution is governed by the optimising rule for the objective function.

Ogunfowora and Heady (1973), and Day (1963), see the method's advantage to be its ability to accommodate varying technical and economic conditions in the process of optimising one period at a time. Parameters are based on actual performance in the previous

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2 Cf. parametric statis programming considered under multi-stage linear programming case study 2.

time period and expected values of the parameter for the following time period. Thus the model is dynamic, not only in the Hicksian sense but also in the Frisch-Samuelson sense of varying prices and input-output coefficients over time. However, Weinschenck (1971) notes that sequential optimising does not provide an optimum decision rule over time, but rather is more applicable to explaining behaviour: to describing an actual growth path instead of the optimum growth path. Hence its value is in prediction and not as a decision model. Further the cited advantage of adjustment to changing prices is less important when considered as movements in relative prices of inputs and outputs which are less variable. Similarly changing technical coefficients are much less of a problem in the long run for perennial crop agriculture where most of the technological change is embodied: that is, it is as new varieties so that the appropriate coefficients are fixed for the life of a particular stand.

Dynamic Programming

Dynamic programming as developed by Bellman (1957) involves an optimising algorithm based on the Markov chain rule whereby the optimal decision at a particular stage depends only on the state of the process at that particular stage. Stages are intervals into which the process is divided, involving a decision at each stage. The state at a particular stage describes the condition of the process, as described by the magnitude of the state variables. The policy defines the decision applicable for any given state. Dynamic programming provides an optimal policy for all lengths of planning horizon by deriving the optimal policy for an infinite planning horizon, and is the optimal policy for all possible states at the initial stage.

The approach starts with the last year of the planning horizon and works back to the current year. Burt and Allison (1963) find the technique is relevant to many farm management decisions which are sequential, such as machinery replacement, culling of breeding stock, fertiliser application and crop rotations, and to be especially powerful in the solution of such decision problems under stochastic conditions. However the method is efficient only in handling those decisions which can be specified according to the Markov chain rule; that is, relatively simply structured problems where the number of constraints is significantly reduced. For example, the state of the whole process must be capable of description by the level of only one key decision variable.

Given that a decision model and not a predictive model is required in the modelling of smallholder intercropping under coconuts, recursive programming is unsuited for this particular study. Further, in view of the large number of activities and constraints needed to model intercropping of coconuts, dynamic programming is also rejected.

Multi-Stage Linear Programming[3]

The Principles of Linear Programming

The linear programming model has become well established as an effective tool for decision-making under situations where

3 Terms poly-periodic and dynamic are also used. The latter term tends to confuse the method with Bellman's dynamic programming algorithm and so multi-stage is used in this study.

budgeting techniques become ineffective; that is where there are a number of variables with interdependent relationships requiring simultaneous solution in an optimising manner. Such is the case of multi-product firms operating with numerous resource, institutional and subjective restraints.

The model consists of a finite and discontinuous set of linear equations: an objective function to be optimised and a set of constraints. The objective function is a linear summation of variables representing levels of the alternative activities, weighted according to their contribution to the objective to be maximised. The operational constraints are composed of a column vector of resource levels and a matrix of input-output coefficients. In addition there are constraints specifying non-negative levels for each of the choice variables or activities. The solution involves a series of iterations bringing into the basis those activities with the highest contribution coefficients within the limitations imposed by the specified constraints.

Linear programming has the following assumptions:

Linearity: Linearity implies that as output is increased there is a proportional increase in the objective or constant returns to scale. This is not as restrictive as it initially appears since non-linearity can be approximated by fitting linear segments to the traditional production function, each segment being a different activity. For example, diminishing marginal product of additional hours of family labour can be met by establishing two or more labour constraints representing amounts of the 'different-productivity' labour with appropriate input-output coefficients.

Additivity: Additivity implies that each activity or production process is an independent separable process. Thus two activities can have supplementary or competitive relationships without contravening the requirement, but should be combined into one activity where they show a complementary relationship.

Divisibility: Divisibility requires that activities and constraints be represented by infinitely divisible units. One approach to indivisible items such as one labour unit or one tractor is to represent their input in terms of man hours or tractor hours. In the case of an indivisible capital investment a variation of linear programming known as integer programming is used.

Certainty: Certainty requires that quantities of inputs, technical coefficients and prices are known. This is the same assumption made in budgeting approaches and is only truly relaxed in stochastic forms of linear programming. However sensitivity analysis can be readily performed within the linear programming framework to determine the stability of the solution with respect to different price and resource levels.

Time in Linear Programming

Linear programming becomes multi-stage by the introduction of time. The time concept is again Hicksian: that is inputs, outputs and technical coefficients are dated according to the period in which they are used or produced. This represents an expansion of the ordinary simplex model such that the activity to produce X_1 in time t is a separate activity from that to produce X_1 in time t+1. Alternatively, the resource B_2 in time t is a different resource for B_2 in time t+1. Such a separation also occurs in the 'static' framework when, for example, labour is entered with separate seasonal constraints; the separation is formalised in the multi-stage model for all resources, activities anc coefficients.

Other variations in the model relate to the need to account for inter-relationships of activities and constraints through time. Firstly, the objective function represents a stream of net revenues over time. It is necessary therefore, to consider time preference, by using an appropriate interest or discount rate to discount the future stream of incomes to its present value. This is the objective to be maximised.[4] The discounted net revenues may be entered directly as contribution coefficients in the objective function or discounting activities for each period are activated on the net income row to bring total net income into the objective function.

Secondly, in tracing the growth of a firm over time, capital and labour inputs will change. Transfer activities are used to facilitate the movement of surplus in a capital constraint to the next period. Transfer of amounts within the matrix are made by entering the coefficient +1 in the row to be debited and -1 in the row to be credited.

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4 See following section for further discussion on an appropriate objective function.

Finally, in dealing with the family farm it is important to take into account the use of income. Income is needed to meet both fixed and variable farm costs, family living costs, income tax payments, loan repayments, personal savings and capital expenditure. Loan finance should be realistically incorporated and flexible timing of secondary development activities should be allowed. As demonstrated by Pearse (1974) these are all capable of realistic incorporation in a multi-stage linear programme, within however, the limits imposed by matrix size.

Two matrix formats can be adopted. The block-diagonal approach, with activities and constraints grouped by year, has been used by Loftsgard and Heady (1959) and Candler (1960). An alternative form in which the periods are grouped for each constraint and activity is known as the dense matrix form after Stewart and Thornton (1962).

A Summary of Some Empirical Work Using Multi-Stage Linear Programming in Agriculture

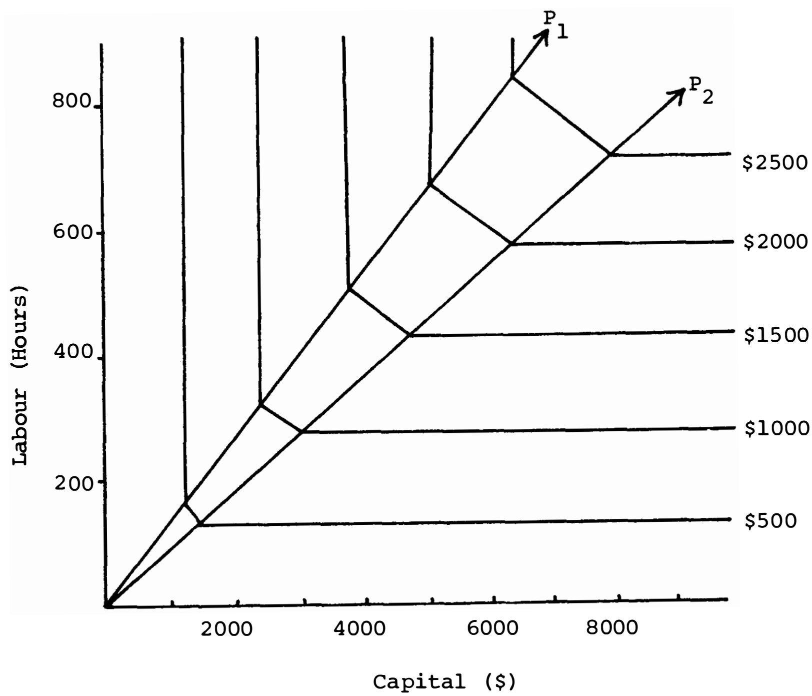
(1) Loftsgard and Heady (1959) were among the early expounders of the model. Their approach was confined to capital accumulation over time with other constraints fixed. No major investments were considered. Family living expenses and fixed costs (machinery depreciation, taxes, insurance and added investments) were determined exogenously. As a fixed cost activity they were forced into the basis by assigning an artificially high contribution coefficient and the false profit so generated was subtracted out at the end of the run. All activities were one period in length and their discounted

net revenue was used as the contribution coefficient. Capital was transferred from one period to the next as the sum of running costs and net revenue for each production activity. The authors stressed that only running costs could be carried forward and not investment costs. Such a straightforward approach was possible only where it was not necessary desirable to incorporate loan activities in the programme or to allow some exogenously fixed costs to be endogenously generated depending on the returns from alternative uses of capital. The value in extension of comparing household drawings with current farm returns to capital was demonstrated as an aid to decisions in the allocation of available funds, though not in the model itself. The authors acknowledged that the fixing of family living involved 'one-way dependence' in the determining of optimum farm plans and that 'two-way dependence' to obtain optimal farm and home plans could be developed using the method.

(2) Candler (1960) subsequently made a number of comments on the Loftsgard and Heady article. He suggested that, on the assumption that each year's input-output matrix was constant and that only capital varied from year to year, that in fact the problem could be simplified to a parametric programming problem. He illustrated the results of parametric capital graphically and demonstrated how, by fixing exogenously a certain level of family drawings, that bankruptcy or an unfeasible solution resulted. The technique was expanded to parametising both capital and labour with the construction of a farm income map. Using data from Loftsgard and Heady's 'numerical illustration', Candler depicted (see Figure 3.2) the

FIGURE 3.2

VARIABLE RESOURCE MAP FOR LABOUR
AND CAPITAL PRODUCING PIGS AND BEEF



Source: Candler, 1960.

opening and Year 1 labour and capital resources situation (A and B respectively) on the map, showing zero marginal product of labour and the inability to substitute labour for capital; hence his point that the family cannot compensate its high drawings by working harder. The observations were valid within the assumptions made. However, the assumptions limited considerably the many flexibilities of planning made possible in the multi-stage linear programming method.

Candler recommended compounding returns to maximise terminal net income. This was done through a capital transfer activity which did the compounding. For example, the transfer activity for period t would show a coefficient of +1 in the capital row for the t period and -1.05 in the capital row for the t+1 period (at a 5 per cent interest rate). The advantage cited was the avoidance of explicit discounting of future costs and returns and hence the chance of logical or transcription errors.

(3) Dean and de Benedictis (1964) provided the next major application of the model in agriculture, in the context of orchard and vegetable enterprises on smallholdings in Southern Italy. One of the significant developments was their approach to comparing perennial and annual crops. The model used a 60 year time horizon, as oranges are regarded as a 60 year crop, grapes 20 years and peaches 15 years. Grapes and peaches were restricted to replacing themselves on the acreages established in each, two and three times respectively within the time horizon. For any given year in which a perennial crop was established it was shown as using resources in that and

subsequent years while the objective function showed the sum of discounted future revenues from that year but discounted back to year 0. In comparison, the annual crops were entered in each year by their use of resources in that year and the objective function contained the discounted net revenue for that year.

Both types of activities carried forward capital to the next year as in the Loftsgard and Heady model, though in the perennial crop case the amount carried forward was reduced by the use of capital in that year.

In the example, the annual crop activities, though of lower return than the perennials, were activated in the initial years to provide capital for the establishment of the perennials. Other capital components were fixed exogenously and were entered into the capital resources level for each year. This included a fixed loan and a fixed repayment schedule. Two levels of consumption expenditure (family living) were investigated for their effect on the development programme. Little delay was found in the optimum development schedule from the high consumption level.

The rapid establishment of the orchards produced a self-perpetuating plan by year 6 making the size of the matrix manageable.

This suggests that Dean and de Benedictis started with a matrix of only two or three yearly periods and then compared the solutions resulting from the addition of one year at a time until a stable solution was found. An alternative approach to containing matrix size within reasonable proportions is to have periods of more than one year. Periods of different lengths are possible though care is needed in defining the coefficients. Variable length periods will allow the optimal solution to be obtained over the full planning horizon where this is necessarily long. On the other hand the aggregation will result in loss of detail for within the periods.

In further analysis Dean and de Benedictis established the break-even discount rate at which the optimum orchard plan gave an equal discounted net revenue stream to an optimum annual crop plan. They also calculated the return to government contribution (subsidised interest rate loans) by comparing the development programme with and without the subsidy and found a high rate of return.

(4) Ogunfowora (1970) presented a case study involving an arable-crop farm settlement scheme in Western Nigeria. Emphasising future uncertainty in prices and technology, he ran the programme for three years only. The farms had crop and livestock activities on 50 acre units supplied by cooperative machinery and marketing services. An initial capital resource was specified together with borrowing limits in each year and a repayment schedule. Borrowing and capital transfer were allowed. The program became self-financing in one-and-a-half years with surplus capital held in 'disposal' for off-farm investment. The program demonstrated a high hired labour component for the optimal plan suggesting limitations for the self-contained family farm with existing technology. Ogunfowora's particular contribution was the specifying of subjective constraints, both maximum and minimum, for

changes in enterprise levels between years as a means of reflecting a managerial constraint. This is the type of constraint used in recursive programming but its specification for a linear programming matrix is not given. Where these constraints were binding, the shadow prices were used to point the direction for future expansion. However such shadow prices will reflect the limitations of the subjective constraint as originally specified and must therefore be interpreted with care.

(5) Pearse (1974) in his example using pasture development alternatives on a 1000 acre North-western New South Wales property in Australia, set out to demonstrate techniques of matrix specification. The flexibility of the approach was emphasised in such facets as variable scheduling of secondary developments, variable family drawings related to farm investment returns, debt repayment, security provisions, loan and capital transfer activities and the specification of taxation requirements.

(6) Manning (1967) reported on the study of diversification in the Hacienda San Jacinto in the Valley of Nepeña in Peru. Rehabilitation of the sugar enterprise was compared with alternative rotations of food crops and livestock enterprises using a multi-stage linear programming model. Development activities considered included well drilling and canal lining, land development (especially drainage) and expansion of plant and equipment. In addition to the above, activities covered corn buying and selling, land transfer from sugar to food crops, loans and water transfer between regions. Hence the

model has been extended to a spatial and a time dimension. The restrictions, as well as imposing suitable maxima and minima on resource availability and activity levels respectively, specified balance equations (equality constraints) in such areas as cash flow by year and the production or purchase and use of intermediate resources such as corn or farm machinery. The cash balance ensured that a cash surplus in any one year was either transferred to the next period to supply development funds or was withdrawn and discounted by an appropriate activity to contribute to the objective function which maximised the present value of net revenues. Analysis covered three phases: obtaining a 'basic' solution with generous capital availability; checking the effects on the optimal plan of progressively reducing external sources of capital; and finally, at an average capital availability, judging the effect of reducing the cane producing area within the constraint of self-financing development. Useful results were obtained on capital needs, vital areas of development and critical areas for further study. Optimal plans were found relatively stable under conditions of increased capital stringency, well drilling was seen as the development most critical to achieving the overall programme and results suggested the need for more reliable information on water availability. Finally, the study provided an interesting approach to the time dimension. The planning horizon was ten years but the programme was essentially complete after six one-year periods. These six-yearly periods permitted detailing of early cash flows, followed by one four-year period allowing the plan of the last planning period to continue over four years. This gave time for a return on investments made in the last planning period and is an alternative approach to introducing terminal net worth into the objective function (refer following section). However even with one-year periods, there is a loss of information on the details of within-year aspects, especially cash flows and the need for within-period finance. An assumption was made that such needs could be met.

This brief examination of some of the applications of multi-stage linear programming to agricultural problems indicates that it is possible to specify the inter-relationships between perennial and annual crops which exist in an intercropping system as well as adequately modelling the economic environment in which intercropping occurs, by means of this technique.

In the remaining section of the chapter the issues of 'otpimising' and of 'alternative specifications for the objective function' are considered with respect to the application of multi-stage linear programming in Western Samoa.

The Applicability of Multi-Stage Linear Programming Models to the Intercropping of Smallholder Coconuts in Western Samoa

The Relevance of an Optimising Approach

Criticisms of producing optimising plans for smallholders are made on the assumptions behind such plans; on the implied ability of the smallholder to apply the optimising concepts in his decision-making and on the social implications and results from the use of such techniques. It is proposed in this section to raise these issues and to present alternative views where these are warranted.

The assumption of insatiability in optimising is often questioned. Chayanov (1966) asserted that the Russian peasant farmer judged his output per day on the basis of the number of consumers he supported in his family rather than by the resources available to him. Alternatively, the social mores of traditional societies are often assumed to set ceilings on acceptable levels of consumption. Fisk (1975) formulated such a ceiling more formally in terms of the accessibility of markets and the ability to use cash income generated, as well as in terms of socially acceptable needs. Pitt (1970) described the social system within Western Samoa, which, while rejecting to a degree the 'Western' doctrine of individual advancement, does generate within the Samoan extended family of aiga a strong desire for goods and services. They were desired for their efficiency and for their symbolic value in the Samoan status system. Pitt saw the individual within traditional Samoan society as having adequate access to the factors of production and obtaining adequate rewards for success in economic activities, particularly in terms of status and as a criterion for a claim on a title. Thus those who leave the village for a wage job prefer to maintain close ties with their family and village. Traditional institutions were shown by Pitt to be compatible with capital formation and that human capital formation through education and good health was equally valued.

Given that goods and services are demanded by the Samoan family, criticism of optimising can still be made on the basis of psychological investigations into human behaviour and motivation. It is suggested that people tend to obtain a satisfactory level of the things they want rather than the maximum.[5] Studies of the land tenure system as it presently operates in Western Samoa might appear to support satisficing in-so-far as the tenure system is seen to reduce economic incentive through lack of security. Thus Crocombe (1973) noted for the South Pacific region as a whole that the functional means of land redistribution in the past, i.e. warfare, had not been satisfactorily replaced, with the consequence that land holding patterns had been frozen, locking up a portion of the land in boundary disputes while other areas became under-utilised. Sutter (1971) however, with specific reference to Western Samoa, observed a great variety in approaches to land use within the traditional structure, relating to personal and social attributes of those involved rather than to environmental or institutional factors. Social constraints on family enterprise appear to operate mainly on large disproportionate increases in land holding through extensive bush clearing. Thus intensification of existing holding through inter-cropping is less likely to bring group criticism. Given that some minor reforms suggested by Sutter are carried through, it is unlikely in the majority of cases that land tenure _per se_ will act as a disincentive to some form of constrained maximising behaviour. Within the general economic context of present day Western Samoa, together with the lack of application of the satisficing goal to decision theory, the adoption of maximising approaches within carefully constrained resource levels, allowing for social obligations and subsistence requirements, can be justified.

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5 See reference to Simon, H.A. in Chapter 17, Cohen and Cyert 1965.

The criticism, that the optimising smallholder is by implication able to intuitively discount alternative investment possibilities or to know future prices and outputs with certainty, does not appear to contribute any insights to the discussion. Given that the smallholder is observed to have expectations of increased levels of goods and services and is observed to be setting about achieving such a goal within the limitations of knowledge and opportunities available to him, it would seem perfectly reasonable to use the techniques of production and investment theory in order to be able to gain insights into ways by which he might better achieve such goals.

The above criticism also leads its proponents to observe that the use of optimising approaches have failed as a means of predicting the courses of action taken by the smallholder. This suggests a misuse in the application of optimising techniques which are designed to provide the farmer with guides to decision-making. The prediction of farmer response is a different field of study, for which techniques such as recursive programming have been developed (refer to previous discussion).

A final critique is that optimising plans and techniques should bear the blame for the failure of many 'development' programmes to achieve such socially desirable goals as improved income distribution, reduced unemployment and a lesser incidence of poverty. Again a misuse of techniques is implied. If the results of an optimal plan developed for a larger 'smallholder' are extrapolated to become the basis for a regional development programme then the problems mentioned must be expected. If however, well specified micro-economic models are developed for those farmers whose incomes most need improving, then the information gained as to which environmental and institutional factors are in fact constraining such farmers' ability to improve their incomes will indicate where policy changes may have the greatest effect. Thus optimising plans for the smallholder are an aid to the evolution of macro-development policy and not a substitute for it.

In conclusion, the observations of Heady (1971) are relevant. Heady emphasised the wide applicability of programming decision models based on the homogeneity of the planning environment. He noted that all farms have plans, whether formal or informal, and that all have limited resources. In addition all are faced with various institutional and subjective constraints including risk aversion. Heady suggested that all farms seek to optimise some objective function and will consider alternative enterprises or activities which compete for the use of resources and which contribute to the objective function according to predetermined weights. Thus he concluded that the ability of the analyst in adequately specifying the environment determines the applicability of the model.

Alternative Specifications of the Objective Function

Heady (1971) suggested that the objective function may include one or a combination of such objectives as maximum profit, managerial utility, physical output of food, net worth or minimum variance of food and income. Work on the theory of the allocation of time emphasised the significance of time as a resource constraint (Becker 1965), leading other analysts to incorporate time into their objective functions. Stryker (1976) had the farmer maximise his leisure subject to the constraint that output per capita equals a subsistence standard. Benito (1976) saw the peasant household as maximising the discounted utility of expected consumption of purchased goods and home grown food through the allocation of time and marketed products. Under conditions of relative 'subsistence affluence', Fisk indicated that the return to labour rather than capital will be the important determinant in deciding how much labour time will be applied to the family land. This is felt to be relevant to the case of the smallholder in Western Samoa in that the contribution coefficients in the objective function should represent the returns to labour in alternative enterprises. Hence cash flows will take into account all relevant capital costs.

Lipton (1967), in refuting the Shultz case that the smallholder in India equates marginal value product of money in each use, pointed to such problems as uncertainty in weather, the influence of custom, taste and law in decision-making, and the dynamic effect of populations which prevent such optimising behaviour. He concluded that the farmer will adopt a survival algorithm best suited to his needs. Upton (1976) also noted that assuming a farmer to be rational does little to reduce the possible set of goals. He saw the only clearly irrational activity to be a level of present consumption that would prevent future survival. However such broad formulations do not appear to have particular application to the objectives of Western Samoan smallholders in the present economic environment.

Considerable attention is given in the literature to the relative merits of the 'present value' group of objective functions as against the 'net worth' group of objective functions.

The maximising of the sum of net present value (SNPV) is widely accepted as an extension of the static model's maximisation of profit, taking into account time preference in the flows of income generated by alternative investments (see Time Section above).

Cocks (1965) showed that maximisation of the discounted profit stream, given that income equals the sum of consumption and investment, is equivalent to the maximisation of the sum of present value of the future stream of consumption within the planning period plus the present value of accumulated net worth at the planning horizon. This was based on the assumption that profits make no contribution to utility until consumed or until, at the plan horizon, net worth is valued at its potential future contribution to generating consumption flows (see Appendix D). Cocks took this objective function one stage further by considering the farmer's allocation decision between consumption and investment in each period. Consumption was redefined as 'luxury' consumption, which was of a similar order to prevailing rates of return on investment. In allocating income the farmer would enjoy luxury consumption where his personal discount rate was higher than the rate of return on investment. Conversely, the farmer would invest when the rate of return on investment was greater than the personal discount rate for luxury consumption. When the rate of return for investment equalled the personal discount factor for luxury consumption, the farmer was indifferent between consumption and investment. Cocks assumed this latter situation to prevail and that in the case of indifference the farmer would always invest. The objective function then became the maximisation of accumulated net worth at the planning horizon, the discount factor being dropped as it was common to all net investment (see Appendix D).

Using this objective function in multi-stage linear programming was seen by Cocks as having the advantage of being able to incorporate the residual value of added investments, and hence to plot the optimal expansion path for the farm. In addition, the fixed costs of supplying productive assets was minimised in the maxisimising of the objective function, by specifying alternative supply activities. The provision to borrow against fixed assets was also allowed where the purchase of such an asset activates a borrowing activity up to some allowable percentage of the asset value. Cocks concluded by bringing luxury consumption back into the objective function with a luxury consumption activity for each year. An appropriate discount value, as contribution coefficient, contributed the present value of the consumption level to the objective function and permitted the competitive use of income between investment and consumption. Thus the balance between maximum growth, given by the terminal net worth formulation and by maximising the sum of present value of consumption flows over the entire planning period, was determined by the time preference rate felt to be appropriate. Rae (1970) avoided a prior decision on time preference rate in his maximising of a utility function, which was a linear combination of tax free cash and terminal asset value. Instead, a number of optimal solutions were generated, each based on a different weighting combination in the utility function. From this efficient set of solutions, representing alternative combinations of tax free cash and terminal asset value, the decision-maker could choose that combination which maximised his utility preferences. However Rae's tax free cash objective is not strictly analogous to consumption in the Cocks' consumption-wealth formulation. Tax free cash is in fact a liquid asset being compounded at the current lending rate. Thus cash has strictly been invested and the optimising process produces a terminal value, in this case, of a liquid asset.

