PRODUCTIVITY AND RELATED ASPECTS OF SMALLHOLDER RUBBER PRODUCTION IN CAPE RODNEY, PAPUA NEW GUINEA

by

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DECLARATION

Except where otherwise indicated, this dissertation is my own work.

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ABSTRACT

This study is a production function analysis of smallholder rubber production in Cape Rodney, using input-output data for a sample of 50 farmers. It attempts to identify the main factors of production, using both the Cobb-Douglas and a modified version of the Transcendental production function models. The latter model is used in the analysis of technical and allocative efficiency, between Local and Non-Local Farmers.

The main factors of production identified to have significant influence on rubber productivity include harvesting labour, trees in tapping, age of farmer, experience of farmer, depth of cut, maintenance labour and capital equipment. Only harvesting labour and trees in tapping were found to have a positive influence on rubber output. The rest had negative output elasticities, indicating that a unit percentage change in each of their usage levels, would result in a general decline in the output level. The negative coefficient of the factor, maintenance labour, indicates that a certain degree of competitiveness exists between the two components of the labour input. The sum of the output elasticities of the significant factors of production was greater than unity, indicating that increasing returns to scale exists for the rubber smallholders in Cape Rodney.

Group dummy variables were used in the analysis of technical efficiency, given the assumption that the production frontiers for the different groups differ in a neutral manner. This analysis revealed that the Western Ethnic Group were the most productive while the Dom Ethnic Group were the least productive. Using the Local and Non-Local Farmer dummy variables, it was found that given an average package of input factors, the former group of farmers were relatively more productive than

the latter group. The Chow Test, however, established that the two groups operated on significantly different production frontiers, differing both in intercept and elasticity. Here, the analysis revealed that technical efficiency differed, depending very much on the scale of operation. At higher levels of harvesting labour input, Non-Local Farmers were technically more efficient. Conversely, the Local Farmers were more efficient at lower levels of harvesting labour usage.

The analysis of allocative efficiency was carried out for the two important factors, harvesting labour and trees in tapping, and also using the Local and Non-Local Farmer groups. With regard to harvesting labour, it was found that Local Farmers were efficient in allocating this resource. Their level of inefficiency was a mere 2 per cent. Non-Local Farmers, on the other hand, were about 50 per cent inefficient in allocating this resource. However, this inefficiency was felt to be caused by a labour shortage problem observed among this group of farmers during data collection. Productive gains therefore exist for the Non-Local Farmers if they can increase their usage of harvesting labour. With regard to trees, both groups of farmers allocated this resource inefficiently. The degree of inefficiency depended very much on the ruling output price. At a low output price, Local Farmers were more efficient while at a high output price, the Non-Local Farmers were more efficient.

The major conclusion from this study is that a proper pricing policy can be a useful instrument in achieving the required productivity levels, especially given that estate contribution to rubber exports have been constantly declining.

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CURRENCY

One Kina (K1) = $US 1.4292 (March, 1980).

CHAPTER 1

INTRODUCTION

This introductory chapter attempts to provide a general background of Papua New Guinea's geographical and economic characteristics. Following this, the broad objectives of the study, description of data and the limitations of the data are outlined.

1.1 LAND, CLIMATE & POPULATION

Papua New Guinea (PNG) extends from the equator to 12° south latitude and from the border of Irian Jaya in Indonesia to 160° east longitude. The total land and inland water area is 462,840 sq kms.

This area consists of the eastern part of the island of New Guinea and hundreds of adjacent islands, the main ones being New Britain, New Ireland, North Solomons and Manus. PNG contains some of the world's most rugged mountain ranges which extend as a backbone through the country. The highest peak is Mt. Wilhelm, some 4,500 m high. Steep slopes and lowland swamps are also common features of the landscape.

The climate is equatorial, with fairly high average temperatures and humidity. A predominant seasonal feature is the regular alternation between two major airstreams; the southeast trade winds (which prevail from about May to October) and the northwest monsoon (which prevail from about December to April). These cause a dry and wet seasonal pattern which in turn greatly influences farm work patterns, especially in subsistence agriculture in the coastal lowlands. The highlands, however, experience fairly cool temperatures and therefore there is no definite seasonal variation. Frosts do occur in the highlands, sometimes causing crop damage and therefore food shortage.

The estimated population in 1978 was about 2,992,000, of whom some 84% lived in rural areas and most of them depended on subsistence agriculture for their livelihood. This is one of the main reasons for the Government's concern with rural development.

1.2 The Economy

PNG is one developing country among many whose basic economic structure is dominated to a large extent by agricultural based activities. Unfortunately, such activities on their own cannot generate the much needed foreign exchange. This has meant that other activities, especially those concerned with exploitation of non-renewable resources, have become increasingly dominant over the last decade or so. Despite this, much of the output has to leave the country in its primary form and therefore sectoral dominance does not necessarily reflect importance to the ordinary citizen. Agriculture, however, can be thought of as the dominant sector and this aspect is discussed further in a later section.

1.2.1 Some General Characteristics of the Economy.

PNG continues to rely heavily on external aid to finance as much as 40 per cent of the government recurrent budget. There is also a high dependence on mineral exports to generate a large percentage of government revenue with significant variations in prices and export incomes. Another effect of such mining activities is that of employment creation which is usually limited only to the mining area and this adds to the imbalance which already exists in the PNG economy. Another notable characteristic is the dependence on export crops such as coffee, cocoa, copra, palm oil, tea and rubber which are also subject to wide fluctuations in prices. Although smallholder production of these crops is being encouraged, about 50% of export production still comes from plantations. Apart from the export crops mentioned above, an increasing contribution to export income also comes from the development of forestry and fisheries resources but with continuing marketing and planning problems in achieving maximum benefits from the utilization of these resources. Another important source of government revenue is from the taxation of overseas-owned mining, commercial and plantation businesses as well as personal income tax. Expatriates who usually enjoy high salaries, but are few in number, pay the highest proportion of income tax compared to their local counterparts. On the whole, therefore, to maintain the existing per capita income levels in view of the present national population growth rate of about 3 per cent a year; national income or GNP must have a similar or if not a higher growth rate.

Although national strategies call for a general effort in achieving self-sufficiency, especially in relation to food items and selected commodity groups, available statistics seem to show the reverse situation. For example, in Table 1.1, imports and domestic production for 1973/74 of selected food items are compared and it is obvious that for important food items like beef, poultry, rice, processed sugar and processed fish, PNG still relies heavily on imports. Domestic production of these selected items is mostly for purposes of satisfying individual family needs and therefore self-sufficiency outside the subsistence sector is probably a mere dream. Food imports represent some 20 per cent of import expenditure (Densley 1978) with fresh and canned meat and fish, rice, flour and sugar representing the major food items imported. Port Moresby, the nation's capital, and Kieta, a major town for the Bougainville Copper Limited (BCL) mine account for some 30 per cent of all food imports.

The overall trade situation is depicted in Figures 1.1 and 1.2. Figure 1.1 shows the balance of trade from 1977 to 1981 while Figure 1.2 shows a comparison of the major export items for the same period.

TABLE 1.1

Selected Food Imports and Domestic Production[1]

(tonnes)

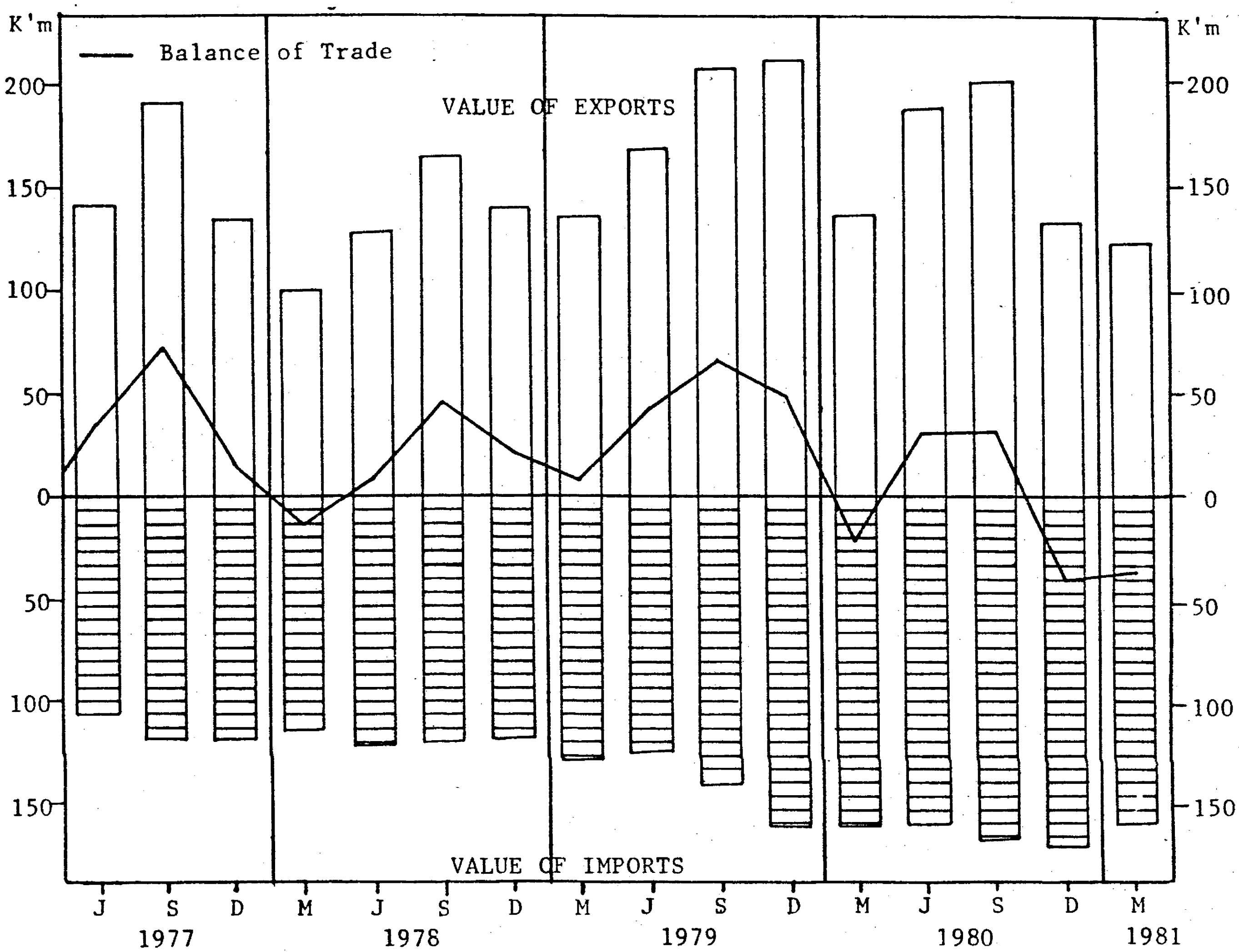
Commodity	Imports		Domestic Prod.		Total Apparent
	Fresh	Processed	Subsistence	Marketed	Consumption
Beef	2430	9119[2]	260	2600	14409
Pork	500	400	20000	600	21500
Sheep	1743	116	Neg	Neg	1859
Poultry	3794	739	500	1869	6902
Dairy	1025	2630	Neg	Neg	3655
Rice	55127	-	N/A	1493	56620
Flour & Cereals[3]	-	27457	84000	N/A	111457
Fish	556	21826	33000[4]	-	55382
Sugar	-	19934	33700[5/6]	-	53634
Fruit & Vegetables	5782	2000	3506000[6]	343200[6]	3856982

1. Refers 1973/74
2. Includes Unspecified canned meat.
3. Excluding Flour and Cereal preparations, i.e. pastry and biscuits, etc.
4. Includes marketed quantity.
5. Sugar equivalent.
6. Based upon the 1961-62 Bureau of Statistics Survey of Indigenous Agriculture and 2% p.a. increase.

Source: Densley (1978), DPI Publication.

FIGURE 1.1

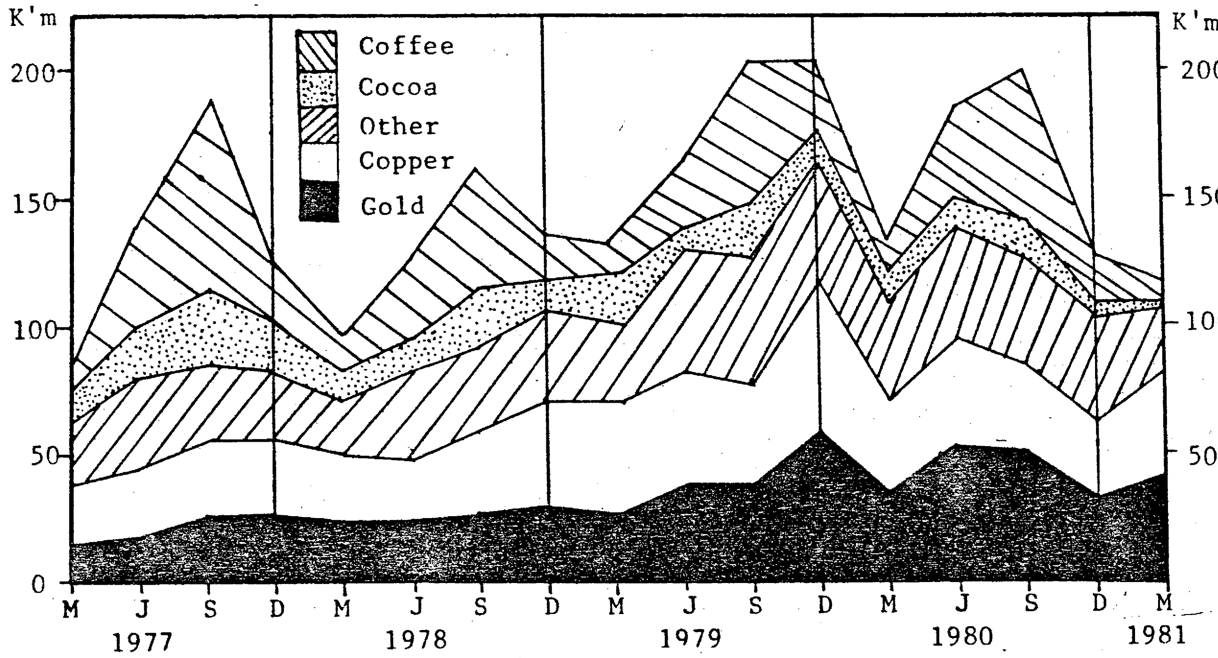
Exports, Imports and Balance of Trade



Source: Bank of PNG; Quarterly Economic Bulletin (1981).

FIGURE 1.2

Composition of Domestic Exports



Source: Quarterly Economic Bulletin (1981).

With respect to the trade balance, PNG's economy has been enjoying a favourable balance, especially since BCL began its operations on Bougainville, producing copper and gold. Unfortunately, the more recent trend is not very encouraging in that export production (i.e. in real terms) is falling while expenditure on imports is increasing. Related to this, the overall trend shows that gains from exports in monetary terms are definitely not increasing while expenditure on imports shows a definite increasing trend. In both cases 'price effects' are more dominant than the effects of changes in quantities.

In relation to Figure 1.2, coffee and cocoa, which are basically smallholder crops, seem to be more dominant in contributing to export incomes than copper and gold; especially during the period before 1981. Fluctuations between the different export crops seem to be interrelated. A good example of this from the graph occurs during the last quarter of 1979 and the first quarter of 1980 where there was an overall drop in the values of all the products and later followed by an overall increase. Finally, looking at both Figures together it seems that movements in the value of coffee exports alone have a significant influence on the overall trade balance.

Although much of PNG's working population is dependent on agriculture for its livelihood, it has been argued that there is a large and increasing level of unemployment. Estimates are that only 15 per cent of the workforce is in wage employment. This results mainly from a high level of rural-urban migration, especially involving teenagers who are forced out of schools by the existing educational system. Such migrants are ill-equipped, having acquired very little or no skills at all and are unable to secure 'formal' jobs. All this adds to a high rate of urbanization, estimated to be growing around 7 per cent per annum. There are also substantial differences in income levels between urban and rural areas. Current figures indicate that urban minimum wage levels are twice those in rural areas (Wheeler, 1978). Finally, there are vast differences in development between different areas of the country with some provinces or districts having little cash crop development, limited roads, transportation services, schools or health facilities. This unfortunately is inevitable in that it is always the end result of initial capitalist development.

1.2.2 Agriculture in the Economy

1.2.2.1 The Subsistence Sector

The subsistence sector can be defined in terms of subsistence agriculture or subsistence production, where the former describes the system as a whole as an agricultural entity. In this section the latter terminology will be used.

If one were to define subsistence production, a very general definition would be that it is production which is undertaken to satisfy the immediate needs of the producer and those dependent on him for livelihood. Likewise, authorities on this subject like Fisk (1962) would identify the producer and those dependent on him as the 'subsistence unit' and then go on to define a 'pure subsistence unit' as:

> "...one which is entirely independent of the outside world for the necessities of life and all items of normal consumption".

Depending on the size of the subsistence unit, one could argue that in real life there is no such thing as a pure subsistence unit. For example, if the subsistence unit includes the producer and those dependent on him for livelihood, there would be others outside this unit (e.g. village pastor or village chief) who may influence how much is produced. Similarly, social activities would also have an impact on the total output of the subsistence unit. Similarly, if the subsistence unit includes the whole village then there would be others outside the village who would influence production or even consumption for that matter.

In subsistence production, surplus is a very common feature. Such surplus is produced, not because there is enjoyment out of working harder, but because of important sociological reasons. The reasons are complex and they can only be understood if one examines the structure of societies where such a production system exists. One basic reason is that of prestige and social status. In such societies, especially in PNG, a man is not recognized by his ability to read and write but by his ability to produce as much food as he can, even if it merely rots away and is wasted. In this respect, surplus production is not an accident, resulting from the high returns which exist, but a deliberate act to achieve certain goals and ambitions.

Even then, there exists surplus labour time which has prompted many to believe that there is what they call 'subsistence affluence'. This in general is a situation where the amount of factor inputs required to produce the maximum required amount of food and other needs is smaller than the actual factor input level available to the producing unit. That is, all factor inputs are not being fully utilized and yet the required amount of output to satisfy the household is easily obtained. In PNG such an underutilized factor is labour and Fisk argues that if proper incentives and opportunities were made available, such an abundant factor could be mobilized to create an agricultural surplus. Incidentally resettlement schemes like the Cape Rodney Rubber Scheme and many others, producing a few main export crops, are classic examples of labour mobilization.

Subsistence production is mainly for purposes of producing the main staple crops. In PNG, these include sweet potatoes in the highlands, taro, yams, bananas and sago in the lowlands and coastal areas. Other supplementary foods like fish, coconuts, pig meat, fruits and vegetables are also included. Food production probably explains only about half of all subsistence production. As shown in Table 1.2, utilization of other plant species also forms a very important part of overall subsistence production.

According to the 1971 population census, about 80 per cent of the total population of PNG lived in 'village' areas with about 63 per cent of the working population engaged mainly in subsistence production (Densely, 1978). Although more recent trends are unavailable, it would generally be true to assume that over 50 per cent of the rural population are still dependent on subsistence production. In terms of the contribution of subsistence production to Gross Domestic Product (GDP), the trend has changed significantly over the last decade or so. The major cause of such a change can be attributed to the multinational mining venture in Bougainville, The Bougainville Copper Limited. Using Table 1.3 and Figure 1.3, if subsistence production is roughly equated to the non-market component then in the early 1970s non-market production made up some 20 to 25 per cent of the GDP, while at the same time being the major source of value added to agriculture. However, after 1973 when BCL became operational the share of the non-market component fell to about 14 per cent and this trend has continued since then as can be seen in Figure 1.3. But in real terms one could argue that the level of non-market component has been somewhat constant over the period in question.

Land and labour are the two basic factor inputs in subsistence production and both are relatively abundant in availability, although not as abundant as they would have been a decade ago. This is especially true for the input factor, land. The basic proof of land being less abundant can be seen in resettlement schemes where people with very

TABLE 1.2

Numbers of Plant Species Used for Subsistence Purposes

Use		Numbers
Foods		251
Stimulants, etc.		18
Medical -	cuts	23
	burns	8
	sores	52
	pains, etc.	49
	toothache, etc.	22
	fevers, etc.	25
	coughs, etc.	38
	intestinal ailments	57
	childbirth and fertility	25
Magic		115
Weapons and tools		80
Canoes and rafts		39
House building, etc.		136
Ropes		40
Cords and textiles		46
Food preparation, utensils		90
Decoration		90
Art		60
Hunting and fishing		43

Source: MacEwan (1978), DPI Publication.

TABLE 1.3

Agriculture in G.D.P.

(Value in million Kina)

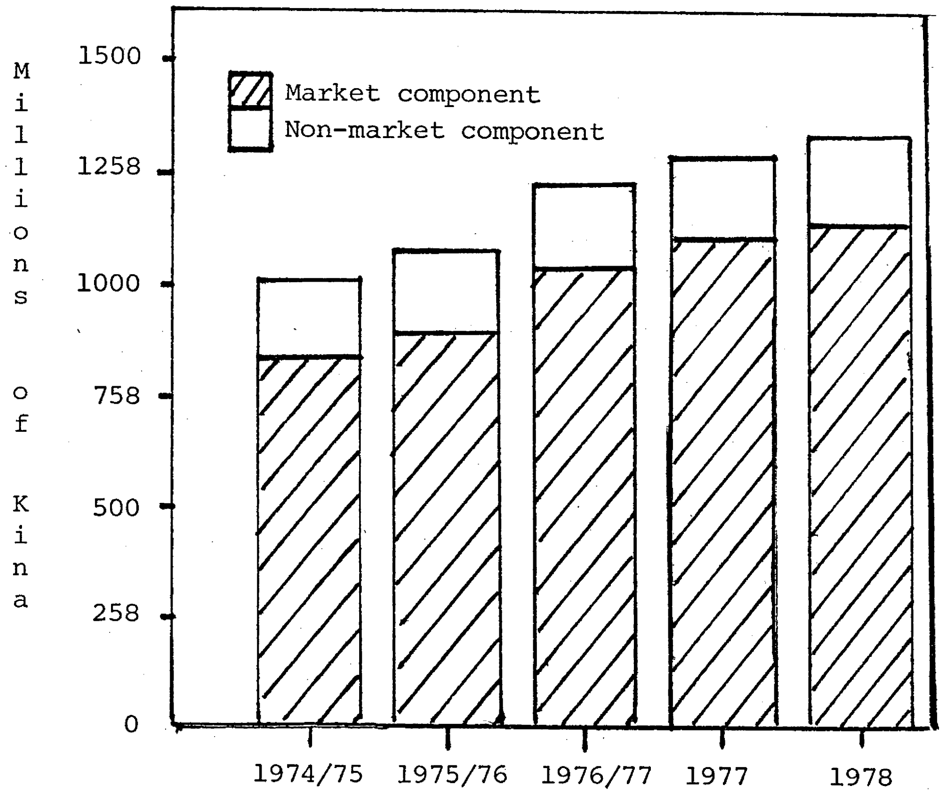
Fiscal year ended 30 June	Value Added to Agriculture[1]			Gross Domestic Product	Agriculture as P.C. to G.D.P.
	Marketed	Non-Market Component	Total		
1970	84.0	129.1	213.1	531.0	40.1
1971	81.8	133.7	215.5	621.7	34.7
1972	75.8	145.6	221.5	645.4	34.3
1973	82.8	160.1	242.9	788.8	30.8
1974	119.3	153.7	273.0	1040.6	26.2
1975	144.3	155.1	299.4	1009.1	29.7

Note: [1] Includes crop-husbandry, livestock, hunting, forestry and fishing.

Source: Koley (1979), DPI.

FIGURE 1.3

Gross Domestic Product



Source: PNG Summary of Statistics (1978).

little land are resettled in other parts of the country where land is not scarce and are given opportunities to produce export crops, thus creating a steady source of income.

1.2.2.2 The Cash Crop Sector

Cash crop development in PNG started as early as the late 19th century when British ruled Papua and Germans ruled New Guinea. This, some argue, was the beginning of the 'global capitalist development' in the Pacific Region and it was preceded by the development of suitable machinery for large scale extraction of oil from copra in the 1850s (Amarshi, et al., p.4. 1979). Hence, copra became the major cash crop commodity with large coconut plantations established around the coastal plains of the country. Copra as a cash crop was then followed by rubber, some cocoa and then coffee in the highlands. Apart from coffee, the other crop developments were mostly in plantations which 'exploited' the vast and cheap resources of land and labour. Other new cash crops recently introduced include tea, oil palm and pyrethrum.

Plantation production of cash crops for exports is, therefore, one major form of commercial agriculture in the country. This form of production was until recently largely in the hands of European operators. Since self government, followed by independence in 1975, efforts have been made to encourage indigenous people to take over such European operated plantations. However, such take-overs have not gone through without problems, both legally and financially. Related to this is the encouragement of smallholder production of the major cash crops listed above. There has been more success in the latter case than the former. According to Table 1.4, given the production of the four major cash crops of coffee, cocoa, copra and rubber, smallholder production of these crops has an increasing trend while that of plantations is definitely not increasing. Individually, the growth in output of

TABLE 1.4

Production of Principal Cash Crops by Holding Type

(in tonnes)

	1973/74		1974/75		1975/76		1976/77	
	Plant-ation	Small-holder	Plant-ation	Small-holder	Plant-ation	Small-holder	Plant-ation	Small-holder
Coffee	9,702	24,382	10,704	26,240	8,745	29,337	7,521	27,195
Cocoa	18,067	11,195	18,747	12,655	14,408	12,642	13,524	11,905
Copra	72,696	54,051	78,682	55,550	70,370	53,484	74,958	60,494
Rubber	6,051	248	5,286	269	3,774	285	3,349	554

Source: Handbook on Agricultural Statistics, DPI, 1978.

smallholder production is clearly depicted in rubber. During the period in question, smallholder production almost doubled while plantation production fell by about half.

Undoubtedly, cash crops are a major source of export earnings not only for agriculture but also for the total economy. They also provide a constant flow of income for many individual producers, scattered all over the country. According to Table 1.5, cash crops in the early 1970s earned as much as 80 per cent of the total export earnings. This figure fell to about 30 per cent in 1973 when PNG started exporting copper and gold from the BCL mine and the trend has remained somewhat constant. Despite this, in real terms, cash crop production is expanding even in the light of highly fluctuating prices.

The production of perennial crops is one form of cash cropping; the other form which has become important in more recent times is what we call 'multi-purpose cash cropping'. This is a situation where any surplus production over and above the needs of the producer and his family is sold and the cash income used to purchase goods and services not readily available to the farmer. This form of cash cropping is very common among indigenous farmers and it involves most of the native root crops like sweet potatoe, taro, cassava and yams and other crops like bananas, sugar cane, bettlenuts, fruits and vegetables. Among all these crops, bettlenut is probably the most important in terms of the net returns it is able to generate. It is commonly consumed throughout the country, even in the highlands where it is not grown because of climatic factors. In most local markets, bettlenuts are a very common commodity and given the fact that it can be stored for longer periods than most crops makes it saleable in areas where it cannot be grown. Sales of this category of cash crops is mostly to urban areas where formally employed people are not able to provide their own staple foods. Even then in most local rural markets, farmers do engage in purchasing each others produce. Despite this, marketing of these crops poses a major problem to producers because of (a) the inherent characteristics of these crops in terms of storage and bulkiness in transporation, and (b) the unavailability of markets because of distance and access.

1.2.2.3 The Importance of Agriculture

Agriculture has and will continue to make an important contribution to the economy of PNG. The vast majority of the rural population are dependent, either primarily or secondarily, on agriculture for their livelihood. Apart from mining, which mostly comes from a single establishment, agriculture is the largest contributor to the national economy, and is the major export earner of the country.

It can be observed from Table 1.3 that the gross value added in the agricultural sector had an annual growth rate of 7 per cent in the five year period between 1970 and 1975. During the same period, GDP had, however, grown at a rate of 14 per cent and this was mainly due to a much faster growth in recent years of the mining sector. This has also meant that the contribution of the agricultural sector to GDP in proportionate terms has declined but at a slow rate. On the whole, therefore, agriculture still makes an important contribution to GDP, despite the faster growth in the mining sector and given that agricultural prices do fluctuate substantially.

Trade statistics for agriculture are shown in Tables 1.5 and 1.6. In the early 1970s agriculture was the major export earner, earning at least up to 96 per cent of foreign exchange. Since the beginning of mineral exports in 1973, agriculture's share of export earnings fell to 36 per cent. Then with the

TABLE 1.5

Agriculture as Export Earner

Commodity	Year ended 30 June (Kina '000 f.o.b.)									
	1970	1971	1972	1973	1974	1975	1976	1977	1977 Calendar Year	1978 Calendar Year
Coffee	20,182	20,572	20,454	23,395	28,847	33,566	42,225	132,619	143,441	107,310
Cocoa	15,549	13,643	11,021	11,175	23,338	40,075	28,614	55,147	86,371	62,955
Copra	13,340	14,207	9,392	8,083	23,672	28,841	11,998	18,827	22,960	24,999
Copra oil	5,801	7,805	5,880	4,982	13,761	14,284	7,322	11,422	11,842	12,448
Copra oil pellets	607	893	588	950	1,012	1,422	1,798	1,291	1,207	1,059
Dessicated coconuts	1,211	1,203	1,065	1,192	498	-	-	-	n.a.	n.a.
Rubber	2,798	2,297	1,995	1,998	3,563	2,576	2,654	3,317	2,896	2,630
Palm oil	-	-	515	1,148	2,685	6,786	6,617	8,535	8,582	10,144
Tea	645	1,094	1,500	2,048	2,601	3,866	3,977	8,022	9.068	7,833
Peanuts (green)	550	518	616	305	324	47	23	n.a.	n.a.	n.a.
Pyrethrum extract	332	286	227	192	215	190	194	143	145	118
Tuna	n.a.	1,317	2.806	3,025	10,434	8,836	5,873	13,564	14,449	20,458
Prawns	648	818	2,016	1,307	2,572	998	2,396	5,103[2]	4,632[2]	4,130[2]
Crayfish	11	57	35	47	860	258	189			
Other fish	n.a.	2	-	8	3	1	30	n.a.	n.a.	n.a.
Crocodile skin	452	264	198	650	585	403	291	778	814	1,222
Timber, logs	2,570	5,300	4,997	5,646	11,588	7,571	6,666	11,678	10,968	11,710
Timber, sawn-conifer	1,024	835	1,131	1,013	1,211	1,058	1,146	7,318[3]	5,897[3]	4,171[3]
Timber, sawn-non conifer	186	235	860	1,675	3,952	2,227	2,083			
Plywood	2,529	2,504	1,996	2,368	3,571	2,663	2,831	2,888	2,141	2,858
Total Agriculture	68,435	73,850	67,292	71,207	135,292	155,768	126,927	280,652	325,413	274,045
Total Exports[1]	71,443	77,447	93,039	200,542	453,009	402,560	335,792	484,504	539,836	504,542
Agriculture as P.C. of total exports	95.8	95.4	72.3	35.5	29.9	38.7	37.8	57.9	60.3	54.3
Cash Crops as P.C. of total exports	84.9	80.7	57.2	27.7	22.2	32.7	31.4	49.4	53.1	45.5

Notes: [1] Excluding re-exports. [2] For 1976/77 and 1977 calendar year, prawns and crayfish combined. [3] For 1976/77 and 1977 calendar year, timber, sawn-conifer and timber, sawn-non conifer are combined.

Source: Koley (1979), DPI.

TABLE 1.6

Volume of Trade in Agriculture

(Value in K'000 f.o.b.)

Quarter ended June	Agricultural Commodity			Total Trade			Agriculture as P.C. Total Trade
	Exports	Imports[1]	Trade Volume	Exports[2]	Imports[3]	Trade Volume	
1970	68,435	43,087	111,522	71,443	210,648	282,091	39.5%
1971	73,850	48,036	121,886	77,447	251,564	329,011	37.0%
1972	67,292	51,681	118,973	93,039	252,782	345,821	34.4%
1973	71,207	53,116	124,323	200,542	225,495	426,037	29.2%
1974	135,290	62,164	197,454	453,009	225,982	678,991	29.1%
1975	155,768	77,766	233,534	402,560	353,421	755,981	30.9%
1976	126,927	79,744	206,671	335,792	346,397	682,189	30.3%

Notes: [1] Includes food and live animals, beverages and tobacco, animals and vegetable oils and fats.

[2] Excluding re-exports.

[3] Excluding outside packages.

Source: Koley (1979), DPI.

increases in earnings of individual commodities like coffee, cocoa, copra, palm oil, tea and tuna, the share of agriculture increased to about 60 per cent. For coffee and cocoa, the increased earnings were mainly due to price increases while for the rest of the commodities, it was mainly due to an increase in quantity exported. The latest figures (1978) show that over half of the total export earnings accrue to the agricultural sector and this trend could very well continue until the OK-TEDI copper mine comes into production.

The trade balance for agricultural commodities is shown in Table 1.6 and it shows that the balance has always been favourable during the 1970-1976 period. Agricultural commodity imports make up only about 20 per cent of the total imports. Such imports include mostly manufactured food items like tinned meat and fish and also rice, flour and sugar. On the whole, agriculture does generate a significant amount of trade, ranging from about 30 to 40 per cent.

Employment in agriculture, shown in Table 1.7, is expressed in terms of the indigenous wage earning workforce and therefore does not include the many subsistence farmers dependent on agriculture. In terms of the number of people employed, the copra-cocoa combination as a single industry employs the highest number of people, followed by coffee and then rubber. The decline over the five years of the wage earning workforce in copra, cocoa, copra/cocoa, and rubber supports the earlier statement that plantation production has declined as wage employment would only be possible in plantations.
On the whole, we can conclude that agriculture still does provide a significant amount of wage employment and with the declining trend of plantation employment, fishing and forestry may become important employment areas in the agricultural sector.

TABLE 1.7

Indigenous Wage Earning Workforce in Agriculture

Industry	As at 30 June					
	1970	1971	1972	1973	1974	1975
Copra	4,679	5,045	3,936	2,679	2,784	2,012
Cocoa	2,857	1,904	1,442	1,224	1,332	1,206
Copra/cocoa	22,605	14,805	13,927	12,796	13,518	12,557
Coffee	6,987	6,866	6,194	7,315	8,111	6,155
Rubber	6,252	4,216	4.036	4,037	3,613	2,190
Tea	5,044	414	2,536	3,993	3,496	2,703
Grazing	358	475	536	428	309	423
Fishing, Hunting and Trapping	141	337	613	602	814	396
Forestry	3,351	672	1,624	3,157	1,222	1,074
Other Agriculture	728	551	404	1,179	2,158	1,616
Total Agriculture	53,002	38,885	35,248	37,410	37,357	30,332
Total Workforce	124,585	124,143	120,014	117,838	93,773	84,366
Agriculture as % of Total Workforce	42.5	31.3	29.4	31.7	39.8	36.0

Source: Koley, (1979), DPI.

1.3 The Research Problem

PNG is a recently monetized economy if compared to the general situation in the rest of the world. This means that the dependence on money to obtain some basic necessities is continually increasing. But before money was introduced as a legal tender, traditional means of exchange were well developed although only on a regional basis. In such a situation an item was recognized as a common means of exchange and such items ranged from sea shells in parts of Papua to dogs' teeth in parts of New Guinea. Furthermore, where contact and trade were possible, a system of barter exchange was developed and this is when the surplus over and above the needs of the family were used in exchange for other goods.

With development and the increasing need for money, more and more people in rural areas are becoming more market oriented, through involvement in cash crop production while at the same time maintaining activities which satisfy their subsistence needs. Resettlement schemes are a classic example of this, where subsistence oriented producers are allowed to produce in fairly monetized environments. According to Fisk's (1962) classifications of degrees of monetization, the above situation is in stage three where production is cash oriented but with supplementary non-monetary economic activity. This also fits into the model described by Nakajima (Wharton, 1969 Ch.6).

Given the above situation, decisions made by the farmer, especially those in relation to resource allocation, can have important policy implications. Unfortunately, in this study, data on subsistence production by the rubber farmers is not available and so the above problem cannot be looked at in totality. What this study will hopefully bring out will only relate to allocation decisions in rubber production. However, analysis and interpretations can be done bearing in mind that subsistence production also takes place.

Another problem area this study aims to look at relates to falling rubber production at the national level. According to the statistics provided in Table 1.4 the combined output for plantations and smallholders for the period in quesiton has a declining trend. This trend, however, is significantly affected by falling productivity in plantations and therefore the extent to which this study can provide some explanation is fairly limited in that only smallholder production is being analysed. Other limitations with respect to this problem include, firstly, that this study is a cross-sectional approach and therefore problems related to time trends cannot be analysed, and secondly, that Cape Rodney is only one producing unit out of the many that exist. Despite those limitations, in relation to the former, plantations and smallholders use the same factors of production and therefore looking at factor productivities can provide some useful insights to the problem. Similarly, Cape Rodney does contribute significantly to national rubber output and therefore any change in its contribution can also lead to changes in national output. In this respect, the analysis of the Cape Rodney scheme may also prove useful in partially explaining falling productivity.

1.4 Nature of the Data

1.4.1 The Sample

In the Cape Rodney Rubber Resettlement Scheme, there are about 180 productive farmers who have tappable trees on their blocks (farms) and therefore can tap and sell latex. Another 120 allotments have either been settled on recently with young rubber plantings or are still vacant because of abandonment by the early settlers. The 180 productive farmers tap some 250 hectares of productive rubber, which is only about 60 per cent of the mature rubber on the scheme (Griffiths in

Workshop No.1, p.12). The major cause for such a situation was overplanting during the early settlement days. Hence, an unmarried single farmer with 2,000 tappable trees on his block is not an uncommon situation on the Cape Rodney Scheme. From the 180 productive farmers on the scheme, a sample of 50 farmers was selected, which is about 30 per cent of the total number. For reasons which will be explained later, the randomness of the above sample is questionable.

Attempts were made to use the same farmers used in previous studies of the Scheme but certain factors made this quite impossible. In this regard, it was also not possible to select a sample which would have been random using the formal selection methods. This being so, the sample used in this study includes only those whom I was able to find and interview during the two weeks of data collection. It should be mentioned here that the sample of 50 was in fact some 75 per cent of the number of farmers who were actually residing on their farms during the period of the survey.

1.4.2 Questionnaire

When this study was being planned, information given was to the effect that the data needed to do a production function analysis of the Cape Rodney Rubber Resettlement Scheme was readily available in the Rubber Section of the Department of Primary Industries (DPI), Port Moresby. On arrival at this office, I found that the available data was not sufficient to make possible a production function study. This being so, and given the time limitations, I then made up a substantially modified version of the questionnaire used by Muharminto (1980) where he studied smallholder rubber production in Indonesia (MADE Thesis 1980). The questions were not pretested before actual data collection. However, it was found that the majority of the questions were relevant and easily understood by the farmers interviewed.

The questions were written in English and they had to be asked either in the local vernacular, which was Aroma, or in Motu, which is the lingua franca for the Papuan Region as a whole.

I was the sole enumerator in this study and therefore problems of misinterpretation and misunderstanding of questions were probably small and insignificant, since I am able to communicate in both languages.

1.4.3 Data Collection

Actual data collection was done over a 14 day period between 14 December, 1981 and 14 January, 1982, but not on a continuing basis. This was due to several factors. Firstly, the existing system on the Scheme provides no tapping during weekends and therefore most farmers get involved in other activities of which the most common ones are the marketing of surplus subsistence produce at local markets on Saturdays and also religious commitments on the two week-end days. The second reason was that during the period of December 24 to 1 January, most farmers, especially those from the nearby villages of Domara, Dom, Kapari and Maopa, had to go to their respective villages to take part in the Christmas celebrations. This then meant that no interviewing of farmers from these villages was possible during the above period.

Actual data collection was done by several means and it involved travelling some 30 kms to get to the Scheme every morning. The Scheme itself is divided up into three sections, each separated by some 10 to 15 km and so each morning I would visit one section interviewing anyone who was present and was willing to answer questions. This is worth recording because in a few cases, farmers bluntly refused to be interviewed. Then in the late afternoons, when most farmers were busy working in their subsistence gardens (which were usually located away from the rubber holdings and their dwellings), I would go back to the DPI office in Moreguina and look at the files belonging to those I had interviewed over the morning period. These files were therefore another source of information where, with cross checking, I was able to verify specific answers, especially those relating to numerical measures. It was in this way that the number of mature and immature trees, number of trees being tapped, area of farm and other information was collected.

Information in files were based on surveys done occasionally by the dozen or so field officers on the Scheme. Having the benefit of file information I found that in some cases farmers did not know the actual number and distribution of trees they had, but their estimates were usually quite close.

Another source of valuable information was the processing factory files and it was from these files that the output and income level of each farmer on a daily basis was obtained. This was probably as accurate as one could get in measuring output and income. Also, from these files, I was able to get the number of tapping days in a year and this in itself is an important variable in determining output, apart from trees.

Further, questions related to the cleanliness of the block and the condition of the tapping panel also required my value judgement, which of course was based only on the very limited knowledge I had on rubber production as a whole. To overcome this problem, I asked the farmers to name the three farmers whom they thought were the best on the Scheme and having identified these three farmers, I was then able to compare other farms with these three.

1.4.4 Problems and Limitations of the Study

As indicated earlier, the basic problem faced during data collection was that of farmers being absent from their farms and staying in their respective villages to take part in the festivities which form an important part of the Christmas celebrations. This was especially so for settlers from Domara and Aroma who were absent for long periods, thus causing a smaller representation in the sample. Because of such overall absenteeism and given the time limitation, a larger sample would not have been practical, let alone a more random one. Despite this, all ethnic groups on the Scheme are to some extent represented in the sample and so are farmers from different locations.

Another problem faced during data collection was that most farmers who were present were not tapping because they argued that the price paid for a kilogram of dry rubber was too low to make it worthwhile to tap. This also meant that hardly any maintenance of the farms was being carried out as well. This was very interesting in that if one looks at this argument in economic terms, the farmers were arguing that since price was lower than the marginal product of labour, there was no point in tapping because the net return to labour would be lower than the cost of that labour used to produce latex. Unfortunately, this meant that some variables like depth and thickness of cut were not measured directly but indirectly using old cuts and estimates based on the farmers' judgement. Finally, a major limitation of this study relates to the fact that rubber is a perennial crop and therefore a cross sectional study like this is not able to capture the whole productive cycle of the trees thus making this study only partial in analysis and interpretation.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA

This chapter describes the study area and also provides a brief background information on the Rubber Industry of PNG. In Section 2.1, the development and the structure of the PNG Rubber Industry are discussed. The latter part of this section identifies its institutional framework and outlines some of the major development plans and policy issues. Section 2.2 specifically describes the Cape Rodney Rubber Resettlement Scheme.

2.1 General Setting

2.1.1 The Development of PNG's Rubber Industry

First commercial plantings of *Hevea* trees in PNG were made as early as the first decade of this century. The development of the industry since then has been very slow with almost a static level of production, compared to the two main producing countries, Malaysia and Indonesia (Refer Table 2.1). The world increases in rubber outputs have resulted from an expansion of acreage under rubber as well as through the adoption of new rubber technology. The PNG Rubber Industry has had only marginal changes in these respects. Its total rubber output and total planted area make PNG one of the world's smallest producers.

Rubber production was almost exclusively confined to estates. Even as recently as 1973/74, smallholder production only accounted for some 5 per cent of total rubber exported.[1] Estates were confined mainly to expatriate ownership, utilizing the abundant unskilled local labour force. In the early 1960s a peak acreage of approximately 14,300 hectares was planted, producing some 6,500 tonnes of rubber by 1971-72.[1] The use of clonal seedlings, which are of low yielding potential as compared to high yielding bud-grafted material, was a common feature in

[1] Densley et al (1978), p.2.

TABLE 2.1

Production of Natural Rubber

(tonnes)

	Indonesia	All-Malaysia	Papua New Guinea	World
1964	648,365	870,729	5,041	2,352,500
1974	880,000	1,549,293	5,553	3,475,000
% Increase	36	78	10	48

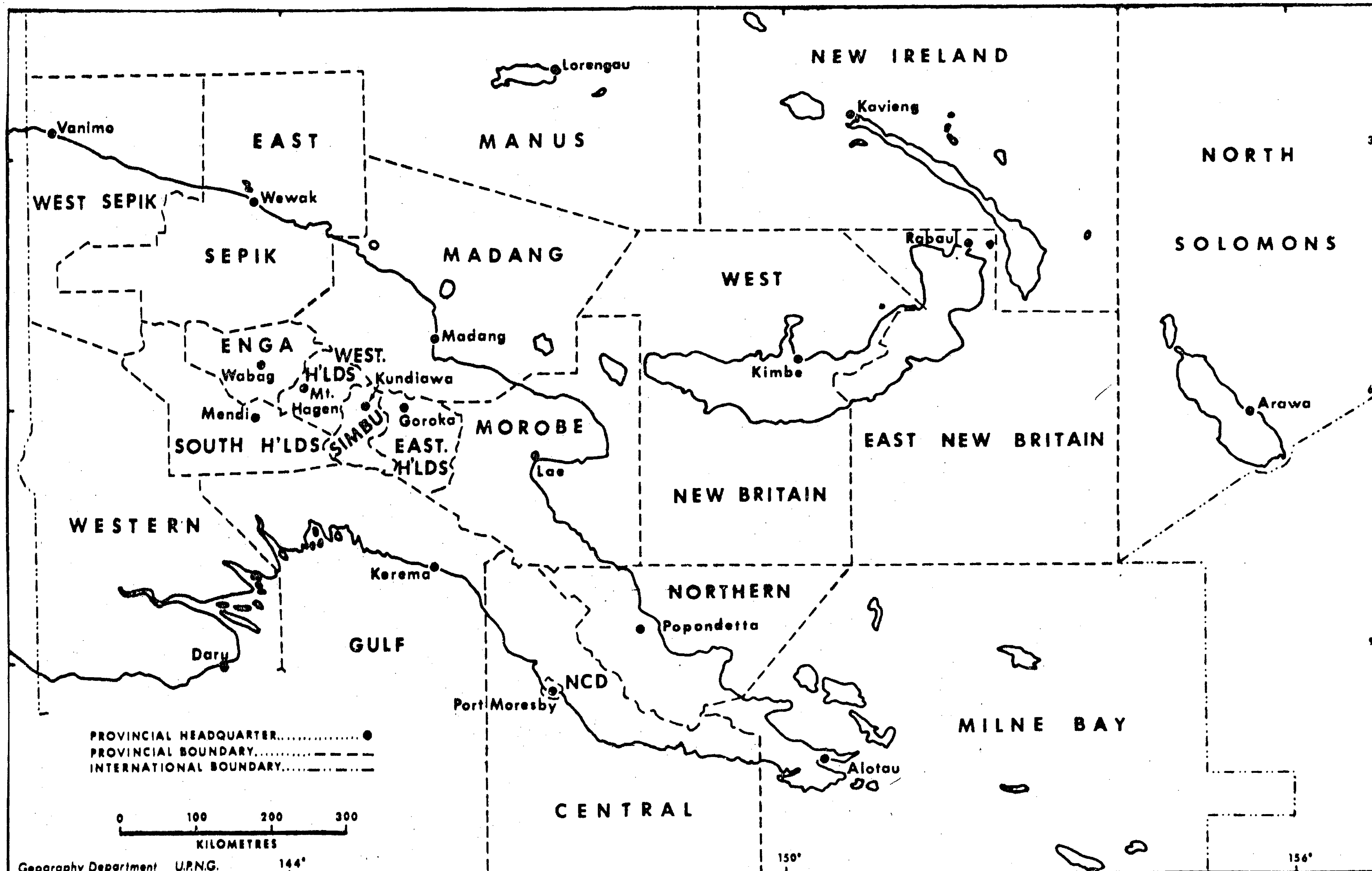
Source: Akhurst and Mitchell (1976), p.13.

the development of the estate sector. Their ability to withstand low tapping standards makes the clonal seedlings preferable to the budgrafted material.