Boussard (1971) discussed the alternative objective function formulations from the point of view of the planning horizon. Boussard adopted the Modigliani definition for the relevant length of the planning horizon: that the horizon is extended only until the length has no effect on the optimal decision for the first time period. Boussard observed that net present value models tended to lengthen the planning horizon beyond the Modigliani optimum, because capital goods with a life duration longer than the planning period and having a small salvage value were penalised in such a model. Boussard also criticised the model from a mathematical standpoint in that it did not guarantee the existence of a planning horizon in, for example, the case of negative discount rates.

Taking the Cocks' consumption-wealth objective function, Boussard, by assuming a linear consumption function, was able to show that maximising the stream of future consumption was equivalent to maximising terminal net worth. He utilised the turnpike theorem to demonstrate the existence of a planning horizon when maximising terminal net worth and established a practical rule for reaching the Modigliani planning horizon based on the theorem of separability of matrices.

Other writers have taken different approaches to the determination of the planning horizon. Renborg (1971) suggested that the horizon chosen was unique to each particular situation being influenced by the length of the production period, the economic lifetime of durable assets, the reducing economic importance of future time periods and the expected lifetime of the entrepreneur. Upton (1976) noted that once a finite planning horizon was adopted difficult decisions are required as to what should be left to the future, i.e. the level of terminal capital stock, and how to value this residual. Upton saw valuing terminal capital stock as requiring knowledge of future cash flows and of the opportunity cost of that capital. In considering which of the objective functions is most appropriate to the problem of smallholder intercropping, the predecisions required in each case should be considered.

The sum of net present value formulation requires the assumption of an appropriate discount rate representing the time preference rate of the decision-maker who will use the results of the model. Some guides as to the order of time preference exist. Higher time preference is expected in situations of short life expectancy and for those with low incomes. It is possible to have the decision-maker consider alternative strategies with different rates of return to obtain his subjective evaluation of his time preference rate. Variations over time and between individuals in time preference further complicate the issue. However it is possible to test the sensitivity of the optimal solution to different values of the discount rate so that the problem can be solved pragmatically.

Adopting the Cocks' consumption-wealth objective function still requires either the determination of a time preference rate in the case of the multi-objective form, or the assumptions that time preference is equal to the rate of return on investment and that the indifferent farmer chooses to invest so that terminal net worth is maximised. Alternatively terminal net worth may be maximised under the assumption of a linear consumption function. This however raises problems in low income situations and where that income may fluctuate leading to the assumption of less than subsistence consumption in some years.

The form of the objective function chosen for this small-holder intercropping study is the maximisation of sum of net present value. This formulation is able to choose between alternative competitive uses of cash generated, and the problem of discount rate will be examined parametrically. Using terminal net worth so as to chart an optimal expansion path for the farm is not relevant in the context of Samoan land tenure, and the minimising of fixed costs of asset supply are of little benefit, as intercropping does not require large capital assets for which there are alternative sources of supply. Further, the defining of the relevant time horizon with reference to the Modigliani criterion is overruled in this case by the wish to consider the potential for intercropping over the life span of a coconut stand, particularly with respect to its income generation capacity in the context of present economic circumstances.

This chapter has shown that as well as meeting the requirements for modelling a modern intercropping system over time, a multi-stage linear programming technique maximising the present value of cash surpluses can be used as an appropriate decision tool for the farm family in Western Samoa, given careful definition of the resource constraints that apply to the family's cash earning activities. These and other aspects of model formulation are pursued in the next chapter.

CHAPTER 4

THE ANALYTICAL MODEL

This chapter proceeds with the specification of the multi-stage linear programming model adopted, using the cash-flow data from Chapter 2 and the intercropping relationships from Chapter 1. Additional information required at this stage is the appropriate resource levels for the farm unit being considered. This is detailed at the outset and is followed by the specification of the objective function, the activities and the constraints of the model.

The Farm Unit in Western Samoa

The operation of the traditional system in the organisation and use of land in Western Samoa has been described by a number of writers. Sutter (1971) noted that land tenure is linked to the traditional family organisation. Each family or _aiga_ is led by a _matai_ who holds the family's traditional title. The _matai_ has _pule_ over family lands. _Pule_ is not ownership but trusteeship, with power to make decisions on how the land will be used and responsibility to do so, for the benefit of the family. The _matai_ may organise the working of family land in a number of ways. The whole family may work together under the _matai_'s direction or married sons and other untitled men in the _aiga_ may be allocated plots to provide for their own immediate family. However, even in cases where untitled members are allocated plots, they will render service to their _matai_ and be expected to contribute to the _aiga_'s communal obligations. Further, the allocation of plots is usually for short term food crops while the planting of tree crops, a sign of permanent occupancy, is a family matter, with the matai granting permission after unanimous family consent. Thus the development of an intercropping system in the coconut zone is certain to be organised as a family concern, irrespective of the particular organisation practised with regard to food crops.

Further consideration of aspects of replanting management would suggest that many advantages could derive from the adoption of the practice of intercropping as a village project, supported by the village council of matai. This could facilitate the work of removing old palms by the Forestry Division and provide for the possibility of consolidation of aiga plots in the coconut zone with the help of the Lands and Survey Department. While this latter move would have some benefits in the working of the land, Sutter (1971) felt that such consolidation would be extremely complex and unlikely to be solved at present.

Three sources of information have been evaluated in arriving at the levels of land, labour and cash needs pertaining to the aiga or rural family. Data comes largely from Fox and Cumberland (1962), Lockwood (1971) and the Survey of Household Living Conditions (1972 Western Samoa. Department of Statistics). Farrell and Ward (1962) presented data for matai holdings from ten surveyed villages. The average area was 13.1 hectares (SD = 14.7 hectares), comprising five plots spread over the various crop zones. The high standard deviation in relation to the mean suggests a skewed distribution of farm size and a mode less than the mean.

The average _matai_ holding from Lockwood (1971) is slightly less than that of Farrell and Ward at 10.8 hectares. Of the total _aiga_ holding, approximately 50 per cent is expected to lie in the coconut zone so that a preliminary land resource constraint is taken as five hectares. Given the variability of land holdings, however, this resource level will be varied in the model.

Results from the 1950 survey by the New Zealand Department of Agriculture of 43 _aiga_ in 14 villages are available (Farrell and Ward 1962). Average family size was 24. Routine garden work involved an average of 4 men and 3 women in 16 and 20 hours of work per week respectively. In addition 5 men and 5 women worked an average of 10 hours per week harvesting and processing copra and cocoa. Using a five hour day, as the basis for the manday unit used in describing labour inputs, and assuming that labour spent harvesting coconut and cocoa to be that available for cash earning activities, there would be available some 1000 mandays per annum per _aiga_.

Lockwood's data on family size gave an average of 17 persons with a breakdown of 9 under 15 years, one over 50 years and four adult males and three adult females. Lockwood's work analysis detailed hours spent in subsistence and cash earning activities. In subsistence food production, the average input was 12 hours per week and 5 hours per week for men and women respectively. For cash earning activities, excluding wage employment, men spent 5 hours and women 2.5 hours per week. Comparison is difficult as the 1950 survey gives hours worked by those actually engaged in the task, while Lockwood's figures are averaged over all adults working in the _aiga_.

However, a considerable difference in the work input by women is still apparent. As Lockwood did a more complete analysis of other subsistence activities, his data is likely to be more reliable. From Lockwood then, the seven adult members would provide 275 mandays per annum for cash earnings activities. This level of labour input is examined with regard to expected changes over the past decade. An increased input in cash earning activities might be expected. Firstly, Lockwood's data was collected just after the 1966 hurricane and he notes a heavy concentration on subsistence planting of taro. In more normal times a reallocation in favour of cash activities would seem a reasonable assumption. Secondly, with the rise in expectations and cash needs over the period, together with the indication that the adopted technology is expected to increase labour returns, an increased labour input can be postulated. Thus the present male input of 5 hours per week per person is increased to 10 hours (from 1 day to 2 days) and the female input from 2.5 hours to 5 hours (1/2 day to 1 day).

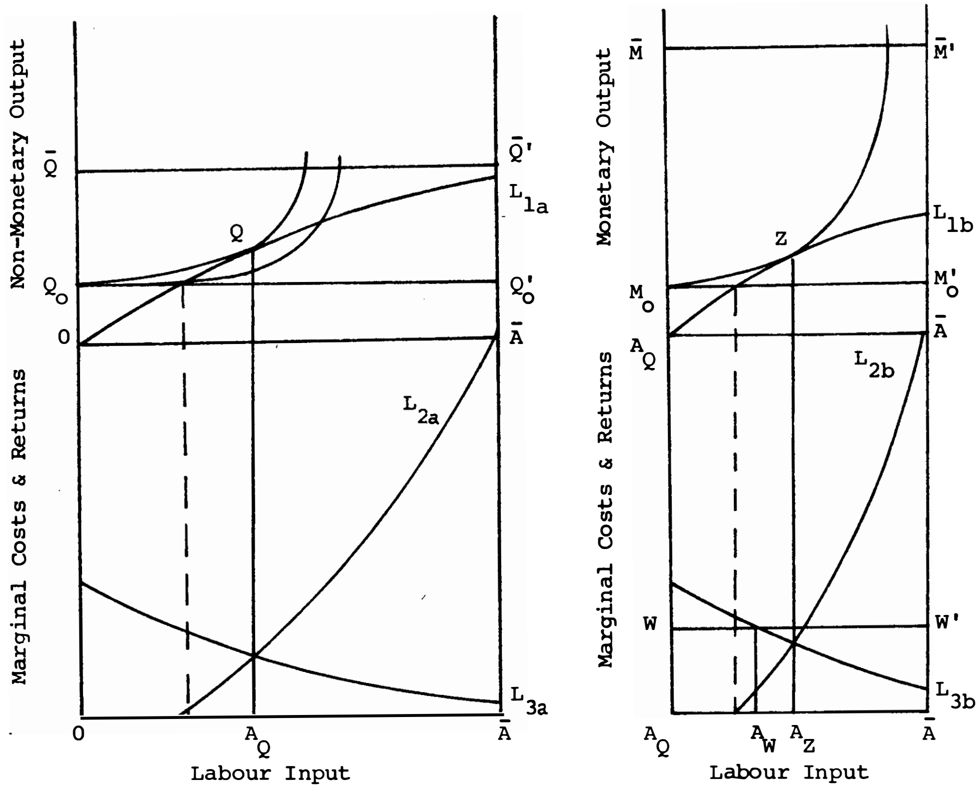
The 1972 Survey of Household Living Conditions (Western Samoa. Department of Statistics 1972) gave data for a 'household' unit, defined as "a group of persons living together and providing for themselves food and other essentials for living". It did not represent the aiga unit, making comparison difficult with the earlier surveys. A breakdown by age however coincided closely with that of Lockwood and was supplemented by classification by activity. For a rural household, children 0-5 years were 17 per cent, students 34 per cent, 5 per cent stayed at home (mostly elderly members), 6 per cent were wage earners and 38 per cent worked on the land.

As the model is dynamic, consideration is given to the possibility of changing labour input over time. Recent macro-analysis (refer to Chapter 1) shows the present tendency for those in the 15-34 age group to take up wage employment in Apia or to emigrate to New Zealand.

The Nakajima-Fisk model (Fisk 1975) provides insights into the application of family labour in subsistence and cash earning activities on the family farm (see Figure 4.1). Diagram A represents existing productivity of present agricultural practices. Low productivity in the production of subsistence output Q, as shown by the flat aspect of L_{1a}, is felt to represent the situation in land-short districts such as North-west Upolu where intercropping would be of particular benefit. The labour input A_Q to produce output Q is substantial with corresponding constraints on the amount of labour available for cash earning output. Cash output Z is also limited by the low productivity of much of the existing stands of coconut and cocoa, shown by the flat L_{1b} curve. The high level of $\bar{M}$ is suggested by the tendency to send family members to New Zealand so that remittances might be used to build a house of permanent materials or purchase a utility-truck or taxi. The present minimum wage of T2.00 per day is represented by WW', which reduces labour input in on-farm cash-producing activities from A_z to A_w. Beyond A_w family labour would attempt to obtain wage employment. Diagram B represents an indication of the potential of intercropping in raising output and inducing increased labour inputs into on-farm activities. Minimum and maximum subsistence requirements remain constant but the subsistence production function is raised due to the production of taro

FIGURE 4.1

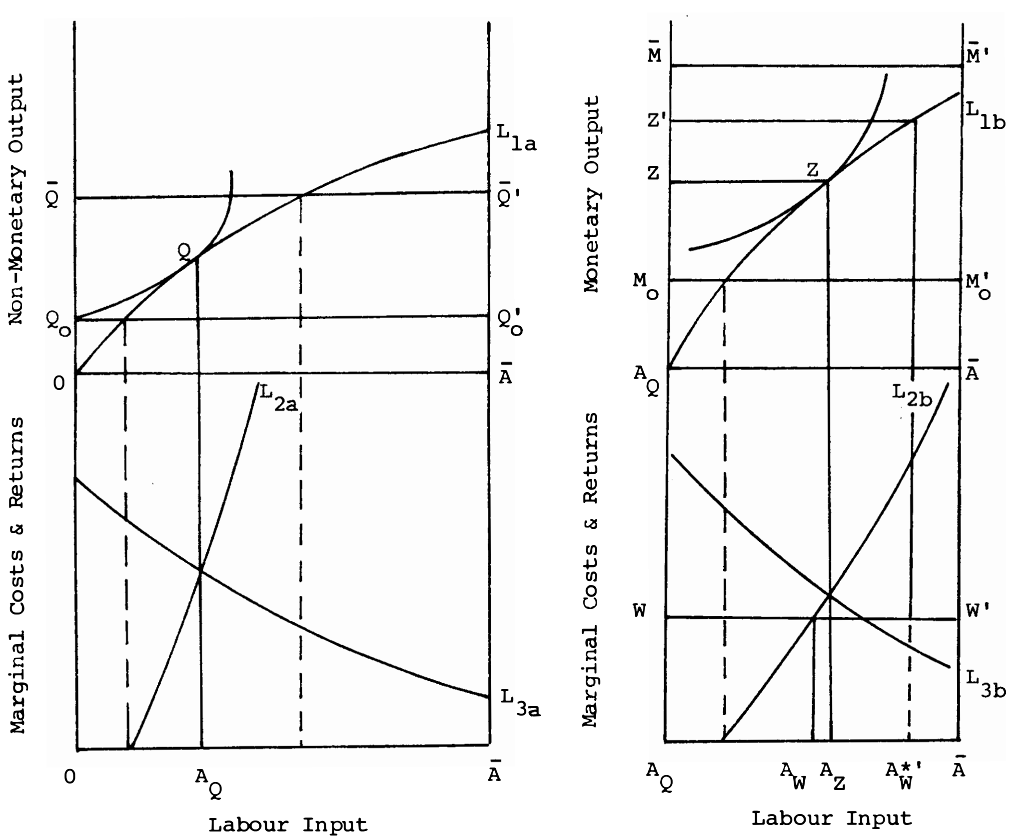
DIAGRAM A: NAKAJIMA-FISK MODEL UNDER EXISTING CROPPING PATTERN



Source: Fisk 1975.

FIGURE 4.1 (cont.)

DIAGRAM B: NAKAJIMA-FISK MODEL
UNDER AN INTERCROPPING SYSTEM



Non-Monetary Enterprise

Monetary Enterprise

Source: Fisk 1975.

in the intercropping model using improved technology. Thus actual subsistence production Q may be somewhat increased while the labour input to produce Q, i.e. A_Q is significantly decreased. This releases a greater amount of labour available for cash earning enterprises, $A_Q\bar{A}$. The production function for cash enterprises is substantially raised implied by the use of hybrid planting material for coconut and cocoa and the application of fertiliser. The minimum cash requirement MoMo' is increased by the requirement for purchased inputs in intercropping. Cash output Z shows a greater surplus over Mo in the intercropping example and a substantial input of family labour is induced by its high marginal productivity L_{3b}. Consideration of the minimum wage WW' suggests some curtailment of family labour input from A_z to A_w and the incentive to hire in outside labour up to an amount $A_wA_{w'}$, with potential increase in output up to Z'.

These findings can be incorporated in the model as follows: Lockwood's data on family component age groups can be modified by the results of the Survey of Household Living Conditions (Western Samoa. Department of Statistics 1972) (see Table 4.1). The rural family breakdown between 'wage earning' and 'working in aiga' reflects an existing situation in which rural family members have moved to join urban relatives and take up wage employment. Thus improved earning potential on the family land could be shown to alter the breakdown as rural family members are induced back into the 'working in aiga' category. It will be assumed that of the 7 adult members of the family, 5 work on the land and 2 are in wage employment. These two members will be drawn into the labour pool for the family farm as the returns to labour in on-farm activities rise above the minimum

TABLE 4.1

FARM AIGA BY AGE AND OCCUPATION

Source:	Lockwood	Household Survey 1972				
Age Group	No.	Group	Urban %	Urban No.	Rural %	Rural No.
0-15	9	0-5	16	3	17	3
		Student	40	6	34	6
15-50	7	Work in Aiga	21	4	38	6
		Wage Earner	18	3	6	1
>50	1	>50	5	1	5	1

Sources: Lockwood 1971; Western Samoa. Department of Statistics 1972.

wage. Initially then, the 5 adult members working on the family land would provide a labour input of 400 mandays per annum in on-farm cash earning activities. The two family members engaged in wage employment will contribute their expected wage earnings of T1000 per annum to the family cash supply. As it can be reasonably assumed that present family subsistence activity would include support for the aiga members in wage employment and hence a return by those members to the farm would not add appreciably to the subsistence requirement, and given that such a movement would involve changing from an 8 hour manday in wage employment to a 5 hour manday on the farm, a one for one exchange in mandays from wage employment to on-farm cash earning activities is adopted. It is noted that the return to the farm would involve a loss in wage earnings available to the family.

Information on family cash expenditure is available from Lockwood and from the 1972 Survey of Household Living Conditions. Lockwood's data, as expected, is substantially lower though indicating differences between villages related to their degree of market contact in 1966. The 1972 Survey gives a breakdown of expenditure by items and has been extrapolated from the per month figures in the report to an annual amount. For the model a basic family living cash requirement of T1000 per annum is adopted. The data is summarised in Table 4.2. As propensity to save is important to the use of a capital transfer activity in the model and to assumptions regarding opening family capital, some information in this area is pertinent. The 1972 Survey reported savings per capita in rural households at T3.60 but noted a skewed distribution. Only 28 per cent of households had any savings. Debts per capita were T1.80 (again for rural households) of which 87 per cent was with a bank and 13 per cent with a trade store. In balance then, cash transfers will be allowed in the model but without accruing interest and no opening capital will be assumed.

The details of model specification are now considered.

The Objective Function

In Chapter 3 a case was made to define the rural family objective as maximising the present value of net cash income from the farm cash cropping enterprises. Terminal net worth has been excluded on lack of evidence for valuing the tree-crop capital asset in Western Samoa and due to the limited range of other capital assets involved in the intercropping system.

TABLE 4.2

FAMILY CASH INCOME AND EXPENDITURE

(a) Average Cash Expenditure Per Aiga (1966) by Village

Village	Expenditure (T)
Uafata	225.58
Poutasi	570.04
Taga	287.96
Utuali'i	560.23

Source: Derived from Lockwood 1971.

(b) Cash Income and Expenditure Per Household (1972)

Income[a]			Expenditure[b]		
Item	Percentage (%)	Amount (T)	Item	Percentage (%)	Amount (T)
Wages	41.56	384.29	Food	48.52	593.39
Remittances	29.28	270.69	Clothing	13.48	164.85
Receipts[1]	29.16	269.67	Household Operation	13.15	160.91
Total	100.00	924.65[2]	Education	6.46	79.08
			Travel	1.67	20.49
			Church	2.64	32.32
			Other	14.08	172.28
			Total	100.00	1223.32[2]

Notes: 1 Receipts = on-farm cash earnings.

2 The discrepancy between income and expenditure is the result of data limitations.

Sources: Western Samoa. Department of Statistics 1972.

a Appendix VII, Table 13, p.89.

b Appendix VII, Tables 36 and 37, pp.110-18.

The discount rate chosen will be that which reflects family time preference. Indications are that time preference in Western Samoa might be expected to be high, where older members of the family are important in decision-making. Problems arise however with a high discount rate adopted for the planning horizon. The horizon is sixty-five years, being the span of coconut production data available and approximating the optimal replacement period for coconuts (Carrad 1977, p.87). Current interest charges for obtaining development finance could alternatively be adopted so that the sum of net present value would indicate a net return on capital from the enterprise. It has been previously indicated that the Development Bank, the main source of smallholder loans and charging 8-9 per cent on relatively short-term loans, is likely to be in a position to set an 'appropriate' interest rate for an intercropping programme, suggesting that a discount rate can be set arbitrarily. As the crops considered vary in their early net income patterns, changes in the optimal solution due to changes in the discount rate could be usefully considered to reflect the needs of producers with differing time preference values. Inflation allowances have not been included in the data set. The net effect of inflation on relative product-input price ratios is expected to be small though positive. More important is the effect of inflation on consumer goods being purchased by the rural aiga. They would expect that current consumption requirements will be maintained against inflation by the level of cash surpluses generated from the intercropping enterprise.

The normal practice of maximising gross margins from alternative productive enterprises is that the surplus will represent a return to management and overhead capital, the cost of labour being deducted in variable costs. In this study however, the cash costs of capital items are deducted in the calculation of cash surplus. Family labour inputs are not costed but act as constraints on enterprise levels. Hence cash surplus in this study, most importantly, indicates the return to the input of family labour. This input must include family labour which is induced out of wage employment into on-farm activity, for, even though the loss of wage earnings is debited in the matrix, such secondary labour becomes part of the total labour input which generates the cash surpluses obtained. Thus the discount rate adopted is taken as the level of pure time preference and the returns will be evaluated as to the overall return to the input of labour and subjectively assessed on their capacity to cover inflationary costs. The model will be operated at a 9 per cent discount rate, while rates of 5 per cent and 12 per cent will be investigated as to their effects on the optimal solution.

There are two approaches to specifying the objective function noted in the literature. One approach (after Dean and de Benedictis 1964) is to calculate outside the model the sums of net present value for the activities, to be the contribution coefficients used in what will be termed the 'A' form of the objective function (see Table 1, Appendix F). The alternative approach (after Manning 1967) is that in which the contribution coefficients are the discount factors for each period, associated with discounting activities which transfer the cash surplus generated in each period from a cash balance constraint into the objective function, where it contributes to the maximand according to the weight of the discount factor. This form will be termed the 'B' form (see Table 2, Appendix F). The A form may have a smaller matrix by not requiring discounting activities. However, in this study family living transfers made the number of activities identical and required 10 additional constraints (the family living constraints). By having the individual contribution coefficients specified under the A form, it is possible to investigate the effects of price changes in important etnerprises on the optimal solution, using a parametric programming package. Using the A form however, the particular contribution coefficients for the non-producing activities may not be immediately clear. The B form can reduce the possibility of error by discounting endogenously but where each period covers a number of years this will involve an approximation in the discount factor chosen. This approximation may be expected to result in differences between A form and B form solutions where within-period cash flows are substantially different between alternative activities. The A form, using present value of cash flows discounted by individual years, will reflect these within-period flow variations. Such variations will be accentuated at higher discount rates and comparison of the two forms will therefore be of value. In using the B form a decision was made to discount from the end year of each period. This facilitated the understanding of how the matrix operation interpreted such aspects as loan repayment specification and cash transfers. A further advantage in using the B form is the ease with which it is possible to consider alternative discount rates. However, by using both the A and B forms in developing the model, the writer was able to learn a number of points about its functioning. This is outlined further in Chapter 5 on Results.

FIGURE 4.2

A SUMMARY OF THE MULTI-STAGE LINEAR PROGRAMMING MODEL

Objective Function B			0	0	0	0	0	0	0	0	d_1-d_{10}
Constraints \ Activities	B Value	Type	Coconuts A, B, C (3 Densities) Period 1	Taro (Root Crop) Period 1,3-10	Cocoa Period 3-7	Pineapple Period 1,4-10	Banana Period 4-10	Secondary Labour Use Period 1-10	Loans Period 1,3-7	Cash Transfer Period 2/3-6/7	Discount Activity Period 1-10
Land Period 1	L_1	Max	+								
Intercrop Land Periods 1,3-10	0	Max	- - -	+ +	+	+	+				
Labour Periods 1-10	N_1-N_{10}	Max	+ + +	+	+ +	+	+	-			
Secondary Labour Periods 1-10	$2N_1$-$2N_{10}$	Max						+			
Allocable Income Periods 1-10	AI_1-AI_{10}	Equ.	- - -	-	- -	-	-	+	+	+	+
Loans Periods 1,3-7	Ln_1, Ln_3-Ln_7	Max							+		
Development Capital Periods 1,3-7	0	Max	+		+				-	-	

Key: Uses of constrained resource: + Sources of constrained resource: -

Activities (refer Table 4.3 and Tables 1 and 2, Appendix F)

Production Activities

The production activities include coconuts, cocoa, taro, pineapple and bananas. The three coconut activities specified are for three planting densities: 178, 156 and 123 palms per hectare. The coconut activities use development capital in period one, the only period during which coconut is established. They contribute to allocable income according to the net revenue in each period except for the first period. Here allocable income includes only the positive net revenues, the negative flows being summed to give the development capital requirements. Finally, coconut activities use labour and primary land and contribute to intercropping land according to their density. This latter point is elaborated under the section on constraints.

The intercrops use only intercropping land contributed by the coconut activity. The intercrop activities cover each crop in each period allowed by the system as technically specified. That is, taro is grown in all periods except period 2. Cocoa is excluded in periods 1 and 2 and is discontinued after period 7 when initial runs of the model showed that later plantings were unlikely to be activated. Pineapple is omitted in periods 2 and 3 while bananas start from period 4. Cocoa has a development capital requirement equal to the sum of the negative net revenue flows in the period in which it is established. Cocoa activities generate cash flow streams in the allocable income constraints and use labour and intercropping land from each establishment period to the end of the planning horizon. Each of the other intercrop activities contributes net revenue to allocable income and uses labour and intercropping land only in the period specified for each activity. They have no long run[1] establishment phase as with coconut and cocoa and so are not shown as requiring development capital. In practice however they will have capital requirements resulting from the pattern of within-period cash flows. These are not readily able to be specified without a substantial expansion in matrix size. An approach would be to have an additional set of capital constraints specifying the opening capital requirements for the one period crops, taro, pineapple and bananas. The allocable income contribution would be adjusted accordingly and additional activities would be needed to supply such a constraint group either by cash transfer or shorter term loans. Advantages would be gained in terms of indicating the needs for savings and cash transfer within the system and also in allowing the model to make a more efficient choice of short term crops with regard to their within-period cash flow situation.

Non-Production Activities

The non-production activities of the model are secondary labour, loans, cash transfer and family living transfers for the A form or discounting activities for the B form.

Secondary labour activities are the means whereby transfers are effected in the model, of family labour from wage employment

1 Long run in terms of period length in the model.

back into on-farm activities. A secondary labour constraint is debited for each manday transferred and one manday credited to the farm labour constraint. As there will then be a loss of wage income, the allocable income constraint will be debited by T2.00 for each manday, being the level of the basic minimum wage. In addition in the A form, the objective function will have a negative coefficient equal to the T2.00, discounted according to the period in which the secondary labour is transferred. Using the B form, the effect of changing the minimum wages level is investigated.

The loan activities are used to supply development capital for the establishment of coconuts and cocoa. Hence six loan activities are specified. Loans are denominated in units of T100.00, debiting the loan constraint and crediting development capital. The two objective function forms allow the repayment requirement to be specified differently. In both cases the repayment is shown as an amount debiting the allocable income constraint. Also the activation of the loan activities, in both forms, depends on the interest rate cost for the loan being less than the cost of alternative sources of cash. The alternative possible in specification between the two forms, then, results from the difference in their matrix operation and representation of their interest rate charge.

In the A form objective function, the interest rate cost is shown explicitly in the contribution coefficients for the loan activities. In the B form objective function, the interest rate cost is implicit in the value of the repayment coefficient shown in the allocable income constraint. Thus in the B form model the repayment coefficient must be calculated to accurately represent the interest rate cost[2]. The repayment coefficient may at best only approximate actual repayments that can be expected in practice. This will reduce the accuracy of the cash flows derived from the allocable income constraint. In the A form model however, where loan activation is determined in the objective function, the repayment coefficient serves solely in determining the cash surplus along with other components of allocable income. The repayment coefficient can therefore be shown as the actual sum of repayments required for any particular period. From the footnote (2) it would appear however that there is little difference to be expected between the B form repayment coefficient and actual repayments, for the case where repayment is made in the same period in which the loan is made. Also, specific information on the Western Samoa Development Bank repayment policies is not available. Hence this limitation in the B form model is not felt to detract from its other advantages and hence its adoption for the study.

The cash transfer activities also supply funds to development capital. They can only supply such funds beginning at period 3

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2 The interest rate on the loan is determined by the matrix discounting operation. Discounting is from the end year in each period. Thus if the loan is repaid in the same period as it is made, the repayment coefficient is obtained by compounding the loan principal (a unit of T100.00) for the length of the period at the given interest rate. For example, using the 6 per cent rate adopted over a 5 year interval for one period the repayment coefficient, it is T133.82. If repayment is in the next period, the interval is 10 years and the repayment coefficient is T179.08.

however, using cash surplus from period 2. The transfer is made in T10.00 units, debiting allocable income in period t and crediting development capital in period t+1. Thus there are five cash transfer activities. The B form of the objective function indicates that the opportunity cost of the cash transfer is equal to the discount rate. Hence the A form should show a negative coefficient in the objective function equal to the discounted value of the discount rate per unit of cash transfer.

In the A form, family living transfers use surplus in each period generated in allocable income, transferring the surplus to a family living constraint allowing the surplus to be clearly distinguished. In the B form that cash surplus is discounted into the objective function. Having the discounting-allocable income coefficients equal to unity means the level of the discounting activities indicates explicitly the amount of cash surplus in each period. An alternative in the A form, omitting family living constraints and activities, would be to change the allocable income to a maximum constraint so that, as formulated, it would show cash surplus as surplus resource level in the optimal solution.

Constraints (refer Table 4.3 and Tables 1 and 2, Appendix F)

The constraints, land, intercropping land, labour, secondary labour, allocable income, loans, development capital and family living are based largely on the study of the farm unit opening this chapter.

Land is available only for planting coconuts in period 1. The average coconut zone area per family was given as 5 hectares. It is also proposed to investigate the results of different land areas on the optimal solution.

Intercropping land is made available through the coconut activities. In this way a coconut activity is forced into the solution and the effects of planting density of coconuts can be defined. For each hectare of land in coconuts at 178 palms per hectare we obtain 0.776 hectares of intercropping land; at 156 and 123 palms per hectare we have 0.804 and 0.845 hectares respectively. This relationship is simply derived from the ground area utilised by the coconut root system based on the CPCRI data (refer Chapter 1). The above areas of land for intercropping are reduced by 0.04 hectares in period 1 due to the existence of stumps left to rot after removal of the original coconut stand. It may also be possible to define density effects in terms of the scheduling of the intercrops; for example, not allowing period 3 intercrops at the highest density. However no data known to the writer was available to allow definition of expected effects in this area. Intercropping land is therefore specified with a zero resource level while activation of a particular density of coconuts will define the stream of intercropping land availabilities over the intercropping periods.

Labour constraints have the level of available mandays defined for all periods (refer section on the Farm Unit). However there are alternative ways of specifying the labour constraint using this data. The aim is to constrain activities using labour to a level that can be met by the available labour per unit of time, for that interval within the overall period when the activity has its highest labour demand per unit of time. Particular intervals that might be expected to be especially demanding in labour usage per unit of time are at planting and harvesting. Data is insufficient to examine seasons within the year. However except in the driest regions, seasonality is far from pronounced and can be assumed not to be significant. Examining the years within a period indicates that coconuts have their highest labour demand in year one of the establishment period (period 1) during which time planting takes place. Subsequent years demand small amounts of labour for maintenance, though by year six (the end of the period) harvesting is making some demands on labour but still not to the year one level. During period 2, output and harvesting labour increase from year 7 to year 13 following which, apart from fluctuations, labour demand levels out. In period 2 therefore, while later years represent the higher labour requirement, the specification using total labour for the period can be regarded as identical.

As coconut is the only crop grown in period 2 its labour use pattern can determine the type of labour constraint specification used. For the remaining periods however, labour use patterns of coconuts and the intercrop together must be assessed in deciding which constraint specification is appropriate. For periods 3 to 10, the within-period trends for coconuts are very small, especially with the shorter five year period intervals. Thus the intercrop labour use patterns are considered for selection of an appropriate constraint specification. For cocoa, the establishment period makes greatest demands on labour in year one. In the next period, output and demand for harvesting labour increase rapidly so that labour demand is highest in the last year of the period. In remaining periods, cocoa yield per period is constant under the yield curve assumed. Hence either total or first year labour will give identical results. On the one-period-crops, pineapple is substantially more tightly constrained by using the first year labour demand, while taro and bananas have evenly spread labour requirements.

In balancing these requirements, a one-year per period labour constraint is adopted except for the second period when total labour is used. The one-year constraint using the first year requirement places the most effective labour constraint on the areas able to be established, in particular for the perennial crops. Cocoa labour demand in the period after establishment is equally well constrained by the one-year labour constraint but in this case by using the last year requirements when harvesting dictates the highest labour usage. However the one year labour constraint creates problems in effectively debiting allocable income by the loss of cash wages from secondary labour usage. From preliminary runs of the model, in which cash flow was debited by only the one year secondary usage, the total labour use for the major crop areas given in the solution was calculated. A suitable ratio was then derived for total period-labour-use to one-year-labour-use per period, and used to weight the per manday cost of secondary labour against allocable incomes.

The adoption of a one-year per period labour constraint also affects interpretation of the farm labour and secondary labour shadow prices. In this case the increase of one manday in the constraint (one manday per year) represents an increase of several mandays for the period. The actual manday increase per period from an increase of one manday in the labour constraint is therefore given by the ratio of total-period-labour-use to one-year-labour-use established above. Hence the shadow price is a return on the one-year labour use ratio to give a return per manday which can be compared with the wage rate or expected return on labour.

Having established the desirable labour constraint form, it is proposed however to check the sensitivity of the optimal solution to both one-year and total formulations. The labour and secondary labour resource levels are set accordingly, with either one-year or total period available mandays.

So far, all constraints considered have been maximum requirements. The allocable income constraints are put as equality constraints in order to ensure that the sources and uses of cash income are balanced. This is essential in the B form so that cash surplus is discounted into the objective function and is regarded as desirable in the A form for clarity.

The resource level for allocable income constraints is a negative value indicating fixed uses of income in that particular period. It is the sum of uses in farm overhead costs and basic family living cash needs minus the exogenous fixed cash supply coming in this case from the wages of family members, initially employed off the farm. The farm overhead costs (see Table 8, Appendix B) are calculated as a sum of enterprise fixed costs, as it is not possible to activate fixed costs by enterprise activities in the matrix, independently of enterprise level. Given the scale of farming being considered, it is felt that an overall fixed farm expenditure on tools and equipment can be better formulated as opposed to trying to incorporate them as variable costs with each enterprise. This is supported by the fact that enterprise requirements are not markedly different.

Within the matrix, sources of allocable income are the net revenues in each period of the productive activities. Uses are secondary labour, debiting the wage supply given in the resource level, loan repayments, cash transfers to development capital in the next period and family living transfers or discounting activities.

Loans are constrained to amounts per period felt to represent the present policy of the Development Bank of Western Samoa. However it is another constraint that can be usefully parametised to assess the implications of bank policy on effectively implementing an intercropping programme.

Development capital has a zero resource level as a maximum requirement and is self-balancing in sources and uses. That is, development capital is only supplied (from loans or cash transfers) where uses are available which give a suitable return. For loan supply, uses will need to return more than the loan costs, while cash trasnfer supply will be activated by uses which return more than the opportunity cost of not consuming in the previous period: that is, more than the time preference or discount rate.

The family living constraints used in the A form are provided to receive cash surpluses available to the family to provide for consumption levels above the basic level assumed in the allocable income resource level, and to meet increases in the costs of consumption items due to inflation. Family living is formulated as a maximum constraint with a zero resource level, so that the family living transfer provides a surplus resource level in the optimal solution equal to the available cash surplus times 10 (the transfers being made in T10.00 units). It is emphasised that the family living constraint receives funds which cannot obtain a better return (than the time preference rate) in the on-farm investment opportunities provided.

CHAPTER 5

RESULTS

The analysis first derives the solution for the basic model. We then proceed to examine the optimal solution under differing time preference situations by changing the discount rate in the basic model. In subsequent stages, the theoretical implications of objective function formulation, within-period cash flows and labour constraint specification are discussed.

Direction for further analysis is obtained by examination of the shadow prices of binding resources to determine the value of deriving further solutions with increased levels of such resources. After examining solutions for different levels of the land resource, first-period loan funds are parametised for the higher level of land. First-period farm labour and third-period loan funds are also parametised for the basic model. As secondary labour is induced back into on-farm activities at an opportunity cost equal to the daily minimum wage, the effects on labour demand with changes in the minimum wage are investigated. This is associated with determining the return to labour input in the model. Return to capital investment in establishing tree crops is discussed in relation to checking the effects of changing loan conditions on the basic solution.

The discussion of solutions seeks to highlight the following important aspects:

(a) the level and consistency of secondary labour utilisation;

(b) the level and consistency of cash surpluses generated and their ability to meet family consumption over and above basic requirements, to cover inflation and to provide a return to labour and to capital invested in establishment of the tree crop component;

(c) the requirement for borrowed capital under the conditions assumed and the level of savings (inter-period cash transfers) necessary for investment in tree crops;

(d) the coconut planting density at which the intercropping model gives the optimal solution;

(e) the level of adjusted[1] shadow prices on limiting or binding resources as indicative of potential returns from expanding those resources.

The Program

The multi-stage linear programming model was run using the parametric linear programming routine written by J.B. Hardaker of the University of New England and adapted to the Australian National

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1 Shadow prices given in the program are their 'present values'. Adjustment is by division using the appropriate period discount factor to give the value of the shadow price in the period when it is binding.

University's DEC10 computer system by R.G. Dumsday of Latrobe University (Hardaker 1978). The program, AGPLP had a matrix size limit of 50 activities and 50 constraints. This proved too small for the various versions of the model used, which ranged from 63 to 70 activities and from 52 to 62 constraints. Hence AGPLP was edited by simple revision of the common and dimension statements to allow up to 78 activities and 78 constraints (a matrix of 80 by 80 allowing for parametising the objective function or resource level column). While large increases in matrix size may be expected to result in rounding errors and computational difficulties, an increase of this order was not anticipated to involve any problems. However in the checking of solutions small discrepancies were found in levels of secondary labour use and in the areas intercropped. These are indicated in the text and suggest that alternative programs may need to be sought for a matrix size exceeding 50 by 50. The program output provides a matrix listing and details of iterations leading to the final solution. For the solution itself output starts with total net revenue and the parameter lambda (λ) value. The interpretation of lambda is discussed subsequently under the parametric aspects of the program. With the basic activity levels which follow, the program prints a range for each activity indicating how much the contribution coefficient can change, up or down without changing the basis, i.e. activities in the optimal solution. Next the output presents the levels of unused resources and then the binding resources and their shadow prices. A binding resource is one fully used in the solution while its shadow price indicates the increment to total net revenue that would result from the addition of an extra unit of that resource. Output also shows a range of the number of units by which that resource can change without a change in the basis and hence a change in its shadow price. Finally the output presents the non-basic activities together with their marginal opportunity costs, the amount by which the contribution coefficient needs to increase in order for that activity to enter the basis. The parametric capacity of the program permits a relaxation of the certainty assumption either for resource levels or net revenues.

The parametising of a resource allows its level to change and to see the effect of such changes on the optimal solution. Only those resources which are binding in the solution are parametised. The resource level is increased by use of lambda (λ) such that the i^{th} resource constraint would be shown as:

$$a_{i1}X_1 + a_{i2} X_2 + \ldots + a_{in}X_n \leq B_i + \lambda \qquad (1)$$

where the X's are activities 1 ...n, the a's are the input-output coefficients, B_i is the resource level of the i^{th} constraint and $0 \leq \lambda \leq + \infty$. The program prints each solution as a particular increase in resource level, resulting from a change in the basis. With each resource increment, its shadow price decreases, with the final solution given for the point at which the resource ceases to be binding and becomes slack (i.e. it moves into the basis).

Parametising a net revenue level is generally a method for considering the possible effects of price changes on the optimal solution. Where the contribution coefficient of the j^{th} activity is to be parametised we can restate the objective function as:

$$\max Z = C_1X_1 + C_2X_2 + \ldots + (C_j - \lambda)\ X_j + \ldots + C_nX_n \qquad (2)$$

Here lambda acts to successively reduce the contribution coefficient for X_j through a series of solutions (basis changes) to a final solution where X_j itself drops out of the basis. Where the aim is to look specifically at price changes for a given product, the production and marketing of that product are redefined as two separate activities allowing price itself to be the contribution coefficient in the case of the marketing activity. The examination of price effects through a parametric objective function was not within the scope of this study.

The 'Basic' Optimal Solution

The 'basic' optimal solution was obtained for a land area of five hectares, a 9 per cent discount rate and loan funds available at 6 per cent interest with repayment in the same period. The B form of the objective function, in which cash surplus is discounted into the objective function in each period, was used with discounting from the end year of each period. A one-year per period labour constraint was adopted.

The 'basic' optimal solution gave a present value of total net revenue of T7268, not in itself particularly meaningful.

In period one the 'basic' optimal solution establishes the full five hectares of land in coconuts B (medium density) and intercrops 3.4 of the available 3.8 hectares of intercropping land with pineapple. All first year farm labour is used and all available secondary labour is called in. At the level of return indicated by the adjusted shadow prices (see Table 5.1 (Section c)), the family might well consider applying more labour to allow full use of the intercropping land available (refer to later discussion). The establishment of medium density coconuts does not require all available loan funds in period one.

Period two is dominated by the requirements of the coconut activity. Of available farm labour only 64 per cent is used leaving secondary labour entirely in off-farm employment. This low level of labour utilisation together with the low level of annual cash surplus (see Table 5.1 (Section b)), gives cause for concern about the potential of the intercropping system as presently formulated.

Period three establishes 4.02 hectares of cocoa, effectively the full area of available intercropping land. Taro in period 3 and pineapple in periods 4-9 enter the solution marginally, probably as a result of rounding errors in the program. Cocoa requires T2487 of development capital for establishment. This is provided by full use of available loan funds at 6 per cent and the remaining T1487 comes from cash transfer from period 2 at 9 per cent. This cash transfer, left in period two, would increase annual cash surplus in that period by approximately 20 per cent. The adjusted shadow price on loan funds in period 3 (see Table 5.1 (Section c)), suggests that borrowing could be profitably expanded to give a return of T0.21 for each dollar borrowed. This could also be a desirable option for the farmer as the cash transfer of T1487 requires that the period two annual cash surplus of T360 be completely saved for the last four

TABLE 5.1

THE 'BASIC' OPTIMAL SOLUTION

Section (a) Basic Production Activities

Period of Establishment	Code	Activity	Level
1	X2	Coconuts (B)	5 hectares
1	X18	Pineapple	3.43 hectares
3	X13	Cocoa	4.02 hectares

Section (b) Basic Labour Use and Cash Activities

Period	Years for Period	Cumulative Years	Secondary Labour Use/Annum (Mandays) (X33-X42)	Loans (Tala) (X49-X53)	Cash Transfers (Tala) (X49-X53)	Cash Surplus/ Annum (Tala) (X54-X63)
1	6	6	500	886		1130
2	18	25			-1487	360
3	5	30	145	1000	+1487	440
4	5	35	128			2800
5	5	40	164			4130
6	5	45	164			4130
7	5	50	134			3770
8	5	55	133			3300
9	5	60	73			2960
10	5	65	58			2580

Section (c) Binding Resources

Period	Code	Resource	Shadow Price*
1	S1	Land	T5.58/hectare
1	S11	Farm Labour	T6.00/manday**
1	S21	Secondary Labour	T4.00/manday**
3	S42	Loans	T0.21/T1.00

* Adjusted by the period discount factor to give shadow price in that period.

** Adjusted by the period total : one-year labour use ratio (refer Chapter 4 - labour constraint).

years of the period. Given that the period 2 annual cash surplus is already the lowest in the model, this saving requirement might well be too onerous. A solution parametising the third period loan is considered later.

Planting of medium density coconuts appears to balance two effects. Not only the levels of cash surplus, but also the period in which they occur are important. Low density coconuts make available a maximum area for intercropping but themselves have a low income stream. Thus they permit higher cash surplus in period one and periods 3 to 10 but give a low income stream through the 18 years of period 2 when only coconuts are grown. Conversely, high density coconuts reduce intercropping potential to provide a relatively higher second period income stream. At a given time preference rate, the balance of density effects on income from coconuts in period 2 and on income from intercropping in periods 1 and 3 to 10 will determine which density is planted.

The choice of medium density coconuts suggests that a balance needs to be struck between intercropping potential and second period income. The difference in available intercropping land from high and medium density coconuts is only 0.14 hectares. The area in pineapples in period one is therefore less than the intercropping land that high density coconuts would make available. However high density coconuts while increasing second period income would have used more of the limited period one labour with a consequent reduction in pineapple planting and period one income. The magnitude of such a loss is in the order of T12.00 per year, set against a similar gain per year in the second period. As the present values of these losses and gains favour the gains attention needs to be given to the later intercropping phase of periods 3-10. In this phase intercropping land, not labour, is the limiting resource. Medium density coconuts have made available a larger area of intercropping land than would high density coconuts. Hence it is concluded that the income stream derived from planting cocoa in period 3 has an important influence on the overall present value of total net revenue. A smaller cocoa area under high density coconuts would give a net loss to the maximand from the balance of period 2 gains and periods 3-10 losses and the larger cocoa area under low density coconuts would similarly give a net loss, this time from the balance of second period losses as against gains in periods 3-10. The balance under medium density coconuts is that which maximises present value of total net revenue.

A further indication of the balance between alternative planting densities can be gained from the marginal opportunity costs for the excluded coconut activities. The marginal opportunity cost for high density coconuts is T6.92 and for low density coconuts is T136.50. Thus a 1.4 per cent increase[2] in the revenue stream advantage of high density coconuts would balance the effects of second period coconut income and cocoa income in periods 3-10. This might be expected with existing revenue streams but at a higher time preference rate.

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2 The marginal opportunity cost as a percentage of the present value of the high density coconut income stream at 9 per cent, i.e. T480.29.

From period 3, use of secondary labour is steady at around 150 mandays per year and from period 4, cash surplus is greater than T2000 per annum (see Table 5.1). However periods 9 and 10 show a drop in secondary labour usage and cash surplus corresponding to the declining production phases for both the coconut and cocoa. Improved data and optimal replacement analyses for both crops would therefore be relevant indicating whether the present planning horizon or assumed replacement interval for coconuts is indeed optimal. Additionally, optimising for an infinite planning horizon, in which the intercropping system is allowed to replace itself, might have brought in later cocoa planting to maintain period earnings and labour use through into period one of the replacement sequence.

In summary, the 'basic' optimal solution establishes medium density coconuts and intercrops with pineapples in period one and cocoa from period 3. Loan funds are used in periods 1 and 3 together with a cash transfer from period 2 to 3. Labour is the binding constraint on period 1 intercropping, while intercropping land is the binding constraint on the cocoa intercrop. Overall land area acts as a weak constraint to the size of the enterprise. Period 2 labour use and cash surplus indicate an area of weakness in the system. The policy and research implications from this are discussed in the conclusions (refer Chapter 6).

Time Preference and the Optimal Solution

Solutions were obtained for the basic model at 5 per cent and 12 per cent discount rates and compared with the 'basic' optimal solution at 9 per cent. The aim was to see in what ways changes in farmer time preference would alter the optimal intercropping plan.

Examining first the solution at a 5 per cent discount rate, production activities and secondary labour use are identical to the basic solution. Given a discount rate less than the loan cost however, development capital to establish cocoa in period 3 is provided entirely by cash transfer at a 5 per cent opportunity cost. This reduces cash surplus per year in period 2 and increases it in period 3 where there is now no loan repayment required (see Table 5.2 (Section b)).