This situation of comparatively low yields and the inability to replant with high yielding planting material has meant that many of the rubber estates are continuously being faced with considerable difficulty in meeting increased costs of production. The major cost increase area has always been wages, especially after the introduction of the Minimum Wages Legislation Board in 1972. Since 1970, estate rubber acreage has had a substantial decline. Some estates diversified with the introduction of complementary activities while others took up new ventures.

The smallholder sector, on the other hand, has been less prone to the problems experienced by its estate counterpart. Such optimism was referred to by Barlow (1970) when writing on the prospects for natural rubber. Prior to 1939, smallholder rubber planting, under the Native Planting Ordinance, was confined to limited village development, especially in the Northern Province (Refer Map 1). In 1964, steps were taken to promote the development of 'village rubber', where villagers were encouraged to grow rubber as part of the subsistence

MAP 1: PAPUA NEW GUINEA



gardening routine. Such development took place mainly in the Gulf and Western Provinces, using mostly planting material other than bud-grafted stocks.

In the period 1964 to 1970, smallholder rubber planting was promoted on land settlement schemes in the Central and Gulf Provinces (Cape Rodney, Bailebo and Murua) and at village level in the Western Province (Suki, Lake Murray, Balimo and Kiunga). (Refer Map 2). Rubber was also an integral part of the development programmes for re-settlement in the Bakoiudu and Kubuna areas of the Central Province (also refer Map 2). Settlement and village rubber schemes as a means of providing economic development in some of the less developed parts of the country was the main emphasis of the Australian administration. These less developed parts included the Gulf, Western and the Central Provinces.

The development of the Rubber Section within the Department of Primary Industries (DPI) somewhat accelerated the development of the Rubber Industry in PNG, especially the smallholder and village rubber schemes. This section co-ordinates planning and development of smallholder and village rubber development programmes. The number of smallholder and village rubber producers increased from less than 2,000 in 1970-71 to around 3,300 in 1976-77 (Densley et al, 1979, p.2). A broad, five year programme was drawn up and it is being reviewed annually by a National Rubber Planning Group (NRPG), co-ordinated by the Rubber Section. Considerable attention has also been directed to the redevelopment of the earlier rubber resettlement schemes. This is because all of these schemes have experienced critical planning problems, especially in relation to settler selection, land disputes and inadequate infrastructure, both in terms of social amenities and marketing facilities. The Cape Rodney and the Gavien Resettlement Schemes (refer

MAP 2: LOCATION OF VILLAGE RUBBER SCHEMES , RESETTLMENT SCHEMES AND ESTATES

<u>VILLAGE RUBBER SCHEMES</u>

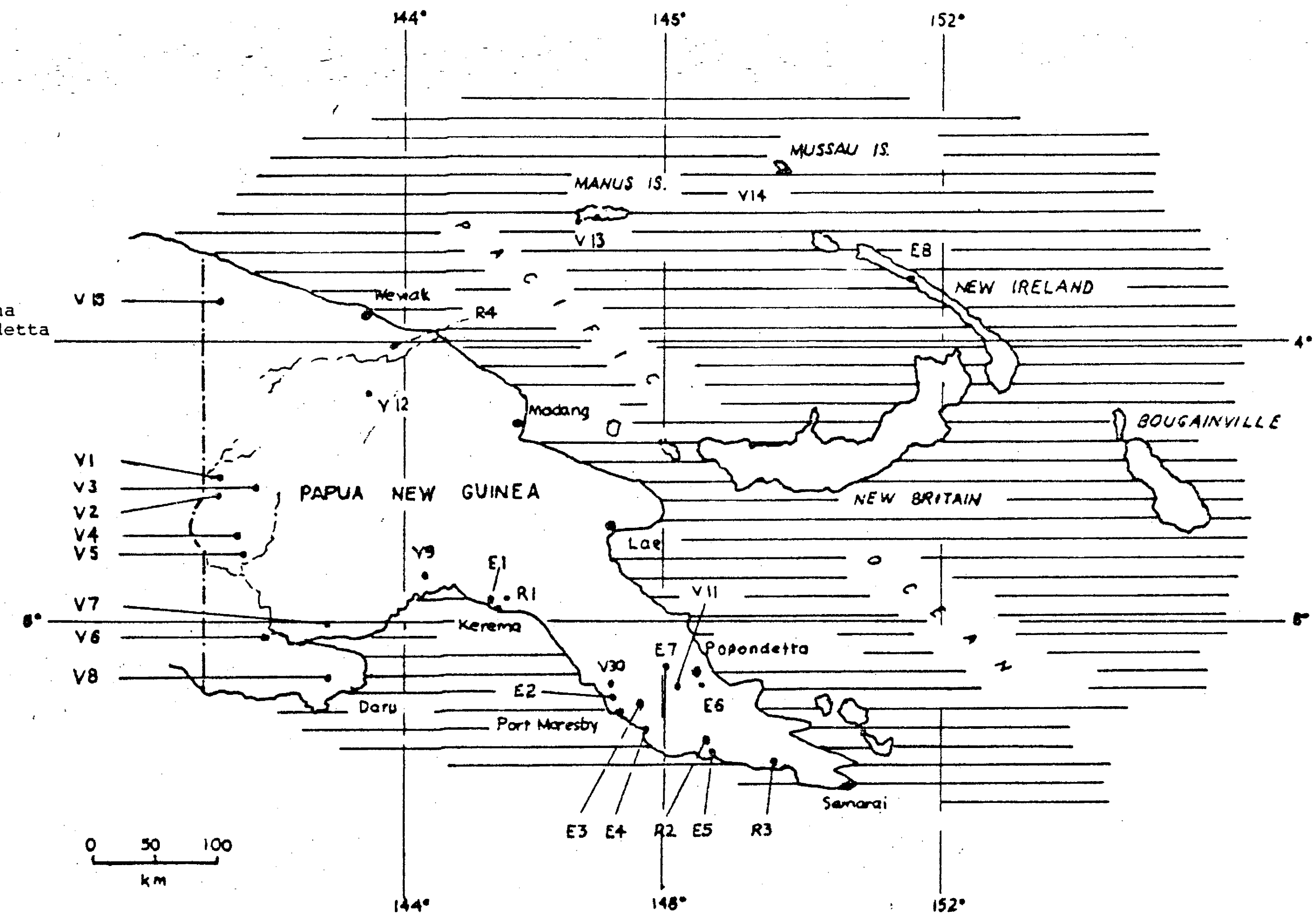
V1 Kiungo - N
V2 Kiungo - S
V3 Debepart
V4 Lake Murray - N
V5 Lake Murray - S
V6 Suki
V7 Balimo
V8 Wipim
V9 Kikori
V10 Bakoidu / Kubuna
V11 Kokoda / Popondetta
V12 Amboin
V13 Mcrus
V14 Mussau
V15 West Sepik

<u>RESETTLEMENT SCHEMES</u>

R1 Murua
R2 Cape Rodney
R3 Bailebo
R4 Gavien

<u>ESTATES</u>

E1 Kerema
E2 Galley Recch
E3 Sogeri
E4 Rigo
E5 Cape Rodney
E6 Popondetta
E7 Kokoda
E8 New Ireland



Source: Carrad (1981), DPI.

Map 2) are the two currently being redeveloped. In Cape Rodney, such redevelopment involves the introduction of cocoa, provision of housing and gardening facilities before actual settlement and the establishment of more and better feeder roads to enhance access and marketing. It also includes the erection of a factory which is capable of producing Technically Specified Rubber (TSR).

Rubber production in PNG, as measured by the exported quantity, has generally declined from a peak of 6,537 tonnes in 1971/72 to 4,177 tonnes in the 1979 calendar year. This trend is as shown in Table 2.2. The decline is the result of falling overall production on estates while at the same time smallholder production is relatively insignificant.

Table 2.2

Rubber Exports from PNG

	Estates (tonnes)	Smallholdings (tonnes)	Total (tonnes)	Value (tonnes)
1970/71*			6,338	2,297
1971/72			6,537	1,995
1972/73			5,846	1,998
1973/74	6,051	248	6,299	3,563
1974/75	5,286	296	5,582	2,576
1975/76	3,774	285	4,059	2,654
1976/77	3,286	554	3,840	3,317
1977 (Calendar Year)	3,946	206	4,152	2,897
1978	3,652	417	4,069	2,630
1979	3,625	552	4,177	3,603

Sources: Carrad (1981), p.43; Koley (1979), p.13; Densley (1978), Table 1.

* The 1970/71 to 1972/73 breakdown between Estates and Smallholdings was not available.

2.1.2 The Structure of PNG's Rubber Industry

2.1.2.1 The Estate Sector

The estate sector, until 1976/77 continuously accounted for nearly 95 per cent of PNG's rubber exports. Available statistics provided in Table 2.3 indicate that there were a total of 53 estate holdings in 1976 and that the total planted area dropped from some 12,630 ha in 1974 to 8,100 in 1976. About 23 of the 53 estate holdings are either government or mission owned, the rest being privately owned. Only about 30 estates are currently producing rubber, of which 18 are in the Central Province, 3 in the Northern Province, 1 in the Gulf Province and the remaining 8 located in the New Ireland and Milne Bay Provinces. The largest estates are situated in the Galley Reach area some 80 km northwest of Port Moresby. Most of these estates are owned and managed by two private companies, namely the British New Guinea Development Company and the Steamships Trading Company. Estates owned by these two companies together account for over 60 per cent of PNG's total rubber production (Densley et al, 1978, p.4).

Densley (1971) in his analysis of estate rubber production found that there were about 12 estates with a planted area in excess of 200 ha. These 12 properties accounted for 73 per cent of all plantings and 81 per cent of total national rubber production. Most of the trees being tapped then were of clonal material while the immature trees were of clonal seedling. These seeds were imported from Malaysia and estates doing so were subsidized by the government.

Fertilizers and yield stimulants are not commonly used on PNG rubber estates while chemical weedicides are increasingly being used to control weed in young rubber. The tapping systems used are basically 'half-spiral' cuts with some older estates still using the 'V-cut'. The frequency of tapping is either alternate daily or third daily. Most estates use

Table 2.3

Rubber Estates - Number, Area Under Crop - Year Ended 30th June (i)

PROVINCE	NO. OF HOLDINGS (ii)				AREA UNDER CROP HA (iii)											
	1969	1974	1975	1976	1969			1974			1975			1976		
	No.	No.	No.	No.	NB	B	T	NB	B	T	NB	B	T	NB	B	T
WESTERN	2	3	3	–	89	937	1026	2	143	145	76	233	309	140	–	140
GULF	3	2	2	1	NA	NA	NA	83	741	824	84	221	305	520	280	800
CENTRAL	40	38	33	28	2105	7435	9540	879	7959	8838	1470	5300	6770	1200	4800	6000
MILNE BAY	3	2	1	2	55	236	291	12	278	290	–	49	49	230	60	290
NORTHERN	21	13	13	3	364	1756	2120	103	1881	984	91	1880	1971	150	450	600
NEW IRELAND	5	7	5	3	448	–	448	127	406	533	225	434	659	20	250	270
OTHER	14	7	4	16	16	143	159	10	7	17	10	4	14	–	–	–
TOTAL	88	72	61	53	3077	10507	13584	1216	11415	12631	1956	8121	10077	2260	5840	8100

Source:– 1969, 1974 Bureau of Statistics, 1975, 1976 preliminary estimates.

Notes:– (i) It is suggested these figures be used with caution. Some estates purchased by National groups may not be included.

(ii) Includes Government trial blocks, etc.

(iii) N. B. – not bearing; B – bearing; T – total.

N.A.:– not available

alluminium cups although a few are now using polybag collection. 'Gouge' tapping knives which are no longer being used in most Malaysian estates because of heavy bark consumption and panel wound problems, continue to be used in most PNG estates. This has often resulted in poor bark quality, lack of good bark reserves and difficulty of tapping on lower panels on a number of estates observed by Akhurst and Mitchell (1976). The poor standard of tapping and the rapid turnover of workers on most estates also result in the above problems. The supply of labour has been the major problem facing the rubber estate sector. That is, there is no permanent resident labour force because most are single men who work at the most for 2 years and then leave, in search of better opportunities.

Estates use sheeting batteries for latex processing and creping units for handling cup lump and tree scrap. Grading of rubber is usually done on the estate and the Ribbed Smoked Sheets (RSS) are baled into 50 kg lots. All sales are made to the Australian market through the Papuan Rubber Pool located in the capital city, Port Moresby.

Actual data on the costs of rubber production on estates is not readily available. However, in 1970, at the sitting of the Board of Enquiry into rural wages, it was estimated that the average costs of production were of the order of 30 toea per kg (Densley 1971), with labour costs accounting for some 50 per cent of the total production costs. The current estimated average production costs are therefore about 50 toea per kg (delivered port basis), given that rural minimum wages have since then increased by some 125 per cent.

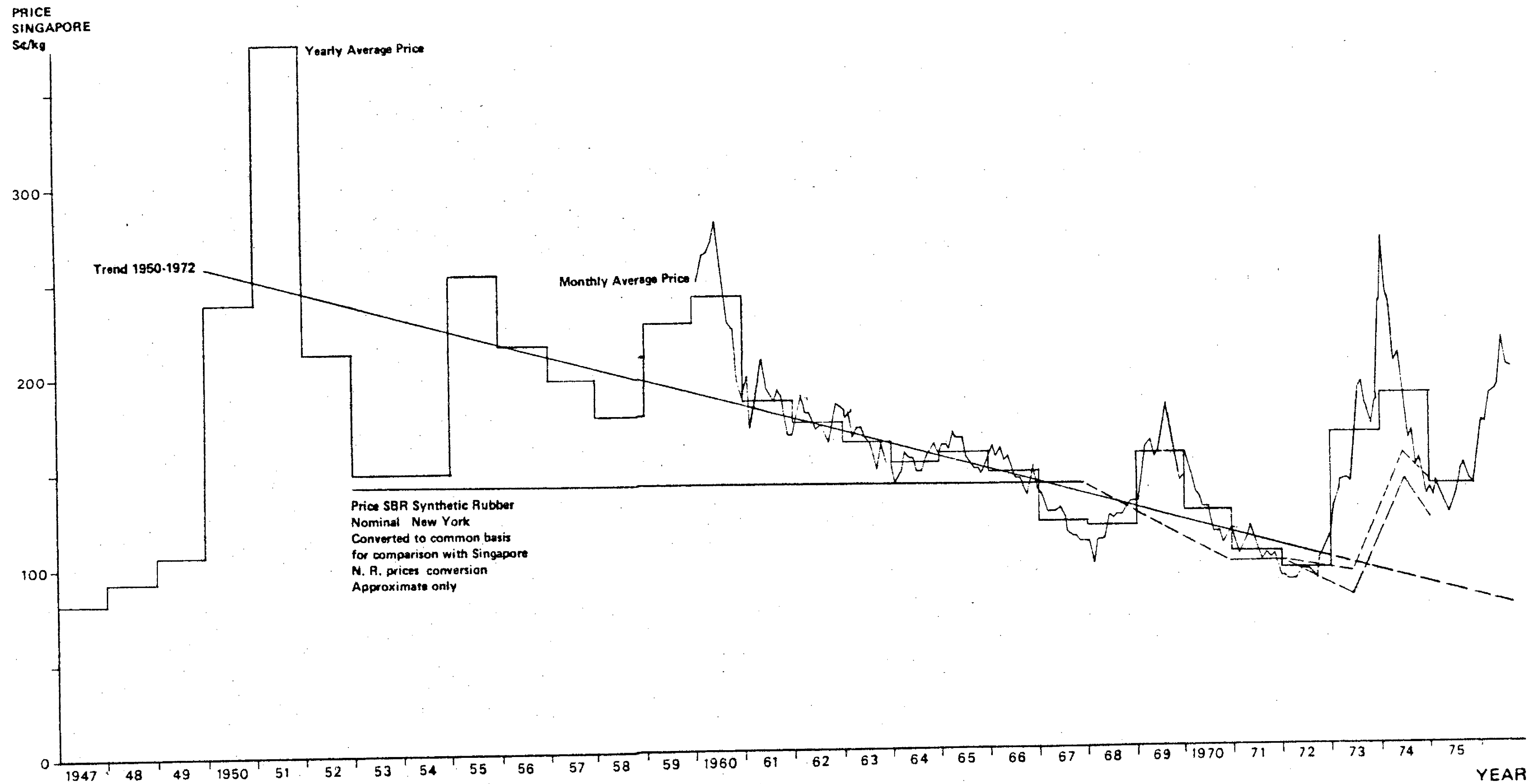
Available information indicates that the present acreage of estate rubber is only half of what it was in the late 1960s. This implies a loss of some 6,000 ha of rubber and about 5,000 jobs. Replanting, especially with high yielding varieties, has been very poor. The reasons for such a poor response include declining trend of world rubber prices (refer Figure 2.1), risk and uncertainty in relation to returns from an investment crop which has a long gestation period, inability to attract a more permanent labour force and the general awareness of the world demand for better quality rubber like TRS instead of the RSS which they produced. The estate sector has, on the whole, failed to provide the required impetus for the development of the PNG Rubber Industry.

2.1.2.2 The Smallholder Sector

The latest statistics available for 1976 indicate that there are about 3,662 smallholdings, with a total planted area of around 2,788 ha (Summary of Statistics (1978), p.52). It has been estimated that some 80 per cent of smallholder rubber plantings exists on village land. These are known as 'Village Rubber Schemes'. The remaining 20 per cent are on formalized land settlement schemes both in the Central and Gulf Provinces. The Gavien Settlement Scheme in the East Sepik Province is one of the more recent developments. There are about 200 separate villages all over the country involved in village rubber schemes. Information on smallholder rubber acreage, projected acreage, production and projected production is shown in Table 2.4.

The establishment of a smallholder rubber holding is usually done by the conventional method of hand cleaning of forest areas, burning, planting, and cover crop establishment. Planting spacing is relatively the same for most smallholders, with some variation depending on soil types, rainfall and topography. Polyclonal seedling was, until the end of 1976, the most common planting material on smallholdings. The beginning of 1977 saw the introduction of high yielding bud-grafted material of PR107 and GT1 clones, most of which was produced at the Bisianumu Station on the Sogeri Plateau in the Central Province. This material has an estimated yield potential of up to 2,000 kg per hectare.

FIGURE 2.1: NATURAL RUBBER PRICES AT SINGAPORE ACTUAL PRICES*



Source: Densley (1978), DPI.

* Prices for Ribbed Smoked Sheet

Table 2.4

Smallholder and Estate Rubber

Current and Projected Area and Production - by Locality

PROVINCE	TYPE	LOCALITY	CURRENT AREA* (Estimated ha)	PROJECTED AREA HA. (1981)	PRODUCTION 1975/76 (tonnes)	PRODUCTION POTENTIAL (tonnes)	
						1981	1985
Western	Village	Kiunga	550	600	17	120	210
		Nomad/Debepari	10	320	–	–	20
		L. Murray	290	525	5	35	120
		Balimo	630	1,125	4	80	240
		Oriomo/Bituri	150	190	–	15	60
	Settlement	Suki	190	235	2	20	100
	Total		1,820	2,995	28	270	750
Gulf	Village	Ihu	5	5	–	–	–
		Hevoro	15	15	1	2	–
		Baimuru	10	15	–	–	5
		Kikori/Kaiam	30	65	–	8	15
	Settlement	Murua	165	170	40	55	80
	Estate	Kerema	1,400	2,000	145	190	240
	Total		1,625	2,270	186	255	340
Central	Village	Rigo	30	30	1	3	15
		Nunumai	15	20	1	5	10
		Bakoiudu/Kubuna	370	375	59	75	180
	Settlement	Cape Rodney	450	710	106	240	280
		Bailebo	105	220	2	15	38
	Estate	Galley Reach	1,792	1,830	1,846	1,703	1,715
		Sogeri	1,681	1,401	1,926	1,127	1,050
		Rigo	95	95	34	76	80
		Cape Rodney	110	140	70	78	78
	Total		5,248	4,821	4,045	3,322	3,446

(contd.)

Table 2.4 (Contd.)

PROVINCE	TYPE	LOCALITY	CURRENT AREA* (Estimated ha)	PROJECTED AREA (1981)	PRODUCTION 1975/76 (TONNES)	PRODUCTION 1981	POTENTIAL 1985
E. Sepik	Village	Amboin	80	800	2	20	100
	Settlement	Gavien	40	910	–	5	700
	Total		120	1,710	2	25	800
W. Sepik	Village	Amanab	–	50	–	–	5
		Imonda	–	–	–	–	–
		Green River	–	–	–	–	–
	Total		NIL	50	NIL	NIL	5
Northern	Village	Kokoda	345	395	67	100	170
		Popondetta	150	160	42	3	NIL
	Estate	Kokoda/Wanigela	453	400	422	351	315
	Total		948	955	531	454	485
New Ireland	Village	Mussau	25	50	–	3	10
	Estate	New Ireland	203	250	119	245	245
	Total		228	300	119	248	255
Manus	Village	Manus (Is)	100	200	–	30	50
	Total		100	200	NIL	30	50
TOTAL	–	–	8,889	13,301	4,911	4,604	6,131
	Summary –	S/Holders	3,755	7185 (+91%)	349	834 (+139%)	2,408 (+189%)
		Estates	5,134	6,116 (+19%)	4,562	3770 (– 17%)	3,723 (– 2%)

Source:– *Estimates by D.P.I. Rubber Section. Figures are subject to substantial change as a result of current surveys being undertaken, and persons desiring more recent figures should consult D.P.I Rubber Section.*

Note:– *Smallholder area (Ha) includes both mature and immature rubber.*
Estates area (Ha) denotes area in tapping only (i.e. does not include "retired" areas).

* – *January, 1977*

Reporting on the smallholder rubber sector, Arkhurst and Mitchell (1976) stated that 'a remarkable feature of the smallholding rubber plantings ... was the absence of any obvious signs of major diseases or health problems in the trees, in spite of the absence of precautionary and preventive measures'. Fertilizers, yield stimulants, weedicides and pesticides are hardly used by smallholders. The average imputed area planted per farmer was about 1.1 ha, although this can be as high as 7 ha in some of the settlement schemes. This was found to be the case in Cape Rodney, the scheme being used for analysis in this study. Latex produced on most settlement schemes, apart from Murua, is centrally processed in factories operated by DPI field staff. Latex is either collected or delivered to the central factory where RSS is produced. Most schemes don't have facilities capable of processing scrap and cup lump. Village scheme producers process and smoke their own rubber as RSS.

With the maturity of rubber trees, smallholders can obtain loans from the Development Bank of PNG to assist them in purchasing essential harvesting and processing equipment. Such loans, in arrangement with the Bank, are repaid through periodical deductions from rubber income. Some smallholder rubber growers receive income from the production of other commodities such as cattle, crocodile skins, chillies and vegetables. The Cape Rodney farmers are fortunate in this respect in having a large vegetable market at the capital city, Port Moresby, which is readily accessible. Such income is usually very useful, especially during the initial immature period.

Tapping procedures are of the conventional type, with the gouge tapping knife being widely used. The DPI field staff, however, are now promoting the use of the Malaysian 'jebong' which is preferred as a safer and more efficient tool. Both V-cuts and half-spiral (S/2) cuts are used, the latter being the more common system among settlement scheme growers, with an alternate daily frequency. The village scheme growers, on the other hand, find that the full-spiral fourth daily (S/1, d/4) is a convenient system, especially in relation to the many customary and social obligations they are faced with in a village environment.

No empirical measure of average costs of production has ever been done for the PNG rubber smallholders. However, given that all smallholders use only family labour and that labour costs make up about 50 per cent of the total cost on estates, the average cash cost of production on smallholdings must be less than half of that incurred on estates. Besides, processing equipment on smallholdings is either government owned or is very simple in nature and is therefore less costly.

Despite the general optimism for the development of smallholder rubber production, PNG smallholders have encountered some specific problems, which may have had negative impact on the overall development of the industry. The most common problem among village scheme growers has always been that of isolation. This results in farmers not being able to obtain tapping and processing equipment as required and also causes extension and marketing problems. Problems on the settlement schemes are numerous and varied. They include:

(a) successful applicants not being able to take up their blocks or fulfill lease covenant conditions resulting in insufficient production to warrant early establishment of central processing facilities;

(b) lack of adequate infrastructure (roads, schools, clinics, etc.) and low staffing levels making continued residence on isolated blocks fairly unattractive to settlers;

(c) continuing land disputes, especially in Cape Rodney, between the government and traditional land owners, involving the amount of land compensation.

Smallholder rubber production figures are provided in Table 2.2. They show that the level of smallholder rubber production is still very low, accounting for only some 4 to 14 per cent of the country's total rubber production. What is encouraging, however, is that it is increasing annually. The provincial breakdown in Table 2.4, indicates that over half of the national smallholder rubber output comes from the Central Province, of which the Cape Rodney Resettlement Scheme is the major producer.

2.1.3 The Institutional Framework

The main features and institutions of the PNG Rubber Industry are presented in Figure 2.2. It indicates three distinct divisions within the industry. These are (a) external bodies and buyers; (b) policies, purchasing, management and extension; and (c) production coming from estates and smallholdings. Only the main features of its internal structure will be discussed below.

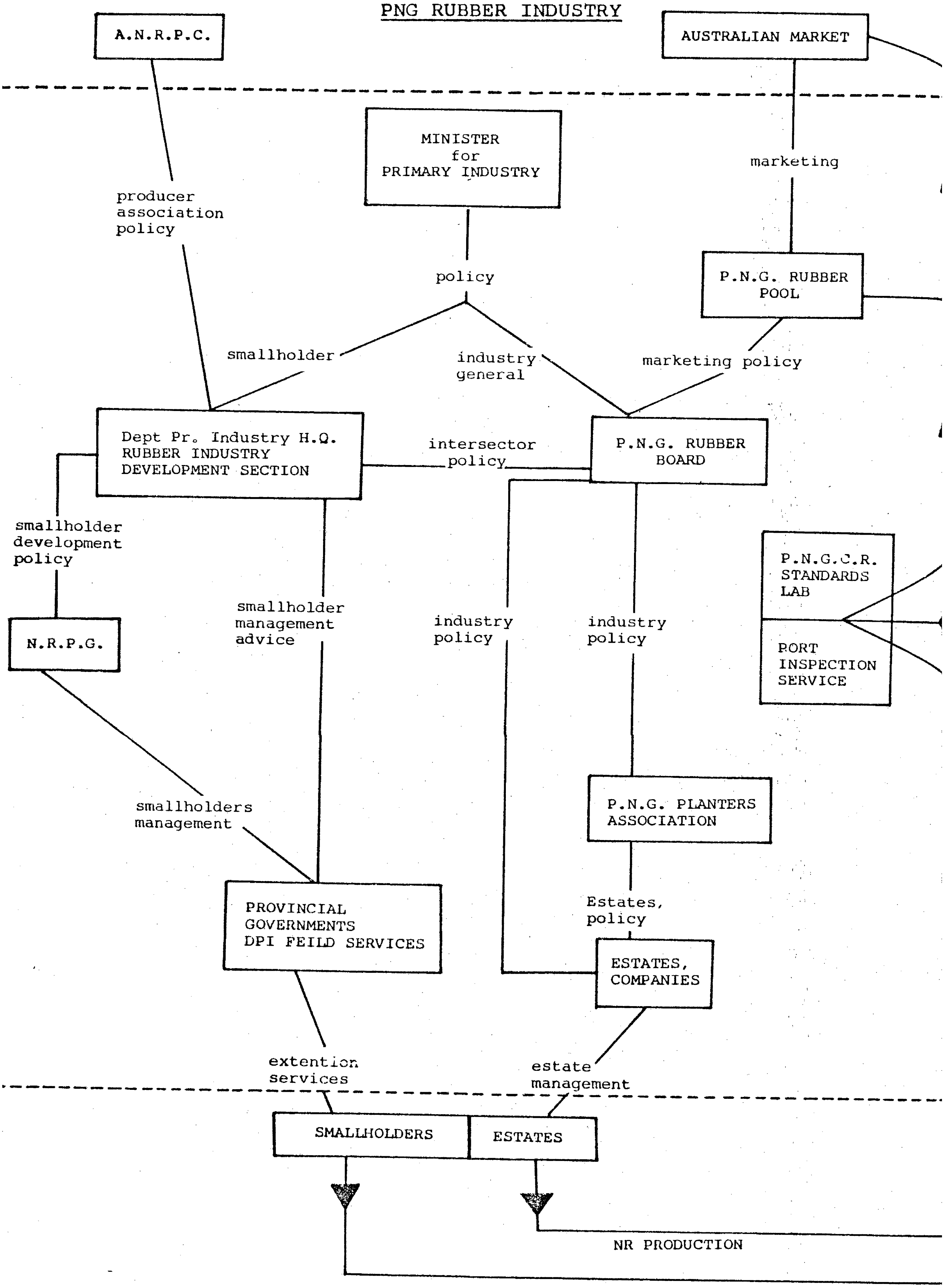
2.1.3.1 The Department of Primary Industry

The Rubber Section within DPI is responsible for the management of all matters relating to smallholder production. It is involved in the planning of new investments as well as assisting in overseas investment programmes. The PNG Rubber Board also comes under its administration, although it is somewhat of a semi-independent body.

All smallholder rubber output is bought by DPI which then transfers it to the Rubber Board and is then exported through the PNG Rubber Pool. DPI, through its Planning, Economics and Marketing Branch, also administers a price equilisation scheme as an overall effort to reduce

Figure 2.2

PNG RUBBER INDUSTRY



Source: Carrad (1981), DPI.

the negative effects of highly fluctuating rubber prices.

2.1.3.2 The PNG Rubber Board

The establishment of the PNG Rubber Board took place through the 1953 Rubber Act, passed by the then Australian Administration. The Board itself was fairly dormant until 1973 when it was re-activated by the Minister for Primary Industry. Since then, it has been particularly active in areas of quality control, market presentation, containerisation and the PNG Classified Rubber (CR) Scheme. The Board manages the PNGCR Standards Laboratory and provides a port inspection service for exports.

2.1.3.3 Provincial Government

Only 3 years after independence in 1975, the fiercely debated issue of provincial governments came to an end. All the 19 provinces of PNG now have their own provincial governments, out of which some 8 provinces have planted rubber areas and several others are potential producers. The main government departments have been decentralized and all officers working out in the field are administered by provincial governments. Since each province can now determine the types of economic activities they want to pursue, rubber has now become a popular crop. There has been an overall increase in the demand for planting material as well as technical support and extension advice.

2.1.3.4 PNG Rubber Pool

The PNG Rubber Pool was established in 1950 and it is responsible for the marketing of all PNG rubber. It is made up of a group of agency houses which receive a commission of 2 per cent c.i.f. value as payment for services they provide. Australian tyre manufacturing companies are the major buyers of PNG rubber, who between them, purchase some 80 per cent of all PNG exports. This marketing arrangement is based on a 1958 trade agreement between PNG and Australia, which guarantees Australian purchase of all rubber exported from PNG.

2.1.3.5 Credit

The PNG Development Bank (PNGDB) is the major source of smallholder credit, making finance available for tapping and processing equipment, building material and marketing facilities. On settlement schemes, bank staff usually operate through the project managers in arranging and managing loans and repayments. Repayments are automatically deducted from the farmer's fortnightly payment. On village schemes, bank agencies are established to handle loan and repayment arrangements. Smallholder loan terms are generally reasonable, with an average of 9 per cent interest rate payable over a 13 year period. On estates, depending on ownership, financial arrangements are either made through commercial banks or through the PNGDB. Generally, finance (credit) is not a constraining factor in rubber production.

2.1.3.6 Smallholder Groups

Individual smallholders getting together to form groups for marketing and business purposes related to the production of rubber is not uncommon in PNG. Some even develop into co-operatives, but with mixed fortune. Village schemes especially have had many failures in this respect. Settlement schemes, however, have Settlers' Councils which have been fairly effective in airing grievances and helping new settlers to adjust to the new way of life.

2.1.3.7 Planters Association of PNG

The Planters Association of PNG was established before World War II and membership is open to both the estates and smallholders. However, only a handful of smallholders are members of this Association, the majority being estate owners. Since its establishment, membership has been declining, such that the Papuan Region, which has the majority of the country's rubber growers, only has less than a dozen members. The major role of the Association has so far been that of making submissions to the National Government on issues related to estate rubber such as wages, freight and shipping costs.

2.1.4 Government Policy

Government policy towards agriculture and rubber has been broadly stated in its Improvement Plan, 1973/74. The major emphasis is on rural development taking place on a more equal basis. Among the crops of economic importance, rubber is specially mentioned for expansion as a smallholding industry where it is regarded as particularly suitable.

Broad policy guidelines for the PNG Rubber Industry were adopted in January 1978, by the National Executive Council which is the major decision-making body of the National Government. These are summarized by Carrad (1981) as follows:

(a) That rubber as a cash crop is a suitable vehicle for rapid rural development, especially in areas where smallholder schemes have been already established, and in lesser developed areas.

(b) That the nucleus estate type of development is an ideal form in which rapid smallholder development of rubber could be achieved.

(c) Approaches should be made to reputable national and foreign companies seeking development proposals based on the nucleus estate principle.

(d) That adequate technical personnel would be necessary to achieve industry development.

(e) Importance of planting material development, research and training, better marketing and quality control and the long-term need for the establishment of a rubber goods industry.

2.2 The Cape Rodney Rubber Resettlement Scheme

2.2.1 History

Considerable emphasis has always been placed on overall agricultural development throughout PNG. Such development has taken place through many ways, the major one being the exploitation of cash crops, most of which are perennial tree crops. Rubber is one such crop, generating numerous projects throughout the country. The Cape Rodney Rubber Resettlement Scheme is one of these projects.

Before the actual establishment of the scheme, a number of land surveys were carried out by the DPI Land Utilisation Section, the largest of which covered some 15,000 hectares between the Mori and Bomguina Rivers (Refer Map 5). These surveys recommended rubber as a suitable crop for the area. Most of this land was 'Crown' land. The land was then subdivided and allocated over a period of about 7 years starting in 1961. Included in this number were 14 larger portions which were leased to non-smallholder expatriates and missions, the rest being smallholder lease grants.

There are 24 ethnic groups within the scheme and most of them are minority groups. The 5 dominating ethnic groups are Domara, Ianu, Aroma, Dom and Kerema, all of which except the last named are from the Cape Rodney area itself. Early settlement on the scheme was carried out with great difficulty. Roads were virtually non-existent and initial planting material had to be carried into the blocks by hand. Other facilities like aid posts, schools and retailing stores were also not developed. A number of blocks were initially settled while others were abandoned at various stages of development. Policing of PNGDB loan expenditure was not adequately carried out with the result that some settlers, after using all their living and tool allowances without developing their blocks, abandoned them, owing money to the bank. To date, no serious effort has been made to recover the money.

In 1972, DPI erected a factory at Moreguina (refer Map 5) and commenced buying latex from settlers who had persisted in spite of the many difficulties. This was a very simple factory, using manually operated rollers to roll rubber sheets which were then dried in Devon type driers. The situation has improved since then with a major improvement being the installation of brick tunnel-type driers. This facilitated the handling of a larger volume of latex and consequently lowered the average costs of production.

Output from the scheme has increased from a mere 50 tonnes in 1973 to some 400 tonnes in 1980; an eight-fold increase over 7 years. Initial output prices paid to smallholders were very low, averaging in 1972/73 at around 19 toea/kg[a] dry rubber. This has gradually increased over the years and at the time of this study the average price was 50 toea/kg, with a minimum price of 17 and a maximum of 80 toea, during the year.*

The average monthly income in 1980 was about K100 or some K1200 per annum, with extreme variation between individual farmers, the highest amount being some K500 per month. Currently there are about 180 settlers tapping some 250 hectares of rubber. This is approximately 60 per cent of the mature rubber on the scheme. In addition, there are some 100 hectares of immature rubber, giving a total of 550 hectares of rubber.

(a) K1 = $A1.30
* Prices for same grade material.

2.2.2 General Features

2.2.2.1 Location and Administration

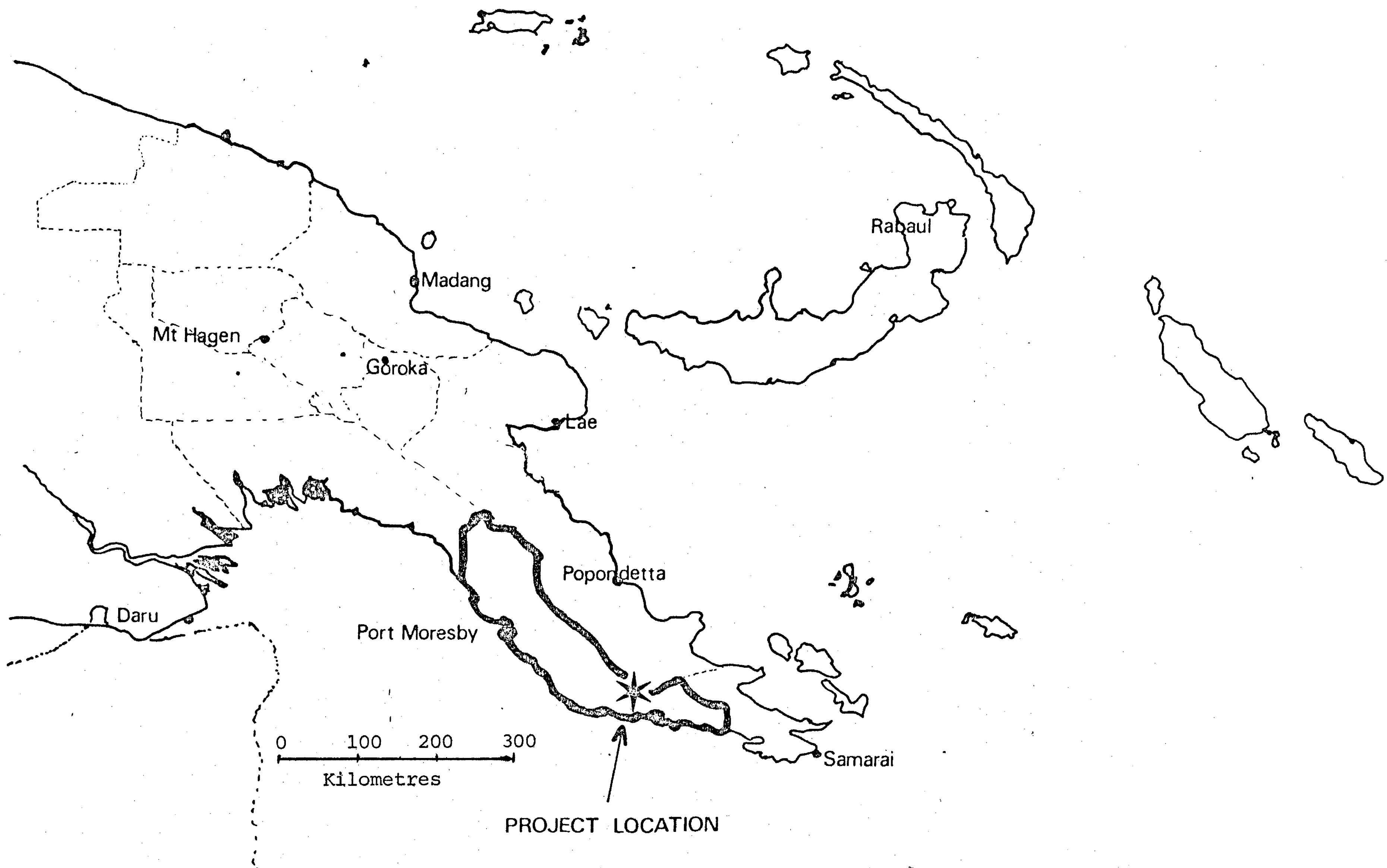
The Cape Rodney Rubber Resettlement Scheme is located some 250 km southeast of the capital city, Port Moresby, in the Central Province (Refer Maps 3 and 4). Being a 'national' project rather than a provincial one, all funding and administration comes from the national government. DPI is the government department which has overall control of the scheme. The Rubber Section within the DPI, in particular, is the central administration unit not only for this scheme but all smallholder schemes throughout the country.

Located within the project area is Moreguina Town, the local administrative headquarters, where project officers are posted whose task is to liaise between the farmers and the staff of the Rubber Section (Refer Map 5). The Scheme has a project manager and a project co-ordinator who have overall authority over the dozen or so field officers and a few clerical staff working on the scheme.

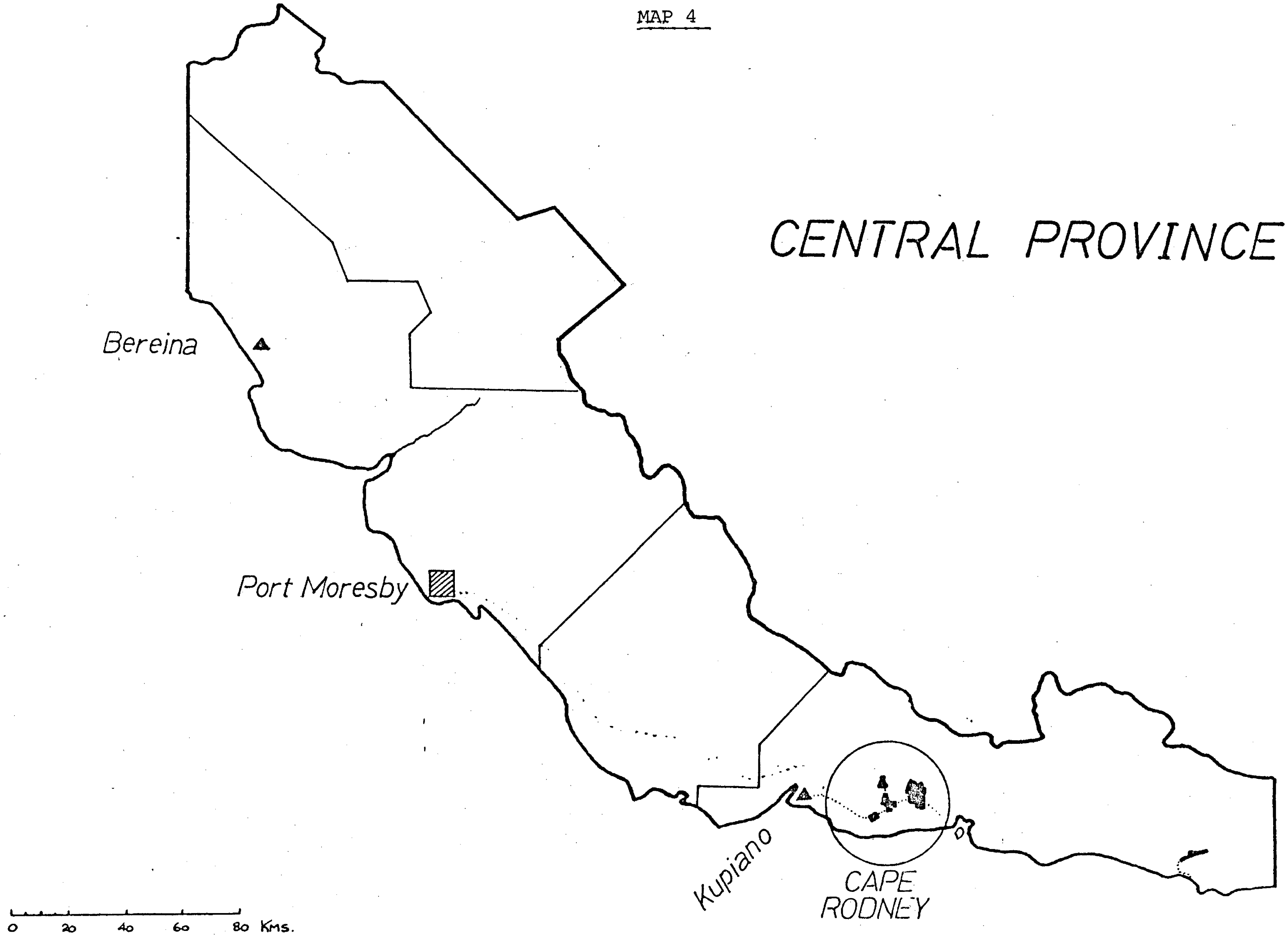
The project area is divided into sections so that field officers work only on one section during the allocated time. These divisions and the number of officers working in them are: Manabo and Ianu divisions with 2 officers each, and Cocoalands division with 7 officers, the latter being the new redevelopment area (Refer Map 5). The scheme has its own nursery producing usually bud-grafted material. Currently, about 5 officers along with numerous labourers are involved in nursery work. The remaining 2 officers are involved in 'Small Crops and Nutrition' work. This involves the promotion of small crops such as peanuts and chilli as well as the provision of nutritional advice to the smallholders.