The solution for the high discount rate of 12 per cent is however different. Only 4.6 hectares are established in coconuts, still at the medium density. It has also changed marginal opportunity costs so that low density coconuts have a marginal opportunity cost less than high density coconuts. This suggests that increased time preference has moved competition from late intercropping versus period two incomes to early intercropping versus period two incomes. The result has been to favour early intercropping by switching the allocation of labour from coconut establishment to pineapples, planting all 3.59 hectares of available intercropping land. This is done at the expense of period two annual cash surplus (see Table 5.2 (Section c)) so that time preference considerations do not correct the deficiency of loan period 2 cash surplus. Farm labour utilisation in period 2 falls by 22 mandays per annum.

The area established to cocoa in period 3, unlike the 5 per cent and 9 per cent solutions is less than the full available

TABLE 5.2

OPTIMAL SOLUTION AND TIME PREFERENCE

Section	Period	Activity	Units	Activity Level 5%	9%	12%
	1	Coconuts B	Hectares	5.0	5.0	4.6
	3	Taro		0	0	0.07
A	3	Cocoa		4.02	4.02	3.62
	1	Pineapple		3.43	3.43	3.59
	4	Pineapple		0	0	0.07
	6	Cocoa		0	0	0.07
	1	Secondary Labour	Mandays	500	500	500
	3			145	145	104
	4			128	128	94
	5			164	164	132
	6			164	164	117
B	7			134	134	90
	8			133	133	90
	9			73	73	36
	10			58	58	22
	1	Loans	Tala	886	886	822
	3			0	1000	1000
	6			0	0	44
	2-3	Cash Transfer		2487	1487	1240
	1	Cash Surplus	Tala/Year	1133	1133	1190
	2			302	358	333
	3			711	444	445
	4			2800	2800	2610
C	5			4130	4130	3800
	6			4130	4130	3780
	7			3770	3770	3510
	8			3300	3300	3100
	9			2960	2960	2800
	10			2580	2580	2450
		Binding Resources		Shadow Prices		
	1	Land	Tala/Ha.	1624	3.32	-
	1	Farm Labour	Tala/Md.	6.00	6.00	5.01
	1	Secondary Labour		4.00	4.00	3.05

area of intercropping land. The balance of 0.07 hectares is put into taro in period 3 and pineapple in period 4. Then in period 6 it is planted to cocoa. The small area of taro in period 3 supplements the level of cash surplus while cocoa is being established. The net effect of around T16 per year by which cash surplus would fall if the full area was planted to cocoa is small. A further complementary effect however is to require less funds to be transferred from period 2, a total amount of some T44 should the full intercropping area have been planted in cocoa. These gains outweigh the losses in subsequent periods from reduced cocoa acreage. Pineapple planted in period 4 only partly compensates this loss as cocoa returns in their second period exceed pineapple returns by T126 per hectare or T9 for the area involved. Similarly, the planting of cocoa in period 6 partially compensates the losses from reduced cocoa planting in period 3. The net effects therefore are for small second and third period income increases from reduced cash transfer and taro plantings to outweigh subsequent reductions in the income stream at this higher discount rate.

Summarising then, time preference effects have not altered the optimal solution in the lower range except to substitute cash transfer for borrowing in supplying development capital. In the higher range time preference has reduced the coconut area planted to obtain a larger period one cash surplus from use of binding labour in intercropping. It can be concluded that consideration of increasing total area in the intercropping system is only relevant at lower time preference rates. Time preference has not influenced the optimal planting density for coconuts.

Objective Function Type and the Optimal Solution

Two types of objective function were discussed in Chapter 4. The A form required putting explicit contribution coefficients into the objective function for each activity and required that each be exogenously discounted according to the period in which that activity took place.[3] The B form takes cash surplus generated in each period from the allocable income constraint and discounts it into the objective function using the discount factor for the end year of each period. Initial solutions were obtained for both A and B forms in an attempt to understand the workings of the model.

Solutions were obtained at a 5 per cent discount rate, using borrowed funds with a quoted interest rate of 8 per cent and a repayment schedule, calculated at an 8 per cent interest charge after allowing a 'one-period' grace on repayment. In deriving the A form, decisions were made as to the appropriate contribution coefficients for the loan and cash transfer activities. For the loan activity, the quoted interest rate of 8 per cent was used. The cash transfer activity was arbitrarily decided to have an opportunity cost of 5 per cent and the appropriate coefficient calculated per unit of cash transfer. It was initially a coincidence that the contribution coefficient for the 5 per cent discount rate used was the true opportunity cost, though incorrect for runs at any other discount rate.

Comparison with the B form solution indicated that development capital in period 3 was supplied by cash transfer only in the A solution, but by borrowing within limits of available loan funds in the B solution. The latter used an identical repayment schedule as

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3 The discounting of A form contribution coefficients is assumed and for brevity is not made explicit in later sections of the text.

given in the A form. Consideration of the operation of the B form matrix indicated that the repayment schedule put into the matrix would determine the actual interest rate and that the discount rate represented the opportunity cost of cash transfer by not consuming cash surplus in one period but transferring it to generate cash surplus in subsequent periods. The loan repayment is treated by the B form matrix as a lump sum repayment at the point of discounting instead of as a series of yearly payments. Discounting this lump sum back to the point of borrowing indicated that its implied interest rate was considerably less than 8 per cent and also less than the 5 per cent cost of cash transfer: hence the preference for supplying development capital by loan funds in the B form solution.

Subsequently solutions were obtained for A and B forms with identical loan and cash transfer conditions. For the loan activity, an interest rate cost was fixed at 6 per cent and this value was entered in the A form objective function. The B form repayment was calculated as the principal unit (T100.00), compounded at 6 per cent to the end of the period in which repayment was to be made. Repayment amounts at the end of the same period appeared more reasonable. The same repayment was used in the A form matrix. However, this was an unnecessary detail as identical use by the two approaches depended only on comparability between the A form contribution coefficient and the B form repayment amount. The A form repayment amount does not influence the introduction of the loan activity. Thus the A form is seen to offer additional flexibility in programs requiring periods that aggregate years, in that actual interest rate cost can be given in the objective function while actual repayment amounts per period can be entered against allocable income to accurately debit cash surplus. In this study, actual repayments are not expected to be substantially different from that required in the B form matrix to correctly represent the interest rate.

Returning to the later A and B form comparative runs, cash transfers were made identical by entering the discount rate as the contribution coefficient in the A form. Care was also needed with the secondary labour contribution coefficient. As labour, with a one-year per period constraint formulation, required a weighted opportunity cost[4] to debit cash surplus by the total amount of secondary labour wage earnings lost, so the objective function in the A form needs to use that same weighted opportunity cost as the contribution coefficient.

This now allows the comparison to indicate the possible solution changes that could arise from differences in the within-period cash flows of the productive activities (see Figure 5.1). These differences are accurately represented in the A form contribution coefficients which are derived by exogenously discounting the annual cash flows, while in the B form, the cash flows are aggregated into period totals and discounted by one discounting coefficient per period. Results were obtained at the 12 per cent discount rate where the effect of within-period cash flow differences would be accentuated.

Results show substantially different solutions (see Table 5.3). The basic restructuring involves the planting of high

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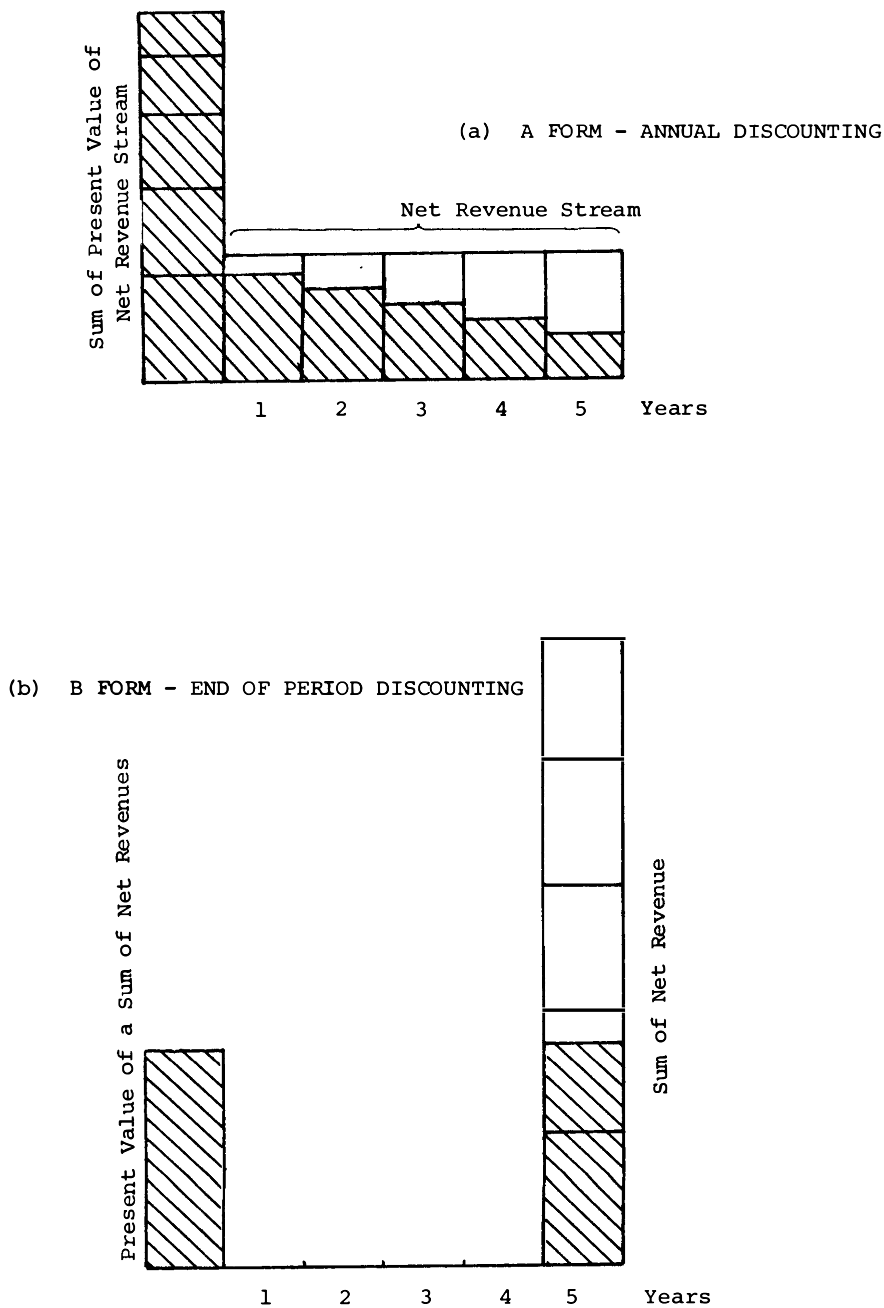
4 Refer Chapter 4 - labour constraint formulation.

FIGURE 5.1

EFFECT OF A AND B FORM OBJECTIVE FUNCTIONS ON THE PRESENT VALUE OF A NET REVENUE STREAM



Key: Shaded areas show the discounted portion of the net revenue.

TABLE 5.3

ALTERNATIVE OBJECTIVE FUNCTION SOLUTIONS

(AT 12% DISCOUNT RATE)

Section	Period	Activity	Units	Activity Level A Form	Activity Level B Form
	1	Coconuts A	Hectares	4.92	0
		Coconuts B		0	4.6
		Taro		0.41	0
A		Pineapple		3.22	3.59
	3	Taro		neg.	0.07
		Cocoa		3.82	3.62
	4	Pineapple		0	0.07
	6	Cocoa		0	0.07
	1	Secondary Labour	Mandays	500	500
	3			158	104
	4			130	94
	5			160	132
	6			160	117
	7			136	90
B	8			135	90
	9			73	36
	10			70	22
	1	Loans	Tala	1000	822
	3			1000	1000
	6			0	44
	2-3	Cash Transfer		1363	1242
	1	Cash Surplus	Tala/Year	1100	1190
	2			424	333
	3			490	444
	4			2720	2600
C	5			3980	3800
	6			3980	3780
	7			3600	3510
	8			3100	3100
	9			2800	2800
	10			2450	2450

density coconuts up to the limit of first period loan funds. This makes available 3.62 hectares of intercropping land as against 3.51 hectares in the B solution. The shift to high density coconuts switches some of the binding labour resource from intercropping to coconut establishment with the result that pineapple planting is reduced. In addition, the competitiveness of taro as a period one intercrop has been increased in comparison with pineapple in the A form by annual discounting. Instead of using less than the available intercropping land by planting only pineapple, the full area is now planted by introducing taro, a lower labour demanding crop, to substitute for much of the pineapple area. In periods 3 to 10, the A solution has returned to a cocoa-only intercropping system, all planted in period 3.

The result in terms of cash surplus and labour use is interesting. The A solution shows a cash surplus reduction in period one of approximately 9 per cent due largely to the reduced pineapple planted but more importantly a 27 per cent increase in the period two annual cash surplus. The secondary labour use in the A solution corresponds more closely to that for the 5 per cent and 9 per cent B form solutions. The similarity in the two solutions is that neither have planted the full land area to coconuts. To that extent the A form solution still emphasises period one intercropping. However by planting high density coconuts, the A solution increases the weighting of the period two income from coconuts. By discounting the period two coconut income stream at the end of the period, the B form has understated the present value of coconut income and shifted the balance in favour of the intercropping contribution to the objective function. The lack of short-term intercrops for periods 3 and 4 in the A solution indicates that present value is not increased by establishing part of the intercropping area in such crops. Thus annual discounting has favoured cocoa vis-á-vis the short-term intercrops.

As the cash surplus generated in period 2 represents the most critical area of the present model, the approximation in discounting cash surplus by period is emphasised. The present length of period 2 has accentuated the difference between aggregate and annual discounting which would be reduced by having two or three periods in place of the present period 2.

An Expanded Model

A deficiency in the basic model is the overlooking of within-period cash flows and the financing of within-period deficits for the short term crops. This tends to understate the possible need for cash trasnfers and the demand for loan funds. It might also be expected to influence the choice of alternative short term crops where differences in within-period cash deficits are substantial.

An analysis of the short term crop cash flows indicated that the cash deficit during taro establishment was negligible, that during banana establishment it was T324 and for pineapple it was T1035. To meet this requirement for the establishment of pineapple in period 1, the amount was entered in the development capital constraint along with coconut capital needs. The supply of loan funds for period 1 development capital is relaxed to a level of T1500. To meet the opening capital needs of pineapple and bananas in periods 4 to 10, opening capital constraints were put in to be supplied only by cash transfers from allocable income in the previous period. The opening capital constraints, like the development capital constraints have a zero resource level and receive funds only where they can be used to return more than their opportunity cost of supply. The expanded model, using the B form objective function, was run at a 9 per cent discount rate with a 6 per cent loan specification for comparison with the basic model. Results are given in Table 5.4.

Period 1 brings an immediate change, with pineapples being constrained by available loan funds to less than one hectare. This brings in taro on the remaining intercropping land with a reduction in first period labour use to only half the available secondary labour. The fall in cash surplus in period 1 of over 40 per cent, comes partly from the substitution of taro for pineapple and partly from the increased burden of loan repayments. Cash transfers for opening capital are called on for the small planting of bananas in period 4.

Conceptually then, there does not appear to be any particular difficulty in modelling within-period requirements for financing, though it may be desirable to specify such requirements separately from long term capital needs so that different loan requirements can be handled.

Labour Constraints and the Optimal Solution

The specification of the labour constraint received considerable attention in formulation of the model. As the one-year

TABLE 5.4

COMPARISON OF AN EXPANDED MODEL AND THE BASIC MODEL

Section	Period	Activity	Units	Activity Level Basic Model	Activity Level Expanded Model
	1	Coconuts B	Hectares	5.0	5.0
		Pineapple		3.43	0.75
		Taro		0	3.23
A	3	Cocoa		4.02	3.94
	4	Bananas		0	0.18
		Cocoa		0	0.14
	6	Cocoa		0	0.16
	1	Secondary Labour	Mandays	500	252
	3			145	133
	4			128	153
	5			164	165
	6			164	174
	7			134	147
B	8			133	125
	9			73	70
	10			58	55
	1	Loans	Tala	886	1500
	3			1000	1000
	4				90
	6				101
	2-3	Cash Transfer		1487	1386
	3-4				29
	1	Cash Surplus	Tala/Year	1130	650
	2			360	360
	3			440	440
	4			2800	2710
C	5			4130	4060
	6			4130	4080
	7			3770	3860
	8			3300	3420
	9			2960	3090
	10			2580	2700

labour constraint involved specification difficulties in terms of debiting allocable income by the actual loss of cash wages arising from secondary labour use (refer Chapter 4 - labour constraint), the importance of specifying labour by the year of maximum usage in a period was checked by comparison of solutions for both one year and total period labour use constraints. The comparison was made at a 5 per cent discount rate and a land area of five hectares. Results are summarised in Table 5.5. The total labour solution was obtained for an earlier loan specification which proved to have an interest rate less than 5 per cent and hence the differences in period 3 borrowing and cash transfer. The one-year solution used the basic 6 per cent loan specification. Results indicate that coconut planting is unchanged. However, the reduced binding power of the total labour specification is clearly seen in the first period. Coconuts use only about 60 per cent of the available labour in total specification compared with the one-year constraint so that full intercropping of the area available is now allowed and few mandays of secondary labour are called on. Similarly, in period 3 during the establishment period for cocoa, the requirement for secondary labour is considerably understated. For the remaining periods, use of secondary labour is roughly equivalent. The cropping pattern however differs, with the total labour solution reducing cocoa planting in order to plant a small but significant area to taro in period 3 and pineapple in periods 4 to 10 with the exception of period 8. The reason for this is not immediately obvious, as total labour was not binding during these periods under the one-year labour specification. Intercropping land is the operative constraint for both labour

TABLE 5.5

LABOUR CONSTRAINTS AND THE OPTIMAL SOLUTION

(AT 5% DISCOUNT RATE)

Section	Period	Activity	Units	Activity Level 1 Year Labour	Activity Level Total Labour
	1	Coconuts B	Hectares	5.0	5.0
		Pineapple		3.43	3.82
	3	Cocoa		4.02	3.69
		Taro		0	0.33
A	4	Pineapple			0.32
	5				0.32
	6				0.32
	7				0.33
	9				0.21
	10				0.33
	1	Secondary Labour	Mandays/	500	4
	3		Year	145	32
	4			128	99
	5			164	166
	6			164	167
B	7			314	142
	8			133	178
	9			73	100
	10			58	54
	1	Loans	Tala	886	886
	3			-	1000
	2-3	Cash Transfer		2487	1285
	1	Cash Surplus	Tala/Year	1130	1980
	2			300	310
	3			710	950
	4			2800	2560
	5			4130	4000
	6			4130	4000
	7			3770	3670
	8			3300	3150
	9			2960	2880
	10			2580	2590
		Binding Resources		Shadow Prices	
	1	Intercrop Land	Tala/Ha.	0	2264
	3			658	696
	4			1510	2266
	5			1142	2267
	6			1143	2265
	7			1142	2264
	8			1265	9031
	9			1183	2264
	10			30100	1327

specifications and shows an increase generally, in shadow price, for the total labour solution. This suggests that total labour is less binding, permitting a greater return to increments of intercropping land. It does not help in examination of the shift in cropping pattern however. A reconsideration of net revenue per manday shows that shifting from one-year to total labour in evaluating the return gives a relative movement in favour of the short term crops. Thus while any absolute advantage ceases after the cocoa establishment period, this appears the only plausible explanation, short of program computational and rounding errors.

In summary however, the important point from the comparison is to confirm the need for labour demand to be specified at the point of maximum demand, in spite of any approximation that may be required in debiting allocable income for wages lost through use of secondary labour.

A Parametised Labour Constraint

First period labour, both farm and secondary, is fully used in the 'basic' optimal solution in establishing coconuts and in planting a portion of the available intercropping area to pineapple. Shadow prices indicated a return per manday of T6.00 for on-farm labour or a net return to secondary labour of T4.00 (refer Table 5.1 (Section c)). By relaxing the first period labour constraint, on-farm labour is increased by 79 mandays per year (a 20 per cent increase) to plant the full intercropping area of 3.82 hectares in pineapple. First period cash surplus increases to T1340. There is no influence on coconut planting or second period cash surplus.

The subsequent iteration, in which on-farm labour is increased by 500 mandays per year to substitute for using any secondary labour in on-farm activities, is not a meaningful result.

Changes in Land Resource

The reasons for investigating solutions for a range of land areas is not that the farm family can readily add to its land resource and hence improve the utilisation of other resources and increase total net revenue but that, given considerable variation in the size of family land holdings, it is important to consider the changes in the optimal solution that might arise from changes in the land holding. With this in mind, the resource level was firstly set at values ranging from 2.5 hectares through to 8 hectares. The lower land resource levels were considered at the 9 per cent discount rate for comparison with the 'basic' optimal solution. The examination of an 8 hectare resource level however, was done at a 5 per cent discount rate, as time preference results have previously indicated that utilisation of increased land areas is likely to be restricted at the higher rates. The solution for the greater land area also involved parametising the first period loan constraint as initial solutions indicated that available loan funds restricted expansion of the coconut area able to be established.

Land Resource Levels Less Than Five Hectares

Solutions were obtained for 3 hectares and 4 hectares. At 2.5 hectares the solution was unfeasible indicating that this land area was insufficient to meet assumed fixed costs and family living expenses with the production activities available. The present value of total net revenue declined 12 per cent and 34 per cent from the 'basic' optimal solution level for 4 hectares and 3 hectares respectively. In each case the full land area is established in medium density coconuts without using all available loan funds for the first period. Pineapple remains the only period 1 intercrop. However period 1 secondary labour has become slack and the full intercropping area available is planted for both the 3 and 4 hectare solutions. The later intercropping phase shows some interesting changes. As the land resource decreases there is an apparent shift from cocoa to short term crops. The 4 hectare solution is confusing, as cocoa in period 3 occupies the allowable intercropping area of 3.2 hectares, but taro and pineapple areas still come into the solution. Again computational and rounding errors are assumed. At the 3 hectare resource level the cropping pattern shift is more clearly shown. Cocoa planting in period 3 is 2.14 hectares of the available 2.4 hectares. The remaining 0.26 hectares is planted to taro in period 3, pineapple and bananas in period 4 and bananas in periods 5 to 10. The change from pineapple to bananas, in the 4 hectare and 3 hectare solutions as the major short term intercrop in periods 4 to 10, reflects a change from labour to land area as the most binding constraint. This is confirmed by a comparison of the shadow prices (see Table 5.6 (Section d)). Hence bananas, with a greater return per hectare, substitute for pineapple, which has the greater return to labour input.

Reduction in the use of secondary labour is considerable. During periods 3 to 10, the 4 hectare use of secondary labour is about one third the 'basic' optimal solution usage and at 3 hectares secondary

TABLE 5.6

RESTRICTED LAND RESOURCE AND THE OPTIMAL SOLUTION

Section	Period	Activity	Units	Activity Level 3 Hectares	4 Hectares	5 Hectares
	1	Coconuts B	Hectares	3.0	4.0	5.0
		Pineapple		2.4	3.17	3.43
	3	Cocoa		2.14	3.2	4.02
		Taro		0.44	0.24	
	4	Pineapple		0.32	0.24	
		Banana		0.23		
A	5	Banana		0.27		
	6	Pineapple		0.08	0.22	
		Banana		0.24		
	7	Banana		0.33		
	8	Banana (B)		0.33		
	9	Pineapple (P)		0.33		
	10			0.33		
	1	Secondary Labour	Manday/	188	384	500
	3		Year		52	145
	4				43	128
	5				63	164
	6				62	164
B	7				24	134
	8				73	133
	9				25	73
	10				34	58
	1	Loans	Tala	535	716	886
	3			1000	1000	1000
	2-3	Cash Transfer		289	989	1487
	1	Cash Surplus	Tala/	877	1075	1130
	2		Year	235	290	360
	3			390	440	440
	4			1870	2440	2800
C	5			2550	3530	4130
	6			2560	3415	4130
	7			2330	3110	3770
	8			2075	2790	3300
	9			1845	2540	2960
	10			1630	2270	2580
		Binding Resources			Shadow Prices	
	1	Land	Tala/Ha.	2356	2053	5.60

Contd. over/

TABLE 5.6

(Cont.)

Section	Period	Activity	Units	Activity Level 3 Hectares	4 Hectares	5 Hectares
		Binding Resources		Shadow Prices		
	1	Intercrop Land	Tala/Ha.	2121	2121	0
	3			1499	658	658
	4			2529	1510	1510
	5			3553	5755	5541
D	6			2527	1140	1142
	7			3433	3060	1142
	8			3448	1264	1264
	9			4140	965	1175
	10			3432	1216	9073
	1	Farm Labour	Tala/M.D.	2.00	2.00	6.00
	3			0	2.00	2.00
	4			0.78	2.00	2.00
	5			0.04	2.00	2.00
	1	Secondary Labour		0	0	4.00

labour use is negligible. In period 1 there is a similar reduction from full use in the 'basic' optimal solution to 75 per cent and 35 per cent of available secondary labour for the 4 hectare and 3 hectare solutions respectively. Cash surplus also drops, especially in the critical years of period 2 (see Table 5.6 (Section c)).

<u>Land Resource Greater than Five Hectares with Loan Resource Parametised</u>

With loan funds in period 1 still constrained to T1000, the extra land planted to medium density coconuts is 0.65 hectares. As first-period labour was previously binding, the extra coconut planting requires a reduction in pineapple area from 3.43 to 3.27

hectares. Later periods follow an essentially similar pattern. Cocoa planted in period 3 leaves some intercropping land for marginal plantings of taro and pineapple in periods 3 and 4 respectively. In periods 6 and 7, cocoa plantings leave intercropping land completely in cocoa. Secondary labour use increases in periods 3 to 8 by 45 per cent over the 'basic' optimal solution and cash surplus shows a decline in periods 1 and 2 but increases thereafter.

With loan funds increased to T1377, the program brings in a small area of low density coconuts to supplement the medium density planting and use the total available land area. First period pineapple drops to 2.85 hectares to free labour for coconut establishment. The period 3 to 10 cropping pattern follows the first solution with slight increases in period 3 taro and period 4 pineapple. The cocoa plantings in periods 6 and 7 complete cocoa coverage of available intercropping land so that the area of 0.18 hectares of pineapple in period 7 appears to result from program rounding errors.

There is almost full utilisation of secondary labour. While the period 1 cash surplus has fallen further to T735 per annum, the second period cash surplus has increased substantially to T495 per annum, giving a more stable return to family labour and increased insurance against inflation on consumption items. The shadow price for both farm and secondary labour in period 1 is the same as in the 'basic' optimal solution, indicating that extra mandays would be used to increase first period pineapple planting up to the available intercropping land area.

TABLE 5.7

SOLUTION AT EIGHT HECTARES AND LOAN PARAMETISED

(AT 5% DISCOUNT RATE)

Section	Period	Activity	Units	Activity Level First Solution	Activity Level Final Solution
	1	Coconuts B	Hectares	5.65	7.77
		Coconuts C			0.02
		Pineapple		3.27	2.85
A	3	Cocoa		4.42	6.09
		Taro		0.01	0.02
	4	Pineapple		0.01	0.02
	6	Cocoa		0.01	0.02
	7	Cocoa		0.1	0.12
		Pineapple		0.14	0.18
	1	Secondary Labour	Manday/Year	500	500
	3			221	455
	4			212	444
	5			255	500
	6			229	466
B	7			193	417
	8			202	430
	9			137	340
	10			120	317
	1	Loans	Tala	1000	1380
	2-3	Cash Transfer		2738	3770
	5-6			6	16
	6-7			69	91
	1	Cash Surplus	Tala/Year	1040	735
	2			350	495
	3			740	800
	4			3060	3980
C	5			4490	5890
	6			4450	5840
	7			4085	5340
	8			3610	4710
	9			3280	4240
	10			2860	3670
		Binding Resources		Shadow Prices	
	1	Farm Labour	Tala/M.D.	6.00	6.00
	1	Secondary Labour		4.00	4.00
	5				16.80

Loan Fund Availability and Loan Conditions

Loan funds are binding in the optimal solution only in the case of the third period supply of development capital for cocoa establishment. This limitation brings in the cash transfer activity to supply the remainder of required funds so that cocoa planting is not restricted. However the cash transfer has a higher opportunity cost (9 per cent) than the loan activity and extra loan funds could be profitably used. This is particularly so as the cash transfer draws on the limited cash surpluses generated in period 2. It was previously indicated that four years of complete surplus savings would be required to effect the transfer. If loan funds in period 3 are increased through parametising the resource level, one extra solution is generated in which borrowing is increased by T1487 to substitute completely for cash transfer. The result is a very small increase in total net revenue, an increase in the second-period cash surplus of 22 per cent to T440 at the expense of a dramatic decline in the period 3 annual surplus from T440 to T45. The period 3 decline results from the heavy repayment burden on a loan of T2487, the level of which is likely to be well beyond the Development Bank's credit limits for smallholder farm loans.

Loan conditions were not able to be adequately investigated in the model as formulated, as the cash surplus was largely a residual to labour. If the surplus was compared with the level of borrowed funds the implied return was vastly overstated. This situation permitted the model to continue to generate solutions for very high interest rates on loans (up to 30 per cent), though in practice farmers would be unlikely to borrow at such levels. Having cash surplus as a return to labour was justified as it is regarded as the important parameter in family decision-making. The interest rate adopted, is therefore assumed to represent the necessary return on capital.

Returns to Labour and the Level of the Minimum Wage

The level of the daily minimum wage is important as regards the ability of the model to bring family labour in wage employment (secondary labour) back into on-farm employment. The model will utilise secondary labour provided the return to labour in the on-farm activities is greater than the return in wage employment, taken to be the daily minimum wage. It was therefore proposed to investigate the response to increases in the daily minimum wage as an approach to assessing the return to labour in on-farm activities. The model was run for daily minimum wages at T2.50 and T3.00. Changes were made both to the allocable income resource level and the allocable income debiting coefficient for secondary labour use. The T3.00 solution was unfeasible while that at T2.50 is presented in Table 5.8. The T2.50 solution indicates reduced planting of coconuts to maximise intercropping with pineapple, with full use of secondary labour. Later periods however use less secondary labour due to the smaller areas in coconuts and cocoa. Given the infeasibility of the solution at a T3.00 basic minimum wage, the return per manday was assessed to be between T2.50 and T3.00 for on-farm activities.

This was borne out from calculations of the actual return of the total available mandays: 23,085 were allocated to on-farm

TABLE 5.8

DAILY MINIMUM WAGE (M.W.) AND THE OPTIMAL SOLUTION

Section	Period	Activity	Units	Activity Level M.W.=T2.00	Activity Level M.W.=T2.50
	1	Coconut B	Hectares	5.00	4.60
		Pineapple		3.43	3.58
	3	Cocoa		4.02	3.58
A		Taro			0.11
	4	Pineapple			0.11
	6	Cocoa			0.11
	7	Cocoa			0.01
	1	Secondary Labour	Manday/	500	500
	3		Year	145	106
	4			128	100
	5			164	133
	6			164	116
	7			134	91
B	8			133	91
	9			73	37
	10			58	23
	1	Loans	Tala	886	822
	3			1000	1000
	6				69
	2-3	Cash Transfer		1487	1216
	1	Cash Surplus	Tala/Year	1130	1330
	2			360	430
	3			440	660
	4			2800	2810
C	5			4130	3970
	6			4130	3970
	7			3770	3700
	8			3300	3315
	9			2960	3050
	10			2580	2700

activities and 34,915 remained in wage employment earning T2.00 per manday or a total of T69,830. Thus on the total undiscounted cash surplus of T134,040, T64,210 were produced from on-farm activities returning T2.78* to the on-farm labour input. The total return per available manday averaged T2.31**.

The economic analysis of the multi-story intercropping system has provided many important insights which are not obvious from either the technical specialisation of the system or the cash flow analysis. The final chapter brings together these conclusions and suggests some policy implications for Western Samoa.

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* T64,210/23,085 mandays = T2.78.

** T134,040/58,000 mandays = T2.31.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The rural aiga or extended family in Western Samoa is widely acknowledged to be the foundation on which economic development must be built.[1] The resources of the economy are largely based on the land holdings, the family labour and organisational strengths of this unit. Yet in spite of this situation, there is an extreme paucity of economic analysis of the family farm, of its alternative enterprises, its requirements for cash income and of its deployment of the family labour resource.

A most important point at which the national interest and that of the rural aiga are likely to diverge as a result of this paucity, is in the present practice of copra production. While acknowledging the value of the coconut in providing a range of subsistence needs, the areas planted to coconut and the resources committed to the industry by the public sector, determine that its major role is, and must be, as an export earner for the country, and therefore, as a viable cash crop for the farm family. Its present management and exploitation by the family however indicate that it is low on the scale of returns to labour compared with the other cash

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1 Sceptical views on the willingness of matai to accept changes are commonly expressed by workers expecting short term revolutions. The critical relationship between central government and the village requires that the latter's independence under the authority of the matai is not seen to be threatened by the programme being advocated. In this context, extension approaches and content are crucial. The content will be considerably improved by the results of this and other such studies.

earning opportunities, chiefly off-farm wage employment. This leads to observations of poor maintenance (Leach et al. 1976), and sporadic utilisation linked to target cash requirements occurring in the intervals between cash remittances from family members in New Zealand (Harrison 1974). The investigation of the coconut income stream in Chapter 3 indicated, even under the assumptions of better management and productivity, that the coconut as a mono-crop is likely to give disappointing results in terms of national performance. This is largely because it fails to meet the cash return needs of the extended family as shown by the return per manday, which even in the coconut's most productive phase only just reaches the present daily minimum wage.

The investigation of a coconut intercropping system was therefore considered from the standpoint of cash surplus generation and from the ability to compete with off-farm alternatives in the allocation of family labour.

The intercropping system was largely taken from that developed at the Central Plantations Crops Research Institute at Kasaragod in South India. The data available was used to estimate the density effect on available intercropping land and to establish the time sequence for the intercropping phases. The limitations of the present system relate to the lower earning potential over the long intermediate period when no intercrops are currently possible. By establishing the relationship between density and the time sequence of intercrops, the possibility of a reduction of the non-intercropping phase at lower densities may be found. Information on very shade tolerant crops that could be grown during this phase would also be invaluable, as would establishing the feasibility of livestock enterprises. The tapping of the coconut inflorescence for toddy, a complementary output, is an approach adopted in some countries.

The data used in the cash flow and later programming analysis was put together with some difficulty. Of the data available, less is available over the time period of a perennial crop's economic life than that for short term crops, less is applicable to economic analysis than to assessing technical efficiency, and less is based on the smallholder's situation and needs than on estate production systems. It would seem vital therefore, that experimental designs for coconut investigations be constrained by the needs to investigate intercropping systems, to measure long term response patterns to management practices, to provide full data on inputs and outputs for economic analysis and to be carried out in the context of the smallholder production constraints and requirements. A further aspect of the data concerns the planning horizon. The horizon for the analysis was based on indications of the approximate optimal replacement cycle for coconuts. As the particular horizon used substantially limited the ability to investigate in detail the parameters of the system over time, improved data and analysis for optimal replacement would more clearly establish the need for this length of planning horizon or indicate by how much it could be reduced. Alternative approaches to the problem of the planning horizon follow.

The programming model used in the analysis was the multi-stage extension of linear programming. This proved to be a valuable tool for the modelling of the intercropping system. It allowed consideration of family living and farm overhead costs, the competitive use of cash surplus in development or consumption and the competitive use of a portion of family labour between wage and on-farm employment. Most importantly, multi-stage linear programming enabled an optimal decision on coconut planting density based on the maximising of cash surplus from intercropping coconuts through time.

Some of the limitations found in the model were more the result of lack of experience by the writer with the technique, and hence indications are given of improvements that could be made in future analysis. Fixed costs for individual crops were not very important except perhaps in the case of bananas. With the linear programming format used, it is not possible to bring in fixed costs, independently of the level of the activity. The alternatives are either to incorporate fixed costs as variable costs or to include them in farm overheads. The latter approximation was felt more relevant given the scale and low capital intensity of the system. Secondly, aggregation of individual years into periods of differing lengths involved difficulties in the endogenous discounting form of the model where activities are compared on the basis of their aggregated period cash flows. Specifically this under-valued the contribution of coconut cash surpluses in the non-intercropping period, resulting in solutions having medium density coconuts as optimal. High density coconuts were established when the exogenous discounting form was used. The endogenous form however has advantages in investigating time preference changes and in reducing errors from exogenous discounting, but has no flexiblity in independently specifying the interest rate charge from the repayment schedule. Again this need only arises when aggregating years into periods. The understatement of within-period cash deficit financing as a result of using multi-year periods was partially overcome in the expanded model at some expense in matrix size. A further approach would involve using the results of the program and returning to the cash flow streams. Combining these according to the linear programming results would allow the annual cash flow pattern to be investigated and credit needs to be obtained.

Alternatively future analysis could usefully look at approaches to investigating, in more detail, shorter segments of the intercropping system. This could be approached from the Modigliani definition of the optimal planning horizon, progressively eliminating end periods from the matrix until the first period decision variables were changed. This shorter time span might then be disaggregated, particularly increasing the number of periods for the non-intercropping phase in the case where endogenous discounting is used. Such a shorter time span might need to include the terminal net worth of the perennial crops in the objective function being maximised.

The linear programming package available for the study appeared to have approached the limits to which its matrix size could reliably be increased. That it may have gone beyond those limits was suggested by small discrepancies in specified constraints on intercropping area and in levels of secondary labour use.

The results obtained need to be tempered by previously indicated limitations on data and modelling and be subjected to further investigation before recommendations could be reliably based on them. Some important general principles remain however.

The ability of the family farm to use all family labour in competition with wage employment varies significantly with the phase of the intercropping system and with farm size. Following the early intercropping phase in which full utilisation of secondary labour occurred (except where taro was grown instead of pineapple), there is an 18 year interval in which no secondary labour is required and 36 per cent of farm labour is unused. This is the non-intercropping phase and its problems may be mitigated in a number of ways. First, this problem phase of low cash surplus and labour use may already be partly completed for a good portion of areas replanted early in the Coconut Project. In this situation, high returns would be imminent with the establishment of cocoa for the later intercropping phase. Secondly, the phasing of public works programmes in districts might be usefully timed to coincide with the non-intercropping phase of a district program of coconut replanting and intercropping. The technical improvement of the system itself has been previously discussed and shade tolerant intercropping or tapping for toddy were suggested as ways to improve labour utilisation and incomes.

For the family intercropping on three hectares of available coconut land, total net revenue is maximised by leaving all secondary labour in wage employment. At five hectares approximately one half of a man-year will be optimally utilised on the farm.

A flexible employment sector would therefore be important in such a situation. Social considerations would point to increasing such employment opportunities through decentralisation. Co-operative cocoa processing (see Appendix A: Technical Appendix 2) would provide such employment. Families with an eight hectare land resource (or 0.47 hectares/capita) are able to use virtually all family labour in the intercropping system but still rely on wage employment for all secondary labour during the non-intercropping phase. Further, the expansion of the area planted in coconuts has been shown to occur only where the family decision-makers have a lower time preference rate. Higher time preference reduces the coconut area in favour of the early phase intercrop and then temporarily delays a portion of investment in cocoa establishment to reduce the level of cash transfer from the non-intercropping period.

Cash surplus generated per period is net of basic family living and fixed costs. The surplus represents a return to family labour. In aggregate, the return is T2.31 per manday for both wage and on-farm employment, while the on-farm portion of cash surplus and labour input returns approximately T2.78. The cash surplus levels show substantial earnings during the later intercropping periods but reduced earnings for the first three periods covering 30 years. This was the case even with an increase in the time preference rate. An improved specification for the present intercropping system might therefore have been to use a minimum constraint on the use of labour in the non-intercropping period. However a comparison of incomes produced from the intercropping model with income levels measured in the 1972 Survey of Household

Living Conditions (refer Chapter 4, Table 4.2) shows that total intercropping income (cash surplus plus basic family living) is 50 per cent higher in period 2 and up to five times greater in the later intercropping periods.

The loan requirements in the model were not excessive and the formulation used did not indicate sensitivity to interest rate charges. The requirement for cash transfer to establish cocoa puts a heavy burden on families to save during the period when their incomes are lowest. The alternative of meeting total establishment costs, by borrowing in period 3, gave an even smaller cash surplus for period 3 than the period 2 level, due to the repayment required. An intermediate solution might be obtained by considering the annual cash flows as previously mentioned.

The crops brought into the solution were quite stable under the range of conditions examined. Cocoa, with a high comparative return to labour dominated the later intercropping periods, in spite of lower returns in the establishment period. Pineapple, next highest in returns to labour, was the early phase intercrop, except in the expanded model where pineapple had an opening capital constraint to be supplied from limited loan funds, and in this case taro was the main intercrop. Short term crops were used in the earlier periods of the later intercropping phase at the higher time preference rate and in the reduced land resource cases.

Finally the decision on optimal coconut density must remain qualified. The medium density of coconuts was optimal for all solutions using the endogenous discounting form except for a small area of low density coconuts included in the solution for the increased land resource. However the alternative form of the model, at the high discount rate, found high density coconuts to be optimal. This latter result is favoured for the model as specified because of the understatement of coconut contribution in the endogenous discounting form. Information on the 'density-crop scheduling' relationship to reduce the non-intercropping period, or obtaining suitable enterprises for that period, would swing the balance back in favour of lower density coconuts and increased intercropping potential.

In conclusion, the systematic intercropping of productive stands of coconuts is felt to be a viable farming system in much of the Western Samoa rural sector, and to be capable of making an important contribution to the social and economic development of the country as a whole.

APPENDIX A

TECHNICAL APPENDIX 1 : COCONUT

1. World Situation

The major coconut products on the world market are copra, coconut oil and copra cake, the latter two resulting from oil extraction of copra. They form a component of the extensive general commodity grouping of fats and oils with a wide range of uses in edible and industrial products. While technical interchangeability is a growing trend in the commodity group reflecting processing developments, coconut oil has a specific technical advantage in soap manufacture due to the lathering qualities of lauric oil. However, its use is much broader than soap manufacture as shown by an analysis of the use of the 362,000 tonnes of coconut oil consumed in three major Western European countries per annum for the period 1958-1960. Soap manufacturing used 19 per cent of the total, while 35 per cent was used in margarine, 11 per cent in shortening, 21 per cent in other edible uses and 14 per cent in industrial uses. Thus in many areas of usage (81 per cent) coconut oil is faced with direct price competition from other fats and oils. Trade liberalisation during the 1960s significantly increased areas of competition and substitution while there was also strong competition from synthetic petroleum-based detergents for soap itself. The considerable expansion of U.S. soybean production and export met the major part of increased demand during the 1960s so that prices remained constant for the commodity group. Within this general pattern, however, prices for individual fats and oils fluctuated considerably over the period. Price elasticity of demand for copra on the world market is higher than for the commodity group as a whole to the extent that substitution is possible. Income elasticity of demand is low in developed countries but high in the LDCs implying future expansion of domestic demand thus reducing foreign exchange earnings. The stable trend in average price for the commodity group for the period 1950-65, using the 1952-54 average as a base period, is converted to a 14 per cent declining trend when deflated by the FAO Index of Manufactured Products. The degree of fluctuation in the copra price for the same period was considerable as indicated by a coefficient of variation of 13.2 per cent. Major fluctuations in the group relate to the supply position for U.S. soybean and USSR sunflower-seed with Indian groundnut, Canadian rape-seed and Brazilian soybean becoming increasingly significant. While the export share of LDCs has risen in the 1970s it is attributable to a limited number of countries. Imports to meet increasing domestic demand in other LDCs has risen 6 per cent per year (150,000 tonnes) during the period. In 1974 a number of countries put export bans on fats and oils in an effort to control domestic prices and inflationary pressures.

Recent price trends have improved somewhat and prospects appear reasonably assured by such international initiatives as the EEC Lomé Convention and UNCTAD proposals of a buffer stock scheme for lauric oils, the latter having been shown to be technically and economically feasible (FAO 1971).

2. Coconut Production

A large number of strains of coconut are found around the world in the different growing areas, distinguished by locality names and showing a wide variety in such productive characteristics as nut yield, nut size, copra per nut, precocity[1] and flowering period. Given the method of distribution of the coconut many such strains are likely to have arisen from a few original seed nuts. The general strain grouping of 'tall' or '*typica*' varieties are mainly open pollinated giving a variable population, while the 'dwarf' variety grouping is to a significant extent self-pollinating and more homogeneous in its characteristics.

Breeding and selection in coconuts is hindered by the length of life cycle: a minimum of 12 years between generations. Additionally, given the open pollination of tall varieties, selections of parents do not breed true unless grown in isolated seed gardens.[2] Charles (1961) reports a 40-50 per cent yield advantage for the top 5 per cent of palms based on 4 years of measurement reducing to a 15-20 per cent advantage over 4 years but with selection of the top 5 per cent based on a single observation. Such mother palms will generally have uncontrolled pollen parents so that maximum potential improvement is half the above. Further, such differences have not been found in practice (Ceylon Coconut Research Institute - 'Latin Square Experiment' 1939), suggesting

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1 Defined here as number of years from planting to first flowering.

2 A perimeter of one kilometre with no coconuts (preferably in forest) is necessary for isolation.

that observed advantages in selected mother palms have a significant environmental basis. Thus the selection of valuable parents can only be reliably based on progeny testing, with the problem of long generation interval. The greatest potential for finding improved planting material appears to lie in the production of hybrid varieties produced from the many strains of coconuts available. To date, work has concentrated on natural pollination with 'dwarfs' the female parent and 'talls' the male parent. Frémond and de Nucé de Lamothe (1972) report on hybrids produced using the West African tall and the Malayan Yellow Dwarf. They found the hybrid to be as homogeneous as the 'tall' parents, emphasising the need to select homogeneous high yielding 'tall' palms. They conclude, from an examination of individual characters contributing to yield, that as the hybrid lies within the range of the two parents, the clear superiority of copra yield by the hybrid is not the result of heterosis but due to an advantageous combination of yield contributing characters. The yield advantage (see Table 1) by year nine to the hybrid was 100 per cent in cumulative copra output. No selection of the hybrids had been made.

Child (1974) describes the conditions suitable for coconut production. Temperatures should always be above 20°C and diurnal range limited to some 5°-7°C. Rainfall can vary within the range 1300 mm to 3800 mm. However it needs to be well distributed and at the lower extremes supplemented by suitable ground water conditions while at the upper levels, good drainage and not excessive cloud cover are important for high productivity. Abeywardena (1968) established a basis for crop prediction in coconuts based on rainfall in critical sub-periods during the 18 months prior to yield assessment.

TABLE 1

PRODUCTION OF MALAYAN YELLOW DWARF X WEST AFRICAN TALL HYBRIDS (KG COPRA/HA/YR)

Age (Yr)	Hybrids Plot 30 160 Trees/Ha	Plot 32 143 Trees/Ha	Plot 31 (230 Trees) 143 Trees/Ha	West African Tall Plot 31 (245 Trees) 160 Trees/Ha
4	265	330	665	
5	1840	2560	2635	
6	3570	2790	4132	1434
7	4050		4500*	2390
8	4100*			2878
9				2512
10				3078
11				3914
12				3010

* Estimated.

Source: Frémond and de Nuce de Lamothe

Factors in crop development, initiation of inflorescence primordia, flowering and premature nut fall were found to be equally moisture sensitive. However sub-period differences in moisture sensitivity did result from the interaction of day-length, humidity and temperature. The concept of effective rainfall is used, being the maximum amount of moisture which can be utilised by the plant. When rainfall is in excess of this amount, only the effective level is put into the predictive equation. Using these variables he was able to develop a crop forecasting formula using multiple regression techniques of very high efficiency (R^2 = .87).

Light conditions are optimum at around 120 hours per month or 2000 hours per year. Stunting and poor development of replanted palms under significant shade from old palms is noted. Information on humidity suggests that excessive levels are associated with fungal diseases while low levels result in high transpiration accentuating any existing moisture stress. Wind is not important to pollination, insects playing the major role. High winds increase transpiration or in the extreme (cyclones) cause physical damage. Coconuts have commonly been established in coastal regions, possibly for economic reasons, but the condition of subsoil water movement favoured by the coconut root system is also present along the base of foothills. Extremes of latitude or altitude reduce production.