The factory where all the latex is processed has a manager, an experienced Malay and two other officers who help in keeping up-to-date

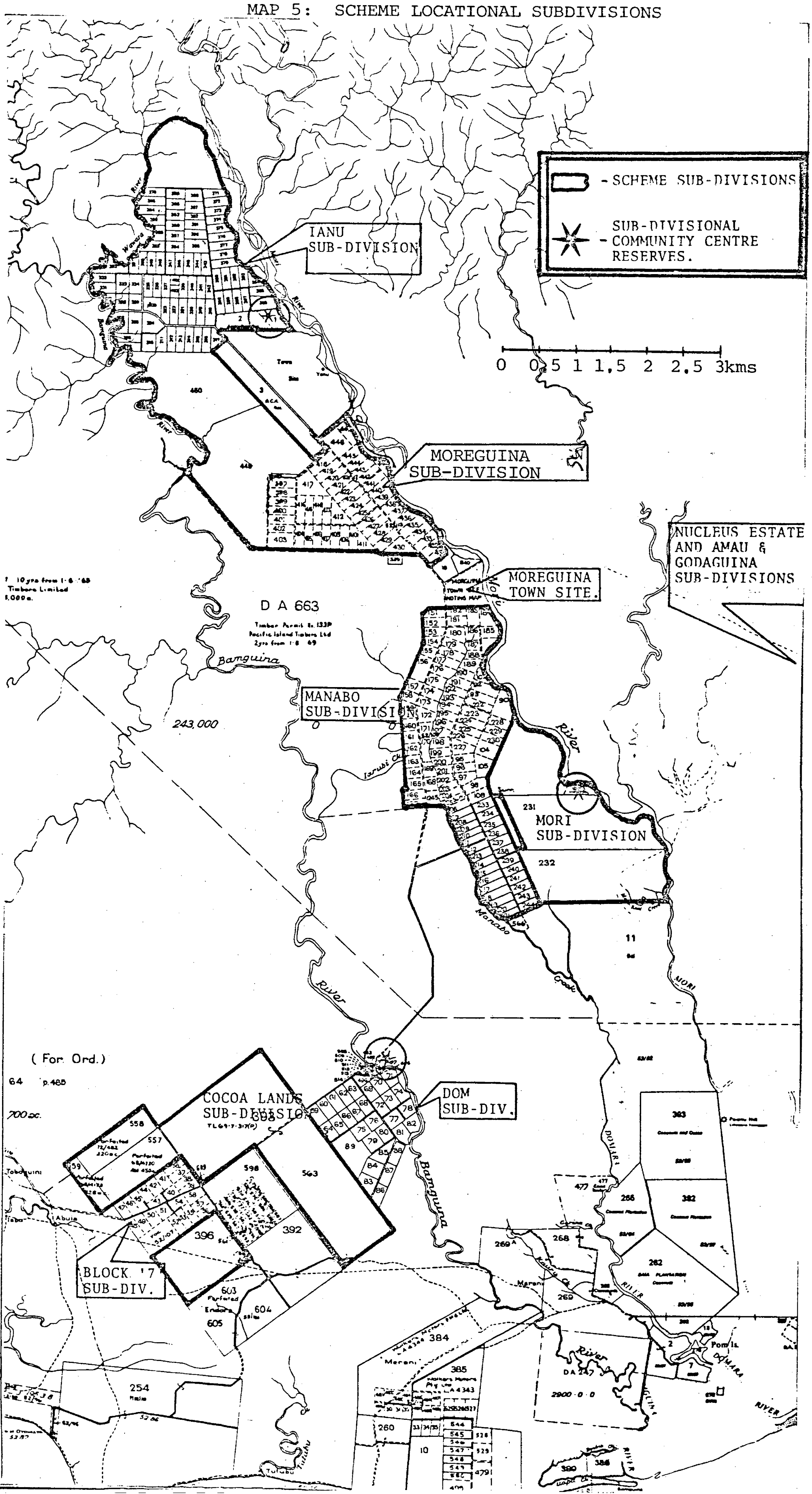
MAP 3: PROJECT LOCATION



MAP 4


CENTRAL PROVINCE
Bereina
Port Moresby
Kupiano
CAPE
RODNEY
0 20 40 60 80 Kms.

MAP 5: SCHEME LOCATIONAL SUBDIVISIONS



and accurate records. Each working day (Monday to Friday) factory staff go around all the blocks, weighing latex tapped each morning. Numerous weighing centres are situated along the roadside and they are all within easy reach, at the most some 5 minutes walk from tapping areas. At fortnightly intervals farmers come to the DPI office in Moreguina to collect money they have earned selling latex. To prevent malpractices all farmers keep some form of record, indicating their daily produce.

2.2.2.2 Environmental Factors

Like the rest of the country, the climate is tropical and is influenced by a monsoon cycle. Generally, the southeast air stream prevails from April to October and the northwest from November to March. The average annual rainfall in the area is about 2175 mm, with a reliably high rainfall period existing between March and September as shown in Table 2.5. The rubber planting season usually commences in January, following which 6 to 7 months of increasing rainfall is beneficial to the young immature rubber.

Throughout the scheme area soil surveys have shown that there exists a complex distribution of soils, generally being medium to fine textured alluvial and lateritic types. The topography of the area is generally flat, with patches of undulating and gently sloping land. Because of location within a few kilometers from the edge of the Owen Stanley Ranges (the mountain range forming the central divide) the scheme area has generally cooler temperatures than the sea coast.

2.2.2.3 Major Economic Activities

Within the Cape Rodney area, are seven established plantations, producing a mixture of rubber, coconuts and some cattle. These were initially owned by expatriates living in the area but are now in the

Table 2.5

Rainfall Averages by Month

(10 Year Average

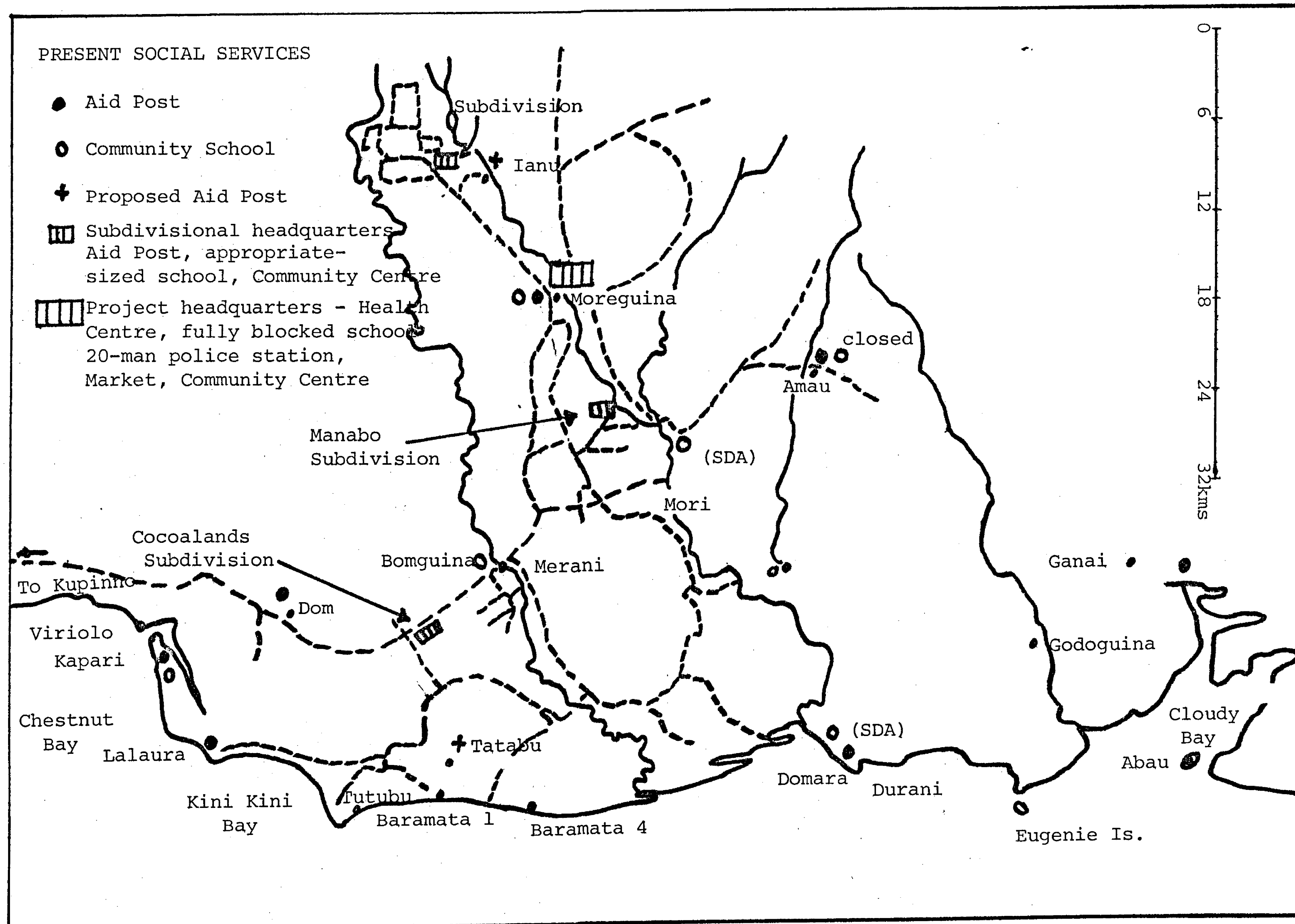
Month	Rainfall (mm)
January	103
February	91
March	253
April	256
May	289
June	276
July	205
August	261
September	163
October	80
November	61
December	71
Average	175.75

Source: DPI - June 1979.

hands of a few public companies like the Burns Philp and the Steamships Trading Company.

Only some 20 kms away from the scheme itself is the Associated Pulp and Paper Mills Ltd (APPM) which has interests in timber extraction and processing in the area. It supplies products to the PNG building industry as well as exporting to the Australian and Japan markets. After several changes in ownership, the Company is now owned and managed by the Steamships Trading Company. Its installations at Kapari and Kupiano (refer Maps 4 and 6) are major sources of employment for both skilled and unskilled labour in the district.

MAP 6: PROJECT AREA



The majority of the local population live in coastal villages and most are engaged in subsistence production, selling whatever surplus they can produce at the local markets. Copra production is now not as common as it used to be some 20 years ago. The main reason for this is that alternative sources of income are more attractive. Fishing has always been a major source of income, especially for the Viriolo people (refer Map 6), who are migrants in the area and are therefore not landowners.

With the development of better roads, linking villages, town centres and the capital city (Port Moresby) many people including settlers and villagers have taken up trucking business, retail stores and other small business activities. The ordinary villager now has more opportunity to earn money than ever before.

2.2.2.4 Subsistence Production by Settlers

Mention has already been made of the situation that all rubber smallholders, apart from producting rubber , also engage in the production of subsistence crops. An effort will now be made to provide a general description of the relationship which exists between the two distinct modes of production.

Before the initial planting of rubber trees, a subsistence garden is usually established on the cleared land. This procedure serves two main purposes. It provides a source of food and supplementary income during the maturing stages of the rubber trees and at the same time acts as cover crops for the young rubber. Crops such as banana and cassava are usually used for this purpose. Other crops grown in subsistence gardens include mostly root crops such as sweet potato and taro along with a few other minor fruit and vegetable crops. Just before the harvest of all the food resources in the subsistence garden, a new area is usually cleared and the same procedure is more or less repeated with new rubber plantings being made only in every third or fourth garden, depending on the recommendations of the field officers. The farm area occupied by the new subsistence gardens is usually much less than that occupied by the rubber trees.

The division of labour generally differs depending on the time period in question. During the initial stages of development when the rubber trees are still immature, division of labour is based on the traditional pattern: men doing the heavy clearing and maintenance tasks while the women are engaged mainly in the planting and harvesting activities. When the rubber trees become ready for tapping, the average time spent by the men in the subsistence garden generally declines while that spent by women marginally changes. The general pattern of work then is that men do the harvesting and maintenance of the rubber trees while the women take care of the subsistence garden. Even then, the heavier tasks in the subsistence garden still have to be done by the men, implying therefore that the rubber farmers generally work a lot harder than the ordinary subsistence gardener.

The importance of this discussion lies in how the production levels of both activities are related, that is, whether the activities are complementary or competitive. The exact relationship can only be determined through an empirical study. But on the basis of observed facts, the general trend of this relationship can be established. This is attempted in the following discussion.

Even without knowing the settlers previous levels of subsistence production, we can safely argue that it has not declined when combined with rubber production. Several observed facts justify this argument. Firstly, at local markets which are used by both the settlers and the nearby villagers, it was generally noted that the settlers tended to bring as much as 3 to 4 times more produce than the average village vendor. Related to this is the observed situation that settlers tended to travel more to the capital city in search of markets for their subsistence produce than a comparable average village producer. Thirdly, despite increases in family sizes which must have taken place during their settlement period, the availability of subsistence produce is more than sufficient, usually resulting in a surplus. The above arguments clearly indicate that the subsistence component of production carried out by the rubber smallholders has somewhat improved when combined with rubber production.[1]

The important question for the purpose of this study, however, is that of the impact of subsistence production on rubber production. Clearly, this would vary from farm to farm, depending very much on factor constraints and the desires and aspirations of individual farmers.

Where labour is a constraining factor of production, as observed on a couple of farms, the two activities become competitive. That is, as more labour is allocated to one form of production, less labour time is spent on the other. For example, if more labour time is spent in subsistence production, a larger amount of surplus will be available for sale which would probably mean more time spent in selling as well as travelling to markets. The exact impact of this on the level of rubber production will depend largely on the component of labour being sacrificed. If maintenance labour is being sacrificed the level of rubber output will only change marginally. On the other hand, rubber output will drastically decline if harvesting labour is being sacrificed. The opposite situation would apply if more labour time is allocated to rubber production.

Land is not as yet a constraining factor of production for the settlers on the scheme. This means that farm land area devoted to each of the activities can be increased independently and at the same time,

[1] Tend to work longer hours to handle the extra activities.

assuming that other factors of production are allowed to vary, accordingly. At present, the average farm size is about 11 hectares, much of which is under rubber, with some farmers having as much as 7 hectares of rubber both mature and immature trees. Because rubber is initially planted in areas established also for subsistence gardens, we can argue that the relationship between the two activities in relation to land is a complementary one. The productivity of both activities cannot be easily compared because of the differences in their gestation periods as well as the obvious difference in the nature of output.[1]

Some equipment can commonly be used in both types of activities. These include bush knives, grinding stones, axes and spades. Others, however, are more specific, especially to rubber production. These are tapping knives, cups, spouts and buckets. Using equipment like knives, axes and spades in both activities may indicate a higher degree of utilisation, but it also inevitably leads to a higher depreciation rate of the equipment. This in turn implies that the period of replacement is much shorter. This increases the average costs of production which in turn affects the farmer's profitability, the main motive for being engaged in rubber production. Hence, the use of common equipment is somewhat competitive but this doesn't necessarily influence the output levels of both activities since they are used in one activity only when not needed in the other.

On the whole, it seems certain that rubber production has, to some extent, enhanced subsistence production, especially in terms of the production and marketing of subsistence produce. The rubber smallholders not only produce rubber for sale but they also deliberately produce more subsistence products for the sole purpose of selling. Hence, they are not strict subsistence producers. Instead they are

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1 The gross value added per hectare per year and the labour inputs can be compared provided sufficient data is available.

more market oriented in their approach, although the element of production for subsistence purposes is in fact the initial motivation for doing so. Similarly, some element of competitiveness does exist between the two activities, especially in relation to labour use and availability.

2.2.2.5 Services

The Rubber Section within DPI, through their officers located on the scheme, provide all the agricultural services required by farmers on the scheme. The most important of these are the buying and processing of latex produced by the smallholders. Another is the provision of high yielding bud-grafted planting material from their nursery. Transport is also provided to deliver such material directly to the farm concerned. Loan applications to the PNGDB are processed and recommended by the project co-ordinator who usually supports all applications made by the farmers. Information, advice and treatment of tree diseases are also performed by the field officers. Advice can be in terms of extension, technical or even nutritional, not only to the farmers on the scheme but also to villagers who wish to grow rubber. Currently, very few villagers have so far taken up rubber, despite its promotion on the scheme.

All settlers on the scheme have easy access to roads which, until recently, had been poorly maintained. The real problem, however, is the inconsistency in transport availability, resulting in some farmers having to walk about 5 kms to get to trading stores. This also makes it difficult for the marketing of the large subsistence surplus generated on the scheme.

Map 6 provides a detailed guide to the number and location of social services currently available and planned for establishment in the near future. It shows that between the Cocoa-lands and the Ianu subdivisions, the two extreme areas of the scheme, there is only one established aid post, servicing both the settlers and the villagers in the area. However, each of the divisional centres has its own community school, with Moreguina having an International school mainly for the expatriate children.

Despite two major rivers flowing through the scheme area itself (Refer Map 5 - Bomguina and Mori Rivers), water has always been a problem for the settlers. Underground water pumps were provided initially as part of the loan arrangement, but most of them are currently out of order. Some farmers use 44-gallon drums to catch rain water but this doesn't usually last long. Most farmers, therefore, rely on water from nearby streams and wells.

All farmers have to build their own houses, soon after settling on the blocks. Most farm houses are built from locally cut timber from the nearby sawmill in Kapari. The standard of housing is therefore relatively high but with a great deal of variation. Some farmers still have shed type housing while others, after successfully obtaining loans, establish 'modern' type houses with iron roof, weatherboard or fibro walls, proper timber flooring and in one case, concrete posts. All field staff houses are established at Moreguina along with housing facilities for the field staff from other departments.

Located at the project headquarters in Moreguina is a single trade store owned by the settlers co-operative and run with marginal success. Only about 10 kms down the road at Bomguina are two more successful trade stores owned by two private individuals. These two trade stores provide a greater variety of goods, especially because of availability of electricity.

The scheme itself has two local foodstuff markets, both located at Moreguina and Bomguina (Refer Map 6). But the two major markets commonly used by the settlers are at Kupiano (Refer Map 4) and Kapari (Refer Map 6). Both the Kupiano and the Moreguina markets are open during the 5 working days of the week while the remaining two open only on Saturdays. Transport services to each of these markets is generally unreliable.

Other services generally provided in the area include a wharf and an airstrip at Kupiano, the district headquarters. Postal services for the scheme personnel are also provided at Kupiano. Communication facilities, however, are only available at the scheme headquarters, Moreguina. A road, recently completed, also connects the scheme area with Port Moresby (refer Map 4).

Currently, the settlement scheme is undergoing some major changes as part of the re-development plan. The major components of this plan are:

(a) Establishment of a modern TSR factory;

(b) Improvement of infrastructure and services; and,

(c) Improvement of initial settlement.

The first component, establishment of a TSR factory, is in line with government policy of converting visually graded rubber into TSR which will be known as PNG Classified Rubber (PNGCR). Sophisticated rubber processing machinery will be used to produce good and high quality rubber as required by the stringent test measures applied during the marketing process. Related to this is the establishment of a cocoa factory at a later stage, during the re-development period.

The second component of the re-development plan is mainly that of improving existing infrastructure as well as providing more services. Some examples include the establishment of community centres, sports fields and rural aid posts for each of the scheme subdivisions, upgrading of educational and health facilities and in some cases electricity provision. Increased staffing is also an integral part of the plan, with the creation of new positions such as welfare and business development officers.

The improvement of initial settlement is being attempted through several means. The most important of these is the establishment of a low cost housing before actual settlement. Along with this is the initial clearance of the planting area, on which a subsistence garden will also be established before actual settlement. The cost of this initial establishment will be part of a pre-approved loan from the PNGDB which will be paid back over a certain time period, beginning in the actual production year.

2.2.3 Settler Selection

Settler blocks are surveyed by the Department of Lands Settlement Division, which advertises the blocks when they are ready for distribution. Applicants are interviewed by government officers in their respective locations. The interview schedules are then scored according to the settler selection criteria provided in Appendix 2. These score schedules are passed on to the Land Board which re-interviews applicants and allocates the blocks to the successful ones. The Land Board consists of a Chairman from the Department of Lands and two representatives, one each from DPI and the Central Provincial Government.

CHAPTER 3

RUBBER PRODUCTION VARIABLES AND THEIR SPECIFICATION

This Chapter describes the different variable inputs which are usually found in any rubber production situation. Section 3.1 attempts to identify the logic of the rubber production process as observed in the study area. This logic will then be used in the following chapter to select an appropriate rubber production function. The next two sections give detailed classifications of variables, in terms of controllable and uncontrollable variables. Only those variables for which data was collected will be used in specification. The final part of this Chapter discusses the dependent variable, output.

3.1 Logic of the Rubber Production Process

3.1.1 The Botany of Hevea

The perennial para rubber trees (*Hevea brasiliensis*) can grow up to 30 metres when fully mature with branches extending upwards and leaves formed from three elliptical leaflets. The immature trees are characterized by several leaf storeys, usually far apart from each other. An important feature of mature rubber tree is the 'wintering' period which occurs once every year where the tree sheds its leaves. This period is usually followed by a decline in yields.

For optimum growth, Hevea requires a warm humid atmosphere with well distributed annual rainfall and can flourish in most soils at altitudes of 300 metres above sea level. The bark, which is of great economic importance, is made up of several distinct layers. Like all trees, hevea has a hard inner wood, next to which lies the cambium which is a 'thin layer of cells which by active division produce new wood cells to its inner side and soft bark outwards; the latter consists of the latex vessels' (Barlow, 1978, p.114). These latex vessels are tubes running up the trunk of the tree in a spiral fashion.

The latex which flows from these vessels is a by-product resulting from the process of metabolism.

3.1.2 Breeding

The process of breeding has been of immense value to the ordinary rubber farmer. In many instances, this process has resulted in average yields increasing substantially. Breeding of rubber trees is usually accomplished through cross-fertilization of the male and female organs. Vegetative breeding has also been used where the stock of a particular mother tree is divided up and these separate pieces are then used for propagation. Another method of breeding is known as 'bud grafting'. This occurs when buds from high yielding trees are grafted onto the stock of seedlings and such trees are usually known as 'clones'. Bud grafting can often take the form of 'green budding, crown budding or seed grafting' (Barlow, 1978). This procedure of breeding is common in PNG.

3.1.3 Planting

Before any planting can actually take place, there is the tedious task of clearing the vegetation and burning it when it is dry. In Cape Rodney this means clearing and burning virgin forest which is usually done by the farmer himself. Once clearing is completed, spacing procedures are undertaken, followed by actual planting of seedlings obtained from the Department of Primary Industry's (DPI) nursery located in Newtown, the administrative centre of the scheme (Refer Map 4). Cover crops are also established and this usually occurs in the form of a subsistence garden, planting crops such as banana, sweet potato, pineapples, taro and other minor crops. These subsistence crops are then the major source of food and revenue for the farmer and his family. Such an arrangement in planting is of benefit to the farmer because the maintenance of the young trees is done as part of his role in maintaining and harvesting the subsistence garden. Since harvesting of the subsistence garden is done on a continuing basis, the rubber trees are well established before the farmer moves onto a new site to make a new garden. In many instances, such movement make possible the planting of more rubber seedlings, thus resulting in farmers having more mature trees than they could comfortably tap. The young established rubber trees are then left to mature with very little weeding and no inputs of fertilizer or insecticides. Sometimes the undergrowth under the immature tree is cleared to foster the growth of 'catch crops'. In Cape Rodney, the main catch crop is pineapple and some rubber farmers have been known to produce so much that they are not able to sell the whole crop, even in city markets, resulting in wastage of pineapples. This practice can adversely or beneficially affect the immature rubber trees. The adverse effect is that the intercrops have to compete with rubber trees for soil nutrients. It is beneficial in the sense that the speed of undergrowth is slowed down either by the intercrops themselves or by the farmer who also does some clearing during the harvesting period. Furthermore, during the early growth period, there is also the need to prune the trees and replace the dead ones. Pruning is done to secure a clean straight branch as well as preventing the tree from having rapid branch growth so that the incidence of wind damage is reduced. Replacements in this study account for only some 5 per cent of the mature trees. Thus the trees being analysed in this study are roughly of the same age.

3.1.4 Exploitation

The harvesting procedure used in rubber production is known as tapping. This involves cutting across the bark of the tree at an angle, usually from high left to low right so that a maximum number of latex vessels are intercepted. Initial tapping usually results in a smaller volume of latex which is often concentrated and viscous. Further tapping thereafter creates a larger and more dilute flow of latex.

The free flow of latex is influenced by several factors. The first of these is the 'hydro-static' or 'turgor' pressure within the latex vessel. This pressure is highest in the night and early hours of the morning and lowest during the afternoons due to heavy transpiration caused by the higher temperatures. A greater turgor pressure results in a larger volume of latex. After tapping, latex flow slows progressively and stops eventually after some 2 to 3 hours. This stoppage is due to what is called 'plugging' where a cap of dried latex covers the tapped portion, thus preventing further flow. The rate of plugging varies according to the type of material planted as well as the length of cut. Wintering, as mentioned earlier, also affects the flow of latex.

Tapping in Cape Rodney starts between five and six o'clock in the morning, sometimes with lamps being used to provide light. This is when the turgor pressure is greatest. Before cutting the bark, a strip of coagulated latex resulting from the previous day's tapping has to be removed. This is kept as scrap and it can be sold but most farmers are reluctant to sell this for some unknown reason. Following this, the rough surface of the bark is scraped with a home-made tool made from grass-knife metal. The farmer rapidly shaves thin slices of the bark along the downward sloping tapping panel with his tapping knife. This rapid shaving has to be completed before any latex can actually flow. This implies that when there is high turgor pressure, the former has only a couple of seconds to complete cutting one tree. Tapping is therefore a task which requires a great deal of precision and skill.

Latex flows down the sloping tapping panel onto a spout (an inwardly shaped metal instrument to direct latex flow) which directs the latex into an aluminium or glass cup placed on the ground. After tapping the trees the farmer either rests, has breakfast, or does some clearing of undergrowth while waiting for latex to flow. The flow of latex slows down after about two to three hours, due to the 'plugging' process. This is when latex from the cups is emptied into buckets and placed at the nearest buying centre ready for sale to the DPI buying trucks. The trucks only stop at the buying centres. Latex is bought only during the five working days of the week. Actual buying of latex does not take place straight after the latex is collected. The buying trucks merely weigh the latex and its actual weight is converted into a Dry Rubber Content (DRC) measure, which is some 30 per cent of the actual weight of the latex. At the end of ten working days, farmers then go to the administrative office to collect their earnings. In this study, therefore, output of rubber is measured on a DRC basis in kilograms. All processing of latex is done at the government factory located on the scheme. Prior to this study, latex was processed into Ribbed Smoked Sheets (RSS) and exported. The present redevelopment plans have, however, resulted in the erection of a government-owned factory which is capable of producing Technically Specified Rubber (TSR).

Rubber harvesting has other characteristics. One of these relates to the depth of cut. The depth of cut in the inward direction has been found to be an important significant factor in determining the level of output. A tapping cut must penetrate far enough to open up the maximum number of latex vessels, but not so deep that the cambium is cut. When the cambium is touched, this causes irregularity in the renewed bark which may later cause tapping difficulties or even abandonment of tree. Bark renewal is another characteristic of the rubber tree. After tapping, the first renewal can take up to seven years while the second renewal can take as long as ten years. The rate of bark renewal usually depends on the vigour of growth of the individual trees.

3.1.5 Upkeep

Rubber production not only involves breeding, planting and exploitation, but also the general maintenance of the trees as well as the farm. Maintenance of rubber trees can start as early as the day the seedlings are planted. The task of maintenance can occur in the form of weed control, fertilization and pest and disease control. Weed control was the main form of maintenance observed in the Cape Rodney Resettlement Scheme. This usually involves selective weeding as opposed to clean weeding where the undergrowth is controlled so that it doesn't interfere with the tapping process. Such undergrowth is mainly small shrubs and grass.

Fertilization as a means of improving soil fertility is not practised at all in the study area. One reason for this, as indicated by a farmer, was the poor knowledge they have on the existence of such inputs, especially on how they should be used and what the costs and benefits are. Other technical reasons, like the poor response of low yielding varieties to fertilizer, may explain why fertilizers are not encouraged by DPI.

The incidence of pest and disease damage among the Cape Rodney rubber farmers was found to be fairly small, if not negligible. The task of maintenance in this respect is therefore less time consuming. In the few cases of disease attack reported, control measures were usually carried out by the DPI field officers. The main diseases known to attack rubber trees are the pink and root disease which, if serious, can completely kill the tree. Otherwise, they usually lead to a general decline in yields. The main pest commonly reported in Cape Rodney is the white ant. This ant usually attacks the branches of rubber trees.

On the whole, the maintenance of trees and the farm area is, in itself, an important part of rubber production. The process of rubber production, as briefly outlined above, is biologically and economically a complex process. Efforts to capture this complex process in a mathematical expression may, at best, be estimates of the real process. In this sense, a production function analysis is only limited to the portion of the process it can capture and explain.

3.2 Factors of Rubber Production

Input factors used in rubber production can be classified into two distinct categories. The specific classifications are shown in Table 3.1. On the one hand are controllable or decision variables. These variables are controllable in the sense that they can be easily influenced by whatever decision the farmer makes. Such influence can be in terms of quality or quantity. Controllable variables can be further subdivided into 'point' and 'multipoint' input factors. Point input factors are those variables whose quality and quantity once employed are fixed for the lifetime of that input. Such inputs include Rubber Trees, Farm Size and Planting Material, all of which are also essential variables. Conversely, multipoint input factors are those variables whose quality and quantity can change over time, depending on the decisions made by the farmer. Under this category come a whole host of inputs such as harvesting and maintenance labour, tapping system, fertilizer application, yield stimulants, pesticides and weedicides, other chemicals, management and sociological factors. In this category of inputs only harvesting labour and tapping system are essential inputs. The rest are supplementary or non-essential inputs. The distinction between essential and non-essential inputs is made later in Chapter 4. On the other hand, we have the set of uncontrollable variables. These are variables which cannot be easily controlled by the farmer, either in terms of quality or

Table 3.1

The Classification of Input Factors in Rubber Production

Classes of Inputs	Controllable (decision) Variables		Uncontrollable (state) variables
	Point	Multi-point	
Essential	Rubber Tree	Harvesting Labour	Age of trees
	Farm size*	Tapping system*	Soil types*
	Planting materials*	Equipment	Topography*
			Rainfall
			Solar radiation
Supplementary		Maintenance labour	Humidity, etc.
(non-essential)		Fertilizer input	Wind velocity
		Yield stimulant	Areas of high disease incidence
		Pesticides & weedicides	
		Other chemicals	
		Management & sociological:	
		technical knowledge	
		management and sociological factors	

Notes: * Binary variable

quantity. They include ecological factors such as soil types, topography, climatic conditions (including rainfall, solar radiation, temperature, relative humidity, and wind velocity), age of trees and the incidence of disease.

3.2.1 Controllable Variables

3.2.1.1 Point Input Factors

3.2.1.1.1 Rubber Trees

Rubber trees, one of the most important essential input variables in rubber production, is defined in this study both in terms of the total number of trees being tapped and the total number of trees. The planting density determines the number of trees which can be planted in a single hectare. This will in turn determine the yield level, either on a per tree or per hectare basis. Where there is a low planting density, one would presume that yield per tree will be relatively higher than at a higher density. In Cape Rodney, the present trees being tapped all had a planting distance of 6.3 m x 4 m., which made possible the planting of some 400 trees in a single hectare. It would seem therefore that the number of trees planted in one hectare has an important influence on the overall output level. The problem in specifying the tree variable in this manner is that not all trees in any single hectare are available for tapping. Some trees die and they have to be replaced so that during initial tapping the number of trees tapped is usually less than the number of trees in that hectare. This point indicates that the number of mature trees can significantly influence rubber output. However, in Cape Rodney, it was found that in many instances the number of trees being tapped was usually much less than the number of mature trees on the farm.[1] This implies that for the Cape Rodney data the number of trees in tapping should be specified as a variable representing trees as an input factor in rubber

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[1] Periodical resting of certain stands can also explain this finding.

production. However, for the sake of obtaining correlations, the total number of trees will also be used in regressions. The variables, number of trees in tapping and total number of trees are specified in this study as X_2 and X_9 respectively. It is expected that these two variables are highly correlated in a positive manner.

The statistics provided in Appendix 3.1 show that the average number of trees in tapping for the whole sample is 799.5, with a minimum of 65 and a maximum of 2,916 trees. The existence of such a big range may have been the result of several factors. Among those who have a large number of trees in tapping, there may have been a tendency to plant more trees in a single hectare than was recommended. In such a case, the incidence of risk is an important factor in determining the number of trees actually planted. It may also indicate the high level of confidence farmers have in rubber as 'the' investment crop. The reasons for having fewer trees than most farmers include mere laziness, fire damage and long absenteeism periods.

In terms of the breakdown used in Appendix 3.1, the most important one for analytical purposes in Chapter 5 is the Local and Non-Local Farmer divisions. For these two groups we find that the former have less trees in tapping, an average of 756, than the latter who have a higher average of 847 trees[1]. Ethnic wise (D_3 to D_9) we find that the Western Ethnic group have a higher average number of trees in tapping of 1,647, followed by Aroma (1,426), Domara (729), Kerema (697), Ianu (670), New Guinea (664) and Dom (486). The range between the minimum and maximum number of trees in tapping within the different ethnic groups is also large. The same reasons mentioned earlier also

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1 This difference is not statistically significant at the 5 per cent level. The procedure used is outlined in footnote of subsection 3.2.1.2.2.

apply here. The average statistics for the total number of trees are also available in Appendix 3.1, but are not discussed here because the variable itself is not considered significant in influencing rubber productivity.

3.2.1.1.2 Farm Size

Farm size has always been an important consideration when looking at the productivity of farms. The most common approach has usually been to study the effect of farm size on efficiency questions such as technical, allocative and overall economic efficiency. A few examples of such studies are reviewed in Section 4.2.1.2 of Chapter 4. Generally it is argued that smaller farms have a relatively higher level of economic efficiency than the larger farms. This, in turn, has a significant influence on farm productivity. It would therefore seem that there is an important relationship between farm size and farm productivity.

In this study, farm size is defined as the total land area under the control of the farmer. This implies the total land area he has been allocated under the resettlement program. The land allocation is on a lease basis for a period of ninety-nine years. The farmer has the freedom of choosing how much land he should allocate to each of the activities he is willing to undertake. The two most common activities are rubber planting and subsistence gardening. It is important to note that the whole farm area is not usually used in rubber production. In many cases, both rubber and the subsistence garden occupy only a portion of the farm area. For example, using again the average statistics provided in Appendix 3.1, we find that the average farm size for the whole sample is about 11 hectares while the average area occupied by productive rubber is 2 hectares. The total number of productive rubber trees is about 800, implying that there are, on average, 400 trees in one hectare. The average total number of trees is about 1,330. Dividing this by the number of trees per hectare gives us 3.325 hectares, the average area of the average farm occupied by rubber trees. This indicates that on average, only about one-third of the total farm area is occupied by rubber trees. Allowing for the portion of the farm area occupied by the subsistence garden we can presume that only about half of the total farm area is used in production, producing both latex and subsistence crops. Now since farm size, as an input variable is defined in this study in terms of the total farm area, it is postulated that it will not be a significant variable in influencing the level of rubber output. It is specified as input variable X_6.

The extent of variations in farm size seems to be large, especially when the sample is drawn from a resettlement scheme where one would presume that land allocations are relatively similar in size. This would certainly be true for the Cape Rodney Scheme, where the average farm size is about 11 hectares. The variation is then due to several other factors. The two most common reasons would be misreporting by the farmers or acquiring of new lands abandoned by previous owners who may have been relatives of the present owners. The former would probably be more common than the latter, because during interviews most farmers seemed to have no real idea of how big their respective land allotments were. The influence of the farm size variable on rubber output is not clear. Its inclusion in actual regression will reveal this influence. Besides, if farm size were to be specified in terms of land occupied by productive rubber, this would cause multicollinearity problems because this variable is already represented by the variable, number of trees in tapping, given that tree spacing is the same for all farmers.

3.2.1.1.3 Planting Material

One basic complication when analysing rubber productivity is that of variety or clonal differences. Three broad categories of rubber trees are clones, clonal seedlings and ordinary seedlings. Clones are rubber trees obtained mainly from a vegetative propagation technique known as budgrafting. Likewise, clonal seedlings are rubber trees grown from seeds selected from clones. Ordinary seedlings, on the other hand, are young rubber trees found anywhere at all which are allowed to grow into mature rubber trees. Not surprisingly, trees which develop from ordinary seedlings are known to have the lowest yields. The others produce a comparatively higher yield. This implies that with new rubber varieties higher average yields are imminent. Planting material, as an input variable, is therefore a good example of embodied technical change in rubber production. It is postulated that the type of planting material used would significantly influence the overall level of rubber output.

In this study, however, planting material is not specified as an input variable because of two reasons. The first is that the nature of data collection and available data made it quite impossible to determine the different varieties of trees presently being tapped. Secondly, all farmers on the scheme obtain most of their seedlings from the same source; the DPI nursery in Newtown. This implies that trees being presently analysed in this study come from the same variety of rubber, mostly from poly-clonal seedlings. Assuming that the distribution of these varieties is roughly the same on all farms, then there is no need to specify a planting material variable because it is constant for all farms. Besides, it is documented in the project redevelopment plan that the initial planting material used were mostly polyclonal material (DPI, 1979, p.6). These arguments justify the omission of this important and essential variable, planting material.

3.2.1.2 Multi-Point Input Factors

3.2.1.2.1 Harvesting Labour

Rubber production is a labour intensive activity. Given the present state of technical knowledge there seems to be no effective practical way in which tapping could be conveniently mechanized. Despite this, new tapping instruments are being developed which can somewhat reduce the labour input in harvesting.

Apart from rubber trees, harvesting labour is another important essential input in rubber production. It consists of several activities performed sequentially. In sequential order, these activities are tapping, resting, collecting and selling. Time spent harvesting depends largely on the number of trees to be tapped. That is to say that a farmer with more trees in tapping has to spend more time harvesting than another farmer with fewer trees to tap. This implies that there may exist a high correlation between the variable number of trees in tapping and the harvesting labour variable.

The first activity in harvesting, which is tapping, requires considerable skill. In order to obtain the maximum amount of latex a farmer should cut as close as he can without wounding the cambium and at the same time maintain the correct slope of cut so that a maximum number of latex vessels are intercepted during tapping. The thickness of bark being cut is also important because it can determine the rate of exploitation. For example, a thick shave will marginally produce a larger quantity of latex but it will substantially reduce the time taken by this farmer to fully exhaust all his trees. Therefore, provided a farmer does all the correct things, the amount of time he uses in harvesting will strongly influence the amount of latex he obtains. Hence, harvesting labour is a significant input variable in rubber production.

In this study harvesting labour is measured on an annual basis in terms of 8-hour man-days. It is the sum of time spent in all harvesting activities by all tappers in the family. To obtain the family's annual input of harvesting labour, the above sum is multiplied by the number of days the family was able to tap during the year. The data on the number of tapping days was obtained from the Factory records kept at the administrative centre of the scheme.

The formula used for the computation of the annual harvesting labour is a modified version of that used by Sepien (1978, p.119). It is as follows:

$$L_j = P_j d_j \frac{1}{60} \qquad (3.1)$$

where, L_j is the j^{th} farm family's annual harvesting labour in man-days;

P_j is the estimated number of hours the j^{th} farm family spent in all harvesting activities on a single tapping day;

d_j is the number of tapping days spent by the j^{th} farm family;

60 is a factor to convert hours into 8-hour man-days

$j = 1, 2, ...50$

The average statistics for L_j, P_j and d_j are provided in Appendix 3.1. These results show that average number of hours spent in harvesting per day, for the whole sample, is about 3 with a minimum of 1 and a maximum of 5 hours. This difference of 4 hours is mainly due to the vast difference which exists in the number of trees in tapping between farms. The Ethnic divisions in Appendix 3.1 show that the Western Ethnic group spend more time per day in harvesting than any other group. We find that the farmers in this group spend about 3.75 hours harvesting, with a minimum of 2.5 and a maximum of 5 hours: indicating that a farmer from this group actually spends the maximum time in harvesting. Grouping the others in sequential order we have the Domora Ethnic group with an average of 3.3 hours followed by Ianu (3.09), New Guinea (2.92), Kerema (2.86), Aroma and Dom both with 2.75 hours per day spent in harvesting.

The average number of tapping days for the whole sample is about 117, with a minimum of 5 and a maximum of 200 days. Since farmers are not allowed to tap during weekends and on rainy days, the maximum of 200 days is probably some 80 to 90 per cent of days available for tapping. This shows that not all days available for tapping are actually used for tapping. One of the main reasons for this, as mentioned in the introductory chapter, was that most farmers were not tapping because of the low output price during the survey period. The big difference between the minimum and the maximum number of tapping days may well have been due to the abovementioned reason. Another important explanation could be that most farmers from nearby villages tend to return to their respective villages for a certain time period each year, some for as long as 6 months. Related to this, some farmers, although having trees which can be tapped, prefer to do other things like getting formal employment and running other businesses such as trade stores and trucking activities. This probably explains why some farmers tap their trees for only 5 days out of the 200 or so available days during the year.

Harvesting labour in terms of hours per day and the total number of tapping days are both used to derive the input variable harvesting labour in man-days per year. The statistics in Appendix 3.1 show that the average value of this variable is some 45 man-days with a minimum of about 2 and a maximum of 125 man-days. The cause of such a big range in this variable is explained earlier. With respect to the Local and Non-Local Farmer divisions, we find that the latter group tend to spend more time harvesting than the former. That is, Local Farmers spend about 41 man-days while their Non-Local counterparts spend some 49 man-days in harvesting activities. This difference could be due to the difference in the number of trees in tapping between the two groups. It could also be attributed to the high absentee rate common among Local farmers. Either way, the difference in harvesting labour (man-days) between the two groups is not statistically significant at the 5 per cent level[1]. In this study, harvesting labour (man-days) is specified as the independent variable X_1. Differences in skills in harvesting labour would certainly exist but this is not considered here because these differences may be captured by another variable, Experience of Farmer, which will be discussed later in another section.

3.2.1.2.2 Maintenance Labour

Maintenance labour is the other part of the overall labour input where the main activities are those concerned with maintaining the cleanliness of the farm as well as maintaining the trees and the fertility of the soil. It is generally felt that in rubber production a well maintained farm can produce a higher output than a relatively similar farm which is poorly maintained. Teo (1976), however, argues that maintenance labour in the form of weeding and handslashing merely

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[1]
$$T = \frac{(\bar{X}-\bar{Y}) - 0}{\sqrt{\frac{\alpha_x^2}{n} + \frac{\alpha_y^2}{m}}}, \qquad t \sim (n + m - 2)$$

Where $\bar{X}$ = mean of group 1

$\bar{Y}$ = mean of group 2

α_x^2 = variance of group 1

α_y^2 = variance of group 2

n & m = sample sizes for groups 1 and 2 respectiv enhances the tapping activity. This argument was also found to be true by Sepien (1978) for the independent rubber smallholders in his study. This study defined maintenance labour in terms of family and hired labour used for manual and chemical weeding, controlling pests and diseases and manuring.

Maintenance labour in this study is defined only in terms of family labour engaged in weeding and slashing where the basic aim is to keep the undergrowth to a certain minimum. These activities not only enhance tapping but also improve the productivity of individual trees through their influence on the girth size. That is, proper maintenance increases the girth of the tree. The inclusion of this variable in regression would also indicate whether this variable is a complementary or competitive factor to harvesting labour. This relationship can be established merely by observing the sign of the coefficient of the maintenance labour variable.

Maintenance labour is again measured in terms of 8-hour man-days, calculated by using the formula (3.2) below;

$$L_m = \Sigma M_j \frac{1}{8} \qquad (3.2)$$

where M_j is the number of hours the j^{th} family members spend on all maintenance activities, $j = 1,2, \ldots 50$

and, $\frac{1}{8}$ is a factor to convert hours into 8-hour man-day equivalents.

We note in formula equation (3.2) that there is no differentiation between the productivity of different maintenance labour categories. For example, there is no distinction made between male, female and child labour, although their contributions would certainly differ given a constant time limit. Etherington (1973) in his study of tea production in Kenya differentiated these labour categories on the basis of the amount of tea leaves plucked per hour. Unfortunately, in this study such distinct categorization is not possible because of data deficiency.

The average statistics in Appendix 3.1 show that all farmers in the study, spent, on average, some 40 man-days doing maintenance activities, with a minimum of 12 and a maximum of 78 man-days. Such a wide range can also be explained in terms of the differences in the total number of trees farmers have. This is because the more trees one farmer has, the more time he has to spend maintaining them. The Ethnic division statistics show that the Aroma Ethnic group spend more time in maintenance activities, with an average of 47.44 man-days followed in sequential order by Western (45.5), Ianu (43.73), Dom (43.13), New Guinea (37.84), Domara (37.55) and Kerema (34.96). In terms of Local and Non-Local Farmer divisions we find that the former tended to spend more time in maintaining their farms than the latter, with their respective average figures being 42.97 and 37.44 man-days respectively.

In this study, the maintenance labour variable is specified as the independent variable X_{10}. Related to this, is the dummy variable, condition of farm (D_1) which is weighted on the basis of good, average or poor depending on the cleanliness of the farm. A clean and well kept farm was given a total of 3 points, an average farm 2 points and a poor farm only 1 point. This is not an important variable although it will be included in actual estimation to indicate the degree of its importance.

3.2.1.2.3 Tapping System

A tapping system refers to the manner in which rubber trees are harvested. The two important components of a tapping system are length of cut (spiral wise) and the frequency of tapping. The length of cut refers to how much of the circumference of the tree is tapped per harvesting period. Hence, if half the circumference of the tree is tapped, this is denoted by S/2, indicating a 'half-spiral' cut. Likewise, S/1 and S/3 would denote full and one-third cuts respectively. The frequency of tapping refers to the number of days a single tree is tapped during a working week of 5 days. Thus, daily, alternating or every third daily tapping frequencies can be denoted by D/1, D/2 and D/3 respectively. A tapping system expressed as S/2.D/2, therefore, refers to a half spiral cut every alternate day. Similarly, S/1.D/4 refers to a full spiral cut every fourth day. These two tapping systems are commonly used and they are arbitrarily assigned to have a 100 per cent tapping intensity. Other systems can either be less or more intensive. The most popular tapping systems among the PNG rubber growers are the S/2.D/2 and S/2.D/3 types.

The type of tapping system adopted can very much depend on the age of the trees, the variety and other inherent characteristics. The variety of tree is probably the most important consideration. This is because different varieties have different growth characteristics, of which the rate of bark renewal is the most crucial. Generally, the tapping system is adapted so that the rate of bark renewal is faster than the rate of bark consumption. The reverse situation usually leads to the problem of 'brown bast', where latex no longer flows because the tapping panel is dried up.

The most common tapping systems used in Cape Rodney are S/2.D/2, 100 per cent and S/2.D/3,66 per cent. Usually, farmers with 400 or less trees use the former system because they are able to tap so many trees in any single tapping day. Farmers with more trees, on the other hand, have to divide their trees into groups which they call 'tasks' and each task on average has about 400 trees. Thus a farmer with 800 trees, or two tasks, uses the S/2.D/2,100 per cent tapping system, but he is able to tap his trees on all the 5 days available for tapping. Likewise, a farmer with three tasks uses the S/2.D/3,66 per cent system, but he is able to tap on all 5 days. Some farmers even have up to 2,000 mature trees. In such cases, the number of trees in a single task is greater, but not all mature trees are tapped. On average, a single tapper is able to tap about 300 trees per tapping day.

In this study, no individual variable is specified to represent the effects of the tapping system on the output level. The main reason for this is that the tapping system is highly dependent on the number of mature trees. This may have resulted in multicollinearity problems in the analysis. Secondly, the total number of tapping days which is largely determined by the tapping system is already used to derive the harvesting labour variable. Hence, we could argue that the input variables number of trees in tapping and harvesting labour have inherent qualities which would be sufficient to allow for differences in tapping systems used. Besides, only the frequency of tapping differs and not the nature of the cut (spiral wise).