Soils relate to climate and coconuts are grown on a range of alluvial, latosolic, coralline, volcanic, clay and peat soil types. Water-logging or lack of water retention are deleterious. Child notes that there are difficulties in correlating traditional soil analyses to yields. Soil pH ranges from 5.0 to 8.0 in most coconut soils. In the alkaline range, potash and trace element deficiencies emerge while the acid soils, especially laterites, are deficient in bases generally and fix phosphate. Child ranks potash levels as the most critical in coconut production, also backed by Green and Foale (1961) in the Solomon Islands. Frémond and Ouvrier (1972) report potash levels as vital from the time of establishment, with palms fertilised with potash from commencement of bearing only suffering a 15-20 per cent yield reduction over nine bearing years in comparison with palms fertilised from establishment. Von Uexküll (1972) notes potash as increasing drought resistance and grey-leaf spot resistance, with responses occurring from 3 months to 3 years depending on the degree of deficiency. Child discusses the problems of the Truog test for phosphate, noting that different phosphate responses have been shown by soils with identical phosphate levels from the above test. He suggests Olsen's test to give a better correlation with expected responses. Von Uexküll (1972) describes the coconut as efficient in utilising soil phosphate, but that responses will occur on deficient soils such as the lateritic soils of Sri Lanka. Child, discussing nitrogen nutrition, feels chemical nitrogen alone is insufficient and stresses the importance of organic matter. Von Uexküll points to nitrogen deficiencies with poor maintenance (excessive competition from weeds), low rainfall and high calcium. Response to nitrogen is largely shown in number of nuts and will occur over 2 to 5 years from application. The balance of nitrogen to potash is important. Chew Poh Soon and Lee King Wat (1972) obtained economic responses to nitrogen applied on coastal clay soils in Malaysia for a period of five years with response 1 to 2 years after application. Yields were increased 25 per cent and profitability by 13 per cent. Child reports on the Coconut Fertilizer Demonstration Scheme in India during the 1950s. Starting the scheme in 1952 were 170 farms of which 154 remained in 1957. Annual applications of 0.34 kg N, 0.15 kg P and 0.56 kg K per palm gave an average response of 367 kg copra per hectare over controls which on many farms still received local manures. The establishment of critical nutrient levels for the 14th frond as a basis for fertiliser application has gained considerable support as an alternative to soil testing (Frémond 1966, Kanapathy 1972). Nutrient removal for given yields has also been calculated as a guide to fertiliser needs. The complex of climate, soil and plant inter-relationships between fertiliser application and output limits the application of nutrient removal measures in this way, however. De Silva (1976) raises a number of important factors in evaluating the fertiliser response of coconuts. First, measurement of fertiliser response requires to be set against a well-defined base production stream over time for coconuts. De Silva's U-shaped response curves for coconuts fertilised at different nutrient levels and combinations are possibly reflecting the underlying production stream for coconuts of 30 years of age through to 60 years of age. Secondly, fertiliser response over time is complicated by nutrient carryover effects involving soil and plant complexes. De Silva suggests that nutrients will accumulate in the soil and palm in the nature of a reservoir, to be drawn on at some later time for directly productive processes. The carryover phenomenon, and the implied surplus of nutrients in one time period, is to be regarded therefore as fundamentally different from that of lagged responses, where the nutrient applied affects processes which in turn affect yield in some later time period. In lieu of data on nutrient reserves in the plant or soil, the carryover effect is difficult to test. The estimation of a carryover function in the case of nitrogen applied to perennial grass swards has been accomplished iteratively using difference equations, whereby change in grass yield is related to nitrogen applied over a period. (Stauber and Burt 1973). De Silva sees difficulties in applying the technique to coconuts, given the greater complexities of dealing with additional nutrients and a reproductive as opposed to a vegetative output process. A final difficulty in response over time is the likelihood that response to different nutrients will change with the age of the palm. This can be established a priori from a consideration of the growth and development processes of the palm. Initially the coconut requires nutrients largely for vegetative growth, then a balance of vegetative and reproductive growth and later for largely reproductive growth. The requirements for nutrients might be expected to be different from those for vegetative growth. Taking this a step further, it is possible that the life cycle of a perennial such as coconut includes a series of phases with emphasis alternatively on vegetative and then reproductive growth. This fact provides a possible explanation for the distinct carryover effect suggested previously. Such a phenomenon is implied in the U-shaped response function (De Silva) and by the analysis of yield over time for some of the Russell Island estates (Green and Foale 1961). The economic implications of lagged and carryover response functions are related to the problem of determining optimum application rates under fluctuating prices such that an optimum rate calculated on today's price ratio may not be optimum at the time the yield response occurs. Also, the price ratio considered will involve a discounted price for copra for the time interval of the lagged response, further reducing the economic optimum level of application.

Establishment of coconuts involves the transplanting of seedlings that have been established in a nursery. Density of planting is a subject of considerable discussion but of limited definitive data, owing to the problems of comparing sufficient alternatives under uniform environmental conditions (i.e. one soil type over a large area) and for a time period long enough to enable definition of the production function. Several theoretical approaches have been proposed as an alternative to lengthy experimentation. Semler (Child 1972) based his criterion on frond development and the need to prevent overlapping adjacent canopies. His recommendation was 9-10 metre spacing. Developing this approach, later writers suggested optimum density would therefore be achieved with a triangular spacing pattern, e.g. Copeland: 10 m triangle, and Sampson: 9 m triangle (Child 1972). The Sri Lankan recommendation is 160 palms per hectare on poor ground and 140 palms per hectare on good ground. This again uses Semler's criterion, the implication being smaller frond size of palms on poor soil. Whitehead and Smith (1968) and Smith (1972) clearly express their criterion for optimum density as yield per hectare rather than yield per palm implied in the above examples. Densities less than 120 palms per hectare were found to result in significant drops in yield per hectare and densities of up to 220 palms per hectare for pure stands were recommended. Smith (1972) saw a need to derive a measure as a function of leaf spread which defined soil area exploited in order to derive optimum density. Density in relation to intercropping has led some writers to suggest planting patterns such as concentrated hedges or clumps, without any empirical testing of the approach. Nelliat et al. (1974) have produced a satisfactory basis for determining density as a preliminary technical approach to intercropping. The influence of density of the coconut stand on the economics of the subsequent intercropping regime is the aim of the analysis for this paper.

The convention in transplanting was to dig a 1 m cube hole, put two layers of husks on the bottom and a mixture of topsoil and wood ash (rich in potash) around the seedling (Child 1972).

Liyanage, experimenting on sandy and gravelly soils (well drained with easy root penetration), found no yield depression from digging a minimum size hole with a post-hole borer involving minimum soil disturbance. The recommended depth of planting (0.3 m) was also found by Liyanage not to be critical (Child 1972). Transplanting of 7 to 8 month seedlings at the beginning of the rainy season is the normal practice. Older seedlings may suffer root damage and incur higher nursery costs while younger seedlings are less hardy and take longer to establish. Supply (replacement) of dead or poor seedlings is usually required one year from transplanting and involves on average some 5 per cent of plants (Child 1972).

Approaches to weeding vary in different areas. Hand-weeding with a mattock may be undertaken in a circle from 1 m to 2 m radius, with the recommendation that the weeds be left as a mulch afterwards. Herbicides have been used satisfactorily in the West Indies and Malaysia. Smith (1967) found dalapon, atrazine, diuron and paraquat, singly or in mixtures, to give good control and improved rate of establishment in young palms. The use of hormonal weedkillers is ruled out. In Malaysia, Barnes and Evans (1972) evaluated a range of herbicides and recommended MSMA and sodium chlorate as most suitable, noting that six-weekly spraying gave a 20 per cent (300 kg/ha) increase in copra output. Hew Choy Kean (1972) reviewed work in weed control using cultivation and found its benefit to be confined largely to heavier coconut soils where compaction was common. He compared slashing (six times per year), cultivation (three disc harrowings per year) and herbicide (MSMA) treatments on coastal clay soils and recorded results favouring herbicide, then cultivation, with slashing showing detrimental effects due to nitrogen competition induced by rapid regeneration of slashed weeds.

Pests and diseases in coconuts vary considerably between growing areas. Those of concern in the South Pacific region are the rhinoceros beetle, Oryctes rhinoceros: Linnaeus, which bores into the bud (unfolded leaves) and eventually destroys the crown; rats; and the leaf-eating Hispidae group of insects, especially Brontispa longissma, which is similar in its attack to the rhinoceros beetle. A regional research programme for the biological control of the rhinoceros beetle has produced viral and fungal parasites of the beetle. Such biological control needs to be complemented by on-farm sanitation to remove potential breeding sites and inspection of palms to remove beetles (in newly established plantings). Losses from rats have been estimated at between 70 and 100 per cent in some areas of the Cook Islands and 0.34 tonnes copra per hectare in the Gilbert and Ellice Islands (Child 1974). Control is achieved by individual metal bands on trees or by using warfarin bait at the rate of one block per 6-12 trees every 2-3 months. Damage to coconut stands from lightning and hurricanes is also a significant source of loss.

Replanting practice has emphasised the importance of removing old palms to facilitate proper development of the replanted seedlings. Liyanage (1963) compared yields from three approaches: (a) removal of old palms at transplanting, (b) gradual removal over an 8 year period from transplanting, and (c) removal 8 years after transplanting. The yield streams (nuts per hectare) are given for new palms only and cumulative twelve year yields (nuts per hectare) given for all palms for each approach (see Table 2). Economic evaluation of these approaches would be useful in deciding on a replanting policy. However, information would be needed on long-term effects on the yield streams, the yield streams for the old palms during replanting and the costs for each approach, particularly those associated with the removal of the old palms under the quite different conditions involved with the different approaches. Hubbard (1972) presents a study of replanting under the situation of high water tables resulting in significant yield declines from 35 years after planting. Under normal conditions Hubbard notes that replanting is often avoided due to lack of reliably higher-yielding planting material, the ease of supplying vacancies (of cocoa) and the long period over which yields decline only slowly especially with good management. Unlike Liyanage, Hubbard suggests the objective of cumulative output is likely to be the one favoured by most farmers because of the provision of continuity in cash flow. Alternatives compared by Hubbard were: underplanting with assisted natural wastage (involving the removal of palms when it was evident they were about to topple), underplanting with removal of all old palms at year nine and clear felling of old palms and replanting. The effect of a seven year delay on cumulative nut output was checked by repeating the treatments after that interval. One treatment modification in the later period was to the removal alternative, with removal of remaining palms at year 3 instead of year 9. Results could be expected to reflect the interaction of density and age effects. Thus in Table 3 the densities of original palms are given along with the yield streams

TABLE 2

YIELDS UNDER ALTERNATIVE REPLANTING STRATEGIES

(A) NEW PLAMS ONLY (NUTS PER HECTARE)

Year	Removal at Year 8	Removal During 8 Years	Removal at Year 0
7	30	80	239
8	151	339	711
9	370	720	1052
10	505	754	1089
11	1081	1321	1618
12	1401	1720	1914

(B) CUMULATIVE OUTPUT TO YEAR 12, NEW AND OLD PALMS (NUTS PER HECTARE)

	Removal at Year 8	Removal During 8 Years	Removal at Year 0
New Palms	13,173	19,568	25,160
Old Palms	35,000	20,000	nil
Total	48,173	39,568	25,160

Source: Liyanage 1963.

TABLE 3

TOTAL YIELD STREAM UNDER ALTERNATIVE REPLANTING STRATEGIES

(000's NUTS PER HECTARE)

Year	Natural Losses	Removal at Year 9	Removal at Year 0	Natural Losses	Removal at Year 3	Removal at Year 0
1	8.2	7.4	0	5.7	4.9	0
2	8.9	7.9	0	5.5	2.0	0
3	7.4	6.9	0	5.4	0	0
4	7.2	6.7	0	5.2	0	0
5	7.4	6.0	0.7	4.9	0	0.5
6	7.3	5.3	2.5	6.7	0.3	2.2
7	7.2	4.7	2.8	4.9	1.0	2.6
8	6.4	4.9	3.2	6.7	1.7	2.6
9	7.6	3.2	4.0			
10	7.6	2.7	4.7			
11	9.1	4.2	5.9			
12	7.4	4.2	5.6			
13	9.1	6.4	6.9			
14	9.3	7.4	6.2			
15	9.6	7.3	7.4			

Source: Hubbard 1972.

TABLE 3a

NUMBERS OF REMAINING OLD PALMS UNDER

ALTERNATIVE REPLANTING STRATEGIES

Year	Natural Losses	Removal at Year 9	Removal at Year 3	Natural Losses
1955	104	101	104	106
1960	89	96	94	91
1965	77			79
1970	62			64

Source: Hubbard 1972.

associated with the treatments. Considering only the output differences between the treatments and without time preference, Hubbard shows that, assuming an 'economic' life of 40 years, that over the remaining 25 years, 'removal at the 9th year' and 'clean felling' need to produce an annual increment over 'natural wastage' of 1235 nuts per hectare and 3210 nuts per hectare respectively to give identical cumulative output. Time preference considerations would require an even higher yield differential in latter years to balance the early yield advantage of 'natural wastage'. The data to year 15 suggests that the 'natural wastage' treatment was still maintaining an appreciable annual yield advantage (23 per cent). Intercropping introduces an alternative to maintaining old palms as a means of sustaining farmers' cash flow during replanting. The intercrop at replanting could be expected to be less competitive for sunlight than the original palms, thus facilitating maximum early development of the yeild stream of replanted coconuts. Additionally, the intercrop might also be economically superior to the net returns produced by the declining yield stream of the original coconuts. However subsistence requirements for coconuts would need to be considered in the replanting alternative adopted.

3. The Copra Industry in Western Samoa

From the time of contact with Europeans in the early 19th Century, the coconut was regarded as the most significant resource in which traders saw potential. In 1867 Theodore Weber, an agent for the German firm of J.C. Godeffroys and Sohn, introduced copra processing as a significant step in improving quality and reducing transport costs (Davidson 1967). Extensive planting was undertaken during the time of the German administration. The influenza epidemic of 1918 and the Mau, a period of political unrest in the 1920s, brought the expansion to a halt. This was followed by a period of neglect of plantations through the low prices of the 1930s, while the post-war boom in banana production further curtailed the development of the industry (Lockwood 1971). Thus from the 1930s, copra exports have remained relatively constant (see Table 4). More recently, replanting and new planting has taken place, starting on the Western Samoa Trust Estates Corporation in the late 1950s. Then in 1966, with the initiation of the First Five Year Development Plan, a Coconut Project under the Department of Agriculture provided cash bonuses, fertilisers and planting material for replanting old stands and for establishing new stands. Plantings reported under the Coconut Project (Department of Agriculture Annual Reports) were 35,650 hectares to the end of 1976. Records of the Coconut Project show a 1:2 ratio of replanting to new planting for the period 1968-72. Assuming the same proportions through to 1976, the areas replanted and newly planted are 11,829 and 23,821 hectares respectively. To this area developed under the Coconut Project is added the estimate of coconut area prior to the Project of 27,927 hectares (Wright 1963) giving a total area of 51,748 hectares of which some 23 per cent is replanted. In virtually all cases of replanting on village land, old palms still remain, producing etiolated poorly developed new palms, slow to come into bearing and giving low yields when they do so (Hung 1976). The reason given is the high cost of removal of old palms (an estimate of T353 per hectare). Other reasons relate to subsistence needs and farmers' cash flow needs.

TABLE 4

WESTERN SAMOA COPRA EXPORTS 1961-75

Year	Volume (Tons)	Value f.o.b. (T)	Copra: Total Exports (%)
1961	13,912	1,345,789	34
1962	10,683	1,309,810	23
1963	15,389	1,742,000	33
1964	15,358	1,840,108	36
1965	12,370	1,678,276	40
1966	14,017	1,642,982	50
1967*	7,405	927,966	30
1968	12,623	1,880,238	49
1969	14,550	1,797,849	39
1970	9,619	1,366,242	40
1971	17,781	2,028,751	45
1972	18,722	1,379,000	41
1973	13,946	1,643,000	41
1974	12,335	4,623,000	66

* The hurricane of 1966 severely reduced the 1967 crop.

Source: Western Samoa Third Five Year Plan 1975-79. Appendix Tables 15, 18 and 19.

The industry in Western Samoa is strongly influenced by the Western Samoa Copra Board established under the 1948 Copra Board Ordinance with sole responsibility for exporting. Its other functions are price stabilisation through the operation of a reserve fund and the fixing of prices to be paid at various levels of the marketing channel. The Department of Agriculture performs a number of supervisory and regulatory functions. Officers of the department carry out sample inspections to check grading and quality. Inspections are done at merchants' storage sheds and in villages where advice is given on copra dryer operation. Under the Ordinance, the department issues copra buying licences to traders and merchants whose facilities are found adequate. The Copra Board in its trading operations sells forward, usually on the London market on a c.i.f. contract. The Board has also supported the development of coconut production through its financial support of the government Coconut Project. The government has undertaken other moves to ensure future development of the industry through its membership of the Asian and Pacific Coconut Community and through initiating feasibility studies into the processing of coconut oil and dessicated coconut. The Third Five Year Development Plan 1975-79 acknowledges the dominant position of copra in the export economy of Western Samoa, but points to past low yields and returns as being limiting factors in the development of the rural economy. Adoption of new technology including hybrid varieties, full application of improved management practices and intercropping are advocated. A programme to make available hybrid planting material in the early 1980s and the planting of 40,000 acres in the following 20 years is established as a national goal.

APPENDIX A

TECHNICAL APPENDIX 2 : COCOA

The World Scene

"Cocoa and chocolate are derived from the seeds of *Theobroma cacao*, a small tree indigenous to the forests of Central and South America" (Urquhart 1955, p.1). Urquhart continues to describe cocoa cultivation by the Maya and Aztec civilisations, its adoption by the Spanish and Dutch and the consumption of drinking chocolate in the 17th Century courts of Europe. Production was spread by the Dutch and Spanish to the East and West Indies but, not until van Houten developed the process for extraction of cocoa butter which led to the production of eating chocolate, did consumption expand dramatically during the late 19th Century and up to the middle of the 20th Century. This coincided with the rapid development of cocoa production in West Africa, which today produces 65 per cent of the world crop.

Cocoa varieties are classified as flavour cocoas, deriving from the 'Criollo' and hybrid 'Trinitario' groups, and the higher-producing more robust 'Forastero' group. The latter includes the 'Amelando' and 'Amazon' cocoas of West Africa and South America respectively. In manufacturing, the flavour cocoas are blended with the base Forastero types.

The growth of the industry in modern times from a production of 250,000 tonnes in 1920 to 1.5 million tonnes in 1970 has been most erratic. Cocoa production is highly susceptible to climatic conditions and the infestations of pests and diseases. Weymar (1968) established cocoa price movements were sensitive to supply variations and Ady (1968) shows price levels influencing supply through planting decisions and short-term maintenance levels. Thus periods can be distinguished of supply growth and downward price trends on the one hand, followed by supply shortages and dramatically increasing price levels. This follows from a low price elasticity of demand (-0.3)[1] and the supply situation (Guri 1975). However with an income elasticity of demand of around 0.7-0.8, the continued development of the industry is closely linked to growth in population and per capita income in the consuming countries and in particular those in the middle income group, as taste for cocoa products develop. Thus the industry sees a danger in short-term high prices as damaging to long run demand. Substitutes are available for cocoa butter, the fat extract from the bean. This concern, expressed at the International Cocoa Conference in 1946 (Urquhart 1955, p.172), is re-expressed in the FAO Commodity Review and Outlook (1975-76). While prices in 1974 soared to US80c/lb, when the International Cocoa Agreement (1972) was renegotiated to come into effect in October 1976, it adopted a wider price range for stablisation (US39-55c/lb compared with US22-32c/lb) and made projections for steady growth in demand at a level not exceeding US50c/lb through to the mid 1980s. This is equivalent to $WS825/tonne f.o.b..

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1 Demand elasticities are difficult to calculate as cocoa (beans) is not a final product and processed cocoa and cocoa butter account for less than 20 per cent of the retail price of milk chocolate.

Cocoa Husbandry and Production

The main study of cocoa husbandry and production is that of Urquhart (1955). He describes cocoa as a perennial tree crop with a variable age at first bearing ranging from 5 to 10 years (3 years for improved hybrids) and reaching full bearing by approximately year 15. Individual trees may bear pods for over 80 years, with yield per tree increasing with age. However, tree mortality is high, so that yields per unit area will decline after 20-30 years depending on environmental and management factors.

Cocoa thrives best under uniformily warm and humid climatic conditions. Average annual temperatures of around 25°C and 80-90 per cent humidity are suitable and an evenly distributed rainfall in excess of 1300 mm is necessary for good production. With rainfall of up to 5000 mm cocoa will produce all year round[2], while at lower levels of precipitation bearing is seasonal with one main and one secondary crop.

Soil is a vital factor in achieving a production stand of cocoa. Well drained and structured loamy soils with high organic matter and free root penetration for 150 cm are favoured. Water holding capacity in relation to precipitation should ensure an adequate supply of moisture in the root zone (Smyth 1967).

Husbandry methods vary widely between producing regions and between estate and smallholder systems. The West African smallholder system is described by Urquhart (1955) as having evolved in

2 Gazelle Peninsula, Papua New Guinea.

isolation from knowledge of conventional practice. Forest is partially felled, leaving shade for the new cocoa seedlings. Seeds are planted 'at stake', 2 to 3 per stand and 90-150 cm between stands. Food crops are intercropped. There is a minimum of soil disturbance at planting, conserving organic matter and moisture, and the dense canopy resists capsid bug attack. Death of individual trees still leaves an adequate plant population.

Modern husbandry advocates planting of seedlings or rooted cuttings of selected clonal material. Spacing conventions vary from traditional 3.6 m and 4.6 m squares in Sri Lanka and Papua New Guinea respectively to 2.5 m and 2.0 m squares now being recommended to achieve advantages of quick canopy formation and self-shading, reduced weeding and higher initial yields (Blencowe and Hubbard 1972). Shade in cocoa monoculture is usually grown prior to planting of seedlings, at which stage shade requirement is most critical. Mainstone (1972) shows that, for cocoa, photosynthesis is at a maximum at 25 per cent of full daylight intensity. Further, he notes that overheating of leaves leads to necrosis and abscission with consequent loss of photosynthetic potential. Leaf overheating is prevented through the cooling associated with transpiration. Shade by limiting direct radiation reduces leaf temperature, so that under less than optimum soil moisture conditions it provides an alternative mechanism to transpiration for leaf temperature control. Yield increases in mature cocoa after shade removal are possible only under the specific conditions of adequate year round moisture and shelter from strong winds. Shading is said to reduce fertiliser requirements. This is due to the nitrogen-fixing capacity of some of the recommended shade trees and to the addition to and maintenance of surface organic matter from leaf litter.

Weed control is important in establishing stands of cocoa prior to canopy coverage and in old stands when the death of trees has caused the canopy to open up. Beckett's study of Akokoaso in the Gold Coast, suggests that weeding involves 33 per cent of the total labour cost (Urquhart 1955, p.198). Estates employ various practices including clean weeding, slashing and spraying. Work by Brown D.A. and Boateng B.D. in Ghana, Tan, Mainstone and Fua in Malaysia and Kasasian and Donelan in Trinidad (cited in Urquhart) point to satisfactory control with paraquat, diuron and simazone. Dalapon produced toxic reactions in young trees and MSMA induced zinc deficiency symptons. The mulch effect from sprayed weeds performed a useful function whereas close slashing resulted in the problem of carpet grass development as well as being demanding of labour. Urquhart suggests that work on fertilising of cocoa is at an early stage, and that recommendations are specific to particular soil environments. Significantly only one paper on fertilising of cocoa was given at the 1972 Cocoa and Coconuts Conference of the Malaysian Planters Society (Wyrley-Birch 1972) and the literature quoted appeared limited. The relationship between shade and nutrient requirements is stressed as is the importance of potassium. A summary table from Wyrley-Birch's paper of fertiliser recommendations is presented (see Table 1), (Wastie and Earp 1972).

Pests and diseases are major problems in cocoa production. Black pod disease results from the fungus Phytophthora palmivora which is prolific in times of high rainfall and humidity. Removal of

TABLE 1

FERTILISER RATES REPORTED FOR COCOA

(GM/PLANT/ANNUM)

Source	Situation	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)
Murray 1971	Year 1	17	17	24
	2	34	34	48
	3	68	68	95
	4	136	136	190
Nair et al. 1975	Year 1	33	55	38
	2	66	11	76
	3	100	17	116
von Dierendonck 1959 (Assume 450 Plants/Acre)	Young Trees	87	50	66
	Old Trees	174	100	132
Jacob and von Uexküll 1963 (Assume 450 Plants/Acre)	≤3 Years	30	40	35
	>3 Years	50	40	80
Cunningham 1963	Unshaded Producing 2.5 Tonnes/Ha	103	53	215

Source: Wyrley-Birch 1972.

infected pods and spraying with fungicide (copper or zinc) are used in control of the disease. The fungus also causes canker of the stem when the bark is bruised or cut during harvesting, planting or weeding. Witches Broom disease is also fungal and can be controlled only by regular removal of infected branches which are then burnt or buried. The major virus disease is swollen shoot disease spread by mealy bugs. Infected areas must be cut out and burnt. Capsids are one of the major pests in cocoa and are controlled by DDT application.

Harvesting of pods is done by hand, the pods are split and the beans removed with the pulp for fermentation, drying and then bagging for export. The harvest is seasonal in most growing regions and accounts for more than 50 per cent of the labour input in small-holder cocoa production. Ripe pods need removal at 1-2 week intervals during the peak season and at no longer than 3 week intervals at times of reduced maturation. Smallholders generally carry out fermentation in baskets under the trees followed by sun-drying while estates and cooperative processing centres use 'sweating boxes' for fermentation and drying is done with a combination of artificial and solar heat.

Cocoa in Western Samoa

Van Hall (1932) describes the first introduction of cocoa into Samoa by a German company in 1883, of 'Criollo' varieties from Ceylon and Java. These proved susceptible to canker (*Phytophthora palmivora*) which was also responsible for Black Pod. Following heavy tree losses, Forastero material was introduced from Ceylon in 1898 and through open-pollination with the existing 'Criollo' varieties, produced the present day Samoan 'Trinitario' with some resistance to canker. The mixed population produces flavour cocoa which commands a premium in those markets of the world which demand flavour cocoa. The Samoan cocoa is based entirely on the above introductions, suggesting a limited germplasm base.

Western Samoa exports from 1951 are summarised in Table 2 together with cocoa price f.o.b. Apia. From the peak in 1962 of 5200 tons, production has dropped to less than 2000 tons in the 1970s.

In the 1950s plantations produced 40 per cent of the crop and village agriculture the remaining 60 per cent. It is now estimated that 80 per cent is produced by village farmers on customary land.

TABLE 2

WESTERN SAMOA COCOA EXPORTS AND F.O.B. PRICES
(1951-74)

Year	Volume of Exports (Tons)	Cocoa Price f.o.b. (T)
1951	3212	497
1952	2448	486
1953	3743	494
1954	2399	777
1955	3118	552
1956	3338	399
1957	3069	422
1958	4209	590
1959	4023	494
1960	3721	384
1961	4101	289
1962	5258	439
1963	4324	384
1964	4480	321
1965	2991	303
1966	2723	442
1967	3116	468
1968	2587	491
1969	3017	595
1970	2442	424
1971	2890	445
1972	1912	469
1973	1218	874
1974	1816	1030

Source: Western Samoa Third Five Year Plan 1975-79, Appendix Tables 15, 18 and 19.

Development work in cocoa by the Department of Agriculture has been concentrated around replanting and new planting using a locally selected clonal strain Lafi 7, which, while having a degree of resistance to Black Pod, has not been shown to be a superior yielding strain.

The Western Samoan Cocoa Board was established in 1972 to set and stabilise prices paid to the farmer, and to control exports. It has not to date investigated the expensive methods of reconditioning (washing and polishing) carried out by the merchants which in the past have limited the payout to growers to less than 50 per cent of the f.o.b. price. Thus the benefits of the supposed premium for flavour cocoa are not received by the producer (Friend 1975).

Murray (1972) lists such production problems as poor planting material, old trees, wide spacing, lack of permanent shade, coupled with no fertilising, excessive pruning, clean weeding and inadequate disease control (Black Pod) as major factors contributing to low yields, high production costs and low profit margins. Hence the extreme sensitivity of the industry in maintenance practices to price fluctuations resulting in further long-term yield decreases. Present spacing of 4.6 m provides for 494 trees per hectare. Yields quoted by Murray range from 276-439 kg/ha on WSTEC to 674-786 kg/ha on the Va'ai Brothers' plantations at Vaisala Savaii.

Murray makes recommendations for field practice along the following lines:

(a) spacing between 3.6 m square to 3.6 m by 1.8 m,

(b) early temporary shading from bananas intercropped to cover establishment costs,

(c) holes for seedlings a maximum 30 cm cube and minimum soil disturbance,

(d) provision of permanent shade,

(e) minimum weeding and weeds left as mulch plus leaf litter to build up organic matter,

(f) fertilising with 113 gm of NPK 15.15.21 per tree per quarter doubling each year to 990 gm per tree in year 4 and subsequent years,

(g) pruning to promote canopy development and removal of chupons (sucker growth),

(h) Black Pod control, rat control and the harvesting of only ripe healthy pods,

(i) replanting at 30-35 years.

Due to fermentation problems with small quantities of beans (less than 45 kilograms) Murray advocates central fermentaries with producers selling wet beans as their final product. He suggests that the improved fermentation would so improve the final product and its price, that farmers could receive for wet bean what they presently receive from selling fermented dried beans.

A report on the Western Samoa Cocoa Industry to the Australian Development Assistance Agency (Friend 1975) noted current plans for the development of seed gardens and the production of improved planting materials. A broad development policy for cocoa covering rehabilitation, extension and research was, however, yet to be formulated. The Development Bank had indicated its interest in financing long-term loans for sound cocoa rehabilitation and development proposals.

APPENDIX A

TECHNICAL APPENDIX 3 : PINEAPPLE

The Pineapple Industry in Western Samoa

Pineapple, a tropical fruit crop, has been grown in Western Samoa by smallholders at low intensity for the production of fresh fruit for the local market. More recently, intensive production methods have been studied at the Agricultural College, and processing and marketing studies conducted by the FAO Special Fund Project have considered the potential of pineapple as an export crop.

Processing alternatives investigated included the canning of rings, pieces and crushed pineapple, the production of juice and juice blends, crystallised pineapple, pineapple cordial, jams and jellies. It was also a significant component in fruit salad and chutney formulations (Martin 1971).

Costs of processing were researched with respect to the two small canning and processing ventures operating in Western Samoa, to judge their viability in supplying products at preferential tariffs on the New Zealand market. Costs per can for a typical small cannery were derived using the processing of canned pineapple rings as an example. An output of 6000 cans per day was the basis for the costing although it was noted that raw material shortages frequently prevented the attainment of this theoretical maximum. Costs were 0.92 sene[1] per

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1 sene = $\frac{1}{100}$ Tala (Western Samoa currency).

can for direct labour, 0.72 sene per can for indirect (managerial) labour, 0.33 sene per can for 10 per cent depreciation on plant of T50,000, 1.38 sene per can for maintenance and general factory expenses, 5.16 sene for a can, 1.00 sene for syrup, 0.69 sene for a label, 0.50 sene for carton packaging and 6.65 sene per can for fruit at 3 sene per pound and giving a 56 per cent yield. Total cost was thus 17.35 sene per can or $NZ2.60[2] per dozen cans. Selling price was recorded as $NS2.72 per dozen cans f.o.b. Apia or a margin of 4.6 per cent on costs with optimistic assumptions on through-put. Selling price includes the effect of the preferential tariff available to Western Samoan produce vis-à-vis competitors in pineapple production such as Malaysia and Taiwan (Martin 1971). This profit margin is noted by Martin as insufficient to operate a business especially when the requirements of sales development, tax and expansion are considered. Martin feels a 35 per cent profit margin on ex factory cost is essential to profitable operation, which at present prices requires producing a can at a total factory cost of 11.8 sene. The main area for possible savings is seen in the fruit cost which at 3 sene per pound or $NZ84 per ton is well above ruling world prices.[3] The need for reducing fruit cost is stressed after reviewing comparative labour costs in competing countries and demonstrating that no particular cost advantage exists in this area.[4] Martin also sees the present scale of cannery operation as leading to high overheads and overall costs. He advocates larger scale

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2 Exchange rate of T1 = 1.25 $NZ (1971); for 1977 T1 = 1.15 $NZ.

3 Malaysia $NZ21/ton, South Africa $NZ25/ton, Hawaii $NZ35/ton.

4 W. Samoa $US0.25/hr, Kenya $US0.22/hr, Taiwan $US0.21/hr, Singapore $US0.31/hr and Fiji $US0.33/hr - ILO data 1967-68.

mechanised processing to improve quality in the final product and to reduce costs. With such a plant, raw material supply becomes critical, which leads Martin to advocate 'plantation-scale' production on an area attached to the cannery to ensure supplies with additional quantities purchased from smallholders as they become available. These latter points are not developed further and no consideration is given to alternative production strategies at the smallholder level.

At present little change has occurred in the industry. Existing producers sell part of their output to the canneries and part as fresh fruit on the local market. One producer supplies fresh fruit to the New Zealand market. The Third Five Year Development Plan makes no explicit mention of pineapple which is grouped under horticultural development, food and animal feed production and pig and poultry development. It is proposed that larger scale production of crops for food processing will be based on the Western Samoan Trust Estates Corporation, to be spread to the private sector when it is clearly demonstrated to be profitable. The problems of demonstrating profitability in smallholder production from data based on large scale estate production are not discussed in the Plan. Thus there are no detailed plans for expanding pineapple production at the smallholder level. However, the Government's Food Processing Laboratory is currently paying 2.5 sene per pound for pineapples while local market prices fluctuate considerably with supply.

Pineapple Production

Collins (1960) elaborates soil and climatic requirements for pineapple production. Temperatures for optimum growth should be within the range 20°C-36°C. Pineapples can be grown in areas where temperatures drop briefly at night to near 0°C without permanent damage, but growth processes will have ceased. Hence production is normally within the 25° latitude band and at lower elevations. Rainfall in the major growing areas ranges from 600-2540 mm per annum, though the optimum is thought to lie in the 1000-1500 mm range. In Sri Lanka, pineapple production under coconuts occurs in the low country wet zone in areas where rainfall does not exceed 3299 mm (Kotalawala 1968). The pineapple has the ability to store water and utilise dew produced at night in high humidity areas when periods of drought occur. Lack of adequate sunshine reduces sugar content and fruit size, while excessive sunshine causes scorching of nearly mature fruit. Kotalawala (1968) contends that light penetration in coconut plantations over 35 years old is sufficient for good pineapple production.

The major soil requirements for pineapple production can be summarised as good drainage and low calcium content or low pH. Chlorosis[5] will occur in soils of higher pH due to manganese ions converting soluble ferrous ions to the insoluble ferric form. Spraying of ferrous salts is practised in less acid soils. The gravelly lateritic 'kabook' soils of Sri Lanka are considered suitably acidic (Kotalawala 1968).

Collins (1960) describes the main planting period as autumn, with harvesting in the summer 18 to 22 months later, and a first ratoon crop in the next year. Land preparation follows over the

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5 Loss of chlorophyll in the leaves.

next 8-10 months prior to replanting in year four. Time from planting to production will vary however with the planting material used and the growing area. Shoots produce fruit in 16 to 18 months, slips at 18 to 20 months and crowns at 20 to 24 months. The more tropical the area, the shorter the time to fruiting within the ranges specified. Hence fields or sections of fields are planted with different planting material to spread the harvesting period. Little specific data on pineapple cultural methods are given with respect to the multi-storey cropping concept developed at the Central Plantation Crops Research Institute at Kasaragod. Nair et al. (1970) describes a three year planting cycle with fruit production in two years suggesting a main and first ratoon crop. The Australian pattern includes a second ratoon crop in a five year planting cycle. Yields for each ratoon crop decline progressively.

Spacing and planting density vary between countries and cultural systems. Kotalawala (1968) describes 'traditional' planting methods aimed at producing large fruit (6 kg) with planting in single rows, 45 to 60 cm spacing inter-row and 215 cm between rows giving some 10,000 plants per hectare. Common commercial spacings lie in the range 30-40 cm inter-row, two rows 50-60 cm apart on a bed with 80-120 cm between beds. This gives planting densities ranging from 30,000 - 42,000 plants per hectare.

Kotalawala (1968) recommends planting on contour and drainage development for many potential growing areas under coconut in Sri Lanka.

Fertilisation is a major factor in commercial pineapple production. In Hawaii, Collins quotes a preliminary application of 110 kg per hectare ammonium sulphate either prior to planting or three months after planting. Applications follow at 3-6 month intervals as indicated by leaf colour. Cumulative application is between 450-670 kg per hectare ammonium sulphate, 220-460 kg per hectare potassium sulphate and 170-280 kg per hectare diammonium phosphate. In Australia applications of NPK 10.6.10 is alternated with ammonium sulphate at three monthly intervals from establishment. Total application is 780 kg per hectare of 10.6.10 and 470 kg per hectare of ammonium sulphate. In Taiwan the rates are reported as 700 kg per hectare ammonium sulphate, 300 kg per hectare superphosphate and 200 kg per hectare potassium sulphate in split dressing. Research suggests that the potash rate should be increased (Collins 1960). Kotalawala (1968) notes the high requirements of pineapple for nitrogen and potash and recommends application of urea in solution, sprayed on with insecticides while potash is applied as a basal and six-monthly side dressing. Nair (1976) provides nutrient application recommendations in the intercropping context on a per plant basis. His data are presented comparatively with those previously given (Table 1).

Pest and disease problems vary from country to country. Kotalawala (1968) reports the main pest facing Sir Lankan farmers as being mealy bug induced wilt. Control is effected by use of healthy planting material and three-monthly spraying of malathion.

Weed control in pineapples by hand methods is an arduous and unpleasant task. Other approaches have been to cover the planting beds with black plastic mulch and to employ such weedicides as monuron, diuron and amino-triazole in pre- and post-emergent sprays (Kotalawala 1968).

TABLE 1

COMPARISON OF FERTILISER RECOMMENDATIONS FOR PINEAPPLE PRODUCTION (GM PER PLANT)

Source		N	P_2O_5	K_2O
Nair (1976)	South India	6	8	10
Collins (1960)	Hawaii	7.5	2.5	10.5
	Australia	24	6.5	10.5
	Taiwan	11.7	4.5	8
NPK 10.5.20 .05 Kg per Plant		5	2.5	10

Harvesting has been mechanised on the large pineapple estates in Hawaii and chemical sprays to hasten fruit maturity have been used to spread the harvesting period by some three to four weeks (Collins 1960).

APPENDIX A

TECHNICAL APPENDIX 4 : TARO

Taro in Western Samoa

Taro commands an important place in the agriculture and economy of Western Samoa. As the principal staple food, it still provides a major contribution to the diet of the Samoan family. It is certainly the preferred staple. The 1972 Survey of Household Living Conditions recorded expenditure on taro as greater than bananas or imported rice.[1]

No data are available on total production but an estimate[2] puts consumption per capita at 0.68 kg per day, or a total consumption per annum of 37,300 tonnes for a population of 150,000. Export production averages approximately 3000 tonnes giving total annual production of 40,000 tonnes. Average yields were estimated at 11.3 tonnes per hectare suggesting area planted to be in the order of 3500 hectares. This omits consideration of the bush fallow area required to maintain that planted area in production. On the other hand, as taro matures at eight to nine months and seasonality is not a problem, three crops may be produced in two years reducing the planted area necessary to achieve the stated output.

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1 In the case of subsistence production its value was imputed at the 'average market price'.

2 IBRD Technical Assistance Mission (IBRD 1975).

As a traditional crop, its production is associated with the social fabric of Samoan village life. The presentation of gifts of food on important village occasions should include taro. The introduction of plantation-type practices in the production of other crops has in general not carried over into taro production which continues to be produced under a bush fallow rotation. Land per capita constraints in some districts, declining fertility of some soils and the development of commercial markets for taro both locally and for export have brought pressure to change technology and organisation in the production of taro. An important aspect of development therefore, and of maintenance of the quality of village life, is the integrating of new methods and production scheduling to meet the needs of stable marketing while retaining the place of taro in agriculture and the social structure.

The New Zealand export market for taro was studied by Rhee (1974c). Price fluctuation is a feature of the market, associated with production variability and irregularities of shipping. The present practice of shipping on consignment allows New Zealand agents and retailers to take a fixed margin while the New Zealand consumer and Samoan producers and shippers are faced with the full impact of the fluctuations. From January 1972 to July 1974, average price per 32 kg case was T5.63. The range was T1.97 to T11.47 with the proportion less than T4.00 increasing from 18.4 per cent to 50.7 per cent and the proportion greater than T8.00 decreasing from 20 to 7 per cent. Thus there was a declining trend in average price plus increased variability. Rhee estimated that the number of cases to maximise returns to the producer in Western Samoa was 2700 cases for a regular two-weekly shipping schedule and a production cost of T1.00 per case. For production cost of T1.50 the optimal shipment reduces to 2400 cases. For each additional 1000 cases per shipment price received would drop by T0.897 per case. Under such optimal conditions, Rhee estimates producers' net price at T2.67 per case. Improved stability in the market is noted to benefit the consumer and hence long-term market development.

As other countries in the region are also supplying this market, the South Pacific Economic Commission is investigating the need for quotas and export standards, developments in packaging, promotional activities and prospects for processed products such as taro chips.

Taro Production

The term taro is often used to refer to a range of tuber species and varieties, but is restricted in this study to the plant *Colocasia esculenta* (L) Schott var esculenta. Even for this variety there is a range of cultivars giving it wide adaptability to a range of soil and climatic growing conditions.

In Western Samoa, taro is normally the first crop grown after clearing from bush or bush fallow. Planting will be sufficiently spread to meet subsistence needs through the year because taro cannot be stored. However, the early wet season is favoured especially in the drier districts. Stalks and shoots are planted, the bigger pieces giving higher yields. Spacing is traditionally 90 cm by 90 cm giving 12,000 plants per hectare. Closer spacing

(60 cm x 60 cm) or a density of 29,300 plants per hectare with the use of fertiliser is recommended from experimental work (Reynolds 1975). Planting is performed using a planting stick and plant debris is left as a mulch around the plants. Up to six weedings take place before harvesting at 8-10 months. Yields range from 2.5 to 25 tonnes per hectare with good soils producing around 15 to 17.5 tonnes per hectare while the overall average for the country is approximately 11 tonnes per hectare. Average tuber size is 1.4 kilograms. Mature taro cannot be stored by leaving it in the ground; in dry weather a delay of up to four weeks is possible. Farmers also lift the tubers and then re-bury them in loose soil for up to one month but with the risk of losses to pigs and rats. Bush fallow periods vary considerably with soil type and previous cropping history: the range may be as much as three to ten years after two or three crops have been taken, again depending on fertility and the vigour of the increasing weed population. No data are available on the feasibility of continuous cropping in dryland situations or on the use of legume fallow crops and shorter rotations.

Research on taro at Alafua College has investigated closer spacings, 60 cm by 60 cm and 60 cm by 45 cm with the use of up to 1.26 tonnes per hectare of NPK 10.5.20. Yields of 1.6 kg per tuber and 25 to 42 tonnes per hectare have been obtained. Recommendations on fertiliser are for 0.45 kg per 50 plants of 10.5.20 applied at one and three months plus five applications of urea foliar sprays at the rate of 1.4 kg per 1000 plants.

APPENDIX A

TECHNICAL APPENDIX 5 : BANANAS

The Banana Industry in Western Samoa

The banana industry in Western Samoa and in the South Pacific has been the subject of numerous studies and considerable government attention over the past decade. An examination of export data over the past three decades shows a rapid increase in the early post-war period as the crop became popular, replacing many areas planted to cocoa. From 1951 to 1958 exports rose from 5m lb to 64m lb. However, from 1958 to 1966 production declined as bunchtop and leaf-spot diseases became prevalent. In 1966 a major hurricane destroyed the majority of the country's banana plantations. The post hurricane period saw a rebuilding of the industry with considerable government and overseas aid inputs. The Department of Agriculture division, Produce Marketing, Bunchtop Control and Extension all worked, sometimes competitively, to re-establish production in the way each felt likely to give the best results (Leung Wai 1974). The rapid expansion of plantations in all districts of the country was beyond the servicing abilities of the Department of Agriculture. The period 1969-71 saw exports reaching an average of 14m lb. From 1971 a steady decline has again occurred with 1972-76 averaging only 3m lb. Reasons advanced for the latest decline include rising local consumption, continued damage from hurricanes and gales and increased incidence of major pests and diseases such as bunchtop, leafspot, nematodes and scabmoth. The inflation of costs over the period has been largely borne by the government with continued subsidies on misting oil, fertiliser and disease control services. The disease problem is aggravated by the dispersion of growing areas and the existence of wild bananas and abandoned plantations as foci for the spread of disease.

Shipping services for exporting have been insufficient and irregular and packaging methods imposed by the New Zealand importer prevent the marketing of a high quality product (Walker 1976).

Hence bananas are included in the model somewhat tentatively, with the proviso that government policy should, and in the future may, limit the areas where export bananas can be grown and receive government services and subsidies. A further problem in the present uncertain situation, particularly with regard to the pest and disease situation, is that of projecting yield and input levels for some period into the future.

APPENDIX B

SUPPLEMENTARY TABLES: CASH FLOW ANALYSIS

TABLE 1

COCONUT FIXED COSTS: TOOLS AND EQUIPMENT

Item	No.	Cost/Unit (T)	Replacement Interval (Years)
Bushknives	2	3.00	2
Spade	1	6.00	-
Knapsack Sprayer	1	40.00	10
Donkey and Cages	1	25.00	10
Axe	1	3.00	5
Copra Knife	1	3.00	2
Sack Needle	1	1.00	1
Gum Boots	1 pair	5.00	2

TABLE 2

FERTILISING COCOA

NUTRIENTS SUPPLIED AT ADOPTED FERTILISER RATES (GM/PLANT)

	Year	Rate of Application (Gm/Plant)	Nitrogen (N) (Gm)	Phosphate (P_2O_5) (Gm)	Potash (K_2O) (Gm)
Recommended Nutrient		15.15.21			
Level Based on NPK	1-4	113.5	17	17	24
15.15.21 (Murray	5	227	34	34	48
1971)	6	454	68	68	95
	7	908	136	136	190
Nutrient Supplied		10.5.20			
by NPK 10.5.20	1-4	125	12	6	25
	5	250	25	12	50
	6	500	50	25	100
	7	1000	100	50	200

COSTS OF FERTILISER[1] (T)

Year	Application Rate 10.5.20 Gm/Plant	Cost per Plant (T)	Cost per Hectare (T)
1-4	125	0.025	40
5	250	0.05	80
6	500	0.10	160
7-40	1000	0.20	320

1 Based on an unsubsidised price of T0.20 per kilogram.

TABLE 3

LABOUR INPUT IN HARVESTING COCOA

(Mandays per Tonne: Dry Beans)

Source	Labour Input Quoted	Basis	Derived Labour Input (Manday/Tonne)
Beckett W.H. Akokoaso Gold Coast 1930s	15 M.D./Acre	Assume 400 lb/Acre	82.5
Lukolela Estates Belgium Congo - Urquhart 1955	18 M.D./Acre	600 lb/Acre	66
Recter *et al*. 1972 Bagan Datoh Estates Malaysia	$M0.07/lb	$M3.50/M.D.	44

TABLE 4

FIXED COSTS IN COCOA PRODUCTION

Item	Number	Price per Unit (T)	Year of Purchase	Frequency of Replacement (Years)
Knapsack Sprayer	1	40	1	10
Spade	1	6	1	-
Pruning Saw	1	8	2	-
Secateurs	3	4	4	2/Unit

TABLE 5

PINEAPPLE FIXED COSTS

Item	Number	Year of Purchase	Price/Unit (T)	Replacement Interval (Years)
Bushknife	2	1	3	2
Spade	1	1	6	10
Pick	1	1	6	10
Knapsack	1	1	40	10
Wheelbarrow	1	1	20	5

TABLE 6

TARO FIXED COSTS

Item	Number	Year of Purchase	Price/Unit (T)	Replacement (Years)
Bushknife	2	1	3	2
Planting Stick	2	1	3	5
Knapsack Sprayer	1	1	40	10
Spade	1	1	6	5
Wheelbarrow	1	1	20	5

TABLE 7

BANANA FIXED COSTS

Item	Number	Year of Purchase	Price/Unit (T)	Replacement (Years)
Desuckering Tool	1	1	6	5
Knapsack	1	1	40	10
Mist Blower	1	1	150	5
Puffer	1	1	12	5
Bushknife	2	1	3	2½
Spade	1	1	6	5

TABLE 8

FAMILY INCOME RESOURCE LEVEL AT TWO WAGE RATES

Period	No. Years	Minimum Wage = T2.00				Minimum Wage = T2.50			
		Family Living	Fixed Costs	Wage Income	Net Income	Family Living	Fixed Costs	Wage Income	Net Income
1	6	6000	355	6000	-355	6000	355	7500	1145
2	18	18,000	1414	18,000	-1414	18,000	1414	22,500	2086
3	5	5000	135	5000	-135	5000	135	6250	1115
4	5	5000	158	5000	-158	5000	158	6250	1092
5	5	5000	155	5000	-155	5000	155	6250	1095
6	5	5000	167	5000	-167	5000	167	6250	1083
7	5	5000	147	5000	-147	5000	147	6250	1103
8	5	5000	167	5000	-167	5000	167	6250	1083
9	5	5000	164	5000	-164	5000	164	6250	1086
10	5	5000	167	5000	-167	5000	167	6250	1083

APPENDIX C

COCOA YIELD-AGE COEFFICIENTS - A SUMMARY OF WORK BY BATEMAN (1965), BEHRMAN (1968) AND ADY (1968)

Bateman (1965) used the concept of a two phase yield curve based on the work of W.H. Beckett (1944). During the first k years after planting there is no output. The following year, yield per tree and per hectare increases rapidly to a level b_1, where it remains for the next few years. Then there is a second phase of yield increase, in year s, up to a yield per hectare of b_2. Yield per tree continues to slowly increase over a number of years.[1] However yield per hectare increases slowly for only some five years after the second phase of rapid increase, then remains roughly constant for the next 15-20 years until the effect of increasing tree casualties offset the yield increases per tree and yield per hectare declines. Based on the yield curve assumed, the cohort planting-output relationship is respecified.