Althouth not directly related to tapping systems, the variable depth of cut (X_7) and the weighted dummy variable[1] condition of tapping panel (D_2) are specified in this study as independent input variables. These two variables are included so that the differences in the quality of tapping and the experience of the tapper are accounted for. The quality of tapping is represented by the condition of the tapping panel for obvious reasons. Depth of cut, however, indicates the skillfulness of the tapper. This is because an optimum depth of cut is necessary to maximise the quantity of latex obtained. It is therefore postulated that these two variables will significantly influence the dependent variable, output.

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1 Weighted in terms of good = 3, average = 2, and poor = 1.

3.2.1.2.4 Capital Equipment

Capital equipment used in the exploitation of rubber trees includes that used in harvesting as well as maintenance. Processing and transport equipment make possible the actual production of rubber, an intermediate product. In Cape Rodney, processing and transport equipment are owned and controlled by the government. Therefore, capital equipment is defined here only in terms of harvesting and maintenance equipment. Harvesting equipment used by the smallholders include tapping knives, sharpening stones, latex cups, spouts and buckets. Maintenance equipment include knives (big knives and grass knives), files for sharpening, saws and axes.

Within each category, individual equipment differ both in terms of age, value and quality. It was found that individual equipment used by different farmers had different initial prices. For example, tapping knives used by different farmers had initial prices ranging from K1.00 to K2.50 per knife. Similarly, the initial prices of buckets ranged from K2.00 to K10.00 per bucket. This indicates that farmers face imperfect factor markets. These necessitate the need for some common measure of capital equipment so that it can be expressed as a single input variable. The capital service flow procedure used by Yotopoulos (1967) was adopted for this purpose. The formula is:

$$\bar{R}_i = r\, Vo_i^{T_i} \frac{e^{rT_i}}{e^{rT_i}-1} \qquad (3.3)$$

where, $\bar{R}_i$ is the constant annual service flow from the i^{th} equipment (in Kina);

r is the rate of interest which was set at 12 per cent;

$Vo_i^{T_i}$ is the original (undepreciated) market value of equipment i;

T_i is the life expectancy in years of equipment i.

This procedure is based on the assumption that the annual service flow for each equipment is constant, irrespective of age. This assumption is consistent with the actual situation. A tapping knife, for example, may enhance tapping much more when it is older than when it is new. All the data for the variables in equation (3.3) were obtained during the survey.

The relationship between capital equipment used in rubber production and rubber output is not clearly documented. Despite this, it would be true to say that capital equipment is an essential input variable. This is because without any form of harvesting equipment, rubber cannot be produced. Maintenance equipment, however, is not as essential as the harvesting equipment. But since they make up only a small part of the total capital equipment cost and they are also used in other activities other than rubber production, this study makes no distinction between the different forms.

The mere ownership of more capital equipment, however, does not necessarily result in a higher output level. It is the amount of the equipment used which is important. This in turn is dependent on the available labour force as well as the number of trees in tapping, both already specified as input variables. This implies that there is no direct relationship between output and the capital equipment variable. The relationship which exists between them is what we may call a 'derived' one. Hence, there seems to be no need of specifying an equipment variable. However, because of its essentiality in rubber production and for correlation purposes, capital equipment is included and is specified as X_{11}.

3.2.1.2.5 Management Factors

Management, as a science in its own right, is a relatively new field of study. Because of this, its nature, scope and importance has not yet been fully recognized in agricultural process. Therefore, the term 'management' can be interpreted differently by different people. Management in rubber production can be defined in terms of the general concept, farm management, which is a 'science which deals with the proper combination and operation of productive factors, including land, labour and capital, to bring about a maximum and continuous return to the most elementary operation of units of farming' (Yang, 1965, p.2). Techniques of farm management enable the organization and co-ordination of the existing factors of production so that some form of output is made possible. Decisions as to the desirability and practicability of new inventions and innovations are also made by farm managers. Upton (1973, p.2) defines management as that which 'describes the function of taking decisions about how land, labour and capital resources should be used and carrying out these decisions'.

On a smallholder rubber farm the function of making decisions and implementing these decisions is the sole responsibility of the farmer himself. In this respect, the rubber smallholder is the entrepreneur, the manager and the labourer. Entrepreneurship involves the broad judgement regarding total resource use, choice of enterprise and technology as well as that of product disposition. The labourer is the person who implements the decisions. All these three functions are performed by the smallholder himself with the help of his family members who usually carry out the decisions made by him.

Only until recently has management been specified as an input variable in production function studies. It is now felt that management is an important 'invisible' variable in any production situation. This is because inputs on their own are not able to generate the required output. Someone has to co-ordinate and organize them so that some output is obtained. A good farm manager can obtain a higher level of output merely because of the way inputs are co-ordinated and organized and vice-versa. If a variable is not explicitly specified to capture the effects of differences in managerial ability, then the estimated function is said to suffer from 'management bias'. The nature of this bias will depend on how input factors are correlated with a farmer's managerial ability. A positive correlation will result in an upward bias while a negative one will result in a downward bias.

Massel (1967) illustrates the nature of management bias using the following illustration:

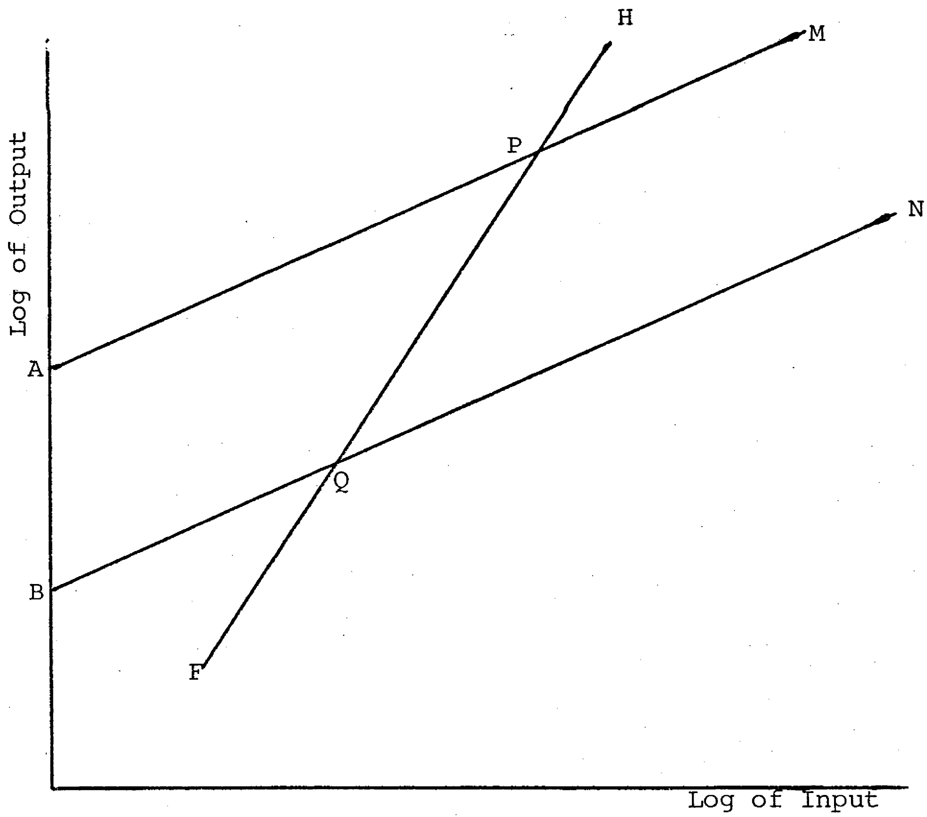

FIGURE 3.1 THE CONCEPT OF MANAGEMENT BIAS

We have two farms, A and B both operating on two production functions AM and BN respectively. Given that the functions are expressed in logarithmic form, both differ only by the additive constant log(A)-log(B), which is the distance AB in Figure 3.1. Because farm A is more efficient, he chooses to operate on point P, while farm B operates to the left of this point at point Q. If a management variable is not specified when estimating a single function for both farms, the ordinary least squares procedure will yield the interfarm function, FH, whereas it is the intrafarm functions, AM and BN, that we are interested in.

This problem was discussed independently by Mundlak (1961) and Hock (1958). These two studies concluded that, to eliminate management bias, time series and cross section data could be pooled, using analysis of convariance, to obtain coefficients which are consistent. Variables specified to eliminate management bias can occur either as zero-one dummy variables or incorporated variables where both the intercept and the slope of the function are adjusted accordingly.

In rubber production, specific aspects of the smallholder farmer can be identified as being associated with management. These are summarized by Muharminto (1980) as follows:

(a) The farmer's education level;

(b) Farmer's experience and technical knowledge;

(c) Farmer's age;

(d) The general condition of his holding;

(e) Proportion of non-rubber income.

In this study, only farmer's age and experience are used as proxies in measuring the management variable. Age and experience would seem to be highly correlated since, as people get older, the more experienced they become in performing certain tasks. However, experience, as recorded during data collection, includes only those years farmers were associated with any form of rubber production. It was found that a common source of experience was from working on rubber estates. Most farmers, however, had very little experience in rubber production before becoming settlers on the scheme. Hence, we could expect that farmers with previous experience may be able to obtain a higher level of output than those with no previous experience. The variables Age and Experience are specified in this Study as X_4 and X_5. Their average statistics are provided in Appendix 3.1.

3.2.2 <u>Uncontrollable Variables</u>

These are variables which cannot be affected by any decision made by the farmer. They are also termed 'State' variables. In rubber production these variables are soil types, topography, climatic conditions, age of trees and natural hazards. Climatic conditions include rainfall, solar radiation, temperature, relative humidity and wind velocity. Only soil types, topography, rainfall and age of trees will be discussed here.

3.2.2.1 <u>Soil Types</u>

Soils differ both in terms of chemical and physical properties. These differences have different effects on rubber productivity. The variety of rubber trees planted will also depend on these properties. A high yielding planting material, if planted on soils with poor chemical and physical properties, will not yield its maximum potential and vice-versa. Chemical properties determine the fertility of the soil while physical properties determine its texture, laterisation and drainage status.

From the limited information obtained on soils in the Cape Rodney Scheme it seems that there exists a complex range of soils in the area.

Although the exact properties of these soils are not known the general indication is that they are suitable for rubber and cocoa growing. Despite this, soil differences would certainly exist, thus causing some variation in output. In this study, however, no specific variable is specified to capture the effects of differences in soil on the output level. Instead, dummy variables are used for the four distinct locational divisions. These are Moreguina, Ianu, Bomguina and Manabo. Since these four locational groups are distinctly separate, we can assume that within a single group, the soil is relatively of the same type (Refer Map 4). It is hoped that the four locational dummy variables will be able to capture the effects of soil differences on the output level. This can be established by examining the signs and the significance levels of the coefficients of the four locational dummy variables. The classification of these dummy variables along with others used in this study are presented in Table 5.6.

3.2.2.2 Topography

Topography is a specific description of one of the physical properties of soils. The other is soil depth, and both make up what is often referred to as 'soil physiography'. The effects of various soil depths on the growth and yield of some specific rubber clones were investigated by Chan (1976). The results indicated that soil depth has a definite relationship with rubber yields. The simple nature of the present study makes it quite impossible to accommodate for such differences, let alone obtain the necessary data. Hence only topography was examined.

Topography describes the slope of a land area, in this case, rubber farms. The two extreme cases are either flat or steeply sloping. In between we have undulating or gently sloping. Topography influences the soil's internal and surface drainage patterns. These determine the soil moisture and nutrient retention capacities which in turn affect the productivity of the soil.

In Cape Rodney, only 2 out of the 50 farms included in the sample did not have flat farm areas. Both had gently sloping land. Since most farms were on flat land, we can assume that this is constant and therefore eliminate the need for the specification of dummy variables for the different topographical characteristics.

3.2.2.3 Rainfall

Rainfall can influence both the quality and quantity of rubber output. The most important of these is the loss of tapping days during the year due to rainfall. Other effects include late tapping, early collection and loss of a day's crop caused by a heavy downpour. All these result in wastage of latex and therefore result in an overall reduction in yields.

A separate set of data, based on 1978 records kept by the Rubber Section in DPI, is presented in Appendix 3.2. Some 42 per cent of the sample used in this study is included in this data set. The results indicate that out of the 24 farmers whose daily activities during 1978 were fully accounted for, the loss of tapping days due to rainfall ranged from 24 to 37 days, with an average of 28 days. This average is some 11 per cent of the 260 days available for tapping during any one year. Allowing for an average of 101 days in which the above 24 farmers were absent from their farms, the percentage of rainy days can be as high as 18 per cent (i.e. 260-101= 159: $^{28}/_{159} \times {}^{100}$). This would imply that the output level obtained was some 18 per cent lower than they should have obtained if it had not been for the rainy days. Given in Appendix 3.2 that the average output per worked day is about 12 kg, the approximate amount of unrecognized output is some 336 kg of rubber.

Hence, we can conclude that the loss of tapping days due to rainfall has a significant negative influence on the output level.

Despite this significant relationship, this study does not specify a rainfall variable mainly because of data deficiency. Furthermore, we cannot assume that this variable is a constant because the data provided in Appendix 3.2 clearly disproves this. One possible justification for not specifying such a variable is that the related variable, the total number of tapping days is already used to derive the Harvesting Labour (X_1) variable. Besides, since the pattern of wet days would differ locationally, the locational dummy variables may be able to capture the effect of rainfall on the level of output.

3.2.2.4 Age of Trees

All perennial crops, unlike annual crops, produce some output as long as they live. The quantity of latex produced by rubber trees of different ages will differ. The general relationship is one of increasing output up to about 12 years, constant up to about 16 years and then a decline, thereafter, as depicted in Figure 3.2.

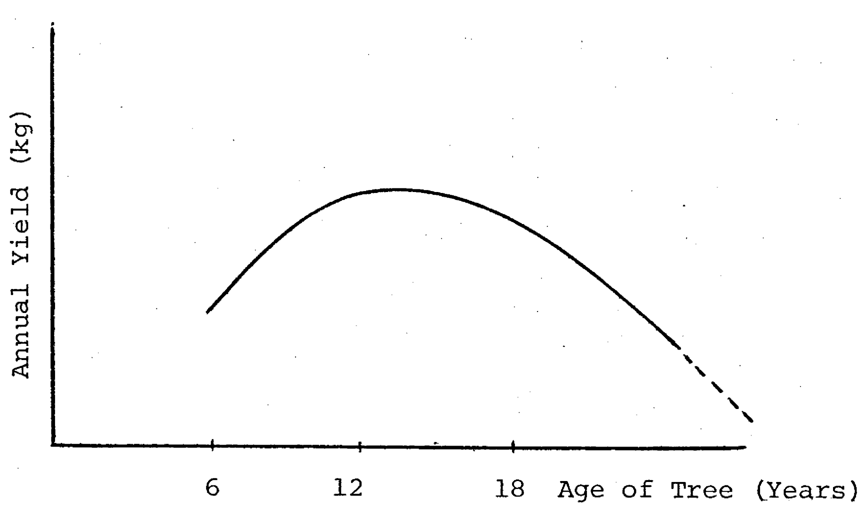

FIGURE 3.2 GENERAL YIELD PATTERN FOR RUBBER

Tapping commences when trees are just about 6 years old and continues for about 20 to 30 years. The specific yield curves will differ according to the variety or clone of rubber. The relationship between age of trees and output is therefore a significant one.

In this study, Age of Trees is specified as the independent variable X_4. The average statistics in Appendix 3.1 show that the mean age of trees for the whole sample is about 15 years, with a minimum of 13 and a maximum of 17. In relation to the yield curve in Figure 3.1 this means that the mature trees being analysed in this study are probably producing at their maximum potential.

A related variable, also specified in this study, is X_3, Year Since Tapping Commenced. This is done because not all farmers open up their trees for tapping as soon as they are mature enough (i.e. when the trees are about 6 years old). The minimum and maximum figures for Age of Trees (X_4) and Years Since Tapping Commenced (X_3) in Appendix 3.1 can be used to prove this point. They indicate that tapping can commence as early as when the trees are 4 years old or as late as when they are 13 years old. This implies that the yield curves for individual farmers would be somewhat different, depending also on the period of tapping commencement.

3.2.3 Output

Output in rubber production is measured in terms of the weight in Kilograms of the Dry Rubber Content (DRC) of latex. In Cape Rodney, the DRC of latex is some 30 per cent of its total weight. Hence, if the total weight of latex is say 100 kg, its DRC is then 30 kg. This DRC is therefore the measure of output (Q), the dependent variable in this study.

The statistics provided in Appendix 3.1 show that the mean output level for the whole sample is 1545.2 kg, with a minimum of 32 and a maximum of 4,800 kg. Such a wide variation in output is a direct result of the differences in the number of trees being tapped between farms. The minimum output level was obtained by a farmer who had formal employment elsewhere.

The Ethnic-wise breakdown in Appendix 3.1 reveals that the Western Ethnic Group obtained the highest average level of output of 3,624 kg, followed in sequential order by Aroma (2,324 kg), Domara (1,476 kg), Kerema (1,449 kg), Ianu (1,178 kg), New Guinea (1,160 kg) and Dom (981.33 kg). This same order was found to apply when looking at the variation in the Number of Trees in Tapping. We can therefore conclude that the input variable X_2 (Number of Trees in Tapping), significantly influences the Ethnic-wise variation in the overall output level. Location-wise differences are not discussed because they are highly correlated with those of the Ethnic divisions. In terms of Local and Non-Local Farmer groupings, we find that the latter produced a relatively higher level of output than the former. This difference is again attributed to the difference in the number of trees being tapped between the two groups. This difference is statistically significant at the 5 per cent level.[1]

3.2.4 Simple Correlations Between Variables

The simple correlation matrix between input variables specified in this study is presented in Table 3.2. It shows that the variables Number of Trees in Tapping (X_2) and the Total Number of Trees (X_9) have a high degree of correlation with the dependent variable, Output (Y). Similarly, X_2 and X_9 are between themselves highly correlated; a correlation value of 0.9040. This indicates that only X_2 should be used

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[1] Using procedure outlined in footnote of Subsection 3.2.1.2.2
T = 2.0699 and t.05 = 2.00.

Table 3.2

Simple Correlation Matrix of Input Variables

	VARIABLE	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	D_1	D_2
Y	Total Output	1.0000													
X_1	Harvesting Labour	0.4411	1.0000												
X_2	Number of Trees in Tapping	*0.7723	0.2971	1.0000											
X_3	Years Since Tapping Commenced	0.4819	0.2421	0.4365	1.0000										
X_4	Age of Farmer	0.1063	0.1382	0.0313	0.3299	1.0000									
X_5	Experience of Farmer	0.2378	0.1995	0.2104	0.3129	*0.5184	1.0000								
X_6	Total Farm Size	0.3070	0.1741	0.3106	0.2818	0.0573	0.0946	1.0000							
X_7	Depth of Cut	-0.1273	-0.1547	0.1212	0.0895	0.1322	0.0170	-0.1820	1.0000						
X_8	Age of Trees	-0.1120	-0.0170	-0.1509	0.2630	0.3242	0.3344	-0.1275	0.2249	1.0000					
X_9	Total Number of Trees	*0.6666	0.3305	*0.9040	0.3773	0.0706	0.1582	0.3120	-0.2787	-0.1929	1.0000				
X_{10}	Maintenance Labour	0.2439	0.1144	0.3460	0.1421	-0.0639	0.2429	0.2001	-0.2217	0.0286	0.3440	1.0000			
X_{11}	Capital Equipment	0.4167	0.1550	0.5174	0.3046	-0.0170	0.0954	0.1007	-0.0019	-0.0027	*0.4556	0.1013	1.0000		
D_1	Condition of Block	0.2496	0.1547	0.2458	0.1980	0.3346	0.1286	0.3346	0.1673	0.0277	0.2532	0.3311	-0.0019	1.0000	
D_2	Condition of Tapping Panel	-0.1273	0.0189	0.1239	-0.1622	-0.1585	0.1138	-0.0244	-0.0352	0.0510	0.0712	-0.2217	-0.1290	-0.0352	1.0000

in actual regression and it is expected that this variable will have a significant influence on Q, as shown by the high correlation value of 0.7723. However, it should be mentioned here that the number of trees not in tapping may depress current output levels, but they would certainly enhance long-term output. This study, unfortunately, cannot show this. Apart from the exclusion of variable X_9, the overall matrix shows that the problem of multicollinearity is not a significant one.

CHAPTER 4

THE THEORY OF PRODUCTION FUNCTIONS

This Chapter attempts to present the basic theory behind the general use of production functions. This theory is then related to the logic of the rubber production process, discussed earlier in Chapter 3. This will involve the examination of various production function models, especially those used in previous studies, looking at rubber productivity. On the basis of consistency with this logic, an appropriate functional form is then selected for empirical estimation purposes. More specifically, Section 4.1 introduces the theory and Section 4.2 examines the different types of production functions. The first part of this section examines the Cobb-Douglas production function model while the second part is devoted to the discussion of a modified version of the general Transcendental production function. Other functional models used in production function studies are also briefly discussed. Section 4.3 discusses some of the appropriate properties of a rubber production function. The final section in this Chapter examines some of the main problems encountered in production function estimation.

4.1 Production Functions

The act of production occurs under three circumstances: (a) when the quantity of the good is changed; (b) when the form of the good is changed; and (c) when the good is finally distributed. Production is then said to take place when any of the above circumstances are satisfied, causing a change which is preferred by society. Production as will be used in these pages only refers to the first circumstance in which only the quantity of the good is changed. This is because the rubber smallholders in Cape Rodney only produce and sell latex. All processing and distribution is done by DPI, the government department responsible for smallholder rubber production.

A change in the quantity of the good occurs when there are significant changes in the inputs applied. If we refer to the different inputs as factors of production and the production of the good as output, the inherent relationship between the factors and output is called a 'production function'. More precisely, a production function is a mathematical expression describing the technical relationship between factors of production and output. This expression can have the following general form: $Q = f(X_1 \ldots\ldots, X_i \ldots\ldots X_n)$ where output (Q) is some unspecified mathematical function of the different quantities of input factors, X's. A more specific representation of this relationship cannot be made because different biological, mechanical and environmental conditions will have different influences on Q, the output level. This is especially true in the case of agricultural production functions where no single function is able to sufficiently capture the different relationships which exist between inputs and output. These different relationships can result from differences in varieties of crops and livestock, differences in environmental conditions and even differences in techniques used in production. In relation to technical differences, a simple example may be useful in clarifying the general production function concept.

Let us firstly assume that there exist techniques which use only two factors, say labour (L) and capital (K). Then each technique, representing a combination of L and K capable of producing a given level of output, say $\bar{Q}$, can be represented as a point in Figure 4.1. Each point on Figure 4.1 represents a combination of L and K which may be used to produce a given level of output, $\bar{Q}$. Technique X_A requires L_A amount of labour and K_A amount of capital while technique X_B requires L_B of labour and K_B of capital. If we now consider a fixed labour

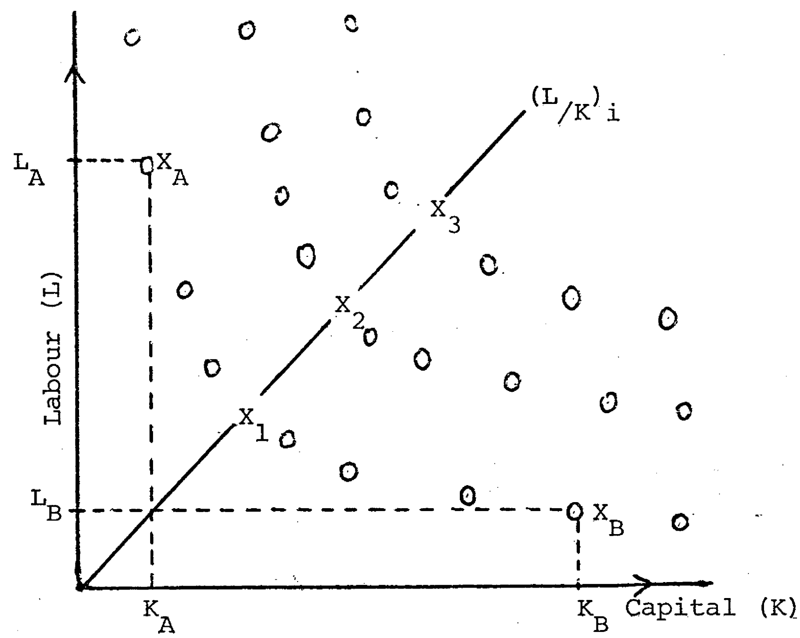


Fig. 4.1: Differences in Techniques of Production

capital ratio, say $^{L}i/K_i$ (represented by the solid line in Figure 4.1), we see three possible techniques: X_1, X_2 and X_3, each of which uses the same factor proportion ($^{L}i/K_i$) and each of which produces the same level of output, $\bar{Q}$. Clearly X_1 is preferred to X_2 or X_3 since less of each factor is needed to produce the given level of output, $\bar{Q}$. If this is repeated for all different levels of factor proportions, the set of most efficient techniques is identified. This set gives us what is often called 'isoquants', and it represents the most efficient combination of input factors, capable of producing a given level of output. Different isoquants will therefore depict different output levels. The number of isoquants present in an 'input-output' space is always infinite. Hence in Figure 4.2,Q_3 is greater than Q_2, which in turn is greater than Q_1. The general slope assumed here (convex to origon) is implied if we assume the existence of diminishing returns. Such returns are suggested by the 'law of diminishing returns', which states that:

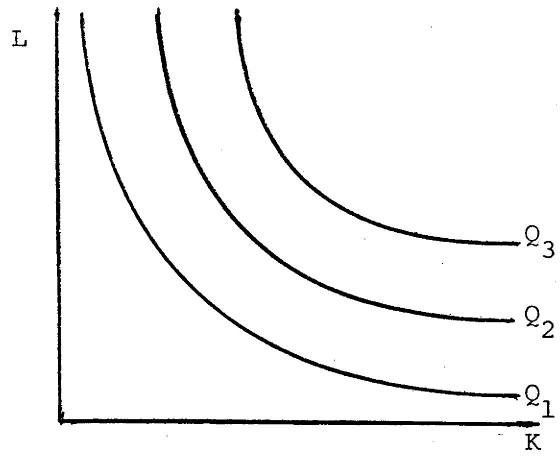


Fig. 4.2: Isoquants

> "as more of one factor is added to a fixed quantity of other factors, then the change in output due to a change in the variable factor will eventually diminish". (Heathfield, 1971, p.19).

On the whole, the production function describes the shape and the position of a specific isoquant.

The specification of the production function is in itself a complex economic problem. There are two basic approaches in the attempt to estimate production functions. One, usually referred to as the 'engineering approach' is where the physical principles of each process are examined and from this an aggregate function for the firm, industry or economy is derived. The other, which is more commonly used, involves the measurement of individual input levels, output and the respective input and output prices. From these observations, hypothesis about the form of the function applied are tested and quantified. The latter is the approach adopted in this study, using a set of cross-sectional data, where each individual farm observed has its own input combinations which give rise to a given output level. The basic assumption in any cross-sectional analysis is that all producers operate in perfectly competitive factor markets. In reality, however, farmers do in fact face different relative factor prices, especially when the sample is drawn from a small area or region as is the case for the sample used in this study, where farmers purchase their equipment from many different sources.

4.2 Types of Production Functions

4.2.1 The Cobb-Douglas

The Cobb-Douglas (C-D) production function is the best known and most widely used Marshallian type of functions which disaggregate a national production function by examining the relationship between a subset of the entire set of factors of production and their contribution to output. The C-D in its best known form is a power function which can be written as:

$$Q_j = \beta_o \prod_{i=1}^{n} X_{ij}^{\beta_i} \tag{4.1}$$

where Q_j = Total output of farm j (j = 1,2,....m)

X_{ij} = Amount of input factor i used by the j^{th} farm (i = 1,2,....n)

β_i = Output elasticity of input factor i

β_o = The constant term.

To estimate this function from a set of sample data, errors are bound to be made since the estimation provides only an average solution. These errors, in statistical theory are referred to as 'random disturbances' and they result from the failure of not including all variables as input factors in the estimated function. To capture the effects of these unspecified input variables, an error term, U_j, is introduced in equation 4.1 as shown in equation 4.2 below:

$$Q_j = \beta_O \prod_{i=1}^{n} X_{ij}^{\beta_i} \; U_j \tag{4.2}$$

where U_j = the stochastic error term. This non linear function becomes linear when all variables are expressed in natural logs (to the base e). Thus, equation 4.2 can be re-written in log linear form as:

$$q_j = b_o + \sum_{i=1}^{n} b_i \, x_{ij} + u_j \tag{4.3}$$

where $q_j = \ln (Q_j)$ $\quad b_o = \ln (\beta_o)$ and $u_j = \ln (u_j)$.

$x_{ij} = \ln (X_{ij})$ $\quad b_i = \ln (\beta_i)$

Equation 4.3 is now the C-D function expressed in log linear form. The error term u_j, apart from capturing the effects of omitted variables, can also represent errors made in actual observation and measurement of different input factors. The parameters b_i and the distribution of u_j's are unknown. The basic problem in production function analysis, is therefore, to obtain estimates of these unknowns, using all observations that make up the sample data. The function to be estimated can then be expressed as:

$$\hat{q}_j = \hat{b}_o + \sum_{i=1}^{n} \hat{b}_i x_{ij} + \hat{u}_j \qquad (4.4)$$

where the hat (^) indicates estimated parameters. This function can be estimated using the Ordinary Least Squares (OLS) procedure which is proven to provide the Best Linear Unbiased Estimators (BLUE) given the assumptions that the error term is normally and independently distributed with a mean of zero and an infinite variance.[1]

4.2.1.1 Properties

The C-D function is commonly used because of the simplicity with which it can be manipulated and results interpreted. The function assumes constant elasticity of production. This means that at given input levels, total output will increase proportionately in response to incremental increases in the inputs.

The marginal product of any input factor is calculated by partial differentiation of the function with respect to this input factor, holding all other inputs at fixed levels. Hence, the general marginal

---

1 $E(u) = o,$
$E(u_i\ u_j) = o,$
$i \neq j$
$E(x_i\ u_j) = o$
$u \sim N\ (o_1\ \ \sigma^2)$

production equation for model equation 4.4 can be derived as follows:

$$MP_{X_i} = \frac{\partial q}{\partial X_i} = b_i \, b_o \, X_i^{b_i} \; X_1^{b_1} \; X_2^{b_2} \ldots X_i^{b_{i-1}} \ldots X_n^{b_n}$$

$$= \hat{b}_i \; \frac{\hat{Q}}{X_i} \qquad (4.5)$$

Since $\hat{Q}/_{X_i}$ measures the estimated average product, equation 4.5 implies that the marginal product of the i^{th} input is equal to the estimated average product multiplied by its coefficient.

The output elasticity of an input factor is defined as the percentage change in output resulting from a one per cent change in the usage level of that input, holding other inputs constant at their respective arithmetic or geometric mean levels. As mentioned earlier, these parameters are assumed to remain constant, irrespective of the intensity of input use. The output elasticity of the i^{th} input factor can be derived as shown below in equation 4.6:

$$\eta_{QX_i} = \frac{X_i}{\hat{Q}} \times \frac{\partial \hat{Q}}{\partial X_i} = \frac{X_i}{\hat{Q}} \left[\hat{b}_i \; \frac{\hat{Q}}{X_i} \right] = \hat{b}_i \qquad (4.6)$$

The first part of equation 4.6 indicates that the marginal product is also employed in deriving the output elasticity. The end result of equation 4.6 implies that the input coefficients, b_i's, are in fact the output elasticities for the respective i^{th} input factors. Hence, if the value of b_i for the input X_2, is 0.31, this then is the output elasticity for the X_2 input variable. The value 0.31 can be interpreted as being the percentage change in the output level, caused by a 1 per cent increase in the use of input variable, X_2.

The sum of the output elasticities (b_i's) measures both the degree of homogeneity and the returns to scale. Both these concepts are inter-related in that the occurrence of one directly implies the existence of the other. For example, linear homogeneity implies that constant returns to scale exist. Returns to scale can either be increasing, constant or decreasing, depending on the sum of elasticities. Increasing and decreasing returns to scale occurs when with a simultaneous one per cent increase in all identified factors of production results in a greater or less than one per cent increase in output, respectively. Constant returns to scale exist when a one per cent increase in all factors taken together causes output to increase by the same proportion. The C-D function allows only one of these situations to occur at any one time.

The marginal product equation 4.5 implies that marginal productivity of an input varies in relation to the intensity with which the input is applied. To detect the trend of such a change in the marginal product, we derive the second order derivative of equation 4.4. This manipulation gives equation 4.7 below:

$$\frac{\partial^2 \hat{Q}}{\partial X_i^2} = \hat{b}_i \, (\hat{b}_i - 1) \, \frac{\hat{Q}}{X_i^2} \qquad (4.7)$$

Now since $\hat{b}_i < 1$, the right hand side of equation 4.7 is negative, indicating that the general marginal product curve for the C-D functional form is downward sloping at all input levels. In other words, there exist only diminishing marginal productivities. Furthermore, equations 4.5 and 4.7 both imply that the marginal product of any input factor is never negative, given that $o \leq b \leq 1$.

4.2.1.2 Literature Review

Studies using the C-D production function model for rubber production have been mainly carried out in thesis research. Two examples of such studies include Teo (1976) and Muharminto (1980). Other studies will also be reviewed.

Teo (1976) analysed smallholder rubber productivity in the Agalawatta District of Sri Lanka, using the C-D model. In particular he analysed the effects of different clones on rubber productivity by estimating two different production functions for two clones, Tjir 1 and PB86. His results showed that clonal differences had significant influences on rubber yields and that yields also varied between trees of different ages. He also analysed technical efficiency using the average and frontier production functions and concluded that technical efficiency varied between relatively similar farms. The analysis of the effect of farm size on the marginal returns to factors of production revealed that there was no significant relationship between farm size and the marginal returns to land. The final part of the study looked at the question of labour utilisation between farms of different sizes and different rubber clones. The basic conclusion here was that labour was being under-utilised on large farms while it was over-used on the smaller ones.

Muharminto (1980) also fitted a C-D production function model in an attempt to identify factors that influence rubber yields on smallholder rubber farms in Kabupaten LIOT and MURA, both in South Sumatra, Indonesia. The average and frontier production functions were estimated using OLS and Linear Programming techniques, respectively. Returns to scale were also tested, finding that LIOT farmers had decreasing returns while the MURA farmers had increasing returns to scale. Another major finding in this study was that factor elasticities remained unchanged between the average and the best groups of farmers, given that the productio functions for each of the groups differed only in their intercept terms. The analysis of yield differences revealed that for the LIOT farmers, tree girth was important in reducing yield variation while for the MURA farmers, number of cuts, condition of tapping panel, depth of cut and education were variables identified to increase yield variation. The major policy recommendation from this study was that smallholder rubber farmers who are technically inefficient can benefit enormously with improved extension services.

Carrad and MacEwan in Carrad (1980) also applied a C-D model on smallholder rubber production data obtained from the Cape Rodney Rubber Resettlement Scheme, the same Scheme being analysed in this study. Their findings are presented in Chapter 5, where a comparison is made between their results and those of this study. Also, in PNG Whitlam (1973) in Carrad (1980) did a similar study, but on the Murua Scheme in the Gulf Province (refer Map 1 or 2). This was a marginal analysis study, looking mainly at average productivities of the two main inputs, rubber trees and harvesting labour in terms of the number of tappers. A somewhat surprising result found was that despite increases in the average family size, the number of rubber trees in tapping fell by some 32 per cent. This was the result of farmers not tapping all their mature trees.

Chandrasiri, Carrad and Teo (1977) attempted to analyse the main input-output relationships in a cross section of smallholdings growing high yielding rubber in the Matugama and Agalawatta areas of Sri Lanka. Factors found to have most impact on output were tree age, planting density, area of mature rubber and tapping frequency. Specification problems associated with these variables and with rubber as a perennial crop were also discussed. Two main types of rubber clones Tjir 1 and PB 86 were compared, especially in terms of yield potential, with the result that the former has a higher yield potential than the latter. Performance of individual holdings were also compared on the basis of the number and type of labour employed. A C-D production function model was used for analysis.

Other general studies using the C-D production function approach will now be reviewed. Despite being developed to fit industry data, the C-D model has been commonly used in recent times in fitting agricultural data; especially in relating gross farm output with land, labour and capital inputs. Some examples of such studies include Massell and Johnson (1968), Yotopolous (1968) and Chandra (1979). It has also been used to measure and compare technical and allocative efficiency between individual farms or groups of farms. Such studies include Chandra (1979), Sahota (1968), Timmer (1970 and 1971), Huang (1971), Gautam (1973). Griliches (1964) used this functional form in analysing the effects of research and education expenditures on agricultural output. He found that such expenditures did, in fact, have a significant influence on agricultural output.

George and Jones (1979) applied the C-D production function to data obtained from Greek Dairy Plants, with output being dependent on labour, capital and material inputs. The function was estimated both cross-sectionally and over time. The results showed that the output elasticity of capital seemed to be low. This they believed was caused by investment decisions being generally dictated by policy and a price structure which was biased towards certain activities within the industry.

Sampath (1979) discussed the appropriateness of the C-D production function approach in measuring economic efficiency. He went further in developing a modified approach and pointed out the superiority of his new programming approach in empirically analysing the economic efficiency of farms. The level of economic efficiency of farmers in Deoria District, Uttar Pradesh was estimated in terms of the developed theoretical framework. Economic inefficiency, on the other hand, was examined using a Linear Programming optimization model. The study showed economic inefficiency in Indian agriculture of the order of 36.5 per cent, indicating that possibilities of increasing farm income existed. This inefficiency resulted from technical inefficiency. For the Indian economy as a whole, factor immobility was responsible for some 2 per cent of economic inefficiency. Allocative inefficiency was found to be the main cause of economic inefficiency for small farms, while for the larger farms, it was technical inefficiency. Small farms were found to be more innovative and enterprising than the large farms in adopting new technology.

Mengo (1979) analysed levels of marginal productivity of factors of production employed in two enterprises; livestock and cereals. A C-D production function was used and was found to be valid and a useful instrument of analysis. The two major conclusions of this study were:

(a) that increasing farm size and the use of more inputs would be of great benefit to farmers as this would provide structural advantages; and,

(b) that agricultural development needed to be sustained by a sound credit policy which would allow for productivity of factors to be harnessed in a more advantageous way than is presently being allowed in Italian credit policy.

Portugal and Degand (1977) did a regional analysis of Belgiam agricultural production. The aim of the study was to try and explain the effects of regional and time differences on farm output. The findings showed that time differences were more important in determining farm output than regional differences. This was attributed mainly to technological progress, climatic and price variations which occur over time. It was also found that less favoured areas had in some cases higher productivity than the ecologically favoured areas. This, they argued, indicated that the type and degree of efficiency in inputs were also important in determining agricultural productivity.

Murthy and Ramanna (1979) analysed the relationship between mulberry output and inputs used in mulberry production in Bangalore District, India; using a C-D production function model. They found that land, fertilizer and irrigation were significant in determining output. The ratios of the Marginal Value Products (MVP) of these inputs to their respective Marginal Factor Costs (MFC) were observed to be more than unity, indicating that they were being economically used in mulberry production. It was also recommended that farm incomes could be further increased through acreage expansion, use of higher doses of fertilizer and irrigation and reduction in the use of other resources such as labour, farmyard manure and other variable costs. Increasing returns to scale existed in mulberry production.

Nguyen (1979) estimated an aggregate production function based on inter-country cross section data for 1970 and 1975. Results indicated that agricultural production was stable over time and that constant returns to scale did prevail in production patterns. Similarly, Dominique (1979) did an analysis of the dynamics of food crop production. The first part of this study examined the production functions underlying food crop production. From output behaviour, an 'index of modernity' was developed for different agricultural systems. The second part used this index to identify the relative strengths and weaknesses of the different agricultural systems. Definite recommendations for change and transformation were made as concluding remarks.

The C-D production function approach, using either cross-sectional or time series data, has also been used to question various policy issues. Two examples of such studies are: Johnson's (1960) analysis of output implications of a declining farm labour force, and Griliches' (1957) study of the sources of productivity growth using 68 regions as observations and including levels of education as an input variable. Both studies were done in the United States.

In spite of its common usage in production function studies, the C-D function has a few characteristics which can be used to question its appropriateness in relation to a rubber production function. One of the most limiting of these characteristics is its homothetic nature which results in the assumption that the Marginal Rate of Technical Substitution (MRTS) between variables on all different isoquants, along a ray from the origon is the same. This implies that the slope of isoquants at these different points are the same so that an increase in the use of one factor will automatically result in a proportionate decrease in the use of another. In real life, such proportionate changes in input use hardly occur.

Another related characteristic of this function which can be criticised is the assumption that the elasticity of substitution is constant and unitary between all input factors. This means that a one per cent change in the factor's relative price will bring about a one percent change in factor proportions. Again, such proportionate changes can hardly occur, especially when farmers operate under relatively imperfect conditions, such that prices do not strictly represent real value.

The C-D production function model has the inherent assumption that all input variables are essential. That is, no output can ever be produced without the application of all input variables. In rubber production, fertilizer for example, is not an essential variable, in that without any fertilizer application rubber can still be produced.

Yet, the C-D model inherently implies that fertilizer is an essential input. Furthermore, this functional form cannot be used satisfactorily for data which is characterised by both increasing and decreasing marginal productivities. That is, if the production process of the crop(s) in question allows for the existence of positive and negative marginal products, the C-D model, if applied, would only present biased results. Similarly, the estimates of this functional form would also be biased if individual farms or groups of farms within a sample have production functions which differ non-neutrally. That is to say that they have different factor elasticities, given their respective resource endowments.

4.2.2 Other Functions

Other functional forms which have been used in various other studies will be discussed briefly in this section. These functions include:

(a) C-D with variable returns to scale;

(b) Constant Elasticity of Substitution (CES);

(c) Spillmans Function;

(d) Polynomial Function; and,

(e) Hyperbolic Function.

As the name suggests, the C-D with variable returns to scale allows for differences which may exist in production techniques, causing production elasticities and returns to scale to differ between individual farms. This model was first formulated and empirically applied by Ulveling and Fletcher (1970).

The CES function is characterised by constant returns to scale, is linear and homogeneous. This function was first proposed by Arrow et al, (1961). Some recent studies in applying this model modified it to allow for changes in the degree of homogeneity in inputs, thus causing the elasticity of substitution to vary between factors of production. Such a modified version is appropriately called the Variable Elasticity of Substitution function (VES). This function only allows for positive marginal productivities over the relevant range of inputs.

The Spillmans function has an exponential form and it allows for changing factor elasticities but disallows negative marginal productivities since the functional form is assymptotic to the maximum total output. The function assumes 'that all responses are diminishing in nature and that successive changes are proportional to each other'. (Chandra, 1979, p.29).

The polynomial functions can occur in the form of simple linear, quadratic or cubic functions. The simple linear function assumes that marginal productivities remain constant at all input levels. Used as a cost function, the simple linear model can be very useful in determining trends when there is a large scatter of observations. The quadratic model assumes diminishing marginal returns and at the same time allows for the existence of negative marginal productivities. The elasticity declines with increases in the usage of all inputs. The cubic function has hardly been used in production function studies mainly because of the problem of losing degrees of freedom.

The hyperbolic function is non-linear in its parameters and it can be used with great success when marginal productivities are expected to increase initially, followed by a decline as the input is applied more intensively.

4.2.3 The Transcendental Production Function

The Transcendental (TRANS) production function, discussed in these pages is a modified version, developed by Abdullah (1978) in an empirical study of the smallholder rubber farmers in Malaysia. This modified function, in its general form can be expressed as:

$$Q = C \prod_{i \in A}^{n} X_i^{a_i} e^{\alpha_i X_i} \prod_{i \in B}^{n} X_i^{b_i} e^{\beta_i X_i} . U \qquad (4.10)$$

where Q = output

A = set of essential inputs

B = set of non-essential inputs

X_i = the i^{th} input, i = 1, 2, ..., n.

C = intercept term

U = the residual term

If i = o, for i in set B and i > o for i in Set A, the general equation (4.10) is reduced to:

$$Q = C \prod_{i \in A}^{n} X_i^{a_i} e^{\alpha_i X_i} \prod_{i \in B}^{n} e^{\beta_i X_i} . U \qquad (4.11)$$

Equation (4.11) portrays two important features of this model. These are:

(i) For $i \in A$, any $X_i = o$, implies that $Q = o$

(ii) For $i \in B$, all $X_i = o$, implies $Q = C \prod_{i \in A} X_i^{a_i} e^{\alpha_i X_i} > 0$.

In other words, feature (i) indicates that for any individual input in Set A not used in production, the corresponding result is that no output will be obtained. This means that all inputs in Set A are essential in the production process. Feature (ii), on the other hand, indicates that if all inputs in Set B are not used in production, some positive level of output will still be obtained. This means that B is the set of non-essential inputs.

Given that there are a set each of essential and non-essential inputs, we likewise have two different measures of marginal productivity (MP). The MP for X_i's in Set A and Set B are as presented in equations 4.12 and 4.13, respectively.

$$\left.\frac{\partial Q}{\partial X_i}\right|_{i\varepsilon A} = Q\left[\frac{a_i}{X_i} + \alpha_i\right] \qquad (4.12)$$

$$\left.\frac{\partial Q}{\partial X_i}\right|_{i\varepsilon B} = Q\beta_i \qquad (4.13)$$

When the MP equations 4.12 and 4.13 are equated to zero (o), the input levels which make possible a maximum level of output are obtained, given that one set of inputs is constrained to being constant. Hence, for the set of essential inputs, maximum output occurs when -

$$X_i = \frac{-a_i}{\alpha_i}; \qquad (4.14)$$

given that all X_i's in Set B are held constant. The second order derivative is:

$$\left.\frac{\partial^2 Q}{\partial X_i^2}\right|_{i\varepsilon A} = Q\left[\frac{a_i^2 - a_i}{X_i^2} + \frac{2\ a_i\alpha_i}{X_i} + \alpha_i^2\right] \qquad (4.15)$$

The level of input X_i corresponding to the inflection point is obtained when equation 4.15 is set equal to zero (o), resulting in equation (4.16)

$$X_i = \frac{-a_i \pm a_i}{\alpha_i} \qquad (4.16)$$

The values of a_i in equation (4.16) can be both positive and negative. This indicates that the TRANS function is characterized by two inflection points. The one which corresponds to a negative value of a_i occurs in the irrational third stage of the production function, where Total Product (TP) is always on the decline (refer Figure 4.4).