Bateman's modified planting:output relationship is:

$$Q_t^* = b_1 \left(\sum_{i=k}^{s-1} X_{t-i} \right) + b_2 \left(\sum_{i-s}^{\infty} X_{t=i} \right) \qquad (1)$$

where k = age at which bearing and the first phase of rapid yield increase starts

s = year in which the second phase of rapid yield increase occurs

b_1 = yield per unit area after the first phase of rapid yield increase

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1 Bateman suggests for up to 40 years.

b_2 = yield per unit area after the second phase of rapid yield increase

X = number of acres planted in year t-i

The equation (1) is represented graphically in Figure 1. The assumption that yield per hectare from year s to infinity can be represented by a single coefficient b_2 is a simplification of the preceeding description where yield per hectare increased slowly for five years, was constant for 15-20 years and then started to decline.

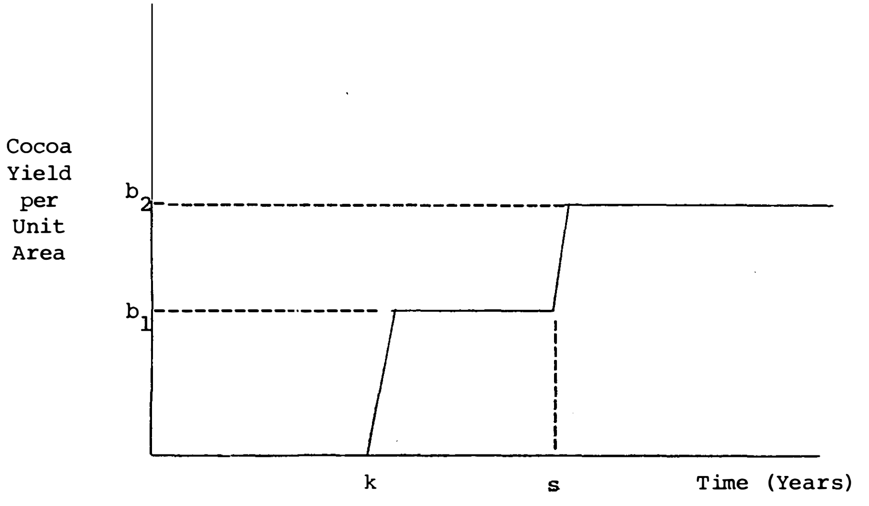
Behrman (1968) in deriving a model of 'desired' acreage to be planted, as opposed to the Bateman model of actual acreage, adopts the same planting-output relationship assumed by Bateman. In support of the two-phase yield development pattern he cites a number of investigations including Amoa R.C. (1965), Bareau P. (1953), Montgomery E.G. and Taylor A.M. (1947) and Pincus J.A. (1963). Behrman overcomes the problem of the sum to infinity in equation (1) by transforming the output relationship to a first-order difference - equation describing the change in the quantity of potential output during period t thus:

$$\Delta Q_t = b_1 \ (\Delta X_{t-k}) + (b_2 - b_1) \ \Delta X_{t-s} \qquad (2)$$

Important information from the empirical studies of Bateman and Behrman relevant to the problem of cocoa yield streams are the values derived for the parameters, k, s, b_1 and b_2. The values for k and s (years in which rapid yield increases occur) are those which maximised the coefficient of determination in the estimation of the supply equations. Results suggest year eight for the initial yield increase and year twelve for the second yield increase (see Table 1).

FIGURE 1

COCOA PRODUCTION FUNCTION



Source: Bateman 1965.

TABLE 1

COCOA YIELD STREAM : YEARS OF YIELD INCREMENT

(k+s Values)

Source	Country/Region	k	s
Behrman	Ghana	8	12
	Nigeria	8	12
	Ivory Coast	9	14
	Cameroon Republic	10	-
	Brazil	6	12
	Ecuador	8	14
	Dominican Republic	7	13
	Venezuela	6	9

Source: Behrman 1968.

The yield per hectare coefficients b_1 and b_2, however, are contained in the final estimating equations as algebraic expressions with coefficients for lagged real prices of cocoa and the substitute, coffee (Bateman) or lagged producer price expectations (Behrman). Solution of simultaneous equations to derive the yield coefficients appears possible only in the case where the estimating equation has significant coefficients for all four variables involving the yield coefficients. For example, in the Bateman model significant coefficients are necessary for the variables of producer prices of cocoa for periods t-k and t-s and producer prices of coffee for periods t-k and t-s. In Bateman's study of 7 producing regions in Ghana, one region fulfilled this condition. However for Behrman's aggregate supply functions for major cocoa producing countries, three out of the eight fulfilled this requirement. Solution of the algebraic combination of the coefficients is therefore presented for the Behrman estimating equation as follows:

1. The planting output equation:

$$\Delta Q_t = b_1(\Delta X_{t-k}) + (b_2 - b_1)\ \Delta X_{t-s} + c\,\Delta P_t + d\Delta P_{t-1} + U_t \tag{3}$$

where the additional terms

ΔP_t = change in current real cocoa price

ΔP_{t-1} = change in real cocoa price in the previous period

U_t = error term

2. The planting-decision equation is combined with the planting-output equation given above to give:

$$\begin{aligned}\Delta Q_t = {} & \alpha_1 \Delta Q_{t-1} - \alpha_2 \Delta Q_{t-2} + c\Delta P_t + \alpha_3 \Delta P_{t-1} + \alpha_4 \Delta P_{t-2} \\ & + \alpha_5 \Delta P_{t-3} + b_1 \partial\beta [a_1 \Delta P_{t-k} + a_2 \Delta C_{t-k}] \\ & + (b_2 - b_1)\partial\beta[a_1 \Delta P_{t-s} + a_2 \Delta C_{t-s}] + \varepsilon_t \end{aligned} \tag{4}$$

where α_1, α_2, α_3, α_4 and α_5 are algebraic expressions in the actual estimating equation not involving b_1 or b_2.

3. Taking the coefficients for ΔP_{t-k}, ΔC_{t-k}, ΔP_{t-s} and ΔC_{t-s} we solve as follows:

$$\frac{\Delta P_{t-k}}{\Delta P_{t-s}} = \frac{b_1 . \partial . \beta . a_1}{(b_2 - b_1) . \partial . \beta . a_1} = \frac{b_1}{b_2 - b_1} \quad \text{and}$$

$$\frac{\Delta C_{t-k}}{\Delta C_{t-s}} = \frac{b_1 . \partial . \beta . a_2}{(b_2 - b_1) . \partial . \beta . a_2} = \frac{b_1}{b_2 - b_1}$$

However the expressions for $\frac{b_1}{b_2-b_1}$ only allow the solution of the ratio of the yield increments b_1 and b_2, the solution for their absolute values being under-identified.

Ady (1968) in her review of supply functions in tropical agriculture questions the basis of the two phase yield curve. Ady reproduces a number of yield curves of dry cocoa per acre by years from planting for a number of cocoa varieties. Most of the cocoa grown in West Africa is the Amelonado type of the Forastero cocoa variety, and is thus the cocoa postulated by Bateman and Behrman to have a two-phase yield development pattern. Its yield curve indicates a steady yield increase from year 5 to year 9, a slight drop in year 10 and then a steady increase again for the remaining two years depicted (see Chapter 2, Figure 2.4). If these curves presented by Ady are to represent a true age pattern, it must be assumed that the stands measured were all planted in the same year as the age axis also corresponds to particular years. Given such a situation then the age analysis must be complicated by seasonal effects.[2]

Ady discusses the 8 and 12 year peak 'yield growth' phases of Bateman and Behrman (average values for k and s for the major cocoa regions in Ghana). She suggests that the existence of such a trend could easily be accentuated into significance by the cultivation practices in common use. Cocoa is commonly established together with interplanted food crops on new clearings from rainforest in the West African region. After harvesting food crops, which had been

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2 Where age analysis derives from a cohort structure due to planting being spread in time, then age coefficients will be contributed to from a number of actual years randomising the weather or seasonal effects.

weeded, at two or three years, Ady notes that the cocoa is often left untended until significant bearing is apparent. At this stage (year 8) there is sufficient cocoa to induce the farmer to commence annual weeding and harvesting. While this would account for an abrupt commencement of output, Ady does not elaborate the reason for the second rapid rise in yield. This might result from a lagged response by the tree to some of the husbandry practices now instituted (e.g. weeding and pruning).

APPENDIX D

THE RELATIONSHIP BETWEEN MAXIMISING SUM OF NET PRESENT VALUE AND MAXIMISING NET WORTH

The maximisation of net present value can be shown as:

$$\max \sum_{j=1}^{n} dj.Pj \qquad (1)$$

where Pj is the farm profit in year j of the planting period j = (1...n) and dj is the discount factor for year j.

Profit is analysed as:

$$Pj = Rj - (Cj + Dj) \qquad (2)$$

where Rj is gross returns in year j, Cj is cash costs in year j, and Dj is non-cash costs or depreciation in year j.

Restating equation (2) we obtain cash surplus equal to profit plus depreciation.

$$Rj - Cj = Pj + Dj \qquad (3)$$

Cash surplus is assumed to be used in consumption (S) or non-recoverable uses, and investment (I) or recoverable uses. Thus

$$Rj - Cj = Sj + Ij \qquad (4)$$

or

$$Pj + Di = Sj + Ij \qquad (5)$$

and so we obtain an expression for profit as the sum of consumption and the difference between investment and depreciation

$$Pj = Sj + (Ij - Dj) \qquad (6)$$

The expression (Ij - Dj) represents net investment INj so that discounted profit maximisation can now be restated as

$$\max \sum_{j=1}^{n} dj\ (Sj + INj) \tag{7}$$

Net investment by definition is not 'consumed' until the planning horizon is reached and thus is discounted from the planning horizon and not from when it is generated. Thus equation (7) is rewritten as:

$$\max \sum_{j=1}^{n} dj\ Sj + dn \sum_{j=1}^{n} INj \tag{8}$$

where dn is the discount factor for year n, the last year in the planning period. Consumption is redefined as 'luxury' consumption in excess of basic consumption, for which a single valued personal discount factor of similar order to return on investment can be expected. The new maximand then becomes

$$\max \sum_{j=1}^{n} dLj\ SLj + dL_n \sum_{j=1}^{n} INj \tag{9}$$

where dLj is the personal discount factor and SLj is luxury consumption. Given the the personal discount rate equals the rate of return on investment and that the indifferent farmer is assumed always to invest, then luxury consumption can be dropped leaving

$$\max dL_n \sum_{j=1}^{n} INj \tag{10}$$

and because dL_n is common to all net investments it can now be omitted such that the farmer will now

$$\max \sum_{j=1}^{n} INj$$

that is, he will maximise the sum of net investment or terminal net worth.

APPENDIX E

A REGIONAL ANALYSIS OF INTERCROPPING POTENTIAL IN WESTERN SAMOA

Ward (1962) elaborated ten regions in Western Samoa on the basis of the physical, social and economic environment. A number of the factors used (soils, rainfall, cropland per capita and communication and markets) have an important bearing on the intercropping potential of an area, so that the regions are a useful basis for assessing that potential. Of the ten regions defined, the eight comprising the major agricultural areas are discussed.

1. Northwest Upolu has the highest population density of all the areas in Western Samoa, encompassing the urban area of Apia. Communications and commercial development have reached a higher level than other areas in the country. The area includes the majority of private commercial agricultural enterprises which have reduced the cropland per capita in village agriculture to the lowest in the country. A longer period of cash cropping has reduced the moderately high natural fertility substantially. Alternative sources of employment in Apia and on the commercial plantations are more accessible in this region than in any other. At the same time markets for agricultural produce are also very accessible. Thus the potential for the proposed intercropping system in this region is, technically and economically, considerable.

2. Anoama'a (Northeast Upolu) also faces restrictions on cropland per capita, in this case due to topographical limitations with land running quickly up into the central range. Access to Apia markets and employment is again readily available with bananas and taro the main cash crops. Cocoa productivity is limited by the rainfall levels which result in a high incidence of black pod disease in the existing Cocoa variety. However, the intercropping system, using new resistant cocoa varieties would fit well in the Anoama'a farming environment. Bananas may still substitute for cocoa in such situations. The low cropland per capita is seen as providing incentive for intensifying production through intercropping.

3. Southeast Atua at the eastern end of Upolu has a large cleared land resource, surface water and easy topography. The old soils are deep, contain little rock but are of low fertility, limiting the productivity of cocoa and bananas presently grown. Coconuts cover more than half the total land area and rainfall is higher than Anoama'a. Thus, while the intensive intercropping pattern could function successfully, the larger land per capita is likely to be more economical if put to a more extensive cattle intercropping model.

4. South coast Upolu has above average cropland per capita and an evenly distributed reliable rainfall. There is a west to east trend of decreasing fertility and increasing rainfall. Cocoa flourishes in the more westerly parts and bananas are reasonably productive given adequate disease control. Traditional bush

fallow rotations are still quite productive in taro production given the greater land area. Incentive to adopt intensive intercropping will be less and the wetter areas would be well adapted to more extensive intercropping with cattle.

The Savaii regions to some extent follow a similar pattern to their Upolu equivalents.

5. Southeast Savaii has similar characteristics to Southeast Atua. It has the most extensive cropland per capita of the regions, a high rainfall and more leached soils than other coastal regions of Savaii. It is the commercial and communications centre for Savaii. However rainfall limits the productivity of cocoa and available cropland suggests that intercropping with cattle is likely to be more economic.

6. Northern Savaii with moderate rainfall and fertility is suited to both bananas and cocoa, though the former is hampered in its marketing by the region's isolation. Recent lava flows limit the cropland per capita and access to forest reserves. Cocoa is presently intercropped with coconut so that the introduction of more intensive modern intercropping appears well suited to the area.

Northwestern Savaii is the driest of all the regions and is the major cocoa producing area in the country. Coconuts have been found difficult to establish though it is expected that the coconut shade would benefit cocoa productivity by reducing leaf die-back. The very rocky soils and the difficulty of establishing gardens has lead to a naturally high level of intercropping. At Falealupo on the western tip of Savaii the coefficient of intercultivation was 40 compared with an average of 22 for the country as a whole (Farrell and Ward 1961). Thus while modern intercropping patterns may be readily applicable, existing intercropping should be studied with a view to understanding the particular requirements of the drier environment.

8. Southwestern Savaii occupies a narrow coastal belt with infertile upland soils only a short distance inland. It is physically isolated and largely dependent on coconuts for cash income. It has the lowest cropland per capita next to Northwest Upolu. The new resistant varieties of cocoa should do well in this region and the land constraint would favour intensive intercropping.

APPENDIX F

MATRIX TABLES

Table 1

The 'basic' model with A form objective function

Objective Function (T)		480	422	332	1176	148	96	62	40	26	17	11	7	634	412	268	174	113	2403	181	118	76	50	32	21	14	206	134	87	5
B Value	Constraint \ Activity	Coconuts (at 3 densities)			Taro									Cocoa					Pineapple								Bana			
		Ca	Cb	Cc	T_1	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	K_3	K_4	K_5	K_6	K_7	P_1	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	B_4	B_5	B_6	B
5 ≥	Land (Has) L1	1	1	1																										
0 ≥	Intercrop Land, Hectares: IC_1	-.736	-.764	-.805	1														1											
0 ≥	IC_3	-.776	-.804	-.845		1								1																
0 ≥	IC_4	-.776	-.804	-.845			1							1	1					1							1			
0 ≥	IC_5	-.776	-.804	-.845				1						1	1	1					1							1		
0 ≥	IC_6	-.776	-.804	-.845					1					1	1	1	1					1							1	
0 ≥	IC_7	-.776	-.804	-.845						1				1	1	1	1	1					1							
0 ≥	IC_8	-.776	-.804	-.845							1			1	1	1	1	1						1						
0 ≥	IC_9	-.776	-.804	-.845								1		1	1	1	1	1							1					
0 ≥	IC_{10}	-.776	-.804	-.845									1	1	1	1	1	1								1				
400 ≥	Labour, Mandays: N_1	41	40	38	103														204											
7600 ≥	N_2	1048	967	799																										
400 ≥	N_3	66	60	52		108								61																
400 ≥	N_4	51	47	42			108							73	61					204							283			
400 ≥	N_5	50	47	42				108						82	73	61					204							283		
400 ≥	N_6	50	47	41					108					82	82	73	61					204							283	
400 ≥	N_7	49	45	40						108				77	82	82	73	61					204							28
400 ≥	N_8	52	48	52							108			73	77	82	82	73						204						
400 ≥	N_9	43	40	36								108		68	73	77	82	82							204					
400 ≥	N_{10}	43	41	36									108	63	68	73	77	82								204				
500 ≥	Secondary Labour, Mandays: $2N_1$																													
9000 ≥	$2N_2$																													
500 ≥	$2N_3$																													
500 ≥	$2N_4$																													
500 ≥	$2N_5$																													
500 ≥	$2N_6$																													
500 ≥	$2N_7$																													
500 ≥	$2N_8$																													
500 ≥	$2N_9$																													
500 ≥	$2N_{10}$																													
-355 =	Allocable Income, Tala: AI_1	-18	-16	-13	-1586														-3183											
-614 =	AI_2	-1952	-1710	-1350																										
-135 =	AI_3	-737	-646	-509		-1500								-397																
-158 =	AI_4	-433	-379	-299			-1500							-3318	-397					-3183							-3436			
-155 =	AI_5	-407	-357	-282				-1500						-5139	-3318	-397					-3183							-3436		
-167 =	AI_6	-412	-361	-285					-1500					-5139	-5139	-3318	-397					-3183							-3436	
-147 =	AI_7	-385	-337	-266						-1500				-4644	-5139	-5139	-3318	-397					-3183							-34
-167 =	AI_8	-280	-246	-194							-1500			-4148	-4644	-5139	-5139	-3318						-3183						
-164 =	AI_9	-231	-203	-160								-1500		-3653	-4148	-4644	-5139	-5139							-3183					
-167 =	AI_{10}	-215	-188	-149									-1500	-3158	-3653	-4148	-4644	-5139								-3183				
1000 ≥	Loans, Tala: Ln_1																													
1000 ≥	Ln_3																													
1000 ≥	Ln_4																													
1000 ≥	Ln_5																													
1000 ≥	Ln_6																													
1000 ≥	Ln_7																													
0 ≥	Development Capital, Tala: DK_1	203	177	140																										
0 ≥	DK_3													619																
0 ≥	DK_4														619															
0 ≥	DK_5															619														
0 ≥	DK_6																619													
0 ≥	DK_7																	619												
0 ≥	Family Living, Tala: Fl_1																													
0 ≥	Fl_2																													
0 ≥	Fl_3																													
0 ≥	Fl_4																													
0 ≥	Fl_5																													
0 ≥	Fl_6																													
0 ≥	Fl_7																													
0 ≥	Fl_8																													
0 ≥	Fl_9																													
0 ≥	Fl_{10}																													

.6	-3.10	-0.23	-0.59	-0.40	-0.32	-0.21	-0.13	-0/08	-0.056	-0.036	-3.57	-0.45	-0.29	-0.18	-0.12	-0.08	-0.068	-0.044	-0.029	-0.019	-0.012										
	Secondary labour use										Loans						Cash transfer					Family living transfer									
3_{10}	$2N_1$	$2N_2$	$2N_3$	$2N_4$	$2N_5$	$2N_6$	$2N_7$	$2N_8$	$2N_9$	$2N_{10}$	Ln_1	Ln_3	Ln_4	Ln_5	Ln_6	Ln_7	CT_{23}	CT_{34}	CT_{45}	CT_{56}	CT_{67}	Fl_1	Fl_2	Fl_3	Fl_4	Fl_5	Fl_6	Fl_7	Fl_8	Fl_9	Fl_{10}
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	-1																														
		-1																													
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									1																						
										1																					
	5.2										142											10									
		2															10						10								
			7.8									134						10						10							
				8.2									134						10						10						
					10									134						10						10					
						10									134						10						10				
							10									134												10			
								9.4																					10		
									9.8																					10	
36										9.6																					10
											100																				
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Table 2

The 'basic' model with B form objective function

Objective function B Value	Activity / Constraint		Coconuts (at 3 densities)			Taro									Cocoa					Pineapple								Bananas				
			Ca	Cb	Cc	T_1	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	K_3	K_4	K_5	K_6	K_7	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	B_4	B_5	B_6	B_7	B_8
5 >	Land (Has)	L1	1	1	1																											
0 >	Intercrop Land Hectares	IC_1	-.736	-.764	-.805	1														1												
0 >		IC_3	-.776	-.804	-.845		1								1																	
0 >		IC_4	-.776	-.804	-.845			1							1	1					1							1				
0 >		IC_5	-.776	-.804	-.845				1						1	1	1					1							1			
0 >		IC_6	-.776	-.804	-.845					1					1	1	1	1					1							1		
0 >		IC_7	-.776	-.804	-.845						1				1	1	1	1	1					1							1	
0 >		IC_8	-.776	-.804	-.845							1			1	1	1	1	1						1							
0 >		IC_9	-.776	-.804	-.845								1		1	1	1	1	1							1						
0 >		IC_{10}	-.776	-.804	-.845									1	1	1	1	1	1								1					
400 >	Labour Mandays	N_1	41	40	38	103														204												
7600 >		N_2	1048	967	799																											
400 >		N_3	66	60	52		108								61																	
400 >		N_4	51	47	42			108							73	61					204							283				
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400 >		N_6	50	47	41					108					82	82	73	61					204							283		
400 >		N_7	49	45	40						108				77	82	82	73	61					204							283	
400 >		N_8	52	48	52							108			73	77	82	82	73						204							28
400 >		N_9	43	40	36								108		68	73	77	82	82							204						
400 >		N_{10}	43	41	36									108	63	68	73	77	82								204					
500 >	Secondary Labour Mandays	$2N_1$																														
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-355 =	Allocable Income Tala	AI_1	-18	-16	-13	-1586														-3183												
-614 =		AI_2	-1952	-1710	-1350																											
-135 =		AI_3	-737	-646	-509		-1500								-397																	
-158 =		AI_4	-433	-379	-299			-1500							-3318	-397					-3183							-3436				
-155 =		AI_5	-407	-357	-282				-1500						-5139	-3318	-397					-3183							-3436			
-167 =		AI_6	-412	-361	-285					-1500					-5139	-5139	-3318	-397					-3183							-3436		
-147 =		AI_7	-385	-337	-266						-1500				-4644	-5139	-5139	-3318	-397					-3183							-3436	
-167 =		AI_8	-280	-246	-194							-1500			-4148	-4644	-5139	-5139	-3318						-3183							-34
-164 =		AI_9	-231	-203	-160								-1500		-3653	-4148	-4644	-5139	-5139							-3183						
-167 =		AI_{10}	-215	-188	-149									-1500	-3158	-3653	-4148	-4644	-5139								-3183					
1000 >	Loans Tala	Ln_1																														
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0 >		DK_7																	619													

Secondary labour use										Loans						Cash transfer					Discounting activity									
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$2N_1$	$2N_2$	$2N_3$	$2N_4$	$2N_5$	$2N_6$	$2N_7$	$2N_8$	$2N_9$	$2N_{10}$	Ln_1	Ln_3	Ln_4	Ln_5	Ln_6	Ln_7	CT_{23}	CT_{34}	CT_{45}	CT_{56}	CT_{67}	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}
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