As illustrated in Table 4.1 and Figure 4.3, the shape of the TRANS function with respect to X_i's in Set A is largely determined by the combination of the values of the estimated parameters a_i and α_i. When a_i's are positive and α_i's negative, the function conforms to a production

Table 4.1

Various Combinations of Values of 'α's' and 'a's' and the Shape of the Transcendental Function

Value of α	Value of a	Shape of the Function $Y=CX^{a}e^{\alpha X}$	Figure
$\alpha < 0$	$0 < a \leq 1$	increases at a decreasing rate until $X = \frac{-a}{\alpha}$, then decreases	4.3(a)
	$a > 1$	increases at an increasing rate until $Y = \frac{-a + a}{\alpha}$, then increases at a decreasing rate until $X = \frac{-a}{\alpha}$, then decreases	4.3(b)
$\alpha = 0^{+}$	$0 < a < 1$	increases at a decreasing rate	4.3(c)
	$a = 1$	increases at a constant rate	4.3(d)
	$a < 1$	increases at an increasing rate	4.3(e)
$\alpha > 0$	$0 < a < 1$	increases at a decreasing rate until $X = \frac{-a + a}{\alpha}$, then increases at an increasing rate	4.3(f)
	$a > 1$	increases at an increasing rate	4.3(g)

Source: After Halter et al. (1957), p.967

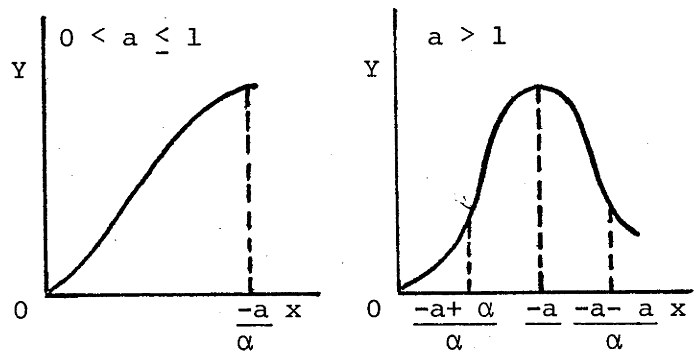
+ When $\alpha = 0$, the function is Cobb-Douglas type.

function which has all three stages of production (refer Figure 4.3b). The output or TP first increases, initially at an increasing rate and then at a decreasing rate. When a maximum is reached, TP has a continued decline. When $\alpha_i = 0$, the function is reduced to the general C-D function, as shown in Figures 4.3(c), (d) and (e). The different figures in Figure 4.3 depict different shapes assumed by the general form of the TRANS function, as discussed in Table 4.1. Depending on the values of a_i's and α_i's, for any Xi in Set A, the marginal product curves can be increasing, decreasing and even negative at different

Figure 4.3

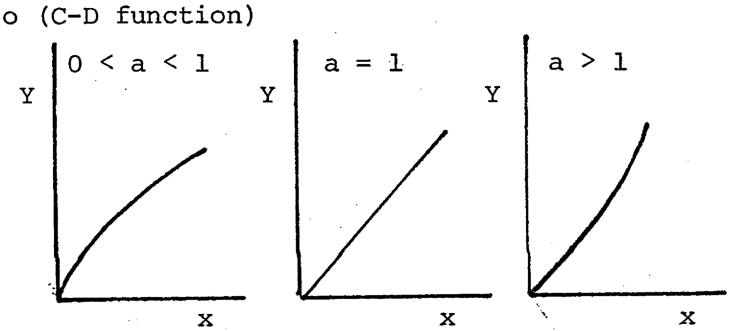
Various Shapes of the TRANS Function

When $\alpha < 0$



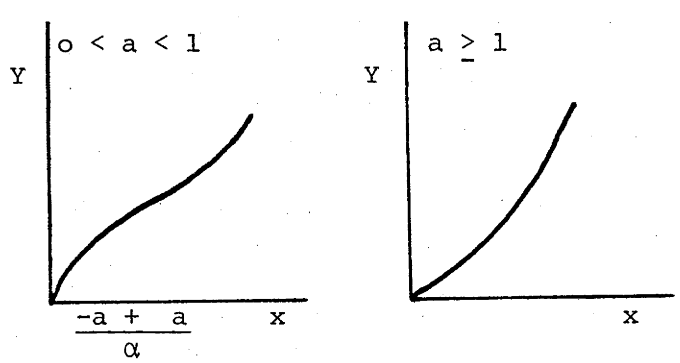
4.3(a) 4.3(b)

When $\alpha = o$ (C-D function)



4.3(c) 4.3(d) 4.3(e)

When $\alpha > 1$

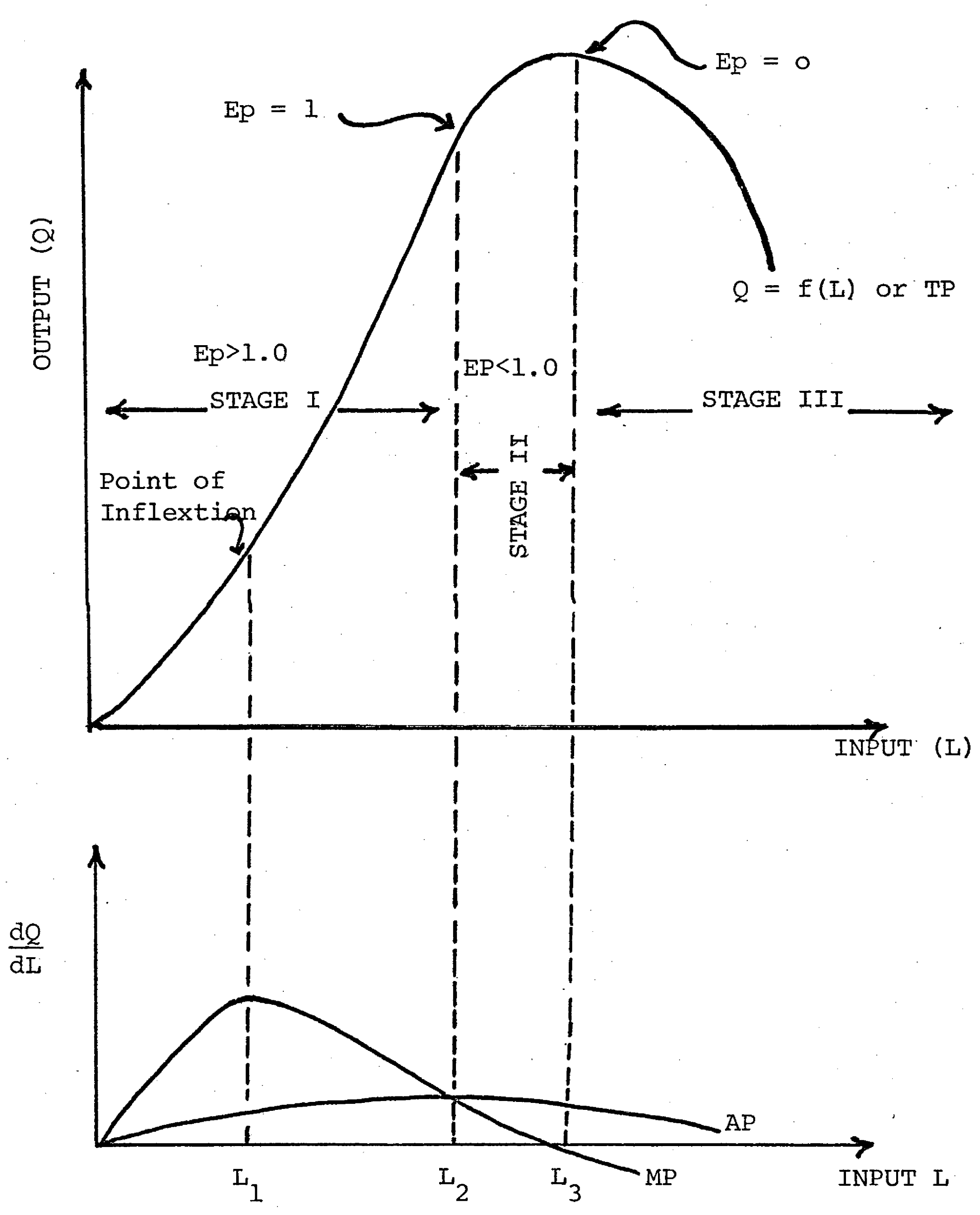


4.3(f) 4.3(g)

Source: After Halter, et al. (1957)

Figure 4.4

The Relationship Between Factor Input to Total, Marginal and Average Physical Products



levels of input application. The different shapes of the marginal product curves can be experienced 'singularly, in pairs or simultaneously' (Halter et. al (1957), p.966). This proves that the TRANS function has non-homothetic characteristics.

The MP of X_i's in Set B, as expressed in equation 4.13 is a linear relationship. To have a non-linear expression for MP of X_i's in Set B, equation 4.11 may be re-written as:

$$Q = C \prod_{i \varepsilon A}^{n} X_i^{a_i} \; e^{\alpha_i X_i} \prod_{i \varepsilon B}^{n} e^{(\beta_i X_i + \gamma_i X_i^2)} \; . \; U \qquad (4.17)$$

Using equation 4.17, the MP of X_i's in Set B can then be expressed as:

$$\left. \frac{\partial Q}{\partial X_i} \right|_{i \varepsilon B} = \left[\beta_i + 2\gamma_i X_i \right] Q \qquad (4.18)$$

To use cross-sectional farm data, equation 4.17 can be slightly modified, as expressed in equation 4.19.

$$Q_j = C_j \prod_{i \varepsilon A}^{n} X_{ij}^{a_i} \; e^{\alpha_i X_{ij}} \prod_{i \varepsilon B}^{n} e^{(\beta_i X_{ij} + \gamma_i X_{ij}^2)} \; . \; U_j \qquad (4.19)$$

where Q_j = annual output of the j^{th} farm

X_{ij} = the amount of input i employed by the j^{th} farmer

C_j = the technical efficiency coefficient

$j = 1, 2, \ldots\ldots. n$

In rubber production Q_j is measured on a DRC basis and the j^{th} farm represents individual rubber smallholders. In double log-linear form, the model equation 4.19 becomes:

$$q_j = c_j + \sum_{i \varepsilon A}^{n} (a_i \, x_{ij} + \alpha_i X_{ij}) + \sum_{i \varepsilon B}^{n} (\beta_i X_{ij} + \gamma_i X_{ij}^2) + u_j \qquad (4.20)$$

where the lower case variables indicate natural log to base e.

When the model equation 4.20 is empirically estimated, the magnitude of c_j reflects the aggregate effects of farm specific productive factors. In any homogeneous production situation, where the same basic production techniques are used and where farmers are exposed to similar random differences, the size of C_j can be used as a proxy in determining technical efficiency or farm productivity, resulting from the use of additional inputs. In rubber production, such inputs include fertilizer, stimulants, weed control measures, environmental, managerial, sociological and other qualitative variables. Environmental variables include topography, rainfall, soil types and climatic factors. Managerial and sociological variables include farmer's age, his attitudes and cultural values. Other qualitative variables include rubber clones, tapping system, farm size and ethnic origion.

In this study, no environmental factors are specifically included in the estimation of a rubber production function. The reasons have already been discussed in detail in Chapter 3. Differences in farm size have been commonly used to analyse questions about farm efficiency. Three classic examples of such studies include Timmer (1971), Massell and Johnson (1968) and Lau and Yotopoulos (1971). Although a farm size variable is included in estimation as an input factor, this study doesn't consider it to be an important determinant of farm rubber output. The reasons have also been discussed in Chapter 3. Similarly, rubber clones are not included in estimation for various reasons outlined earlier, under planting material in Chapter 3.

Since dummy variables are also to be used in estimation, the basic model equation 4.19 has to be modified to incorporate dummy variables. This can be done simply by redefining the parameter C_j in equation 4.19 as follows:

$$C_j = \exp \{\Theta_o + \sum_{k=1}^{n} \Theta_k D_{kj}\} \qquad (4.21)$$

Re-writing equation 4.19, we have:

$$Q_j = e^{\{\Theta_o + \sum_{k=1}^{n} (\Theta_k D_{kj})\}} \sum_{i\varepsilon A}^{n} x_{ij}^{a_i} e^{\alpha_i X_{ij}} \sum_{i\varepsilon\beta}^{n} e^{(\beta_i X_{ij} + \gamma_i X_{ij}^2)} . U_j \qquad (4.22)$$

where D_K = Ethnic, Locational, Farmer Status and Female - Tapper dummy variables.

The farmer status dummy variable indicates whether the farmer is from the local district or not. Similarly, the female tapper dummy variable includes only the farms which have both male and female members of the family doing the tapping. The Ethnic dummy variable groups farmers into their respective ethnic groups. In Cape Rodney, the sample included farmers from Dom, Domara, New Guinea, Aroma, Ianu, Kerema and Western District. Farmers grouped under New Guinea includes all those farmers who are not Papuans. The Kerema and Western Ethnic groups includes farmers from the Gulf and Western Districts respectively (refer Maps 1 and 2). The rest of the ethnic groups are from the local Marshall-Lagoon district. The Locational dummy variables represent the four distinct sub-divisions within the Cape Rodney Rubber Scheme. These are Ianu, Moreguina, Manabo and Bomguina (refer Map 5).

In double log linear form, model equation 4.22 can be expressed as:

$$q_j = \Theta_o + \sum_{k=1}^{n} (\Theta_k D_{kj}) + \sum_{i\varepsilon A}^{n} (a_i x_{ij} + \alpha_i X_{ij}) + \sum_{i\varepsilon\beta}^{n} (\beta_i X_{ij} + \gamma_i X_{ij}^2) + u_j \qquad (4.23)$$

where lower case denotes natural logs to base e.

The basic model equation 4.20 and the dummy variable model equation 4.23 are the two equations which will be empirically estimated, forming the basis of analysis presented in Chapter 5.

4.2.3.1 Properties

The properties of the TRANS function, initially derived by Sepien (1978), are presented in this section. The basic model equation 4.20 is used for this purpose.

The general isoquant equation for the basic model can be expressed as:

$$\sum_{i\varepsilon A}^{n} (a_i x_{ij} + \alpha_i X_{ij}) + \sum_{i\varepsilon\beta}^{n} (\beta_i X_{ij} + \gamma_i X_{ij}^2) + c_j + u_j - q_j^o = 0 \quad (4.24)$$

where q_j^o is the natural log value of some chosen output, $Q_j^o = Q_j$. The same isoquant expression applies for the other model equation 4.23, except that c_j in equation 4.24 is replaced with $\sum_k^n (\Theta_k D_{kj})$.

The Marginal Product (MP_{ij}) and the factor elasticities of output (P_{ij}) equations are presented below. For the set of essential inputs, MP_{ij} and P_{ij} are equations 4.26 and 4.27 respectively.

$$\frac{1}{Q_j} \frac{\partial Q_j}{\partial X_{ij}} = \frac{a_i}{X_{ij}} + \alpha_i \quad (4.26)$$

$$\left.\frac{MP_{ij}}{i\varepsilon A}\right| = [\frac{a_i}{X_{ij}} + \alpha_i] \, Q_j \quad ; i\varepsilon A \quad (4.26)$$

$$\left.\frac{P_{ij}}{i\varepsilon A}\right| = a_i + \alpha_i X_{ij} \quad ; i\varepsilon A \quad (4.27$$

For the set of non-essential inputs, MP_{ij} and P_{ij} are equations 4.28 and 4.29 respectively.

$$\frac{1}{Q_j} \frac{\partial Q_j}{\partial X_{ij}} = (\beta_i + 2\,\gamma_i X_{ij}^2) \quad (4.28')$$

$$\left.\frac{MP_{ij}}{i\varepsilon\beta}\right| = (\beta_i + 2\,\gamma_i X_{ij}) Q_j \quad ; i\varepsilon\beta \quad (4.28)$$

$$\left.\frac{P_{ij}}{i\varepsilon\beta}\right| = \beta_i \, X_{ij} + 2\gamma_i X_{ij} \quad ; i\varepsilon\beta \quad (4.29$$

The concept of Marginal Rate of Technical Substitution (MRTS) for our basic model, will be looked at in three different ways. These are (i) the MRTS between essential variables; (ii) the MRTS between non-essential variables; and (iii) the MRTS between essential and non-essential variables. The general MRTS equation is:

$$\left.MRTS_{ih}\right|_{\substack{i\varepsilon A\\ h\varepsilon A}} = - \frac{\left.\frac{\partial Q}{\partial X_{ij}}\right| i\varepsilon A}{\frac{\partial Q}{\partial X_{ij}} \; h\varepsilon A} = \frac{MP_i}{MP_h} \quad i,h\varepsilon A \tag{4.30}$$

Using formula equation 4.30, the MRTS between essential inputs, between non-essential inputs and between essential and non-essential inputs are equations 4.31, 4.32 and 4.33 respectively.

$$\left.MRTS_{ih}\right|_{i,h\varepsilon A} = \frac{MP_i}{MP_h} = \frac{\frac{a_i}{X_{ij}} + \alpha_i}{\frac{a_h}{X_{h_j}} + \alpha_h} \tag{4.31}$$

$$\left.MRTS_{ih}\right|_{i,h\varepsilon B} = \frac{MP_i}{MP_h} = \frac{\beta_i + 2\gamma_i X_{ij}}{\beta_h + 2\gamma_h X_{hj}} \tag{4.32}$$

$$\left.MRTS_{ih}\right|_{\substack{i\varepsilon A\\ h\varepsilon B}} = \frac{MP_i}{MP_h} = \frac{\frac{a_i}{X_{ij}} + \alpha_i}{\beta_h + 2\gamma_h X_{hj}} \tag{4.33}$$

where A is the set of essential inputs and B the set of non-essential inputs.

Because of its complexity, the concept of MRTS is never easily understood. To avoid this, a simple example will be used to illustrate the meaning of the concept.

Consider the isoquant segment AB in Figure 4.5 with two input factors X_1 and X_2. On AB, all combinations of X_1 and X_2 yield the same level of output. This means that any movement along the curve AB indicates that

X_1 is being substituted for X_2 or vice versa. This does not necessarily mean that X_1 is replacing X_2 in physical terms. It merely reflects the fact that within limits (as defined by the location of the isoquant), the same level of output can be achieved from various combinations of quite different inputs. For example, fertilizer can successfully substitute for irrigation water and give rise to the same level of output, although fertilizer and water have different physical properties.

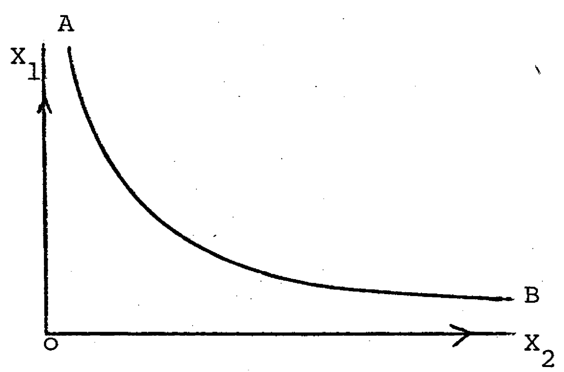


Figure 4.5 Isoquant

A smooth AB curve implies that 'yield contours' do exist, thus allowing for the possibilities of factor substitution. The slope of AB is at all points negative, indicating that this is the economically rational stage of production (Stage II in Figure 4.4). As we move from B to A, it becomes increasingly difficult to substitute X_1 for X_2. This is because more of X_1 is being used each time to replace a unit of X_2. Depending on the direction of substitution, MRTS varies at all points on curve AB. MRTS is therefore a general indication of the ease with which two factors of production can be substituted. More simply, it is the slope of the isoquant curve AB, at specific points.

4.2.3.2 Technical Efficiency

A farmer is said to be technically more efficient than another when he is able to produce a higher level of output, given that both farmers use the same level of inputs. In other words, he obtains a maximum output per unit of input. This implies that different combinations of inputs can result in a single index of technical efficiency.

The concept of technical efficiency can be discussed in the context of Figure 4.6, developed initially by Farrell (1957). For simplicity's sake, let us first assume that farmers use only two factors of production labour (L) and capital (K), and that all farms are within easy access of the best existing technology. Assume also that all farms experience constant returns to scale. On the two factor unit isoquant diagram in Figure 4.6, the input levels of five farms are represented by the points F_1 to F_5. Each of such points represent the input combinations of L and K used by that farmer to produce one unit of output. Efficient production is represented by the smooth curve, AB. Production to the left of the frontier AB is impossible, given the existing level of technology.

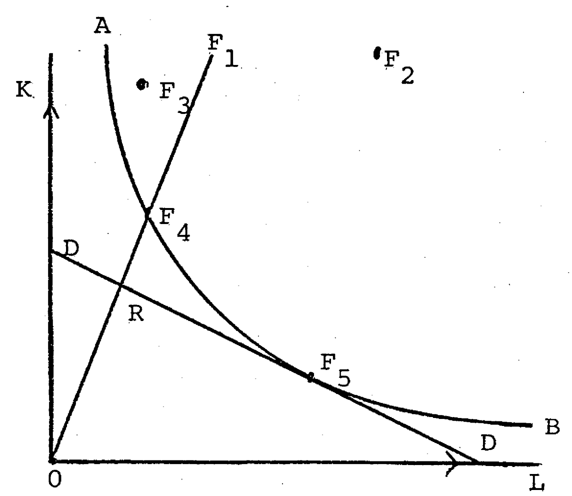


Figure 4.6 The Concept of Technical Efficiency

The method introduced by Farrell measures the technical efficiency rating of Farmers F_1 to F_5, relative to the frontier AB. This method would therefore rate farms F_4 and F_5 as being 100 per cent technically efficient, both farms being actually located on the frontier itself. The other farms (F_1, F_2 and F_3) would then have technical efficiency ratings less than the 100 per cent achieved by farms F_4 and F_5. Their respective distances from the frontier itself indicates the degree of technical inefficiency. Hence, farm F_1's technical efficiency rating can be determined by the ratio $\frac{OF_4}{OF_1}$. Farm F_2 is therefore the least technically efficient, being furthest away from the production frontier, AB. In other words, farm F_2 uses more of both L and K to obtain a unit of output than all the other farms.

Figure 4.6 can also be used to illustrate the concept of price efficiency, assuming that factor prices are known and that factor markets are perfectly competitive. The straight line DD' represents the relative factor prices of inputs, L and K. It is also known as the budget or isocost line and it represents the degree to which farmers are able to use input combinations which are determined by their relative prices. Farmers who operate on the budget line DD' are then said to be price efficient. According to this criteria, only farm F_5, which was also technically efficient, is price efficient. This means that farm F_5 can not only obtain maximum output per unit of input but also obtain maximum output per unit of cost expenditure. Farm F_5 is then said to achieve economic efficiency. Farm F_4 is technically efficient but not price efficient. The degree of its price inefficiency can be measured by the ratio, $^{OR}/OF_4$. Farm F_2 is also the most price inefficient farm, having the highest level of cost expenditure per unit of output.

Technical efficiency can differ between farms depending on the influence of factors such as technical differences, differences in input endowments and other random differences.[1] Technical differences can result from differences in production techniques, differences in types of machinery used and even from differences in general knowledge between farmers. Random differences include differences mainly in

[1] Technical efficiency is defined in this study in terms of a given production technique.

climatic and environmental factors.

The frontier function approach has been commonly used in studies looking at the question of technical efficiency. This function has usually been estimated using Linear Programming (LP) techniques where the basic aim is the minimisation of random errors subject to certain constraining conditions; the most important of which is that the predicted level of output ($\hat{q}$) must be greater than or equal to ($\geq$) the actual observed output, for each individual farm. This method of measuring technical efficiency was initially introduced by Farrell (1957) and later Timmer (1970), Aigner and Chu (1968), Seitz (1970) and Chandra (1979) all used this approach with minor modifications. Other studies using this technique includes Sharma (1974), Teo (1976) and Muharminto (1980).

The frontier function approach to the measurement of technical efficiency has its share of theoretical and conceptual weaknesses. The assumption implied by this approach, that all farmers are output or profit maximisers, may not always be true, especially when one is dealing with societies which have a noted degree of subsistence affluence. That is, if individual or groups of farmers have different objective functions, then this approach will yield results which are not representative.

This approach, however, does succeed in identifying farm specific additional inputs which cause differences in technical efficiency between farms. The weakness, however, is that the importance and the magnitude of these additional inputs are not indicated and therefore the reasons for resource mis-allocation remain unknown (Abdullah, 1978, p.65). Furthermore, since the frontier function is estimated by fitting a frontier to actual farm observations, the relative shape and position of this frontier can be influenced by the number of observations which satisfy the constraining conditions. In fitting a frontier function it is assumed that there is a random element which causes some observations to be outside the mean value of the frontier. This may indicate that the approach is somewhat arbitrary. Besides, the method of the squared deviations on one side is certain to produce an upward bias (Abdullah, 1978, p.66).

Another basic weakness of this approach lies in the implicit assumption that movement from the average to the frontier function occurs in a neutral fashion. This means that factor elasticities between the average and frontier farmers remain unchanged. If this is true, the distance from the frontier can actually indicate the degree of technical inefficiency. If not, the relative measures of technical efficiency are biased. Besides, the level of production chosen by a farmer is very much dependent on the ruling factor and output prices. Other major criticisms of the frontier function approach are made on the grounds of uncertainty, costly information and the inter-dependence of time periods in the operational environment.

The frontier function approach will not be used in this study to measure technical efficiency. Instead, an attempt will be made to incorporate variables which can measure technical efficiency directly into the production function. This approach is more flexible in that neutral and non-neutral shifting functions can be directly estimated, given that the functional form is correctly specified

A neutral shift in the production frontier is said to occur when only the intercept term changes, leaving the variable coefficients unchanged. Figure 4.7 illustrates a neutrally shifting function.

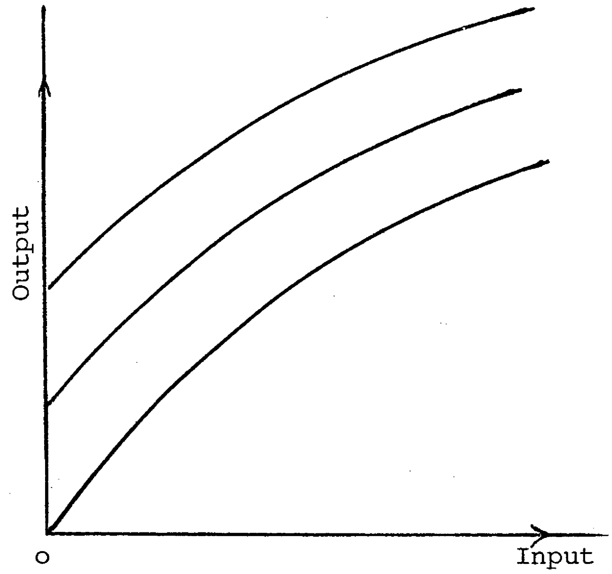


Figure 4.7 Neutral Shifts

This can occur when dummy variables are included as independent variables in actual regression analysis so that the overall intercept term changes with the inclusion of different dummy variables. The dummy variable model equation 4.23 will be used for this purpose.

The estimation of two different production functions for two separate groups, which are found to be significantly different from each other[1] can yield non-neutrally shifting results. This occurs when either the intercept term, the variable coefficients, or some combination of the intercept and the variable coefficients differ between the two groups. Figure 4.8 illustrates non-neutrally shifting production functions for both essential and non-essential sets of inputs. The basic model equation 4.20 will be used for this purpose.

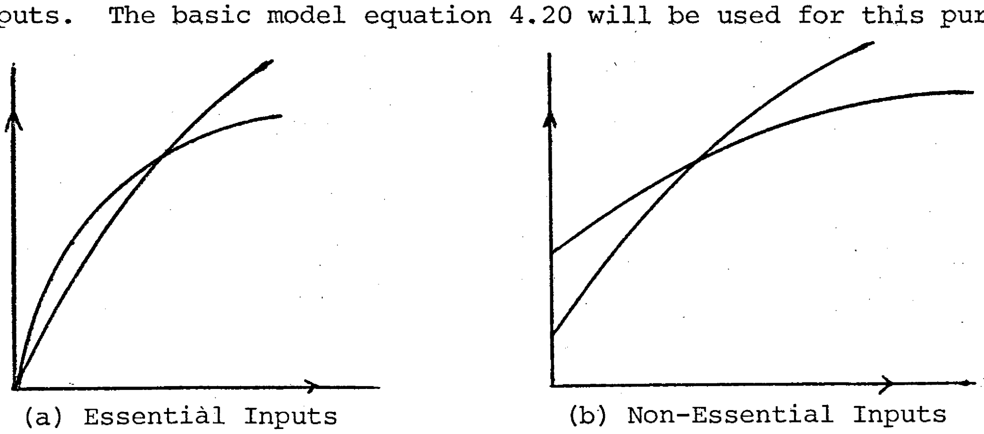


Figure 4.8 Non-Neutral Shifts (After Abdullah, 1978:72)

1 Using the Chow TEST explained in Chapter 5.

4.3 Appropriate Properties of a Rubber Production Function

Having discussed the general features of the two production function models (C-D and TRANS) commonly used in rubber production function studies, this section will now discuss some of the desirable properties of a rubber production function. This will involve relating the logic of the rubber production process discussed in Chapter 3, with the theory of production functions discussed in the earlier part of this Chapter.

4.3.1 Essentiality of Inputs

Inputs used in rubber production can be classified into essential and non-essential inputs. Essential are the set of inputs which if not used in production, will result in no rubber output being produced. Non-essential inputs, on the other hand, are the set of inputs without which rubber can still be produced. These sets of inputs, although being non-essential, can enhance rubber productivity quite significantly.

Essential inputs include rubber trees, harvesting and capital equipment (those used in tapping, planting, clearing and maintenance). The set of non-essential inputs include maintenance labour, fertilizer, weedicides, pesticides, stimulants, management and sociological factors. According to Table 3.1 essential inputs which cannot be easily influenced by farm decisions include age of trees, soil types, topography and rainfall. Age of trees is influenced only to the extent that the farmer has the freedom of deciding the time of planting. Thereafter, the age of the tree cannot be influenced by any decision the farmer makes.

Given that in rubber production, factor inputs can be classified into two distinct sets of inputs (essential and non-essential), an appropriate rubber production function should therefore allow for these differences in its input factors. This then rules out the validity of functional forms such as the C-D, CES, Polynomials, Spillmans and Hyperbolic, all of which make no distinct differentiation between factor inputs with the assumption that all input variables are essential.

4.3.2 Marginal Productivities

The neo-classical input-output relationship implies an increasing production function up to a certain maximum level, after which the function declines. The respective marginal product (MP) and average product (AP) curves behave in a manner similar to that of the total product (TP) function explained above. This relationship is shown in Figure 4.4. It indicates that TP is always increasing but at a slower rate when MP has positive values. The moment MP has values equal to or less than zero, TP begins to decline. This points out that any MP curve should be increasing initially followed by a decline and later have negative values when the input is applied intensively.

Similarly, an appropriate rubber production function should be able to handle increasing, decreasing and negative marginal productivities. Such changing marginal productivities can be viewed in rubber production in terms of the relationship between yield and time. Rubber trees start yielding some 5 to 6 years after planting, when tapping commences. This is followed by a rapid increase in yields up to a certain maximum level, usually predicted by experimental results. They remain constant for some time and then decline as the trees become older. Optimal rubber replacement studies by Etherington and Jayasuriya (1977) and Jayasuriya (1973) clearly indicate that this relationship between rubber yields and time has been found to exist.

On the question of negative marginal productivity, prior knowledge of rubber production would indicate that negative marginal productivities can occur. Two examples of when negative marginal productivities can occur are high tapping intensity and an overdose of fertilizer. Both these practices can reduce the DRC of latex or, in severe cases, kill the tree. For example, a very high tapping intensity of say $^{S}/1$, $^{d}/2$, 200% can cause brown bast and if continued will eventually kill the tree. In PNG, a review of the rubber industry by United Nations officials found that a smallholder had in fact used such a tapping intensity. This was caused by misunderstanding on the part of the farmer who suffered both in terms of falling yields and dying trees (Akhurst, 1976, p.15). In the Cape Rodney Scheme, most farmers tend to use the $^{S}/2$, $^{d}/2$ and $^{S}/2$, $^{d}/3$ tapping systems. However, there were a few reports of farmers overtapping their trees and they had to be warned to revert to the recommended systems.

A major part of maintenance labour time is spent in clearing undergrowth. This contributes to increasing the girth of the tree which, in turn, enhances rubber output.
If clearing undergrowth goes to the extent of clean weeding, the top soil becomes exposed to erosion, causing the loss of important soil nutrients and sometimes accentuates the spread of root diseases. This would then result in maintenance labour, as an independent input variable, having negative marginal productivities.

The argument of increasing, decreasing and negative marginal productivities for some input factors used in rubber production makes it quite impossible to accept functional forms which are not capable of handling such returns. The C-D model used by Teo (1976), Chandrasiri *et al.* (1977) and Muharminto (1980) is, on these grounds, unsuitable because it does not capture the above aspects of the rubber production process.[1]

4.3.3 Homotheticity

An important feature of a homothetic function is the linear expansion path from the origin where the MRTS on different isoquants is the same. This implies that MRTS depends only on the input proportions but not on the scale of production. The C-D and the CES models are examples of homothetic functions.

In rubber production, there is no clear evidence that MRTS differs as the scale of production expands. However, if we accept that estates and smallholders produce rubber using significantly different resource combinations, then it is being implied that MRTS does vary according to the scale of operation. This is especially true given the observation that estates are relatively more capital intensive than the smallholders. Another desirable property of a rubber production function is, therefore, that of changing MRTS in relation to the scale of production. In other words, the appropriate function should be non-homothetic.

4.3.4 Elasticity of Substitution

The elasticity of substitution (σ) can be defined in terms of input prices and MRTS. In the context of the farmer, σ indicates the percentage change occurring in factor proportions as a result of a one percentage change in the factors relative prices. In terms of MRTS, σ is the percentage change in factor proportions resulting from a one per cent change in the MRTS between two factors, holding output constant. All homothetic functions have a constant σ between factors of production. For the C-D model, with σ being equal to one, ($\sigma = 1$),

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1 However, it can model the production process almost as well as the TRANS and is easier to handle.

the response of factor proportions is proportionately dependent on changes in relative factor prices or MRTS, assuming perfect factor markets and uniform objective functions. In a CES function, σ can assume any value, but this value remains constant at different scales of production.

In rubber production, σ is more likely to vary than remain constant. Using the estate and smallholder comparisons again, the former tend to be more cost conscious than the latter which would then cause σ to differ between them. For example, a smallholder using family labour would make quite different substitution decisions than an estate manager employing labour, especially in view of the fact that labour is an important cost component to the estate manager while it is practically costless to the smallholder. A variable elasticity of substitution is another desirable property of a rubber production function.

4.3.5 The Selected Function

Thus far, some of the major limitations of using the C-D model in estimating a rubber production function have been stated. They indicate that the C-D model is not conceptually and theoretically sound. The same can be said about other functions reviewed in this study.

The TRANS model, on the other hand, seems to satisfy all the conditions of an appropriate rubber production function. It allows for increasing, decreasing and negative marginal productivities; it distinguishes between essential and non-essential inputs; it is non-homothetic and it allows for a variable σ ; all of which, we have identified, as being desirable properties of a rubber production function. The TRANS model is therefore selected for use in empirical estimation of a rubber production function in this study. However, for practical comparison purposes, both the C-D and TRANS models are used in empirical estimation in Chapter 5. Only the results of the TRANS model will be interpreted and subsequently used to derive policy conclusions.

4.4 Problems in Production Function Estimation

Production functions used as tools for measuring agricultural productivity and explaining the input-output relationships have their share of problems and weaknesses. Most of these are of statistical nature and they will be discussed briefly in this section.

The first of these is what has often been termed the mis-specification problem where the production function model is either underspecified or oversimplified. A model is said to be underspecified when input variables which significantly influence the dependent variable are omitted. The most common specification error of this type is the omission of the managerial input variable which can often result in biased output elasticities of factors of production. Another example is the estimation of a production function over a time period in which technical change has occurred but a variable to capture this change is not specified. Even if such a variable is specified, the problem may still exist if the variable is inadequately approximated or is measured without any quality considerations. On the other hand, a model is oversimplified if variables which have no direct influence on the dependent variable are included in estimation.

Another difficulty which may be less serious, is the bias due to the application of single least squares to the estimation of production functions based on non-experimental data. This problem is usually referred to as the simultaneous equation bias and it arises when the input-output observations being examined are not generated independently of the dependent variable. These observations may also be influenced by the farmer's maximising behaviour. This implies that factor inputs are not independent of the errors in the estimation equation. Since this latter relationship is not captured, single equation estimates are biased and inconsistent.

On the question of management as an input variable, it has been substantially proven that this is an important factor of production since the quality of this input can significantly influence output. This relationship is such that better farm managers tend to produce a higher level of output than farmers who are not as good. In any set of empirical data, it would be reasonable to assume that individual farmers do differ in managerial abilities which in turn may be a major source of inter-farm differences. If in such cases a management variable is not distinctly specified, the resulting output elasticities will be biased and inconsistent.

Other problems often encountered in production function analysis are those of auto correlation, multicollinearity and aggregation problems. Autocorrelation is said to occur when the error (disturbance) terms move in the same direction as the input variables. That is, they are correlated. Similarly, the problem of multicollinearity is encountered when input variables are highly correlated with each other. In agricultural production functions, correlations of the order of 0.70 or more are an indication that there is a serious multicollinearity problem in the data set. When this happens, only one of the highly correlated variables may be used in actual estimation. Finally, the aggregation problem occurs when two or more variables with similar characteristics are to be aggregated into a single input category. Because it is quite impossible to aggregate perfectly, the result of this procedure is at best an estimate of the real input category.

None of these problems seriously limit the analysis presented in Chapter 5.

CHAPTER 5

EMPIRICAL ESTIMATION PROCEDURES AND RESULTS

This Chapter deals with the procedures used in estimating both the C-D and the TRANS functional forms. Results of the actual production function analysis are also discussed. Section 5.1 discusses the results obtained from fitting a C-D production function. This is undertaken to show how the two models differ, especially in terms of their explanatory powers. In Section 5.2, the same set of data is analysed using the TRANS functional model. These results are then used to examine technical efficiency and allocative efficiency of the major inputs Harvesting Labour (X_1) and Trees in Tapping (X_2); using the two groups, Local and Non-Local Farmers. To obtain policy conclusions from the results discussed, the TRANS model is given preference over the C-D model for reasons outlined earlier.

5.1 The C-D Production Function

The C-D production function used here has the general log-linear form:

$$q_j = b_o + \sum_{i=1}^{n} b_i x_{ij} \qquad \ldots \quad (4.3)$$

Allowing for the inclusion of intercept dummies, the function in equation 4.3 can be modified so that it becomes:

$$q_j = b_o + \Theta_k D_{kj} + \sum_{i=1}^{n} b_i x_{ij} \qquad \ldots \quad (4.4)$$

The C-D model equations 4.3 and 4.4 are estimated using the Ordinary Least Squares (OLS) regression technique provided in SHAZAM, a comprehensive statistical computer program. All logs are to the base e.

The variables used in actual production function estimation include:

- Q — The dependent variable being rubber output on a DRC basis;
- X_1 — Harvesting Labour in man-days;
- X_2 — Number of Trees in Tapping;
- X_3 — Years Since Tapping Commenced;

X_4	Age of Farmer in years;
X_5	Experience of Farmer in years;
X_6	Total Farm Size in hectares;
X_7	Depth of cut (mm);
X_8	Age of Trees in years;
X_9	Total Number of Trees;
X_{10}	Maintenance Labour in man-days;
X_{11}	Capital Equipment (Kina);
D_1	Condition of Block;
D_2	Condition of Tapping Panel.

The independent variables D_1 and D_2 are weighted dummy variables so that the better the condition the more weight they are assigned and vice-versa. In addition, Ethnic and Locational dummy variables are also included in regression, using the model equation 4.4. Details of these dummy variables are given in Table 5.6.

The Ethnic and Locational dummy variables classified in Table 5.6 are used in this study as intercept dummy variables. This means that when they are included in regression, they affect only the intercept term, leaving the slope unchanged. They can have values of either '1' or 'o', depending on the category in which individual observations appear. For example, farmers belonging to a certain ethnic group are assigned values of 1 while the rest are given o values. Not all dummy variables are included in any single regression. The inclusion of specific dummy variables depends very much on the purpose of the regression. If, for example, the purpose of regression is to find out the influence of differences in ethnicity on output or productivity, we include in the regression only 6 out of the 7 ethnic dummy variables, excluding the rest of the dummy variables as well. In this case, the real coefficients of the 6 included dummy variables are the sum of the intercept and their individual estimated coefficients. The coefficient of the excluded dummy variable is implied by the value of the intercept term, Θ.

Results of the 8 regression using the C-D production function model are presented in Tables 5.1, 5.3 and 5.5. The regressions in Tables 5.1 and 5.3 used the C-D model given in equation 4.3 while the regressions in Table 5.5 used the same model but as given in equation 4.4. All regressions using the above model equations 4.3 and 4.4 were run using the whole sample of 50 farmers.

5.1.1 Factors Affecting Rubber Productivity

Regression results presented in Table 5.1 are obtained when all the variables listed earlier are included in the regression, R(1.a). The results clearly show that only 3 out of the 13 variables seem to have any significant influence on output. These variables are Harvesting Labour (X_1), Maintenance Labour (X_{10}) and Condition of Tapping Panel (D_2). An R^2 value of 0.7724 indicates that the model equation 4.3 is successful in explaining about 77 per cent of the variation in smallholder rubber output. The unexplained variation in output is due to either (a) mis-specification of the model, or (b) that some significant variables have been omitted or, if included, have been measured incorrectly. In regression R(1.a), the independent variable X_2 (Number of Trees in Tapping), which is probably the most important input variable in rubber production is unexpectedly not significant. This implies that X_2 has no significant influence on rubber output. But an examination of the coefficient correlation matrix in Table 5.2 reveals that there exists a high correlation between X_2 and X_9, the Total Number of Trees. This then explains why X_2 was not significant in the regression R(1.a). The appropriate action then is to exclude the variable X_9 from all future regressions.

Although most of the input variables in Table 5.1 have insignificant coefficients, the signs of these coefficients can show the general trend

Table 5.1

The Estimated Parameters and Related Statistics Using The Cobb-Douglas Production Function Model for All Variables (Regression R(1.a)

X_1	Harvesting Labour	$(\hat{\beta}_1)$	0.50162***[1] (0.11150)
X_2	Number of Trees in Tapping	$(\hat{\beta}_2)$	0.25589 (0.27934)
X_3	Years Since Tapping Commenced	$(\hat{\beta}_3)$	0.24655 (0.21577)
X_4	Age of Farmer	$(\hat{\beta}_4)$	0.25322 (0.34349)
X_5	Experience of Farmer	$(\hat{\beta}_5)$	0.34171 (0.21898)
X_6	Total Farm Size	$(\hat{\beta}_6)$	0.48139 (0.39033)
X_7	Depth of Cut	$(\hat{\beta}_7)$	0.05670 (0.47616)
X_8	Age of Trees	$(\hat{\beta}_8)$	-0.49652 (1.0003)
X_9	Total Number of Trees	$(\hat{\beta}_9)$	0.31868 (0.28212)
X_{10}	Maintenance Labour	$(\hat{\beta}_{10})$	-0.38091* (0.19354)
X_{11}	Capital Equipment	$(\hat{\beta}_{11})$	-0.08643 (0.18869)
D_1	Condition of Block	$(\hat{\Theta}_1)$	-0.07499 (0.14951)
D_2	Condition of Tapping Panel	$(\hat{\Theta}_2)$	0.39980*** (0.15720)
Constant		(α)	0.05764
Adjusted R^2			0.6902
R^2			0.7724
Overall F Statistic			9.399 ***
D.W.Statistic			2.2892
Number of Cases			50

[1] Figures in brackets are standard errors.
Levels of significance: * 5 per cent; *** 1 per cent.

Table 5.2

Correlation Matrix of Coefficients for Regression R(1.a)

	Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	D_1	D_2
Y	Total Output													
X_1	Harvesting Labour	1.0000												
X_2	Number of Trees in Tapping	-0.1497	1.0000											
X_3	Years Since Tapping Commenced	-0.0500	-0.4644	1.0000										
X_4	Age of Farmer	-0.2452	0.1321	-0.0974	1.0000									
X_5	Experience of Farmer	0.0064	-0.1851	-0.00454	-0.5316	1.0000								
X_6	Total Farm Size	-0.1898	-0.1170	-.0417	0.2134	-0.0729	1.0000							
X_7	Depth of Cut	0.1664	-0.1899	-0.001	-0.0565	0.1369	0.1825	1.0000						
X_8	Age of Trees	-0.0156	0.0836	-0.1833	-0.2541	-0.0278	-0.1017	-0.2089	1.0000					
X_9	Total Number of Trees	-0.0355	-0.6656	0.2542	-0.1922	0.1022	-0.0270	0.3097	0.0801	1.0000				
X_{10}	Maintenance Labour	-0.0663	-0.1143	0.01005	0.2421	-0.1710	0.0899	0.2450	-0.1661	-0.0379	1.0000			
X_{11}	Capital Equipment	0.0682	-0.3774	-0.1098	0.1530	0.0029	0.1536	-0.9129	-0.0317	-0.1298	0.0719	1.0000		
D_1	Condition of Block	0.0769	0.0154	-0.0351	-0.4350	0.2329	-0.3905	-0.3148	0.1908	-0.0400	-0.3637	-0.233	1.0000	
D_2	Condition of Tapping Panel	-0.1299	-0.0441	0.1511	0.3698	-0.2766	0.2240	0.0008	-0.6494	-0.0661	-0.0905	0.2256	-0.3607	1.0000

of the relationship they have with the dependent variables, Output (Q). One of the more interesting ones is the variable, Maintenance Labour (X_{10}), which has a negative and a significant coefficient of -0.3809, at the 5 per cent significance level. The initial interpretation of such a result would be that a 1 per cent increase in labour time used in maintenance activities would result in a 0.38 per cent decline in rubber output. An understanding of the rubber production process would, however, indicate that the negative relationship is the result of the inputs X_1 and X_{10} being competitive, since, in Cape Rodney, the same labour unit is the source of these two inputs. This implies that if more labour is used in maintenance activities, then less is available to accomplish harvesting activities. Besides, rubber farmers not only maintain the trees they tap, but also the immature and the mature trees not being tapped.[1] A negative correlation of -0.0663 in Table 5.2 between variables X_1 and X_9 does provide further support to the above finding.

A negative and insignificant coefficient of the variable Age of Trees (X_8), generally indicates that the trees currently being tapped are at a stage where with the passage of time, productivity of the average tree is on the decline. This is expected, given that the average age of trees is about 15 years. The negative coefficient of the variable Capital Equipment (X_{11}), although not significant, also presents an interesting situation. Since X_{11} is defined in terms of equipment used in tapping, this finding implies that as more tapping equipment becomes available, output tends to decline rather than increase as one might expect. This may in fact be due to errors in the measurement of this variable as it was felt during data collection that most farmers tended to report high prices on their tapping equipment. It may also reflect a situation where rubber smallholders tend to keep extra tapping equipment at hand so that they can be obtained easily when needed. The general indication is, therefore, that of under-utilisation of Capital Equipment. Finally, the negative coefficient of the weighted dummy variable

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[1] Only time spent in maintaining the tapped trees is specified here.

Condition of Block (D_1), indicates that most farms were considered to be below average during the period of the survey. This, as explained in the introductory chapter, was the result of the output price being so low that most farmers were not willing to tap as well as eradicate the undergrowth on their farms.

The results of the regression R(1.b), as shown in Table 5.3, include only significant variables using the model equation 4.3.[1] These re-estimated results indicate that 6 out of the original 13 independent input variables are found to significantly influence rubber productivity. These variables are shown in Table 5.3. They include Harvesting Labour (X_1), Number of Trees in Tapping (X_2), Experience of Farmer (X_5), Total Farm Size (X_6), Maintenance Labour (X_{10}) and Condition of Tapping Panel (D_2). On the basis of R^2, regression R(1.b) explains about 75 per cent of the variation in output, some 2 per cent lower than that explained by regression R(1.a). The adjusted R^2, adjusted for the degrees of freedom, however, indicates that regression R(1.b), explains about 3 per cent more of the variation in output than regression R(1.a). This implies that all variables excluded from regression R(1.b) can be said to have no significant influence on rubber output.

Since the coefficients of input variables in a C-D production function can be interpreted as being the output elasticities, we notice in Table 5.3 that rubber output is, on average, more responsive to the input variable X_1 than any other input variable included in regression R(1.b). Hence, if there is a 1 per cent increase in man-days spent on harvesting activities, rubber output would increase by some 0.55 per cent. As with trees in tapping, a 1 per cent increase in the numbers would result in output increasing by some 0.49 per cent. With similar increases in the input variables X_5, X_6 and D_2, output would correspondingly increase by some 0.44, 0.45 and 0.34 per cent respectively. Conversely, a 1 per cent increase in man-days of Maintenance Labour would decrease output by about

[1] Those variables which are statistically significant above the 5 per cent leve

Table 5.3

The Estimated Parameters and Related Statistics Using The Cobb-Douglas Production Function Model for Significant Variables Only

(Regression R(1.b)

Variable				Parameter
X_1	Harvesting Labour	$(\hat{\beta}_1)$		0.54682*** (0.10018)[1]
X_2	Number of Trees in Tapping	$(\hat{\beta}_2)$		0.49361*** (0.12270)
X_5	Experience of Farmer	$(\hat{\beta}_5)$		0.43743*** (0.17144)
X_6	Total Farm Size	$(\hat{\beta}_6)$		0.45226* (0.23722)
X_{10}	Maintenance Labour	$(\hat{\beta}_{10})$		-0.42790*** (0.16602)
D_2	Condition of Tapping Panel	$(\hat{\theta}_2)$		0.33922*** (0.12950)
	$\Sigma(\hat{\beta}_i + \hat{\theta}_i)$		=	1.84144[2]
Constant		(α)		0.45040
Adjusted R^2				0.7167
R^2				0.7514
Overall F-Statistic				21.664***
D-W Statistic				2.1287
Number of Cases				50

1 Figures in brackets are standard errors

Levels of significance: * 5 per cent; ** 2.5 per cent; *** 1 per cent

2 Indicates the returns to scale.

0.43 per cent. This, as mentioned earlier, can be explained in terms of the competitive nature of the variable inputs X_1 and X_{10}. The sign of $\hat{\Theta}_2$, the coefficient of the dummy variable D_2, is positive and significant at 1 per cent. This indicates that most smallholders in Cape Rodney generally have good tapping skills and practices and that this does somewhat enhance their productivity.

The sum of the coefficients in a C-D production function indicate the returns to scale which exist. In regression R(1.b), this sum is equal to 1.84144 as shown in Table 5.3. Since it is greater than unity, this indicates that increasing returns to scale exist for the smallholder rubber producers in Cape Rodney. A highly significant F-statistic of 21.664 implies that regression R(1.b) has a good overall fit. Likewise, a Durbin-Watson (D-W) statistic of 2.1287 indicates that auto-correlation is not a significant problem in the analysis. The correlation matrix of coefficients of regression R(1.b) is shown in Table 5.4. The low levels of correlation between the coefficients indicate that multi-collinearity is also not a major problem in this analysis. As the signs of the figures in the matrix show, most variable coefficients have negative correlations.

Table 5.4

Correlation Matrix of Coefficients of Regression R(1.b)

Variable	X_1	X_2	X_5	X_6	X_{10}	D_2
X_1 Harvesting Labour	1.0000					
X_2 Number of Trees in Tapping	-0.30461	1.0000				
X_5 Experience of Farmer	-0.18735	-0.21296	1.0000			
X_6 Total Farm Size	-0.2161	-0.19800	0.03615	1.0000		
X_{10} Maintenance Labour	-0.06419	-0.17735	-0.05683	-0.09605	1.0000	
D_2 Condition of Tapping Panel	-0.06345	0.14694	-0.12048	0.07518	-0.34808	1.0000

5.1.2 Productivity Between Groups.

The results of regressions R(1.c), R(1.d), R(1.e), R(1.f), R(1.g) and R(1.h) are presented in Table 5.5. These regressions use the model equation 4.4, where the intercept dummy variables are included along with the significant input variables found in regression R(1.b) of Table 5.3. The regressions R(1.c) and R(1.d) use the Ethnic dummy variables while regressions R(1.d) and R(1.f) use the Locational dummy variables. The regressions R(1.g) and R(1.h) use the Female Tappers and Local Farmers dummy variables, respectively.

The results of regressions R(1.c) and R(1.d) indicate that differences in productivity, between the different Ethnic groups, do exist. The basic assumption implied in such analysis is that all farmers use an 'average package of input factors'. Hence, differences in productivity can also be used as a proxy for technical efficiency, given that there is a neutral shift in the production frontiers of the different groups. This implies that factor elasticities remain unchanged while the intercept terms of the different production frontiers differ, indicating different levels of productivity and hence, technical efficiency.

In regression R(1.b), when the Western ethnic dummy (D_9) variable is excluded, we find that all the included ethnic dummy variables have negative coefficients. This indicates that farmers from the Western Ethnic Group are the most productive, as implied by the positive constant term in the regression. However, the insignificance of the Ethnic dummy variables D_4, D_6 and D_8 in regression R(1.c) implies that the Domara, Kerema and Aroma Ethnic Groups are not significantly different in terms of productivity, from the Western Ethnic Group. Despite this statistical insignificance, the differences in productivity can be approximated by taking the sum of the individual coefficients and the constant term which has a value of 0.7885, the implied coefficient for the dummy variable D_9. If this procedure is applied to all the dummy variables, we find that the frontier function for

Table 5.5

The Estimated Parameters and Related Statistics Using the Cobb-Douglas Production Function Model for Significant and Dummy Variables Only

Variable			PARAMETERS					
			R(1.c)	R(1.d)	R(1.e)	R(1.f)	R(1.g)	R(1.h)
X_1	Harvesting Labour	$(\hat{\beta}_1)$	0.48346*** (0.1086)[1]	0.48346*** (0.1086)	0.5523*** (0.1016)	0.5523*** (0.1016)	0.5458*** (0.1016)	0.5511*** (0.1012)
X_2	Number of Trees in Tapping	$(\hat{\beta}_2)$	0.31981** (0.1508)	0.31981** (0.1508)	0.4073*** (0.1425)	0.4073*** (0.1425)	0.4927*** (0.1243)	0.4866*** (0.1242)
X_5	Experience of Farmer	$(\hat{\beta}_5)$	0.57088*** (0.1980)	0.57088*** (0.1980)	0.5004*** (0.1791)	0.5004*** (0.1791)	0.4360*** (0.1738)	0.4374*** (0.1727)
X_6	Total Farm Size	$(\hat{\beta}_6)$	0.75631* (0.4002)	0.75631* (0.4002)	0.4847+ (0.3393)	0.4847+ (0.3393)	0.4523 (0.3411)	0.3935 (0.3533)
X_{10}	Maintenance Labour	$(\hat{\beta}_{10})$	-0.35359** (0.1723)	=0.35359** (0.1723)	-0.3923** (0.1726)	-0.3923** (0.1726)	-0.4262*** (0.1685)	-0.4112*** (0.1695)
D_2	Condition of Tapping Panel	$(\hat{\theta}_2)$	0.3425** (0.1505)	0.3425** (0.1505)	0.4118*** (0.1478)	0.4118*** (0.1478)	0.3403*** (0.1313)	0.3600*** (0.1554)
Ethnic Dummies:								
D_3	Dom	$(\hat{\theta}_3)$	-0.66061* (0.3889)					
D_4	Domara	$(\hat{\theta}_4)$	-0.0936 (0.3501)	0.5670+ (0.3543)				
D_5	New Guinea	$(\hat{\theta}_5)$	-0.5853+ (0.3789)	0.0753 (0.3343)				
D_6	Kerema	$(\hat{\theta}_6)$	-0.25421 (0.3314)	0.4064+ (0.2868)				
D_7	Ianu	$(\hat{\theta}_7)$	-0.46496+ (0.3324)	0.1957 (0.2785)				
D_8	Aroma	$(\hat{\theta}_8)$	-0.09513 (0.3644)	0.5656+ (0.3808)				
D_9	Western	$(\hat{\theta}_9)$		0.66061* (0.38885)				
Locational Dummies:								
D_{10}	Moreguina	$(\hat{\theta}_{10})$				0.3584 (0.2854)		
D_{11}	Ianu	$(\hat{\theta}_{11})$			-0.0793 (0.2598)	0.2792 (0.2522)		
D_{12}	Bomguina	$(\hat{\theta}_{12})$			-0.3584 (0.2854)			
D_{13}	Manabo	$(\hat{\theta}_{13})$			0.0522 (0.2367)	0.4107* (0.2456)		
D_{14}	Dummy for Female Tappers	$(\hat{\theta}_{14})$					-0.0199 (0.1496)	
D_{15}	Dummy for Local Farmers	$(\hat{\theta}_{15})$						-0.0941 (0.1554)
Constant		(α)	0.78848	0.1279	0.5045	0.1461	0.4673	0.5698
Adjusted R^2			0.7143	0.7148	0.7162	0.7162	0.7101	0.7125
R^2			0.7847	0.7847	0.7683	0.7683	0.7515	0.7536
Overall F statistics			11.235***	11.235***	14.741***	14.741***	18.147***	18.348***
D-W Statistic			2.2636	2.2636	2.1799	2.1799	2.1257	2.1384
Number of Cases			50	50	50	50	50	50

1. Figures in brackets are standard errors.

Levels of significance: + 10 per cent; * 5 per cent; ** 2.5 per cent; *** 1 per cent.

farmers from the Western Ethnic Group has an intercept term of 0.7885, followed in descending order by farmers from Domara (0.6949), Aroma (0.6934), Kerema (0.5343), Ianu (0.3235), New Guinea (0.2032) and Dom (0.1279). The figures in brackets are the intercept terms, indicating the differences in productivity between the different ethnic groups. The results of regression R(1.d) provide further support for the findings stated above. When the Dom ethnic dummy variable is excluded, the coefficients of all the included dummy variables become positive, implying that farmers from the Dom Ethnic Group are the least productive.

In regressions R(1.c) and R(1.d), approximately 79 per cent of the variation in rubber output can be explained by the variables included in these two regressions. This is an increase of some 4 per cent compared to the R^2 obtained in regression R(1.b) in Table 5.3. This indicates that some difference in rubber productivity can be attributed to differences in ethnic origin. This further implies that cultural and sociological differences between farmers do in fact influence farm productivity. The extent of such an influence cannot be tested in this study because of data limitations.

The objective of regressions R(1.e) and R(1.f) is to find out the differences in productivity, if any, which occur between farmers located in different parts of the scheme. The four different locations are Moreguina, Ianu, Bomguina and Manabo (Refer Map 5). The results indicate that farmers located in the Manabo area are more productive than farmers located in Moreguina, Ianu and Bomguina. However, the non-significance of all the coefficients of the locational dummy variables in regression R(1.e) and 3 out of the 4 coefficients in regression R(1.f), indicates that there is no statistically significant difference in productivity between farmers operating on different parts of the scheme. Despite this, a crude comparison using the procedure used earlier reveals that the Manabo Locational Group are the most productive, having a production frontier intercept of 0.5568. They are followed in descending order by Moreguina (0.5048), Ianu (0.4253) and Bomguina (0.1461), the figures in brackets being their respective production frontier intercepts.

The difference in R^2 between the regressions R(1.e) and R(1.f) on the one hand, and regression R(1.b) on the other is approximately 2 per cent. This indicates that locational differences account for some 2 per cent variation in rubber output. This, however, does not imply that definite environmental and soil differences do exist between farms in Cape Rodney, as the scheme itself is located only within some 30 sq km of land.

The two final regressions R(1.g) and R(1.h) in Table 5.5 use the Female Tappers (D_{14}) and Local Farmers (D_{15}) dummy variables, respectively. The results of the regression R(1.g) show that there is no significant difference in productivity between those farms which had some female tappers and those where tapping was a predominantly male activity. This verifies the observation stated in Chapter 3 that rubber harvesting is a predominantly male activity in Cape Rodney. Similarly, the result of regression R(1.h) indicates that there is no significant difference in productivity between Local and Non-Local Farmers. The former group includes those farmers who come from within the local Cape Rodney sub-district while the latter includes all those coming from other parts of the country (Refer map 4). The negative coefficients of the dummy variables D_{14} and D_{15}, however, indicate that the farms which have female tappers and the Local Farmers are somewhat less productive than their respective counterparts.

The main findings of the above analysis using the C-D production function model can be summarised as follows:

(a) The significant productive factors in rubber production are: Harvesting Labour (X_1), Trees in Tapping (X_2), Experience of Farmer (X_5), Total Farm Size (X_6), Maintenance Labour (X_{10}) and Condition of Tapping Panel (D_2).

(b) Harvesting Labour and Maintenance Labour are competitive inputs.

(c) Increasing returns to scale exist in rubber production in Cape Rodney.

and (d) Ethnic differences between farmers does explain some of the difference in farm productivity.

5.2 The TRANS Production Function

This section deals with the estimation of production functions using the TRANS model. In Section 5.2.1, the factors which significantly influence rubber productivity are identified. The two following sections look into questions of technical and allocative efficiency, respectively, using the sub-groups LOCAL and NON-LOCAL FARMERS for comparison purposes.

5.2.1 Estimation Procedures

The two TRANS model equations to be estimated in this analysis are re-written below:

$$q_j = c_j + \sum_{i\varepsilon A} (a_j x_{ij} + \alpha_i X_{ij}) + \sum_{i\varepsilon\beta} (\beta_i X_{ij} + \gamma_i X_{ij}^2) + u_j \quad .... (4.20)$$

$$q_j = \Theta_o + \sum_{k=1}^{n} (\Theta_k D_{kj}) + \sum_{i\varepsilon A} (a_i x_{ij} + \alpha_i X_{ij}) + \sum_{i\varepsilon B} (\beta_i X_{ij} + \gamma_i X_{ij}^2) + u_j \quad .... (4.23)$$

The basic difference between equations 4.20 and 4.23 is the allowance for the inclusion of dummy variables in equation 4.23. A classification of these dummy variables is made in Table 5.6. These equations were again estimated using the OLS regression technique, available in SHAZAM. All logs are to base e. The variables used in this analysis are the same as those used in the C-D analysis. In estimating the model equations 4.20 and 4.23 the independent input variables occur in three different forms. We have variables occurring in their natural number form, natural log form or as exponents to the power 2. The choice of how a variable occurs depends on

Table 5.6

Classification of Dummy Variables

Group	Description	Dummy	Notation
1	Weighted Dummies:[a]		
	Condition of Block	(D_1)	Θ_1
	Condition of Tapping Panel	(D_2)	Θ_2
2	Ethnic Group Dummies:		
	Dom	(D_3)	Θ_3
	Domara	(D_4)	Θ_4
	New Guinea	(D_5)	Θ_5
	Kerema	(D_6)	Θ_6
	Ianu	(D_7)	Θ_7
	Aroma	(D_8)	Θ_8
	Western	(D_9)	Θ_9
3	Locational Dummies:		
	Moreguina	$(D_{10}$	Θ_{10}
	Ianu	(D_{11})	Θ_{11}
	Bomguina	(D_{12})	Θ_{12}
	Manabo	(D_{13})	Θ_{13}
4	Other Dummies:		
	Dummy for Female Tappers[b]	(D_{14})	Θ_{14}
	Dummy for Local Farmers[c]	(D_{15})	Θ_{15}

(a) Weighted according to good = 3; average = 2; and poor = 1.

(b) Includes all farms having male and female tappers.

(c) Includes all farmers who come from within the Abau District.

whether it is an essential or non-essential variable as signified by the sets A and B respectively, in equations 4.20 and 4.23.

5.2.2 Factors Affecting Rubber Productivity

Using the TRANS production function model, when all independent variables, for which data were collected, are regressed on the dependent variable (output), only 2 out of the 13 independent variables are significant at the 5 per cent level. This regression is titled R(2.a) and the results are presented in Table 5.7. The variables X_2 and X_{11}, although being essential in rubber production, are surprisingly not significant. The insignificance of X_2 can again be explained in terms of the high correlation it has with variable X_9, The Total Number of Trees, in the correlation matrix provided in Table 5.8. According to the results of regression R(2.a), only Harvesting Labour and Age of Farmer are found to have any significant influence on rubber productivity.

Despite the non-significance of many of the variables included in regression R(2.a), general relationships between individual independent variables and the dependent variable, Q, can be established merely by observing the signs of the coefficients. Such an observation reveals that the variables X_1, X_2, X_4, X_5, X_6, X_9 and D_2, all have positive coefficients, indicating that any positive increase in the use of each of these variables would result in output increasing by some positive amount. The remaining variables X_3, X_7, X_8 and X_{10} have negative coefficients. This indicates that any increase in each of these variables would reduce output by some positive amount.

An R^2 value of 0.8749 indicates that all the variables included in regression R(2.a) are capable of explaining about 87 per cent of the variation in rubber output. This is some 10 per cent more than that explained by the C-D model equation 4.3 used in regression R(1.a). In this regard, the TRANS model equation 4.20 has a greater explanatory power.

Table 5.7

The Estimated Parameters and Related Statistics Using
The Transcendental Model for All Variables
(Regression R(2.a))

Variable					
X_1	Harvesting Labour	(x_1)	a_1	0.7423	(0.2115)[1]***
		(X_1)	α_1	-0.0107	(0.0058)*
X_2	Number of Trees in Tapping	(x_2)	a_2	0.1376	(0.4961)
		(X_2)	α_2	0.0003	(0.0006)
X_3	Years Since Tapping Commenced	(X_3)	β_1	-0.0508	(0.1586)
		(X_3^2)	γ_1	0.0095	(0.0111)
X_4	Age of Farmer	(X_4)	β_2	0.1010	(0.0404)***
		(X_4^2)	γ_2	-0.0010	(0.0004)***
X_5	Experience of Farmer	(X_5)	β_3	0.0756	(0.0539)
		(X_5^2)	γ_3	-0.0023	(0.0016)
X_6	Total Farm Size	(X_6)	β_4	0.2165	(0.2758)
		(X_6^2)	γ_4	-0.0085	(0.0120)
X_7	Depth of Cut	(X_7)	β_5	-1.4164	(0.8656)
		(X_7^2)	γ_5	0.1318	(0.0811)
X_8	Age of Trees	(x_8)	a_3	-2.6193	(29.672)
		(X_8)	α_3	0.1349	(1.9624)
X_9	Total Number of Trees	(x_9)	a_4	0.5756	(0.7169)
		(X_9)	α_4	-0.0003	(0.0006)
X_{10}	Maintenance Labour	(X_{10})	β_6	-0.0172	(0.0223)
		(X_{10}^2)	γ_6	0.0001	(0.0003)
X_{11}	Capital Equipment	(x_{11})	a_5	-0.1297	(0.4876)
		(X_{11})	α_5	0.004	(0.0080)
D_2	Condition of Tapping Panel	(D_2)	θ_2	0.2187	(0.1524)
Constant			α_o	4.7256	
Adjusted R^2				0.7642	
R^2				0.8749	
Overall F-Statistic				7.906***	
D.W. Statistic				2.3353	
Number of Cases				50	

[1] Figures in brackets are standard errors

Levels of significance: * 5 per cent; ** 2.5 per cent; *** 1 per cent.

Variable		x_1	x_1	x_2	x_2	x_3	x_3^2	x_4	x_4^2	x_5	x_5^2	x_6	x_6	x_7	x_7^2	x_8	x_8	x_9	x_9	x_{10}^2	x_{11}	x_{11}	D_2	
X_1 Harvesting Labour	x_1	1.0000																						
	x_1	-0.8296	1.0000																					
X_2 Number of Trees in Tapping	x_2	-0.2201	0.1574	1.0000																				
	x_2	0.0117	0.0391	-0.7867	1.0000																			
X_3 Years Since Tapping Commenced	x_3	0.1515	-0.1272	-0.4992	0.3255	1.0000																		
	x_3^2	-0.1821	0.1544	0.4721	-0.3113	-0.9666	1.0000																	
X_4 Age of Farmer	x_4	-0.2994	0.1683	0.2085	-0.1776	-0.0790	0.1060	1.0000																
	x_4^2	0.2791	-0.1477	-0.1995	0.1844	0.0834	-0.1150	-0.9889	1.0000															
X_5 Experience of Farmer	x_5	0.01728	0.0062	-0.0391	-0.0058	-0.0958	0.0483	-0.3352	0.3108	1.0000														
	x_5^2	-0.0082	-0.0229	-0.0028	0.0048	0.0981	-0.0500	0.2459	-0.2403	-0.9408	1.0000													
X_6 Total Farm Size	x_6	0.0061	-0.1760	-0.1400	-0.0541	0.0539	0.0061	0.0495	-0.0607	-0.0763	0.0267	1.0000												
	x_6^2	-0.0345	0.1968	-0.1881	0.0467	-0.0506	-0.0345	0.0312	0.0431	0.0789	-0.0272	-0.9936	1.0000											
X_7 Depth of Cut	x_7	0.0936	-0.1692	0.0916	-0.1994	0.0574	-0.0697	-0.0699	0.0781	0.1180	-0.0982	-0.0572	0.0637	1.0000										
	x_7^2	-0.0636	0.1445	-0.0945	0.1848	-0.0450	0.0539	0.0529	-0.0635	-0.1101	0.0905	0.0714	-0.0778	-0.9951	1.0000									
X_8 Age of Trees	x_8	-0.0342	-0.0031	0.2736	-0.2156	-0.1775	-0.0342	-0.0112	0.0194	0.1073	0.0166	-0.4336	0.4464	0.2998	-0.3205	1.0000								
	x_8	0.0332	0.0061	-0.2792	0.2215	0.1827	-0.1700	0.0094	-0.0182	-0.0996	0.0073	0.4289	-0.4414	-0.3021	0.3224	-0.9994	1.0000							
X_9 Total Number of Trees	x_9	-0.0653	-0.0504	-0.4974	0.6236	0.1833	-0.1744	-0.2287	0.2177	-0.0506	0.0671		-0.1998	-0.0198	0.0189	0.0475	-0.0489	1.0000						
	x_9	0.1281	-0.0667	0.4670	-0.7717	-0.0969	0.0811	0.1976	-0.2002	0.0621	-0.0562	-0.0313	0.0399	0.1324	-0.1166	0.0175	-0.0158	-0.9115	1.0000					
X_{10} Maintenance Labour	x_{10}	-0.0885	-0.1537	0.0009	-0.0036	0.0819	-0.1016	-0.0022	-0.0063	0.0611	-0.0664	0.2509	-0.2489	0.0299	-0.0072	-0.0363	0.0349	0.2365	-0.1622	1.0000				
	x_{10}^2	0.1268	0.1331	-0.0738	0.0531	0.0001	0.0151	-0.0021	0.0144	-0.0902	0.0728	-0.1881	0.1824	-0.0896	0.0729	-0.0761	0.0728	-0.2221	0.1406	-0.9678	1.0000			
X_{11} Capital Equipment	x_{11}	0.1263	-0.1408	-0.4262	0.1407	-0.0893	0.0392	-0.1244	0.1179	0.1643	-0.1180	0.3024	0.2989	0.0932	-0.1048	-0.0638	-0.1180	-0.0712	0.1717	-0.0629	0.0720	1.0000		
	x_{11}	-0.0860	-0.1361	0.4559	-0.2610	0.0141	0.0341	0.2359	-0.2263	-0.1677	0.1225	-0.2591	0.2609	-0.0639	0.0732	0.1312	0.1225	-0.0356	0.0387	0.0789	-0.0963	-0.9233	1.0000	
D_2 Condition of Tapping Panel	D_2	-0.1650	0.0865	0.2825	-0.3760	-0.1361	0.1645	0.0801	-0.0499	-0.1311	0.1333	0.0096	0.0049	0.3057	-0.3224	-0.2718	0.1333	-0.1995	0.2361	-0.1064	0.0092	0.1559	-0.0514	1.0000

Table 5.8

Correlation Matrix of Coefficients for Regression R(2.a)

The correlation matrix of coefficients for regression R(2.a) is presented in Table 5.8. The figures in the matrix show two points which are worth mentioning. Firstly, that whenever the same input variable takes on two different forms in a regression, there usually exists high correlation between them. In semi-log functional models, this does not necessarily indicate the existence of the multicollinearity problem. Secondly, the correlation between the two related variables X_2 and X_9 is unexpectedly negative and large, a correlation of -0.77. This indicates that as more new rubber plantings are made, fewer mature trees are actually tapped. This has two implications. Either that there exists a labour shortage problem such that as more trees become mature, the same or even a smaller number of mature trees are being tapped, or that replanting programs were introduced only recently, such that no additional trees have been opened up for tapping since tapping commenced.[1] Both these problems were found to exist in Cape Rodney and they indicate the lack of proper planning during the initial development stages.

The results of regression R(2.b) in Table 5.9 is the estimated function which best explains the data being analysed in this study. This was obtained after many trials, using different combinations of variables. All coefficients are significant above the 10 per cent level. This implies that all variables in this regression, taken as an average package of inputs, have an overall significant influence on rubber productivity. That is, they are identified as the main productive factors of rubber production in the Cape Rodney Resettlement Scheme. A comparison of these results to those obtained in regression R(1.b) in Table 5.3 reveals that the former regression tends to identify more input variables as having some significant influence on rubber productivity than the latter. Besides, the essential input, Capital Equipment (X_{11}) is found to be significant in regression R(2.b) while it was not significant in regression R(1.b).

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1 That is, initial planting may not have been followed by successive new plantings.

Table 5.9

The Estimated Parameters and Related Statistics Using The Transcendental Model for Significant Variables (Regression R(2.b))

Variables				Parameters	
X_1	Harvesting Labour	(x_1)	a_1	0.7713	(0.1808)[1]***
		(X_1)	α_1	-0.0105	(0.0049)**
X_2	Number of Tress in Tapping	(x_2)	a_2	0.5231	(0.1778)***
		(X_2)	α_2		
X_3	Years Since Tapping Commenced	(X_3)	β_1	0.0769	(0.0354)**
		(X_3^2)	γ_1		
X_4	Age of Farmer	(X_4)	β_2	0.1005	(0.0364)***
		(X_4^2)	γ_2	-0.0010	(0.0004)***
X_5	Experience of Farmer	(X_5)	β_3	0.0786	(0.0486)+
		(X_5^2)	γ_3	-0.0025	(0.0014)*
X_7	Depth of Cut	(X_7)	β_5	-1.3848	(0.7463)*
		(X_7^2)	γ_5	0.1281	(0.0703)*
X_{10}	Maintenance Labour	(X_{10})	β_6	-0.0077	(0.0044)*
		(X_{10}^2)	γ_6		
X_{11}	Capital Equipment	(x_{11})	a_5	-0.4562	(0.3714)+
		(X_{11})	α_5	0.0090	(0.0062)+
D_2	Condition of Tapping Panel	(D_2)	θ_2	0.2172	(0.1274)*
Constant			o	2.5638	
Adjusted R^2				0.7900	
R^2				0.8500	
Overall F Statistic				14.17 ***	
Number of Cases				50	

1 Figures in brackets are standard errors.

Levels of significance: + 10 per cent; * 5 per cent; ** 2.5 per cent; *** 1 per cent

N.B. Where there are missing values, these variables were not used in the regression.

On the basis of R^2, the TRANS model equation 4.20, used in regression R(2.a) is capable of explaining exactly 85 per cent of the variation in rubber output. This again is some 10 per cent higher than that explained by the C-D model equation 4.3. An overall F-Statistic of 14.17, significant at the 1 per cent level, indicates that regression R(2.b) has a good overall fit. The D-W statistic with a value of 2.1379 indicates that we are inconclusive as to whether autocorrelation is a problem or not. The correlation matrix of coefficients for regression R(2.b) is given in Table 5.10. The matrix shows that multicollinearity is again not a problem in this regression.

5.2.3 Output Elasticities of Factors of Production (ρ)

The coefficients of variables obtained using the TRANS model are not the output elasticities as is the case with the C-D model. The ρ values for each of the independent variables in regression R(2.b) are calculated using the formula equations 4.27 and 4.29 discussed in Chapter 4. The results are presented in Table 5.11. We find that Harvesting Labour (X_1), as an input factor, has an output elasticity of 0.3015. This implies that if there is a 1 per cent increase in man-days of harvesting labour, rubber output will correspondingly increase by some 0.3 per cent. The returns to X_1 are therefore declining, but still positive. This can also be verified by observing the actual coefficient of this variable in regression R(2.b), where x_1 has a coefficient greater than 0 and less than 1 while X_1 has a coefficient less than 0. This implies that for the Cape Rodney rubber smallholders, output is increasing at a decreasing rate with respect to the input, X_1. The variable Trees in Tapping (X_2), has an output elasticity of 0.5231, implying that a 1 per cent increase in the number of trees being tapped would increase output by some 0.52 per cent. This demonstrates that decreasing returns also exist for the variable X_2. A comparison of these two essential input factors reveals that output is more responsive to changes in the number of trees being tapped than

Table 5.10

Correlation Matrix of Coefficients for Regression R(2.b)

X_1	Harvesting Labour	x_1	1.0000	-0.8522													
		x_1	-0.8522	1.0000													
X_2	Number of Trees in Tapping	x_2	-0.2443	0.1293	1.0000												
X_3	Years Since Tapping Commenced	x_3	-0.1752	0.1221	-0.2473	1.0000											
X_4	Age of Farmer	x_4	- 2926	0.1483	0.1412	0.1337	1.0000										
		x_4^2	0.2698	-0.1319	-0.1296	-0.1580	-0.9891	1.0000									
X_5	Experience of Farmer	x_5	0.0368	0.0023	-0.1144	-0.1387	-0.3712	0.3496	1.0000								
		x_5^2	-0.0444	0.0032	0.0536	0.1196	0.2793	-0.2792	-0.9453	1.0000							
X_7	Depth of Cut	x_7	0.0637	-0.1044	-0.0028	-0.0280	-0.0842	0.0946	0.1155	-0.1409	1.0000						
		x_7^2	-0.0355	0.0891	0.0094	0.0095	0.0641	-0.0761	-0.1028	0.1271	-0.9956	1.0000					
X_{10}	Maintenance Labour	x_{10}	-.0885	-0.0511	-0.1832	-0.0781	0.0297	-0.0149	-0.0347	-0.0217	-0.1545	0.1748	1.0000				
X_{11}	Capital Equipment	x_{11}	0.0878	-0.0919	-0.5882	-0.1583	-0.1917	0.1907	0.1310	-0.0729	0.1742	-0.1844	0.0253	1.0000			
		x_{11}	-0.0211	0.0263	0.3681	0.1606	0.2777	-0.2736	-0.1435	0.0805	-0.1738	0.1810	0.0000	-0.9078	1.0000		
D_1	Condition of Tapping Panel	θ_2	-0.1635	0.1050	-0.1338	0.1538	-0.0028	0.0335	-0.1420	0.1215	0.2262	-0.2438	-0.3215	0.2789	-0.2208	1.0000	

Table 5.11

Output elasticities of Factors of Production in Regression R(2.b) [Table 5.9]

Variable		Equation: $\frac{\rho_{ij}}{i\varepsilon A} = a_i + \alpha_i X_{ij}$ $\frac{\rho_{ij}}{i\varepsilon B} = \beta_i X_{ij} + 2\gamma_i X_{ij}^2$	Result
X_1	Harvesting Labour	$0.7713 - 0.0105(X_1)$	0.3015
X_2	Number of Trees in Tapping	0.5231	0.5231
X_3	Years Since Tapping Commenced	$0.0769(X_3)$	0.6260
X_4	Age of Farmer	$0.1005(X_4) - 2(0.001)(X_4^2)$	-0.1163
X_5	Experience of Farmer	$0.0786(X_5) - 2(0.0025)(X_5^2)$	-0.0956
X_7	Depth of Cut	$-1.3848(X_7) + 2(0.1281)(X_7^2)$	-0.1973
X_{10}	Maintenance Labour	$-0.0077(X_{10})$	-0.3104
X_{11}	Capital Equipment	$-0.4562 + 0.009(X_{11})$	-0.0307
D_2	Condition of Tapping Panel	$0.2172(D_2)$	0.5082
	Total Elasticities		1.2085

changes in man-days of harvesting labour. This has an important implication in that if farmers need to increase output, say in a fairly short time period (e.g. when the output price is at its peak), and given that most farmers do have extra mature trees, they would be better off tapping more trees using marginally the same amount of harvesting labour if possible. Otherwise, the proportion of extra trees tapped should be greater than the proportion of extra man-days used in harvesting activities.[1]

A ρ value of 0.626 for the variable Years Since Tapping Commenced (X_3), indicates that with the passage of time, the productivity of the average mature rubber tree is positive and that it is increasing but at a decreasing rate. The average age of trees in the sample used in this analysis is 15 years, an age where productivity is believed to remain somewhat constant. The output elasticities for the two variables Age of Farmer (X_4) and Experience of Farmer (X_5) are both negative, being -0.1163 and -0.0956 respectively. One would tend to think that age and experience should have positive influences on output. That is, a farmer who is older and has more experience should produce more output than a younger and inexperienced one. An explanation of such a result may be made possible by observing that the average age of farmers in this sample is 47 years (Refer Appendix 3.1). This by PNG standards is considered 'old'. Tapping especially can cause a lot of strain on the back and any farmer who is about 47 years old can find long hours of tapping a painful task. This may result in falling productivity, which is probably the cause of the negative relationship observed in Table 5.11.

The independent variables Depth of Cut (X_7), Maintenance Labour (X_{10}) and Capital Equipment (X_{11}) also have negative ρ values. A ρ value of -0.1973 for variable X_7 indicates that the average farmer in Cape Rodney is at present cutting too deeply, when tapping the trees. The result implies that a 1 per cent increase in the depth of the tapping cut would result in output falling by some 0.2 per cent. The average depth of cut

1 Should have been enhanced by comparing the values of extra outputs and inputs but insufficient data disallowed this.

for the sample is some 5.06 mm. The above finding suggests that farmers who currently cut at or deeper than 5.06 mm into the bark should reduce the depth of their cuts. The exact amount of reduction cannot be determined in this study, as this would require a more scientific approach. The input variable X_{10} has a ρ value of -0.3104. This result is marginally different from that obtained for the same variable in regression R(1.b), using the C-D model. The conclusion that the inputs X_1 and X_{10} are competitive factors of production also applies here. Capital Equipment (X_{11}) as an essential input in rubber production, has an unexpected sign in its ρ value of -0.0307. This implies that a 1 per cent increase in the value of capital equipment used would lead to a reduction in output by some 0.03 per cent. There are two possible explanations to this finding. Firstly, this may reflect the effects of what is often referred to as "factor-indivisibility." In terms of capital, this is a situation where a certain range of output levels can be produced using some fixed level of capital equipment. For example, a farmer who produces more latex may need three buckets and fully utilize them while another, who produces less, also uses three buckets but they are not fully utilized. Secondly, the significant negative relationship may reflect the fact that increases in rubber output have not kept pace with the increases in the costs of capital equipment used in rubber production.

The output elasticity of the dummy variable, Condition of Tapping Panel (D_2) is 0.5082. This generally indicates that most tapping techniques, apart from the depth of the tapping cut, currently being practised in Cape Rodney, have a strong positive influence on rubber output. One such identified technique, which has a direct bearing on the cleanliness of the tapping panel, was the removal of the rough surface on the bark before actual tapping was done. This enhanced tapping and it also left the tapping panel in a better condition. Finally, the sum of all the ρ's in

Table 5.11 is 1.2085. This means that rubber production in Cape Rodney is characterised by increasing returns, where a 1 per cent increase in the use of all inputs would subsequently result in a 1.21 per cent increase in output. This verifies the result obtained earlier using the C-D model, although there is a difference of some 0.6329 between the total elasticities. This difference reflects the fact that there is a significant difference between the two models used in this study. The total elasticity obtained using the TRANS model is somewhat more realistic than that obtained using the C-D model, given that the trees currently being tapped are mostly low yielding poly-clonal material.

5.2.4 Variation in Productivity

In this section, the productivity levels of the different groups of farmers are compared using the results of all the regressions presented in Table 5.12. The dummy variables classified in Table 5.6 determine the different groups to be compared. Those variables identified in regression R(2.b) as having significant influence on rubber output are also included in these regressions. The two basic assumptions made in order to perform such an analysis are: (a) that there exists an average package of inputs which are readily available to all farmers, and (b) that the production frontiers for the different groups differ in a neutral manner so that factor elasticities remain unchanged while only their respective intercepts differ. Such differences in productivity can also be referred to as differences in technical efficiency since all farmers are assumed to use the same average set of input factors.

The results of the regressions R(2.c) and R(2.d) can be used to compare productivity between the 7 different ethnic groups in the sample. In the regressions R(2.c) and R(2.d), the Western and the Dom ethnic dummy variables are omitted, respectively. This results in all the included variables in regression R(2.c) having negative and significant coefficients while those included in R(2.d) have positive coefficients. We can

Table 5.12

The Estimated Parameters and Related Statistics Using The Transcendental Model for Significant and Dummy Variables Only

	Variable		Para-meter	R(2.c)	R(2.d)	R(2.e)	R(2.f)	F(2.g)	R(2.h)
X_1	Harvesting Labour	(x_1)	a_1	1.0288*** (0.1821)[1]	1.0288*** (0.1821)	0.8730*** (0.1878)	0.8730*** (0.1878)	0.7935*** (0.1804)	0.9103*** (0.1748)
		(X_1)	α_1	-0.0199*** (0.0054)	-0.0199*** (0.0054)	-0.0141*** (0.0054)	-0.0141*** (0.0054)	-0.0113*** (0.0050)	-0.0146*** (0.0048)
X_2	Number of Trees in Tapping	(x_2)	a_2	0.2772+ (0.1875)	0.2772+ (0.1875)	0.4572*** (0.1840)	0.4752*** (0.1840)	0.5294*** (0.1766)	0.4414*** (0.1670)
X_3	Years Since Tapping Commenced	(X_3)	β_1	0.0579* (0.0329)	0.0579* (0.0329)	0.0517+ (0.0362)	0.0517+ (0.0362)	0.0749** (0.0351)	0.0711** (0.0327)
X_4	Age of Farmer	(X_4)	β_2	0.0942*** (0.0351)	0.0942*** (0.0351)	0.1026*** (0.0355)	0.1026*** (0.0355)	0.1104*** (0.0371)	0.1111*** (0.0339)
		(X_4^2)	γ_2	-0.0009*** (0.0003)	-0.009*** (0.0003)	-0.0010*** (0.0003)	-0.0010*** (0.0003)	-0.0011*** (0.0004)	-0.0011*** (0.0033)
X_5	Experience of Farmer	(X_5)	β_3	0.0746+ (0.0452)	0.0746+ (0.0452)	0.0878* (0.0475)	0.0878* (0.0475)	0.0789+ (0.0482)	0.0609+ (0.0454)
		(X_5^2)	γ_3	-0.0019+ (0.0013)	-0.0019+ (0.0013)	-0.0025* (0.0014)	-0.0025* (0.0014)	-0.0025* (0.0014)	-0.0020+ (0.0014)
X_7	Depth of Cut	(X_7)	β_5	-1.8477*** (0.7171)	-1.8477*** (0.7171)	-1.3863* (0.7321)	-1.3863* (0.7321)	-1.4811* (0.7451)	-1.6402** (0.6955)
		(X_7^2)	γ_5	0.1727*** (0.0669)	0.1727*** (0.0669)	0.1283* (0.0688)	0.1283* (0.0688)	0.1365* (0.0701)	0.1537** (0.0656)
X_{10}	Maintenance Labour	(X_{10})	β_6	-0.0046 (0.0041)	-0.0046 (0.0041)	-0.0815* (0.0044)	-0.0815* (0.0044)	-0.0083* (0.0044)	-0.0055+ (0.0042)
		(X_{10}^2)	γ_6						
X_{11}	Capital Equipment	(x_{11})	a_5	-0.4929 (0.3822)	-0.4929 (0.3822)	-0.5802+ (0.3758)	-0.5802+ (0.3758)	-0.3770 (0.3744)	-0.5691+ (0.3455)
		(X_{11})	α_5	0.0117* (0.0062)	0.0117* (0.0062)	0.0104* 0.0061	0.0104* 0.0061	0.0074 (0.0063)	0.0133** (0.0060)
D_2	Condition of Tapping Panel	(D_2)	θ_2	0.2162+ (0.1338)	0.2162+ (0.1338)	0.2040+ (0.1395)	0.2040 (0.1395)	0.2040+ (0.1270)	0.2660** (0.1190)
	Ethnic Dummies:								
D_3	Dom	(D_3)	θ_3	-1.1461*** (0.3589)					
D_4	Domara	(D_4)	θ_4	-0.6965** (0.3287)	0.4497+ (0.2754)				
D_5	New Guinea	(D_5)	θ_5	-0.6778* (0.3343)	0.4684+ (0.2800)				
D_6	Kerema	(D_6)	θ_6	-0.5409* (0.3031)	0.6052*** (0.2386)				
D_7	Ianu	(D_7)	θ_7	-0.9543*** (0.3202)	0.1919 (0.2384)				
D_8	Aroma	(D_8)	θ_8	-0.6669* (0.3646)	0.4792+ (0.3411)				
D_9	Western	(D_9)	θ_9		1.1461*** (0.3589)				

.....(Cont).

Table 5.12 (Cont).

Variable									
<u>Locational Dummies</u>:									
D_{10}	Mereguina	(D_{10})	Θ_{10}			0.2084 (0.2353)	0.5994** (0.8928)		
D_{11}	Ianu	(D_{11})	Θ_{11}			-0.1215 (0.1735)	0.2695 (0.2480)		
D_{12}	Bomguina	(D_{12})	Θ_{12}			-0.3910* (0.2206)			
D_{13}	Manabo	(D_{13})	Θ_{13}				0.3910* (0.2206)		
D_{14}	Dummy for Female Tappers	(D_{14})	Θ_{14}					0.1721 (0.1402)	
D_{15}	Dummy for Local Farmers	(D_{15})	Θ_{15}						-0.3604*** (0.1355)
Constant			α_o	5.6094	4.4633	3.198	2.8074	2.2656	3.5101
Adjusted R^2				0.8315	0.8315	0.8020	0.8020	0.7930	0.8211
R^2				0.9003	0.9003	0.8707	0.8707	0.8564	0.8759
Overall F Statistic				13.091***	13.091***	12.671***	12.671***	13.516***	15.993***
D-W Statistic				2.4411	2.4411	2.2512	2.2512	2.2086	2.2166
Number of Cases				50	50	50	50	50	50

1. Figures in brackets are standard errors
   Levels of significance: + 10 per cent; * 5 per cent; ** 2.5 per cent; *** 1 per cent.

therefore conclude that the Western Ethnic group are the most productive while the Dom Ethnic group are the least productive. That is, the former group are capable of obtaining a higher level of output from a given set of inputs than the latter group. The actual coefficients for the Western and Dom ethnic dummy variables are implied by the constant terms in regressions R(2.c) and R(2.d), respectively. The relative productivity of the 5 remaining Ethnic groups can be established by adding their respective coefficients to the constant terms, where a higher resulting figure indicates a higher level of productivity. This procedure gives rise to the results depicted in Figure 5.1. The vertical axis shows the size of the intercept term for the production frontiers for each of the Ethnic groups represented by the histographs on the horizontal axis.

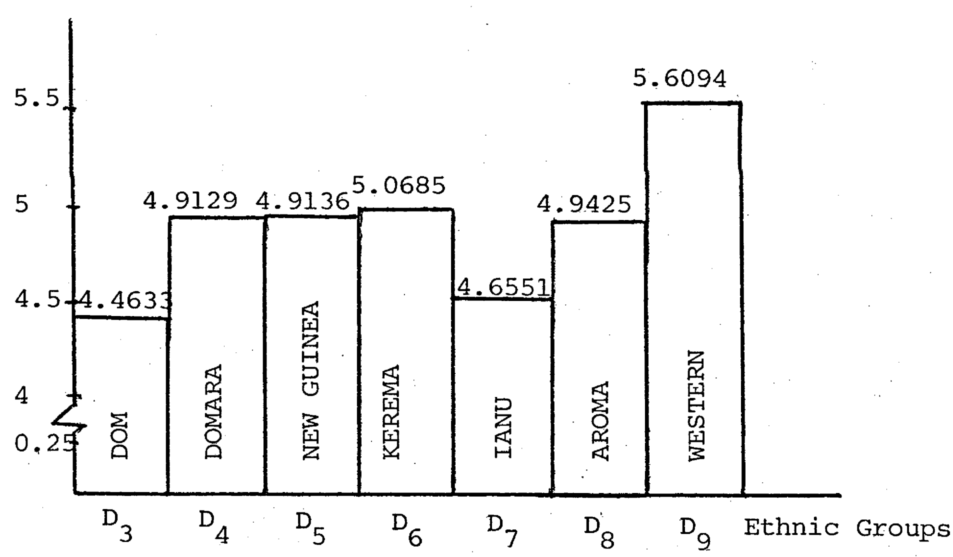

FIGURE 5.1 PRODUCTIVITY DIFFERENCES BETWEEN ETHNIC GROUPS

An examination of Figure 5.1 reveals that there is very little difference in productivity between the Ethnic Groups Domara, New Guinea, Kerema and Aroma, and also between the two least productive groups, Dom and Ianu. A ranking of the Ethnic Groups in terms of productivity can be obtained directly from Figure 5.1. These results are similar to those found earlier, using the C-D model.

The regressions R(2.e) and R(2.f) use the 4 locational dummy variables classified in Table 5.6. The results identify the Bomguina area as having the least productive farmers. This does not necessarily indicate that definite environmental and soil differences do exist between the 4 locational areas, since all the farmers in the least productive ethnic group are located in the Bomguina area of the scheme. This is further verified by the insignificant coefficients of the locational dummy variables, D_{10} and D_{11} in regression R(2.d), indicating that these locational groups are not significantly different from the Manabo locational group in terms of productivity. A crude comparison between the groups would reveal that the Moreguina and Manabo Locational Groups are relatively more productive than the Ianu and Bomguina Groups. That is to say that farms located in Moreguina and Manabo are relatively more productive than those located in Ianu and Bomguina (Refer Map 5). This result, however, is again significantly influenced by the high correlation which was found to exist between the Ethnic and Locational dummy variables.

An R^2 value of 0.9003 in regressions R(2.c) and R(2.d) indicates that the variables included in these regressions are capable of explaining as much as 90 per cent of the variation in rubber output. This is significantly higher than that explained by regressions R(1.c) and R(1.d) using the C-D model. We also find here that all Ethnic dummy variables are able to explain some 5 per cent of the variation in output. This is obtained by taking the difference in R^2 values between regressions R(2.c) or R(2.d) and regression R(2.b). This is marginally different from that obtained doing the same analysis using the C-D model. It also indicates that ethnic factors do have some influence on rubber productivity. Similarly, locational factors explain only about 2 per cent of the variation in output. This is no different from that found using the C-D model.

The regression R(2.g) uses the Female Tapper dummy variable. The purpose of this regression is to see if there is any difference in productivity between farms which have both male and female tappers and those with only male tappers. The results indicate that farms which fall into the former category are relatively more productive than those which fall into the latter category, although this difference in productivity is statistically not significant.

The final regression R(2.h) in Table 5.12 uses the Local Farmer dummy variable, D_{15}. The purpose of this regression is to see if there are any differences in productivity between farmers who come from within the Local Marshall-Lagoon sub-district and those who come from other parts of the country. The results indicate that Local Farmers are definitely less productive than the Non-Local Farmers. This is established by observing that the coefficient of D_{15}, besides being negative, is also highly significant. This implies that given an average package of input factors, Non-Local Farmers would produce a significantly higher level of output as compared to the Local-Farmers. This finding corresponds with the common argument that displaced people, who are solely dependent on agriculture for livelihood, tend to be more productive, if given the opportunities, than those who are indigenous to the area or country. Classic examples of this in history are Indians in Fiji and the Chinese in Malaysia. The difference in productivity between the two groups used in this analysis may also reflect differences in managerial abilities. The following section expands on this finding, using different approaches.

5.2.5 Technical Efficiency Differences Between Local and Non-Local Farmers

This section looks into the question of technical efficiency between Local and Non-Local Farmers, using the assumptions of neutral and non-neutral shifting production frontiers. Isoquants derived directly from the production functions will be used for this purpose. This will involve the use of the two essential input factors, Harvesting Labour (X_1) and Trees (X_2).

To examine technical efficiency between neutrally shifting production frontiers for Local and Non-Local Farmers we use the results obtained in regression R(2.h) in Table 5.12, to construct isoquants. Using these results, the production functions are:

$$q_{LF} = 3.5101 - 0.3604D_{15} + 0.9103x_1 - 0.0146X_1 + 0.4414x_2 + 0.0.711X_3 + 0.1111X_4 - 0.0011X_4^2 - 0.0609X_5 - 0.002X_5^2 - 1.6402X_7 + 0.1537X_7^2 - 0.0055X_{10} + 0.266D_2 - 0.5691x_{11} + 0.0133X_{11} \quad \ldots. \ (5.1)$$

$$q_{NLF} = 3.5101 + 0.9103x_1 - 0.0146X_1 + 0.4414x_2 + 0.0711X_3 + 0.1111X_4 - 0.0011X_4^2 - 0.0609X_5 - 0.002X_5^2 - 1.6402X_7 + 0.1537X_7^2 - 0.0055X_{10} + 0.266D_2 - 0.5691x_{11} + 0.0133X_{11} \quad \ldots. \ (5.2)$$

where q_{LF} and q_{NLF} are Local and Non-Local Farmers respectively. Using the geometric and arithmetric means provided in Table 5.14, the equations 5.1 and 5.2 are reduced to equations 5.3 and 5.4 respectively.

$$0.9103x_1 - 0.0146X_1 + 0.4414x_2 - 5.4883 = 0 \quad \ldots. \ (5.3)$$

$$0.9103x_1 - 0.0146X_1 + 0.4414x_2 - 5.4696 = 0 \quad \ldots. \ (5.4)$$

These are obtained when all other variables, including q, are fixed at their respective arithmetic and geometric mean levels. A graphical representation of the above two isoquants is given in Figure 5.2 where values of X_1 were solved in terms of X_2 using the TI-59 Programmable calculator. The result depicted in Figure 5.2 confirms the earlier finding that Non-Local Farmers are more productive or technically more efficient than the Local Farmers. This is because at any given level of X_1, we find that the latter group require to tap more trees than the former, and yet obtain a lower output level of 1088 kg as compared to the 1295 kg obtained by the Non-Local Farmers.

To examine technical efficiency given non-neutral shifting production frontiers, we first divide the sample into the two groups mentioned above

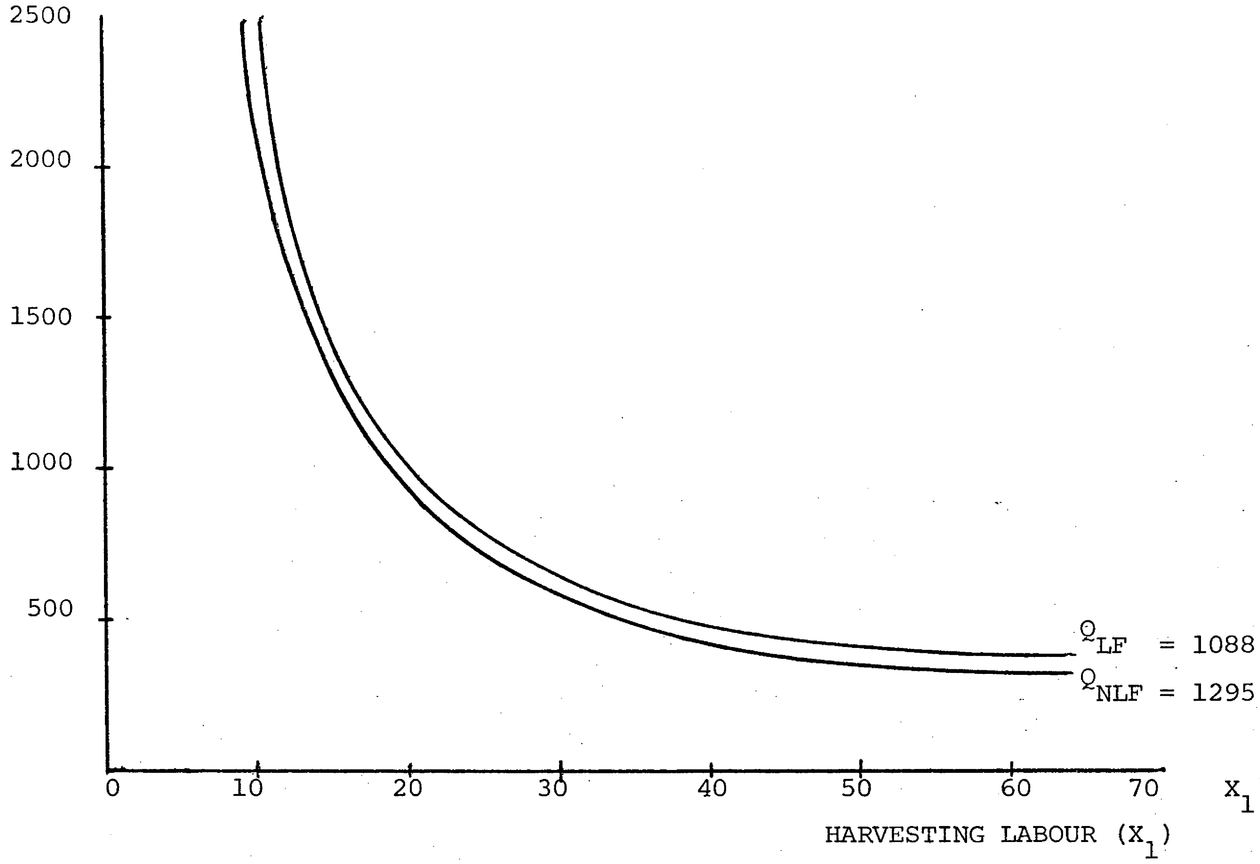

FIGURE 5.2: NEUTRALLY SHIFTING ISOQUANTS FOR LOCAL AND NON-LOCAL FARMERS.

and then using the Chow Test,[1] we test the null hypothesis that the two groups are not significantly different from each other. This involves using the results of 3 independent regressions. These are: (a) Regression R(2.a) in Table 5.7, (b) Regression R(3.a) in Table 5.13, and (c) Regression R(3.c) also in Table 5.13. The results of this test are provided in Table 5.15. They suggest that Local and Non-Local Farmers do in fact operate on different production functions, which differ in intercept terms as well as factor elasticities. This is established by comparing the calculated F-Statistics in Table 5.15 to the tabulated F-value, at the relevant range of the degrees of freedom. The results obtained indicate that the former F-value is always significant and greater than the latter F-value.

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1 Koutsoyiannis (1973), pp.158-63.

Table 5.13

The Estimated Parameters and Related Statistics Using The Transcendental Model for All and Significant Variables Only by Farmer Status (Regression 3)

Variable			Parameter	LOCAL FARMERS All Variables R(3.a)	LOCAL FARMERS Significant Variables (R(3.b)	NON-LOCAL FARMERS All Variables R(3.c)	NON-LOCAL FARMERS Significant Variables R(3.d)
X_1	Harvesting Labour	(x_1)	a_1	1.9000*** (0.3503)[1]	1.9950*** (0.2930)	0.6815*** (0.1710)	0.7967*** (0.1669)
		(X_1)	α_1	-0.0464*** (0.0102)	-0.0497*** ().0095)	-0.0067* (0.0037)	-0.0092** (0.0041)
X_2	Number of Trees in Tapping	(x_2)	a_2	0.4586 (0.3598)	0.530*** (0.1937)	0.1646 (0.1858)	0.3471+ (0.2111)
X_3	Years Since Tapping Commenced	(X_3)	β_1	0.0577 (0.0478)		0.0808* (0.0431)	
X_4	Age of Farmer	(X_4)	β_2	0.0587 (0.0501)		0.2698*** (0.0569)	0.2516*** (0.0453)
		(X_4^2)	γ_2	-0.0005 (0.0005)		-0.0027*** (0.0005)	-0.0025*** (0.0004)
X_5	Experience of Farmer	(X_5)	β_3	0.0516 (0.0830)		-0.0500 (0.0829)	
		(X_5^2)	γ_3	-0.0021 (0.0028)		0.0021 (0.0020)	
X_7	Depth of Cut	(X_7)	β_5	-0.1281 (1.308)	-1.7938+ (1.0627)	-4.0160*** (0.9943)	-3.209*** (0.8423)
		(X_7^2)	γ_5	0.1189 (0.1250)	0.1663+ (0.1018)	0.3721*** (0.0916)	0.3012*** (0.0761)
X_{10}	Maintenance Labour	(X_{10})	β_6	-0.0006 (0.0059)		-0.0021 (0.0067)	
		(X_{10}^2)	γ_6				
X_{11}	Capital Equipment	(x_{11})	a_5	-0.8021 (0.5268)	-0.7768* (0.3891)	-1.8404* (0.8522)	-1.5989* (0.7558)
		(X_{11})	α_5	0.0190** (0.0083)	0.0157** (0.0063)	0.0494** (0.0196)	0.0396** (0.0176)
D_2	Condition of Tapping Panel	(D_2)	θ_2	(0.2195)+ (0.1779)		0.0840 (0.1637)	
Constant			α_o	1.8713	5.2561	12.397	9.1473
Adjusted R^2				0.8234	0.8195	0.9449	0.9192
R^2				0.9223	0.8701	0.9784	0.9508
Overall F Statistics				9.327***	17.219***	29.172***	30.066***
D-W Statistics				2.3691	2.6889	2.6057	2.4851
Number of Cases				26	26	24	24

1. Figures in brackets are standard errors.

Levels of significance; + 10 per cent; * 5 per cent; ** 2.5 per cent; *** 1 per cent.

Having proven that the two groups operate on significantly different production frontiers, the exact nature of this difference can be established by deriving isoquants from two independently estimated production frontiers for the two groups. The results of regressions R(3.b) and R(3.d) in Table 5.13, for Local and Non-Local Farmers, respectively, will be used for this purpose. In constructing these isoquants, the output levels of the Local and Non-Local Farmers will be fixed at their geometric mean levels of approximately 1088 kg and 1295 kg, respectively, as shown in Table 5.14.

Using the results of regressions R(3.b) and R(3.d), the isoquant equations for Local and Non-Local Farmers with respect to X_1 and X_2 are equations 5.5 and 5.6 respectively.

$$5.2561 + 1.995x_1 - 0.0497X_1 + 0.53x_2 - 1.7938\ (5.0769)$$
$$+ 0.1663\ (26.846) - 0.7768\ (3.6631) + 0.0157\ (50.577) - (\ln 1088) = 0 \qquad \ldots.\ (5.5)$$

$$9.1473 + 0.7967x_1 - 0.0092X_1 + 0.3471x_2 + 0.2516\ (47.208)$$
$$- 0.0025\ (2459.8) - 3.209\ (5.0417) + 0.3012\ (26.292) - 1.5989\ (3.6833)$$
$$+ 0.0396\ (43.708) - (\ln 1295) = 0. \qquad \ldots.\ (5.6)$$

Further manipulation of equations 5.5 and 5.6 gives rise to equations 5.7 and 5.8 below:

$$1.995x_1 - 0.0497X_1 + 0.53x_2 - 8.43 = 0 \qquad \ldots.\ (5.7)$$

$$0.7967x_1 - 0.0092X_1 + 0.3471x_2 - 4.709 = 0 \qquad \ldots.\ (5.8)$$

Figure 5.3 depicts the above two equations in the form of isoquants for Local and Non-Local Farmers, represented by the subscripts, Q_{LF} and Q_{NLF}, respectively. An observation of Figure 5.3 reveals that when Harvesting Labour is applied within the range of 10 to 40 man-days, both isoquants differ almost in a neutral manner. This indicates that within this range, the analysis is inconclusive as to which group is technically more

Table 5.14

Geometric and Arithmetic Means of Inputs and Outputs by Farmer Status

Variable	All	Local Farmers	Non-Local Farmers
OUTPUT PER YEAR (kg) (Q):			
Geometric Mean (ln) q	7.0757 (1182.87)[a]	6.9923 (1088.22)	7.1660 (1294.66)
Arithmetic Mean Q	1545.20	1366.00	1739.40
HARVESTING LABOUR (man-days per year) (X_1)			
Geometric Mean (ln) x_1	3.5614	3.5560	3.5672
Arithmetic Mean X_1	44.7390	41.2450	48.5230
NUMBER OF TREES IN TAPPING (X_2)			
Geometric Mean (ln) x_2	6.4655	6.3838	6.5539
AGE OF FARMER (years) (X_4)			
Arithmetic Mean X_4	46.980	46.7690	47.2080
Arithmetic Mean X_4^2	2418.90	2381.10	2459.8000
DEPTH OF CUT (mm) (X_7)			
Arithmetic Mean X_7	5.06	5.0769	5.0417
Arithmetic Mean X_7^2	26.580	26.8460	26.2920
CAPITAL EQUIPMENT (Kina) (X_{11})			
Geometric Mean (ln) x_{11}	3.6728	3.6631	3.6833
Arithmetic Mean X_{11}	47.280	50.5770	43.7080
NUMBER OF CASES	50	26	24
OTHER VARIABLES[(b)]			
YEARS SINCE TAPPING COMMENCED (X_3)			
Arithmetic Mean X_3	8.1400	7.8077	8.50
EXPERIENCE OF FARMER (X_5)			
Arithmetic Mean X_5	15.2200	15.5380	14.8750
Arithmetic Mean X_5^2	258.38	270.62	245.12
CONDITION OF TAPPING PANEL (D_2)			
Arithmetic Mean D_2	2.34	2.50	2.1667
MAINTENANCE LABOUR (X_{10})			
Arithmetic Mean X_{10}	40.315	42.971	37.438

(a) Figures in brackets are antilogs.

(b) Also used in the Neutral Shift Isoquant.

Table 5.15

Chow Test[a] for Differences Between Local and Non-Local Farmers

	Number of Cases (n)	RSS (ΣU_j^2)	Number of Explanatory Variables (k)	F-Statistic[b] with d.f $(k, n_1 + n_2 - 2_k)$
Pooled Data	50	6.3322	15	14.17*
Local Farmers	26	1.4259	15	9.327*
Non-Local Farmers	24	0.5066	15	29.172*

a See Koutsoyiannis (1973:158-63). Results of regressions used in this test are from those using all variables.

b F-Statistic = $\frac{[\Sigma U_{jp}^2 - (\Sigma U_{j1}^2 + \Sigma U_{j2}^2)]/k}{(\Sigma U_{j1}^2 + \Sigma U_{j2}^2)/(n_1 + n_2 - 2_k)}$

where ΣU_{jp}^2 is the Residual Sum of Squares (RSS) of the pooled data regression.

ΣU_{j1}^2 and ΣU_{j2}^2 are the RSS of Local and Non-Local Farmers, respectively.

k is the number of explanatory variables, and

n_1 and n_2 are, respectively, sample sizes of Local and Non-Local Farmers groups.

* Significant at the 5 per cent level. The tabulated value of F15, $\alpha^{0.05}$ is 3.036.

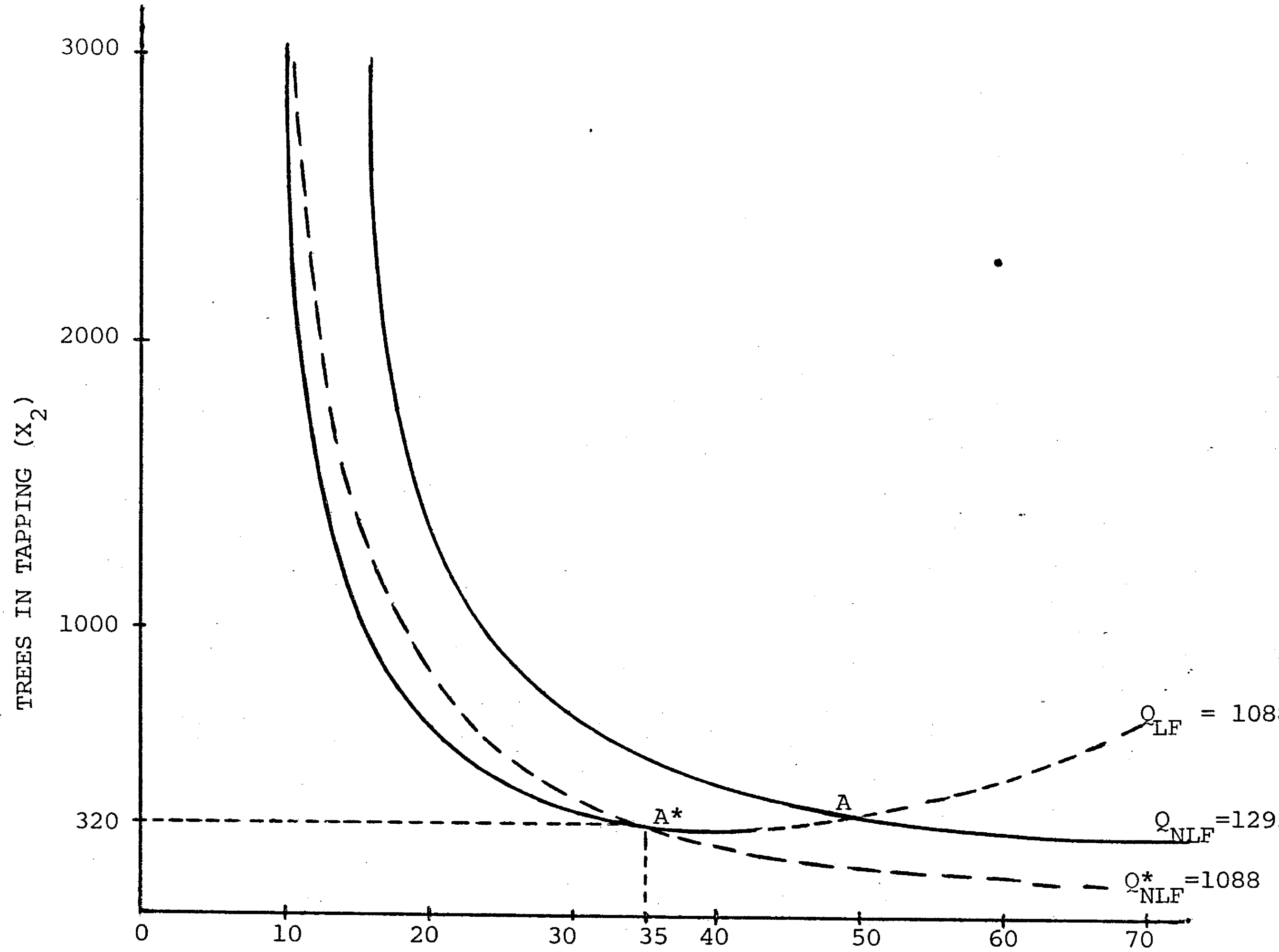

FIGURE 5.3 NON-NEUTRALLY SHIFTING ISOQUANTS FOR LOCAL AND NON-LOCAL FARMERS

efficient. Beyond 40 man-days of harvesting labour, the relationship is definitely non-neutral. Hence, both groups of farmers operate on the same production function, if the level of harvesting labour usage is not more than 40 man-days and more than 300 trees are tapped. However, given that the average levels of labour usage for both groups of farmers is beyond the 40 man-day limit (Refer Table 5.14), we can conclude that both groups of farmers operate on production functions which differ in their intercepts as well as elasticities. We also find that beyond the input combination represented by point A in Figure 5.3, Non-Local Farmers are technically more efficient than the Local Farmers. Besides, Local Farmers would be operating in the irrational third stage of the production function if they used more than 50 man-days of harvesting labour. This is indicated by the rising dotted portion of the isoquant, Q_{LF}.

Also included in Figure 5.3 is the dotted isoquant labelled Q^*_{NLF}. This is obtained from equation 5.6, where instead of including in the equation the mean output level of the Non-Local Farmers (i.e. ln 1295), we include the mean output level of the Local Farmers, 1088. This enables us to compare technical efficiency between the two groups, assuming that they produce the same level of output.

An examination of isoquants labelled Q_{LF} and Q^*_{NLF}, reveals that technical efficiency differs, depending very much on the level of input combinations used. This is because the two isoquants intersect at point A*. This indicates that to the left of point A* (i.e. where Q^*_{NLF} is always above Q_{LF}), Local Farmers are technically more efficient than the Non-Local Farmers. That is, the former group of farmers require less of both inputs to produce 1088 kg of rubber than the latter group. However, to the right of point A* (i.e. where Q^*_{NLF} is always below Q_{LF}), Non-Local Farmers are technically more efficient, since they require less of both inputs to produce 1088 kg of rubber. If we define having more trees to tap using low levels of labour input as being 'capital intensive' and the reverse situation as being 'labour intensive', then this finding suggests that Local Farmers are technically more efficient when production is capital intensive while Non-Local Farmers are more efficient when production is labour intensive.

An alternative comparison of technical efficiency is shown in Table 5.16 where one group's mean input levels are substituted into the other's production function, using the results of regressions R(3.b) and R(3.d). Mean levels of inputs refers to the appropriate geometric or arithmetic means presented in Table 5.14.

Table 5.16

Estimated Output Levels for Local and Non-Local Farmers Using Different Combinations of Functions and Input Levels

Production Function	At Average* Input Levels of Local Farmers	At Average* Input Levels of Non-Local Farmers
LOCAL FARMERS	1086	727
NON-LOCAL FARMERS	2463	1246
Relative Technical Efficiency $(LF/_{NLF})$%	44	58

* At geometric and arithmetic means as appropriate.

Before the results of Table 5.16 are discussed, it is necessary to check if the functions for the two groups are able to yield their respective mean output levels when the appropriate mean values of the inputs are applied. The results of regressions R(3.b) and R(3.d) are used for this purpose. This exercise gives us the output equations 5.9 and 5.10 below:

$$q_{LF} = 5.2561 + 1.995\ (3.556) - 0.0497\ (41.245) + 0.53\ (6.3838) - 1.7938\ (5.0769) + 0.1663\ (28.846) - 0.7768\ (3.6631) + 0.0157\ (50.577) \quad \ldots\ (5.9)$$

$$q_{NLF} = 9.1473 + 0.7967\ (3.5672) = 0.0092\ (48.523) + 0.3471\ (6.5539) + 0.2516\ (47.208) - 0.0025\ (2459.8) - 3.209\ (5.0417) + 0.3012\ (26.292) - 1.5989\ (3.6833) + 0.0396\ (43.708) \quad \ldots\ (5.10)$$

Further manipulation yields the following results:

(a) $q_{LF} = 6.98996$

$Q_{LF} = 1085.68 \simeq 1088$

(b) $q_{NLF} = 7.12771$

$Q_{NLF} = 1246.02 \simeq 1295.$

Since the estimated output levels are approximately equal to the observed geometric mean output levels, we conclude that the two functions do have reasonably good predicting powers. The analysis involving the interchange of mean input levels, is therefore justified. The results presented in Table 5.16 will now be discussed.

These results indicate that on both counts (i.e. when mean input levels for Local Farmers are used in the Non-Local Farmers production function and vice-versa), Local Farmers are relatively less efficient, technically. They are capable of achieving only 44 to 58 per cent of what the Non-Local Farmers can produce; given an average package of inputs.

The estimated output levels of 1086 and 1246 kg for Local and Non-Local Farmers, respectively, can be used to derive average yield figures for the two groups. Given that the average area occupied by productive rubber is 1.89 ha for Local Farmers and 2.12 for Non-Local Farmers, their estimated average yields are approximately 575 and 589 kg, respectively. This small difference in yields is probably due to the difference in the number of days used for tapping during the year. The statistics provided in Appendix 3.1 shows that Local Farmers used an average of some 112 days for tapping while for the Non-Local Farmers it was 122 days out of the 261 days available. A separate set of data provided in Appendix 3.2 shows that the average number of rainy tapping days over a 4-year period was about 26. Subtracting this from the 261 days available for tapping in a single year, gives us 235, the total number of days actually available for tapping to all farmers. Taking the proportions of days actually used for tapping and days available for tapping, we find that Local Farmers used only 48 per cent while Non-Local Farmers used 52 per cent of the days available for tapping. This crude analysis is based on the observations that the common tapping system is the S/2, d/2 type and that the average farmer in Cape Rodney has about 800 mature rubber trees. This implies that the farmers should be able to use all the 235 days available for tapping, allowing for weekends and rainy days. Hence, we can conclude that in Cape Rodney, only about less than half of the potential production of rubber is being achieved. This may reflect the fact that subsistence production is still an important part of overall production on the rubber farms.

5.2.6 Allocative Efficiency

In any production situation, productivity can be enhanced in several ways. Two of the more important means, which are also related to this study, are 'technical change' and 'allocative efficiency'. Technical change can be defined in terms of a productivity index or a production function. In the context of the former, technical change may be defined as the production of a higher level of output with a given quantity of resources. In terms of a production function, technical change can be identified through the positive changes which occur in the parameters of the function. Both these expositions are consistent in that they imply an upward shift in the production frontier. The preceding section dealt with this aspect of production.

The other source of change in productivity is through the achievement of allocative efficiency. In other words, productivity can be enhanced through the improvement of the efficiency with which existing resources are allocated. This can be done if all producers being considered have the same objective function, that of profit maximisation. Only then is one able to detect the existence of inefficiencies in resource allocation which can be improved upon so that all resources are efficiently allocated, resulting in productive gains. Schultz (1964), for example, argues that factors of production in traditional agriculture are already efficiently allocated such that no gains are possible through reallocation.

One could perhaps argue here that inefficiencies may not be very obvious, given that individual producers have different objective functions. That is, not all traditional farmers would be trying to obtain maximum possible outputs using given input levels. In such a case, the analysis of allocative efficiency can yield results which are either absurd or inconclusive.

In Cape Rodney, the smallholder rubber producers, although engaging also in subsistence production, do have this common objective of profit maximisation. That is, they generally aim to produce as much latex as possible using given resources and input levels, so that they are then able to earn a maximum possible level of income. Several observations tend to support this argument. Firstly, the Cape Rodney smallholders hardly use fertilizer or yield stimulants, both generally known and proven to improve rubber productivity. During data collection, all of the farmers in the sample, after being told of the possible effects of these chemicals, indicated that they would be willing to buy and use them to increase productivity and thus incomes, since all latex is bought by DPI. This somewhat proves, although in a crude way, that all smallholders in the scheme are profit maximisers, especially in relation to rubber production, since they are willing to try out anything to increase productivity. Secondly, related to the notion of increasing productivity, some farmers on the scheme were reported to have tried selling latex diluted with water so as to increase its weight and therefore earn more money. The occurrence of such incidents imply that money is an important consideration in rubber production. Besides, latex has practically no alternative use to the smallholder except to get a monetory reward. The act of production for sale in itself denotes that maximising behaviours exist.

Technical change in any smallholder rubber resettlement scheme is bound to be influenced significantly by policy decisions, which are often made outside the schemes themselves. This is very much true for the Cape Rodney Scheme where practically everything is supplied by the government as part of a loan arrangement. Tapping and maintenance systems, clearing and planting procedures and new plantings are all recommended by field officers. In this respect, enhancing rubber productivity through technical change is very much limited. The individual farmer, however, makes his own decisions with regard to resource allocation. He therefore can improve productivity merely by improving the efficiency with which resources are allocated. In this respect, this analysis can prove to be useful to the smallholder himself. The analysis is only marginal in nature, using the results obtained from fitting the TRANS production function model as shown in the preceding section.

An input factor is efficiently allocated when the value of the output obtained from the use of its last unit (or Marginal Value Product (MVP)) is equal to the cost of using this last unit (or Marginal Factor Cost (MFC)). That is, resources are efficiently allocated when their respective MVPs are equal (=) to their respective MFCs. If the MVP of an input factor is greater than (>) its MFC, the former has plenty to gain by using the input more intensively. Conversely, if the MVP is less than the MFC, the use of such an input should be reduced and in doing so the farmer can actually gain. Thus, the reallocation of resources towards satisfying the efficiency condition, MVP = MFC, will always result in productive gains.

To obtain MVP, the marginal product with respect to a specific input has to be multiplied by the output price. Only two of the essential inputs, harvesting labour (X_1) and rubber trees (X_2), will be used in the analysis to determine allocative efficiency. The general marginal product (MP) equation for essential inputs is as shown in equation 5.11:

$$\left.MP_{ij}\right|_{i\varepsilon A} \equiv \left.\frac{\partial Q}{\partial X_{ij}}\right|_{i\varepsilon A} = (\frac{a_i}{X_{ij}} + \alpha_j)Q_j \qquad \ldots. \text{ (5.11)}$$

The corresponding MVP equation is:

$$\left.MVP_{ij}\right|_{i\varepsilon A} = (\frac{a_i}{X_{ij}} + \alpha_i)Q_j..P_q \qquad \ldots. \text{ (5.12)}$$

where P_q = output price.

Another concept which is related to that of MP is the 'output elasticity of a factor of production', which we can denote by the letter rho (ρ). It indicates the percentage change in output which can be expected, given a corresponding change in the use of a single factor of production, holding other factors fixed at their respective arithmetic and geometric mean levels. The sum of all the ρ's for all the input factors shows the percentage change in output which is expected to result from percentage changes in all the input factors defined in the production function. This sum is referred to as the 'elasticity of output' and it indicates the types of returns which exist in the production of a certain output. If this sum is unity, then the production system is said to have constant returns to scale. This is when a proportionate change in all inputs also results in a proportionate change in output. If the sum is greater or less than unity, we have increasing or decreasing returns to scale, respectively. Increasing returns to scale exist when a percentage increase in all inputs taken together results in an even greater increase in the output level. Similarly, with decreasing returns to scale, a one (1) per cent increase in the use of all inputs will cause output to increase by less than one (1) per cent.

Results of regressions R(3.b) for Local Farmers and R(3.d) for Non-Local Farmers shown in Table 5.13 will be used in the analysis of allocative efficiency. These regressions include only significant variables obtained after re-estimation, thus resulting in different variables being included in each of the regressions. The results of the two regressions are as shown in equations 5.13 and 5.14.

$$\hat{Q}_{LF} = 191.7323X_1^{1.995}\ e^{-0.0497X_1}\ X_2^{0.53}\ e^{-1.7938X_7 + 0.1663X_7^2}\ X_{11}^{-0.7768}\ e^{0.0157X_{11}} \quad \ldots.(5.13)$$

$$\hat{Q}_{NLF} = 9389.0557\ X_1^{0.7967}\ e^{-0.0092X_1}\ X_2^{0.3471}\ 4^{0.2516X_4 - 0.0025X_4^2}\ e^{-3.209X_7 + 0.3012X_7^2}\ X_{11}^{-1.5989}\ e^{0.0396X_{11}} \quad \ldots.\ (5.14)$$

where $\hat{Q}_{LF}$ and $\hat{Q}_{NLF}$ are the estimated production functions for the Local and Non-Local Farmers, respectively. The equations 5.13 and 5.14 give rise to the MP and ρ equations summarised in Table 5.17.

5.2.6.1 Valuations of the MFC of Labour and Trees

An input factor is allocated efficiently if its MVP equals its MFC. The MVP of an input can be directly obtained from the production function itself, using equations 5.11 and 5.12. The MFC on the other hand, is determined on the basis of observed facts and circumstances. This makes it somewhat arbitrary and therefore, at best, it is merely an estimate of the real MFC.

Let us firstly discuss the procedure used in determining the MFC or the opportunity cost of labour. The major source of harvesting labour among the rubber producers in Cape Rodney is the farm family itself. It usually includes the farmer himself, his wife and their children. The amount of time spent by the wife and the children in harvesting activities makes up only a small proportion of the total time spent by the family.

Table 5.17

Marginal Product and Factor Elaxticity of Production Equations as Obtained from Results of Regressions R(3.b) and R(3.d)

Inputs		Local Farmers R(3.b) [(a)]	Non-Local Farmers R(3.d)
Labour	(X_1):		
	MP_1	$\left[\frac{1.995}{X_1} - 0.0497\right] Q$	$\left[\frac{0.7967}{X_1} - 0.0092\right] Q$
	ρ_1	$1.995-0.0497\ X_1$	$0.7967-0.0092\ X_1$
Trees	(X_2):		
	MP_2	$\left[\frac{0.530}{X_2}\right] Q$	$\left[\frac{0.3471}{X_2}\right] Q$
	ρ_2	0.53	0.3471

(a) Regressions used

The wife plays a major role in the maintenance and harvesting of the subsistence garden apart from her usual role in the household. The children either go to school or get involved in other activities which do not require very much skill, for example, the clearance of the undergrowth. The older male children, however, often assist in harvesting activities. Harvesting of rubber trees is therefore, in general, a predominantly male activity. Hence, the opportunity cost of family labour in this analysis only takes into account mature male members of the family, who, if given the opportunity would be willing to take up alternative employment.

The approach proposed by Sen (1964) and also used by Abdullah (1978) is used here to value the opportunity cost of labour. The simple equation to serve this purpose is:

$$C = W.\,p \qquad 0 \leq \rho \leq 1 \qquad \ldots.\ (5.15)$$

where C = opportunity cost of labour or MFC

W = wages paid in an alternative employment

and p = the probability of being employed.

The only alternative source of employment available to skill-less or semi-skilled labour in the area is the Timber Sawmill in Kapari, APPM which is owned by the Steamships Trading Company (Refer Map 6). A fortnightly wage of K30 is offered for the services of such workers. A similar wage is also paid to hired labourers at the scheme, who are employed by individual farmers to assist in harvesting and maintenance activities. This justifies the use of K30 as being the value of W in equation 5.15, for both groups of farmers. However, most Non-Local Farmers had some other form of employment before successfully obtaining land leases to produce rubber on the scheme. Most Local Farmers, on the other hand, came straight from their respective villages to the scheme. The probability of securing alternative employment, therefore, differs between the two groups, with the Non-Local Farmers having a better chance than the Local Farmers.

Given that the Timber Sawmill can employ practically anyone who is willing to work hard, we can assume that a Local Farmer has on average, a 50 per cent chance of being employed, while a Non-Local Farmer with more work experience has, say, an 80 per cent chance of being employed at the Sawmill. It should be mentioned here that it would be almost impossible for all the producing rubber smallholders to return to being merely subsistence producers; where some argue that C can assume values close to zero (0). Work at the Sawmill is done on an 8 hourly shift basis, 6 days per week; giving rise to 12 man-days of work per two weeks. Substituting for W and ρ in equation 5.15, we have the following manipulations

$$C_{LF} = 30 \times 0.5/_{12} = 1.25$$

and $C_{NLF} = 30 \times 0.8/_{12} = 2.00$;

where C_{LF} and C_{NLF} are the opportunity costs of labour for Local and Non-Local Farmers respectively. The difference can be said to represent differences in the importance placed on such alternative employment.

The estimation of the opportunity cost of rubber trees, like other perennial crops, has always been difficult. Abdullah (1978) argued that this difficulty is caused by differences in a host of factors, some of which include age, variety, management and environmental. Rubber trees of different ages and different varieties have different productive capacities. Their respective opportunity costs would therefore differ. Similarly, trees under different management and environmental conditions would also differ in productivity. The same argument applies here. These difficulties do not seriously limit the analysis because of two reasons. Firstly, in relation to age and variety differences, trees being analysed in this study are mostly from polyclonal planting material with ages ranging from a minimum of 13 to a maximum of 17. At such an age range, it is commonly believed that the trees produce a somewhat constant level of output. The yield assumptions used in the Project Re-development Plan (DPI - 1979) indicate that between the ages of 12 to 16, trees were expected to produce a constant 1600 kgs of rubber. Secondly, there are no significant environmental differences as the scheme is located within some 30 sq kms of land area. All farms are co-ordinated centrally by the DPI office located on the scheme area itself. This may indicate some degree of central management. But, of course, specific farm decisions have to be made by individual farmers themselves, although such decisions may also be influenced by extension advice from the field officers. On the whole, we can argue that all trees, on average, have the same productive potential. This would then justify the use of a single figure, as representing the opportunity cost of trees. This value is again, at best, an estimate of the real opportunity cost.

The procedure used by Lim (1976) and also adopted by Abdullah (1978) is based on the argument that the MFC of rubber trees represents the return to the owner if he does not tap the trees himself, but instead leases them to a hired tapper. Lim calculated the MFC of rubber trees as being approximately 50 per cent of their average revenue, where the 50 per cent represented a 50:50 crop sharing arrangement. Using this procedure and definition as guides, we can determine the MFC of rubber trees as shown in Table 5.18, where instead of average revenue we try to obtain net revenue per tree. The Net Present Value (NPV) of net revenue per tree is obtained and then discounted by the current interest rate of 11 per cent. A ten year period is used to obtain the NPV since the trees are expected to be productive for another ten years. The results obtained in Table 5.18 indicate that the MFC of rubber trees for Local and Non-Local Farmers are 0.23 and 0.24. These figures can be interpreted as being the amount of net revenue foregone as a result of having to invest in rubber trees instead of the bank, which is probably the next best alternative. In other words, they represent the revenue from interest the former would be earning if he had invested the money he used to purchase each rubber tree in the bank. A general comparison of these figures to those of net revenue per tree in Table 5.18 indicates

Table 5.18

Valuation Procedures of the Opportunity Cost of Rubber Trees (Kina)

	Description	Local Farmers	Non-Local Farmers
1	Average Number of Trees being Tapped	755.54	847.12
2	Average Gross Revenue (Kina)	507.85	679.42
2a	Gross Revenue/tree (Kina)	0.85	0.83
3	Average Cost of Capital Equipment (Kina)	50.58	43.71
3a	Average Cost of Capital Equipment/tree (i.e. 3/1) (Kina)	0.07	0.05
4	Cost of Hired Labour/day (Kina)	3	3
4a	Average Number of Tapping Days	111.81	121.54
4b	Total Cost of Labour (4 x 4a) (Kina)	335.43	364.62
4c	Total Cost of Labour/tree (4b/1) (Kina)	0.444	0.430
5	Net Revenue/tree (2a-3a-4c) (Kina)	0.336	0.35
6	Prestent Value of (5)[a] (Kina)	1.90	1.98
7	Opportunity Cost of Rubber Trees[b] (Kina)	0.23	0.24

(a) At 12 per cent discount rate with n = 10.

(b) The Present Value x Interest Rate (12 per cent).

that the smallholders have done well in their choice of investment. They now enjoy higher returns than what they would be if they had invested in banks. This procedure is adopted in this study mainly due to the lack of necessary data. Its arbitrariness is reflected in the choice of the time period and the discounting factor, as well as the use of net revenue instead of initial cost expenditures.

5.2.6.2 Labour

To obtain MP equations for harvesting labour we use the functional equations 5.4 and 5.12, fixing other variable inputs at their respective arithmetic mean levels. This manipulation results in the equations 5.16 and 5.17 for Local and Non-Local Farmers, respectively. These are obtained using the results of regressions R(3.b) and R(3.4) as shown in Table 5.13.

$$\hat{Q}_{LF} = 6.5037X_1^{1.995} \quad e^{-0.0497X_1} \qquad \text{.... (5.16)}$$

$$\hat{Q}_{NLF} = 51.929X_1^{0.7967} \quad e^{-0.0092X_1} \qquad \text{.... (5.17)}$$

Substituting for Q's in the MP equations given in Table 5.18 for both groups, respectively, we derive the actual corresponding MP equations 5.18 and 5.19, below:

$$MP_{LF} = 12.9749\ X_1^{0.995}\ e^{-0.049X_1} - 0.3232X_1^{1.995}\ e^{-0.0497X_1} \qquad \text{.... (5.18)}$$

$$MP_{NLF} = 41.3718\ X_1^{-0.2037}\ e^{-0.0092X_1} - 0.3232X_1^{0.7967}\ e^{-0.0092X_1} \qquad \text{.... (5.19)}$$

Although farmers on the scheme are all paid the same output price, it has fluctuated quite heavily over the years, especially during 1981, the year in which actual data collection was done for this study. The average output price for the year was 0.54 toea per kg, while the minimum and maximum prices were 0.17 and 0.81 toea, respectively. The minimum price was prevailing during the period of this study. To obtain MVP equations, we use both the minimum and maximum output prices as Hopper (1965) did when analysing allocative efficiency in traditional

Indian Agriculture.

Using the minimum price we obtain the MVP equations 5.20 and 5.21:

$$MVP_{ILF} = 2.2057\ X_1^{0.995}\ e^{-0.0497X_1} - 0.0550\ X_1^{1.995}\ e^{-0.0497X_1} \quad \ldots. (5.20)$$

$$MVP_{INLF} = 7.0332\ X_1^{-0.2037}\ e^{-0.0092X_1} - 0.0812\ X_1^{0.7967}\ e^{-0.0092X_1} \quad \ldots. (5.21)$$

where the subscripts ILF and INLF represent MVP equations using the minimum output price for Local and Non-Local Farmers, respectively. Similarly, using the maximum output price, we obtain MVP equations 5.22 and 5.23.

$$MVP_{2LF} = 10.5097\ X_1^{0.995}\ e^{-0.0497X_1} - 0.2618X_1^{1.995}\ e^{-0.0497X_1} \quad \ldots. (5.22)$$

$$MVP_{2NLF} = 33.5122\ X^{-0.2037}\ e^{-0.0092X_1} - 0.3869X_1^{1.995}\ e^{-0.0092X_1} \quad \ldots. (5.23)$$

where the subscripts 2LF and 2NLF represent MVP equations using the maximum output price for Local and Non-Local Farmers, respectively. The MVP equations are obtained by multiplying the MP equations 5.18 and 5.19 by the two different output prices, both being 'farm gate' prices.

When the MVP equations 5.20 and 5.21, and 5.22 and 5.23 for Local and Non-Local Farmers, respectively are plotted, their respective graphs are as shown in Figures 5.4 and 5.5. Due to the large variation caused by the output price, Figures 5.4 and 5.5 are both reduced to Figures 5.6 and 5.7, respectively, depicting only the essential portions.

An examination of Figure 5.6 reveals that the optimum amount of the input X_1 for the Local Farmers is some 40.1 man-days, given that their MFC of labour is K1.25. This optimum is a mere one man-day away from the present average level of X_1 used, which is 41.2, as shown in Table 5.14. This therefore calls for a reduction in the use of X_1 by one man-day, which would be approximately some 2 to 3 days of actual

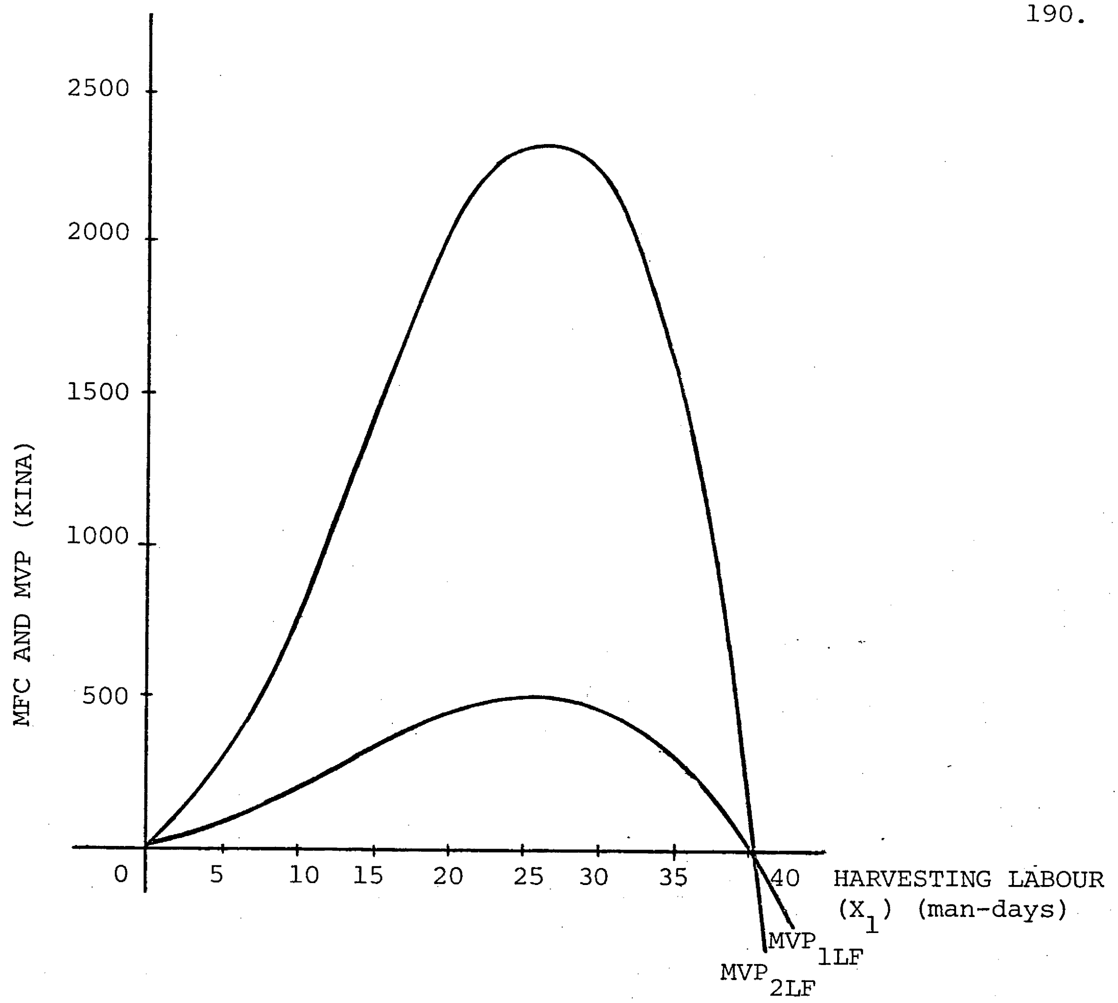

FIGURE 5.4: THE MARGINAL VALUE PRODUCT (MVP) CURVES OF HARVESTING LABOUR FOR LOCAL FARMERS AT THE TWO DIFFERENT OUTPUT PRICES

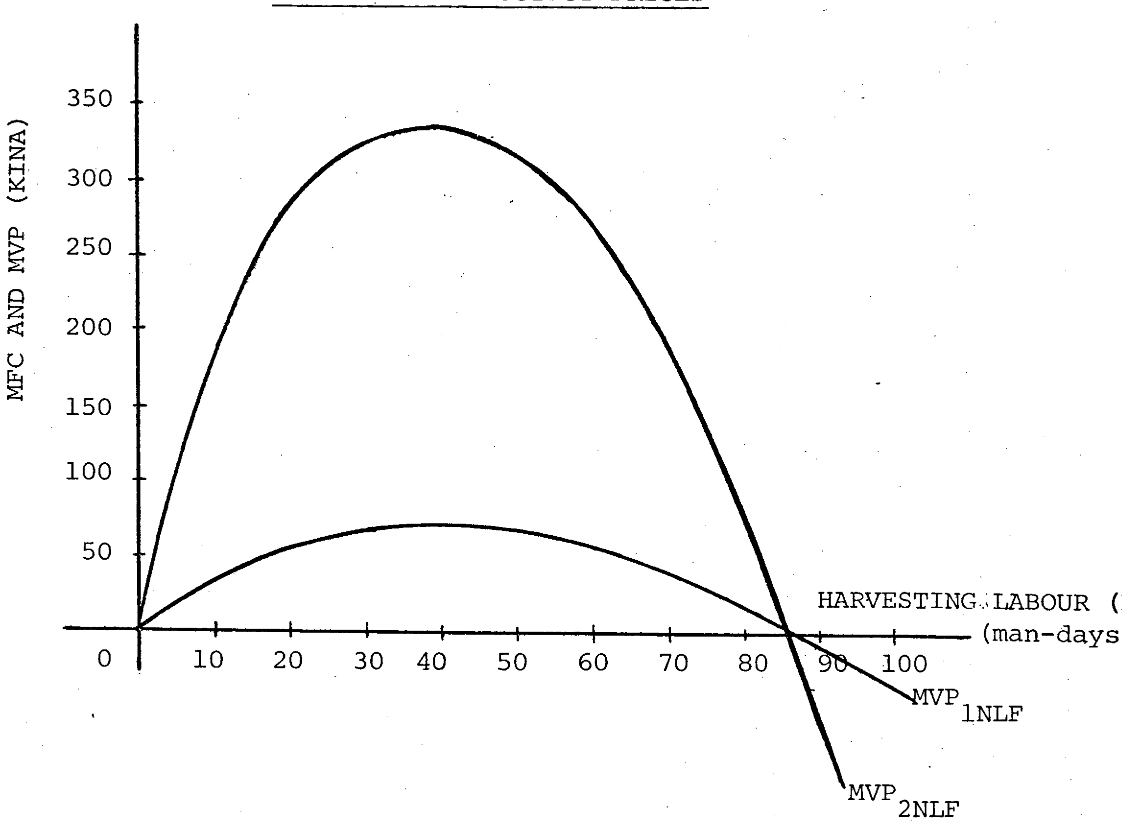

FIGURE 5.5: THE MARGINAL VALUE PRODUCT (MVP) CURVES OF HARVESTING LABOUR FOR NON-LOCAL FARMERS AT THE TWO DIFFERENT OUTPUT PRICES

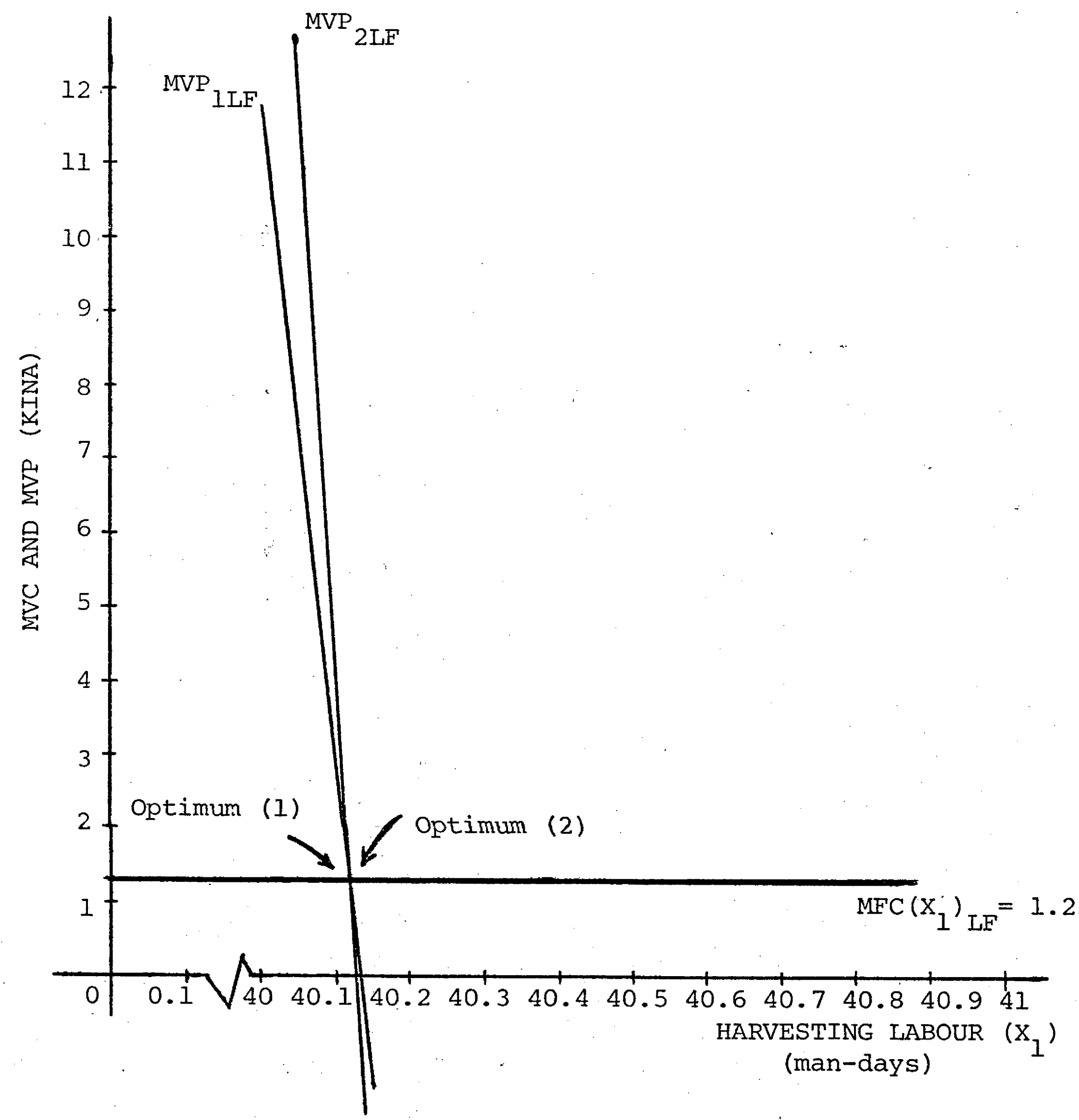

FIGURE 5.6: ENLARGEMENT OF THE ESSENTIAL PORTION OF FIGURE 5.4

harvesting. A MP figure of -566.8 as shown in Table 5.19 provides further support for the above argument, calling for a reduction in the use of X_1 by the Local Farmers. Although the two output prices give rise to two significantly varied MVP curves, as shown in Figure 5.5, they do not cause any variation in determining the optimum amount of X_1. Even if the MFC $(X_1)_{LF}$ in Figure 5.6 was allowed to vary, the optimum level of X_1 would still be around 40 man-days. This shows that this optimum is somewhat stable irrespective of the variation in both the output price and the MFC.

Although one could argue that the difference between the optimum and the observed average amounts of X_1 is very small, the ratios of the MVP's to the MFC's ($MVP_{/MFC}$) in Table 5.19 indicate that this small difference does significantly influence the optimum level. That is, at the lower output price of 0.17 toea, this ratio is equal to -77.13, which is very much less than that which determines the optimum, a ratio of 1. A similar situation occurs at the higher output price of 0.81 toea, where the ratio has an even greater negative value. A negative MP value of -566.8 indicates that any further increase in the use of X_1, given the current average of some 41 man-days, would reduce the overall level of output by a massive 567 kg. This is the direct result of having to operate above the optimum level of some 40 man-days, as shown in Figure 5.6. Local Farmers are therefore inefficient in allocating X_1, although the degree of inefficiency is very small, a mere 2.5 per cent.

The degree of inefficiency is so small that it may probably be not significant.[1] If this is so, then we can argue that Local Farmers are efficient in allocating the input X_1. Such efficiency in the use of labour shows that subsistence oriented producers, producing in a fairly monetized environment, are also able to allocate this resource efficiently. This may indicate that the transition from the traditional subsistence situation to the modern monetized situation has taken place in such a way that the traditionally abundant factor of production, labour, is now being utilized and more importantly, it is being allocated efficiently. The high absentee rates observed among the Local Farmers during the period of this study and by Carrad (1980) are somewhat justified by the findings discussed above. Such absenteeism does not necessarily imply that no

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[1] Statistical tests could not be used because of the complications involved in determining variances (σ) and co-variances (σ_{xy}).

Table 5.19

Comparison of Marginal Products (MP), Output Elasticities of Factors (ρ) and Marginal Value Products (MVP)

Description	Local Farmers	Non-Local Farmers
X_1 LABOUR:		
MP	-566.8064	395.8703[(d)]
ρ	- 0.05488	0.35029
MVP_1[a]	- 96.4154	67.2970
MVP_2	-459.4396	320.6527
MVP_1/MFC[b]	- 77.1323	33.6485
MVP_2/MFC	-367.5517	160.3264
X_2 TREES:		
MP	0.9813	0.3532
ρ	0.53	0.3471
MVP_1	0.1668	0.0600
MVP_2	0.7948	0.2861
MVP_1/MFC[c]	0.7252	0.2500
MVP_2/MFC	3.4557	1.1921

(a) Subscripts 1 and 2 on the MVP indicates the minimum and maximum output price levels of 0.17 and 0.81, respectively.

(b) MFC of Labour for Local and Non-Local Farmers are K1.25 and K2.00, respectively.

(c) MFC of Trees for Local and Non-Local Farmers are K0.23 and K0.24, respectively.

(d) The substantial difference in figures is the result of the way different variables occur in the production function.

work is being undertaken. Given that subsistence production is not adversely affected by rubber production and that harvesting labour is being allocated efficiently in rubber production, this indicates that labour is not a constraining factor of production for the Local Farmers. It should be mentioned here that maintenance labour (X_{10}) takes up nearly the same amount of time as X_1 and yet has been found to make no significant contribution to output (Refer Table 5.14). This may provide some explanation as to why X_1 is being allocated efficiently. The introduction of a second perennial crop, namely cocoa, as proposed in the re-development plan, would probably enable the Local Farmers to achieve further efficiency and productivity by redirecting labour used in maintenance activities into cocoa production. A negative and a small ρ value of -0.0548 implies that a 1 per cent increase in the use of X_1 by the Local Farmers would reduce output by some 0.05 per cent. Rubber output is therefore not very responsive to changes in the amount of harvesting labour used by the Local Farmers.

As for the Non-Local Farmers, an examination of Figure 5.7 reveals that the optimum amounts of X_1 for the minimum and maximum output prices are 85.7 and 86.3 man-days, respectively. And in Table 5.14, we find that the arithmetic mean level of X_1 for the Non-Local Farmers is about 49 man-days. Given that their opportunity cost of labour is calculated to be some K2.00 per man-day, we find that the Non-Local Farmers use only about half the amount of X_1 than is suggested by this analysis. This suggests that they should increase the amount of time they spend in rubber harvesting activities by some 37 man-days. In simple terms, this means that they should spend an average of 99[1] extra days in tapping their rubber trees, given that the average farmer spends about 3 hours per tapping day in doing harvesting work, as shown in Appendix 3.1. This Appendix also shows

[1] 37 x 8 = 296/3 = 98.67.

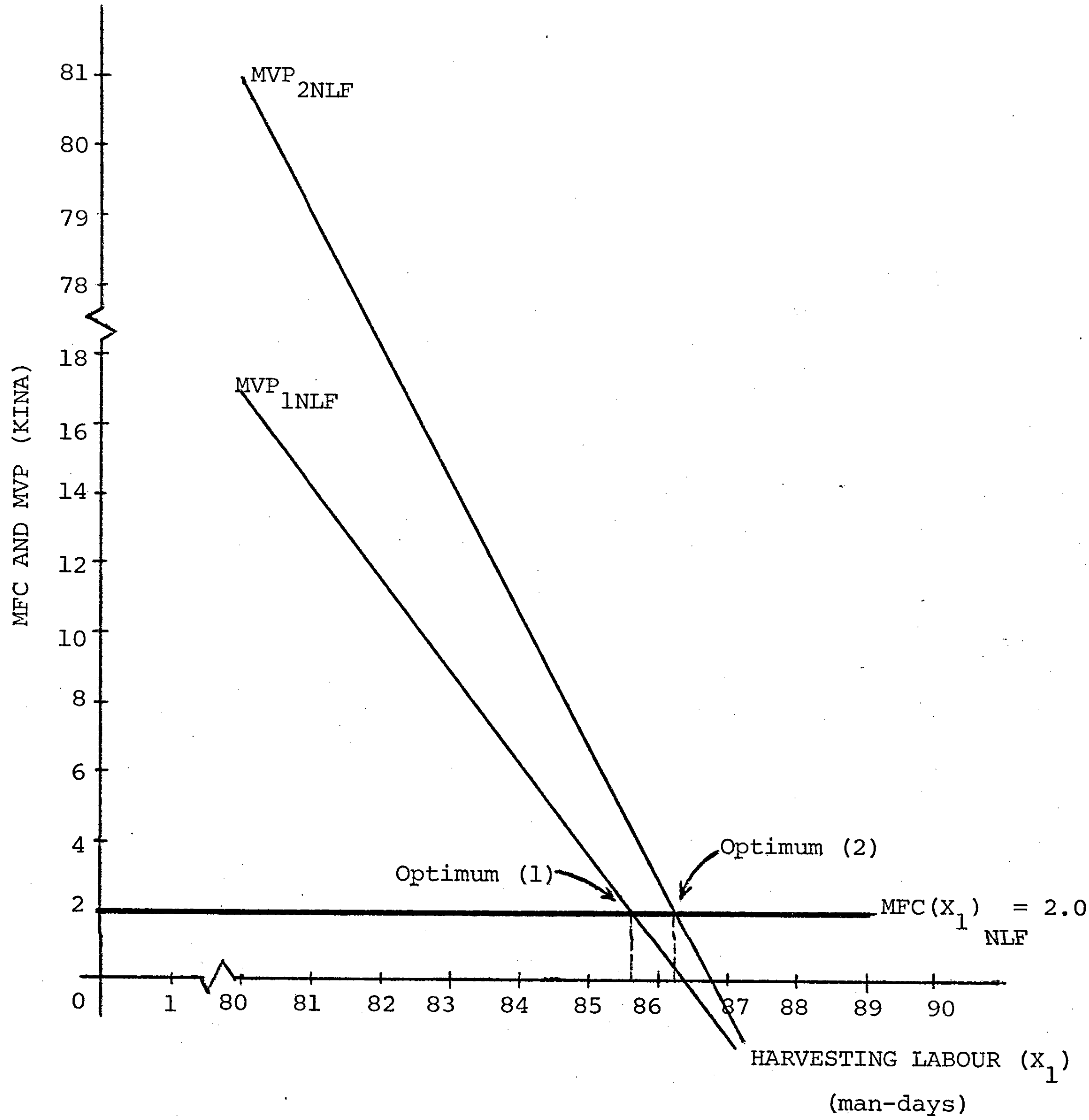

FIGURE 5.7: ENLARGEMENT OF THE ESSENTIAL PORTION OF FIGURE 5.5

that the average number of tapping days for the Non-Local Farmers is about 122. This analysis therefore suggests that they should increase the number of days in which they tap their trees from about 122 to about 221, some 81 per cent increase.

In Table 5.19, we find that the MP of labour with respect to rubber output for the Non-Local Farmers is about 396 kg. This implies that given their current usage of the input X_1, any unit increase in the use of this input would increase output by a massive 396 kg. It would therefore be worthwhile for the Non-Local Farmers to spend more time doing harvesting activities since this would substantially increase their productivity and subsequently incomes. A ρ value of 0.3503 indicates that a 1 per cent increase in the use of X_1 would increase output by some 0.35 per cent. And the MVP to MFC ratios at the two different output prices are both significantly higher than the ratio at which an optimum is said to occur, a value of 1. All these findings support the general trend of results obtained from the above analysis. They indicate that Non-Local Farmers are using their harvesting labour resources well below the optimum level determined by Figure 5.7.

The inefficient allocation of harvesting labour among the Non-Local Farmers is a reflection of the labour shortage problem which currently exists. They do have mature trees which can be tapped so that the efficiency with which harvesting labour is allocated is increased. But part of their available labour force has to be used in subsistence production and currently they spend an average of 37 man-days doing maintenance work on the farm, as shown in Table 5.14. And since a reduction in subsistence production is probably not desirable, the only alternative then is to reduce the amount of time spent in maintenance activities to some minimum required level and use the gained time in opening up more trees for tapping. Obviously, no definite proposal can be made because the subsistence component of overall farm production is not included in the analysis.

Comparing the two groups of farmers, we find that Local Farmers allocate their harvesting labour resources more efficiently than their Non-Local counterparts. The variation in efficiency is approximately 40 per cent. Even if the opportunity cost of labour was allowed to be the same for both groups, Local Farmers would still be more efficient than the Non-Local Farmers. This indicates that monetary considerations are important when making allocative decisions, especially in terms of the costs and returns generated by individual factor inputs. The farmers, therefore, make economically rational decisions. This, in any way, does not imply that Non-Local Farmers are ignorant of the costs and returns of input factors and that they are therefore irrational. Such a conclusion would not be justified, given that they are faced with different labour resource endowments and that the costs and returns of this input factor are different for both groups. A general conclusion which we can draw from the above analysis is that the subsistence oriented producers engaged in rubber production are now more monetary oriented than hypothesised in the introductory chapter of this study. That is, the smallholder rubber producers in Cape Rodney are generally profit maximisers.

5.2.6.3 Trees

The MP equations for rubber trees are also obtained using the functional equations 5.20 and 5.21 and the results of regressions R(3.b) and R(3.4) as shown in Table 5.13. Fixing all other variables other than X_2 in the results of the regressions R(3.b) and R(3.d) at their respective mean levels, we obtain the reduced output functions as shown in equations 5.24 and 5.25, for Local and Non-Local Farmers, respectively.

$$\hat{Q}_{LF} = 41.7149\ X_2^{0.53} \qquad \text{.... (5.24)}$$

$$\hat{Q}_{NLF} = 83.0251\ X_2^{0.3471} \qquad \text{.... (5.25)}$$

Note here that equations 5.26 and 5.27 would be no different to MP equations obtained if we used the C-D model. Since the minimum and maximum output prices are being used to obtain MVP equations, for Local and Non-Local Farmers, we have two different sets of MVP equations. These equations are:

$$MVP_{1LF} = 3.7585\ X_2^{-0.47} \qquad \text{.... (5.28)}$$

$$MVP_{1NLF} = 4.8991\ X_2^{-0.6529} \qquad \text{.... (5.29)}$$

$$MVP_{2LF} = 17.9082\ X_2^{-0.47} \qquad \text{.... (5.30)}$$

$$MVP_{2NLF} = 23.3426\ X_2^{-0.6529} \qquad \text{.... (5.31)}$$

where the subscripts 1LF and 2LF refer to the MVP equations of trees for Local Farmers at the minimum and maximum output prices, respectively. Similarly, subscripts 1NLF and 2NLF refer to the MVP equations for Non-Local Farmers at the minimum and maximum output prices, respectively.

When the MVP equations 5.28 and 5.30 for Local Farmers and 5.29 and 5.31 for Non-Local Farmers are plotted, their respective graphs are as shown in Figures 5.8 and 5.10. Figure 5.9 depicts only the essential portion of Figure 5.8 so that allocative efficiency can be determined at the two different output price levels.

Examining Figure 5.9, we find that at the minimum output price of 0.17 toea per kg and an MFC of 0.23 toea, the optimum number of trees Local Farmers should tap is about 390. However, at the maximum output price of 0.81 toea per kg, the optimum number of trees as determined by this analysis is about 10,000 trees, Currently, the average number of rubber trees being tapped by the Local Farmers is about 756 (Refer Appendix 3.1). Although Figure 5.9 cannot be used to determine the exact extent of rubber tree misallocation among the Local Farmers, it does show that the optimum number of trees which should be tapped is very responsive to variations in the output price. This is especially helpful for the Cape Rodney Rubber smallholders who usually have an excess number of mature trees. This means that they can vary the number of trees being tapped depending on the movement of the output price. At prices as low as 0.17 toea per kg, the

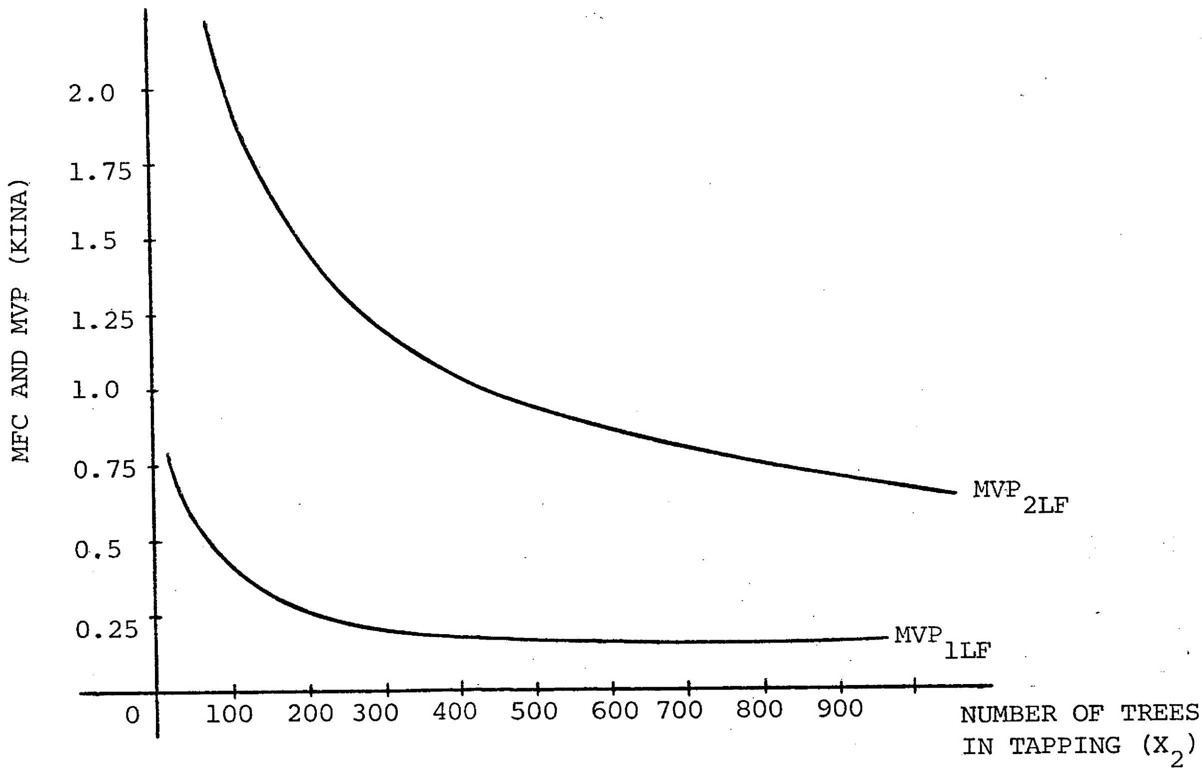

FIGURE 5.8: MARGINAL VALUE PRODUCT (MVP) CURVES OF TREES FOR LOCAL FARMERS AT THE TWO DIFFERENT OUTPUT PRICES

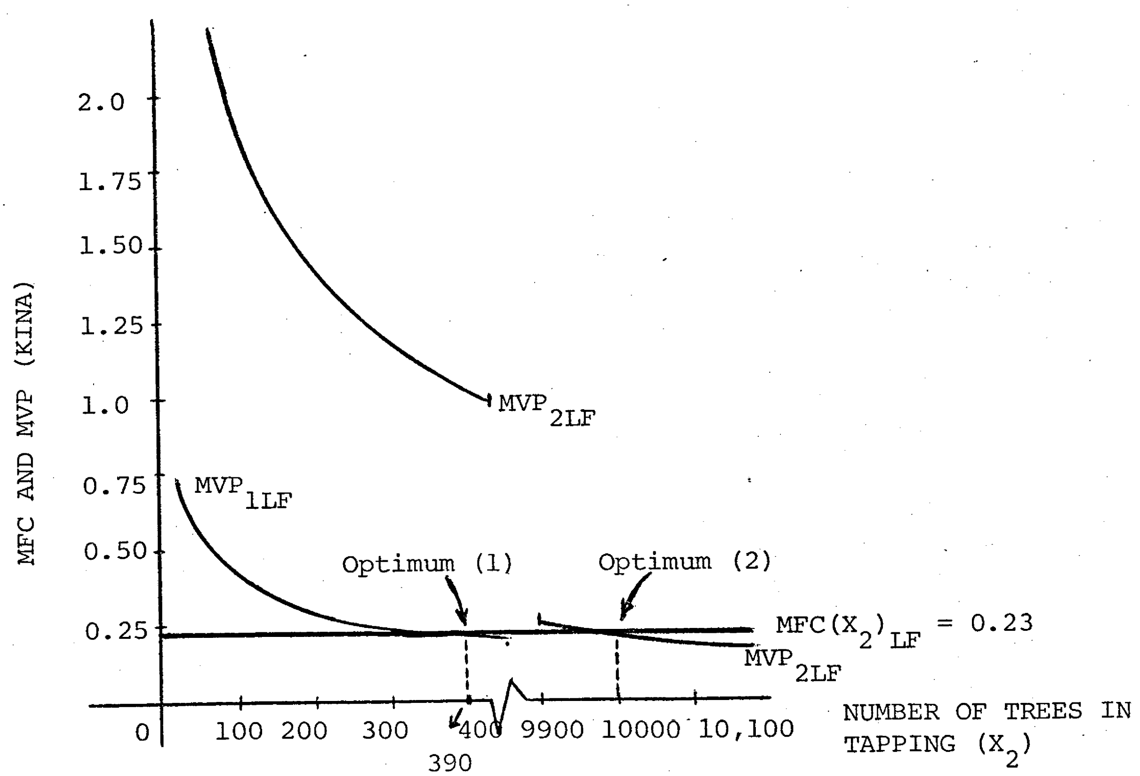

FIGURE 5.9: MARGINAL VALUE PRODUCT (MVP) AND MARGINAL FACTOR COST (MFC) CURVES OF TREES FOR LOCAL FARMERS (MVP CURVES AT TWO DIFFERENT OUTPUT PRICES)

average farmer should tap only a single task, the average task having about 350 to 400 rubber trees. Since the Cape Rodney smallholders or any smallholder for that matter, do not usually have 10,000 mature rubber trees, at prices as high as 0.81 toea per kg, the suggestion implied by the results obtained in Figure 5.9, is that they should tap all the mature trees they have.

In Cape Rodney, such a response to the variation in the output price was observed, especially when the price fell to a minimum of 0.17 toea per kg. At such a price, 78 per cent of the farmers were reported to have done no tapping at all. About half of these were Local Farmers. The remaining 22 per cent continued tapping but only a portion of the total number of mature trees they each had. The decision to reduce the number of trees being tapped was, under the circumstances and according to this analysis, an economically rational one. The decision to stop tapping was, however, an extreme one and farmers tended to lose rather than gain in doing so.

An inspection of Figure 5.10 reveals that the optimum number of trees for the Non-Local Farmers as suggested by this analysis is very much dependent on the output price. At the minimum price of 0.17 toea per kg, the optimum number of trees which should be tapped by the Non-Local Farmers is about 100, given that their MFC is about 0.24 toea. At the maximum price of 0.81 toea per kg, this optimum increases to some 1,100 trees, a number which some farmers already have or even exceeded. Currently, the average number of mature trees being tapped by Non-Local Farmers is about 847 (Refer Appendix 3.1). As was found in the analysis of labour allocation, Figure 5.10 cannot be used to determine the extent of the misallocation among the Non-Local Farmers. It does, however, indicate the general trend of tree allocation in response to extreme changes in the rubber output price. At prices as low as 0.71 toea per kg, Non-Local

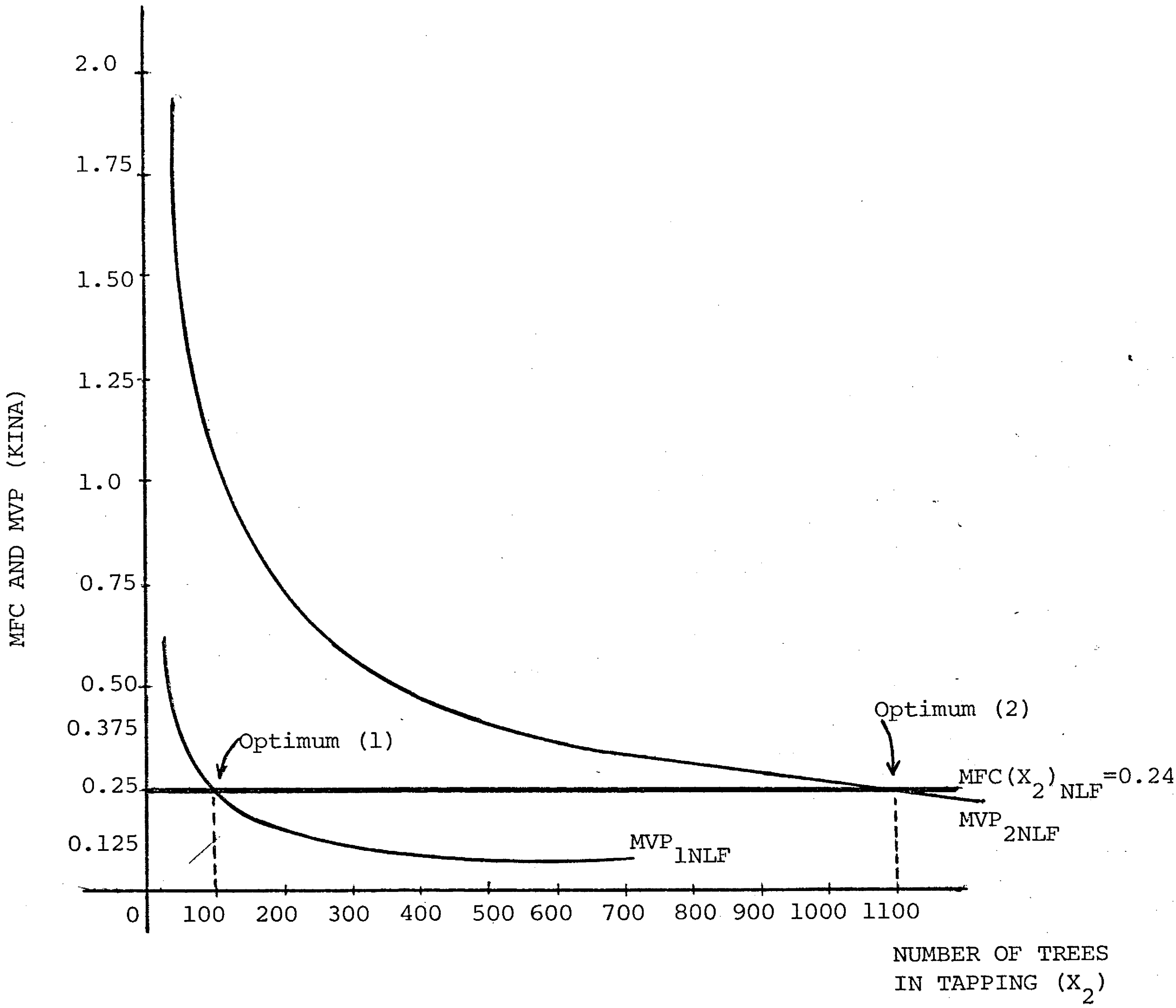

FIGURE 5.10: MARGINAL VALUE PRODUCT (MVP) AND MARGINAL FACTOR COST (MFC) CURVES OF TREES FOR NON-LOCAL FARMERS (MVP CURVES AT THE TWO DIFFERENT OUTPUT PRICES)

Farmers should reduce the number of rubber trees they tap from an average of 847 to about 100. Likewise, at output prices as high as 0.81 toea per kg, this analysis suggests that they should increase the number of trees they tap to some 1,100, given that the current average is about 847 trees.

As mentioned in the introductory chapter, actual data collection was done during the period when the output price was at its lowest; only 0.17 toea per kg of latex on a DRC basis. During this period, it was observed that most Non-Local Farmers were not tapping at all. Out of the

22 per cent found to have continued tapping their trees over this period, only 18 per cent or 2 were Non-Local Farmers. This means that about 92 per cent of the Non-Local Farmers had actually stopped tapping their trees, instead of tapping only 100 trees as suggested by this analysis. This does not necessarily indicate that Non-Local Farmers had acted irrationally. The main reason for this is that subsistence production, an important part of their overall production, is not being considered in the analysis. The gross returns from tapping a 100 or so trees at such a low output price was probably so marginal that they were better off doing other things than harvesting rubber trees. Most farmers tended to spend such times in their subsistence gardens. They were therefore not irrational in deciding to stop tapping rubber trees when the price was as low as 0.17 toea per kg.

The exact degree of resource misallocation with respect to trees among both groups of farmers can be determined using results presented in the lower half of Table 5.19. Here we find that the ratios of their respective MVPs to MFCs at the two different output prices are significantly different from 1, the ratio value at which resource allocation is said to be efficient. At an output price of 0.17 toea per kg and given their respective opportunity costs of trees, we find that the MVP to MFC ratios for the Local and the Non-Local Farmers are 0.7252 and 0.25 respectively. This means that at this low output price, both groups of farmers should reduce the number of trees they tap. The exact level of reduction was discussed earlier. Comparing both groups of farmers, we find from Table 5.19 that Local Farmers are more efficient than their Non-Local counterparts, at an output price of 0.17 toea per kg. That is, at such a low output price, the Non-Local Farmers tend to tap more trees than is required by the optimum suggested in this analysis while the Local Farmers tend to operate closer to their optimum.

At a higher output price of 0.81 toea per kg, the MVP to MFC ratios for the Local and Non-Local Farmers are 3.4557 and 1.1921, respectively. Both these ratio values are greater than 1, indicating that more trees should be made available for tapping at a high output price. This aspect was discussed earlier. Since a ratio of 1.1921 is closer to 1 than 3.4557, we conclude that at high output prices, Non-Local Farmers are more efficient in allocating tappable trees. This means that they operate closer to the optimum suggested by this analysis than the Local Farmers. For every additional tree made available for tapping, this would yield for the Local and Non-Local Farmers, money returns of approximately 80 and 29 toea, respectively. This difference in the monetary returns is mainly due to the difference in their tree marginal productivities, as shown in Table 5.19. This in turn is influenced by the average number of trees in tapping each group has. Hence, a higher MP of 0.9813 for the Local Farmers and a lower MP of 0.3532 for the Non-Local Farmers is mainly due to the former having some 100 fewer tappable trees than the latter. Besides, output seems to be more responsive to percentage changes in the number of trees being tapped by the Local Farmers than by the Non-Local Farmers. This is reflected in ρ values of 0.53 and 0.3471 for both groups, respectively, as shown in Table 5.19.

The optimum levels of trees which should be tapped as obtained for the two groups of farmers and at the two output prices from the above analysis may prove to be a useful piece of information for policy purposes. The optimum number of trees at the lower and higher output prices for the Local Farmers are 390 and 10,000, respectively. For the Non-Local Farmers, these optimums are 100 and 1,100, respectively. This means that on average, Local Farmers should have no less than 390 trees in tapping while Non-Local Farmers should have no less than 100. Likewise, the average Local Farmer should have as many mature rubber trees as he can comfortably maintain and harvest. The average Non-Local Farmer, however, can have no more than 1,100 mature trees in tapping. These figures therefore provide the approximate bounds as to the minimum and maximum number of trees each of the two groups should be tapping. Hence, Local Farmers with less than 390 trees in tapping should be encouraged to open up more trees while the Non-Local Farmers with more than 1,100 trees should reduce accordingly. In the light of the labour shortage problem among the Non-Local Farmers and the excess use of labour in rubber maintenance activities among the Local Farmers, the above recommendation would be of immense benefit to the smallholders themselves. Finally, the above analysis solely rests on the basic assumption that the estimated opportunity costs of labour and trees are good enough estimates of the actual costs.

5.2.6.4 Comparison and Conclusions

This final section compares some results of this study, presented in Table 5.19, with those of a similar study done on the same scheme by MacEwan and Carrad (1980). They also used cross-sectional data for the period July 1977 to March 1978, applying a C-D multiple regression technique. The results of their analysis are summarised in Table 5.20.

Table 5.20

Elasticities and Marginal Factor Products (Cape Rodney)

Variable	Elasticity	Average Product (1) (kg/unit)	Marginal Product (kg/unit)	Marginal Value Product (2) (kg/unit)
Land (Mature Trees)	0.41	1.17	0.48	0.24
Labour (Tappers)	0.18	369.99	66.60	33.30
Days	1.24	9.65	11.97	5.99

(1) At geometric mean values (Trees = 609.54, Tappers = 1.94, Output = 717.79, Days = 74.42)

(2) At K0.50/kg.

Source: Carrad (1980), p.71.

The major conclusions of the MacEwan and Carrad study can be summarized as follows:

(a) That it is not worthwhile to increase either the number of trees or the number of tappers because the marginal products of these two inputs are lower than their respective average products;

(b) That an extra day spent tapping would be of benefit to the farmer since increasing returns to scale exist for increased intensity of tree exploitation.[1]

A comparison of the results in Table 5.19 with those in Table 5.20 reveals that both the marginal products and the output elasticities of rubber trees are roughly the same. Similarly, the MVPs of trees obtained in both studies are roughly equal. The conclusion that it would not pay to increase the number of trees in tapping, by MacEwan and Carrad, is somewhat consistent with the finding in this study, especially given that the former use an output price of 0.50 toea per kg to obtain MVPs, while in this study, such a result was found to exist at an output price of 0.17 toea per kg. A joint conclusion would be that an output price of 0.50 toea per kg is probably not large enough to justify increases in the number of trees being tapped.

With respect to labour, although it is defined differently in both studies, we find that the parameters MP, ρ and MVP have significantly different values as shown in results obtained from Tables 5.19 and 5.20. This difference is more likely to be the result of differences in the functional forms adopted than differences in the actual data set. Hence, a detailed comparison between parameters and conclusions of the two studies is probably not warranted.

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1 Both conclusions tend to contradict.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This chapter summarises the major findings of this study and discusses some of the policy conclusions implied by these findings. The study concentrates on the analysis of technical and allocative efficiency, comparing the efficiency and/or inefficiency of the different groups which make up the sample. The two most important of these groups are Local and Non-Local Farmers. The analysis of allocative efficiency concentrates on the two major inputs in rubber production, Harvesting Labour and Trees.

The study uses two production function models, namely the Cobb-Couglas and a modified version of the general Transcendental model. The results obtained using the two models are not significantly different and they do not contradict. Some differences noticed in actual application lie in their explanatory and predicting powers. In these aspects, the TRANS model was somewhat superior. The same conclusion applies when in Figures 5.4 and 5.5, we observe that the TRANS function is able to explain the existence of negative marginal productivities, if they do in fact exist. This would not have been possible, using only the C-D model.

The input factors identified as having significant influence on rubber productivity are those shown in the results of regression R(2.b) in Table 5.9. The output elasticities of these input factors, presented in Table 5.11, reveal some interesting results which may have policy implications.[1] The output elasticity of trees is 0.5231 while that of harvesting labour is 0.3015. For the smallholders, this implies that where there are opportunities, say high output prices, the farmer would be better off tapping more trees than increasing the labour input in harvesting activities. This is so, given that the simple correlation

[1] Refer to Table 5.11, page 160.
These output elasticities depend on relative prices.

between the two variables is of the order of approximately 0.3 (Refer Table 3.2). For planners and policy makers, this finding suggests that expansion in the number of trees being tapped is an important source of growth in rubber productivity.

The low estimated yield figures of 575 and 589 kg for Local and Non-Local Farmers, respectively, reflects a situation where the total area occupied by mature rubber is greater than the area of mature rubber actually tapped, thus depressing the yield estimates. This, however, points to the bigger problem of a high percentage of untapped mature trees. Combined with falling output prices, they provide an explanation for the overall declining productivity problem, mentioned in the introductory chapter. Hence, given the greater response of rubber output to increases in the number of trees being tapped, much can be achieved by way of increasing national productivity, merely by providing proper incentives and creating the necessary supportive infrastructure and services. Proper incentives include subsidized production or the creation of a 'floor' output price so that it does not decline any lower[1]. The creation of supportive infrastructure and services are important, especially given that most rubber holdings in the country are located in remote and isolated areas. Besides, such isolated producers have no real need for large amounts of money since there are only limited expenditure outlets. This may also provide some explanation as to the lack of full exploitation of the mature trees. If services are provided so that this boosts the need for money, this may encourage the isolated producers to work towards full exploitation.

An output elasticity of -0.1973 for the variable depth of cut (X_7) indicates that the average farmer in Cape Rodney is currently tapping at a depth which actually reduces the output level. That is, the depth is either too deep or too shallow. However, since most farmers were

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1 Subsidized production should be viewed in relation to its national implications.

not tapping during the period of data collection for this study, the measurement of this variable was done in an ad-hoc manner. This may be the cause of the above unexpected finding. If, however, the variable was measured correctly, the above finding has serious implications. It reflects the lack of technical knowledge and skills not only among the smallholders but also among those who manage the industry as a whole. It may also reflect the lack of proper research capable of establishing specific answers, especially in areas relating to the growth and harvesting of rubber trees of different inherent characteristics. Hence, research and the availability of technical skills are essential components of a growing rubber industry.

A total output elasticity of 1.2085 indicates that rubber production in Cape Rodney is characterised by increasing returns to scale. That is, the average smallholder is getting some 0.21 per cent more than what he actually puts into rubber production. Again the potential for increased production does exist but is not being fully exploited. The lack of commitment on the part of the smallholders has often been used as an argument to explain the failures of both the resettlement and village rubber schemes, experienced throughout the country. But surely rational people are more likely to choose an activity which is more rewarding than that which is relatively less rewarding. In Cape Rodney, the better-off smallholders do not usually re-invest in rubber, instead they establish trucking and retailing businesses which are very much needed by the settlers themselves.

The analysis of technical efficiency is based on the assumptions that there exist both neutral and non-neutral shifting production functions between Local and Non-Local Farmers. The latter assumption is verified by performing a Chow Test. Given that the production functions of the two groups differ in a neutral manner, the analysis of technical efficiency reveals that Non-Local Farmers are relatively more efficient than the Local Farmers. That is, given an average package of input factors, the former group is liable to produce a relatively higher level of output than the latter group. However, the results of the Chow Test revealed that both groups do operate on significantly different production frontiers. Given this situation, the analysis of technical efficiency revealed that efficiency between the two groups differs, depending very much on the scale of operation. Where production was assumed to be capital intensive, Local Farmers were technically more efficient. Similarly, where production was labour intensive, the Non-Local Farmers were technically more efficient. This result, however, is very much influenced by the general shape of the isoquant curve. Allowing for this influence, a more realistic conclusion would be that Local Farmers are technically efficient at lower scales of production while the Non-Local Farmers are technically efficient at high scales of production.

The analysis of allocative efficiency of Harvesting Labour (X_1) and Trees in Tapping (X_2) is also performed in the study. The analysis with respect to harvesting labour reveals that Local Farmers are efficient in allocating their labour resources while the Non-Local Farmers are not efficient. The optimum suggested by the analysis for the latter group is about 86 man-days, some 47 man-days more than that actually employed, thus indicating the need to increase labour. This does not necessarily reflect irrational behaviour among these farmers. Instead it may be a reflection of a labour shortage problem. This was especially noticed during the survey period where older men were working on their own farms while the younger working members of the family either had formal employment or were away in the city. This implies that labour is a constraining factor of production among the Non-Local Farmers and therefore consideration should be given in this regard when recommendations for new plantings are made. Productivity of these group of farmers can be improved substantially if the harvesting labour input was increased to around the 86 man-day optimum suggested by the analysis. For the two groups of farmers and at the two different output price levels, the optimums obtained from the analysis differed only marginally, indicating that these optimums still hold, irrespective of the output price.

The analysis of allocative efficiency with respect to trees revealed that the optimum number of trees obtained from the analysis was very much dependent on the output price. For the Local Farmers, at output prices of 0.17 and 0.81 toea per kg, the optimums suggested by the analysis were about 390 and 10,000 trees, respectively. And for the Non-Local Farmers, these optimums were 100 and 1,100 trees, respectively. For the smallholders, the range in the optimums can be used as limits to the minimum and maximum number of trees each group should be tapping, provided the output price is within the range of those mentioned above. For the policy makers, the range in the optimums can be used as a guide when recommending new plantings. It also illustrates that effective price policies can be used as instruments in achieving the much needed growth in rubber productivity.

Using the ratio of MVP to MFC ($^{MVP}/MFC$) results presented in Table 5.19, the analysis concluded that at the lower output price, Local Farmers allocated trees more efficiently while at the higher output price, the Non-Local Farmers were found to be more efficient. But given the average number of trees each group was reported to be tapping, both groups allocated their tree resources inefficiently. The average level of inefficiency was about 24 per cent. On the whole, we can conclude that the Cape Rodney rubber smallholders are efficient in allocating their labour and tree resources.

Finally, the analysis presented in this study is somewhat incomplete in that the other major component of overall production, namely subsistence production, was excluded from the analysis. The main reason for this was the lack of necessary data. In this regard a potential future study area is the relationship between subsistence and rubber production on the one hand, and the effects of this on overall farm productivity, on the other. Such an analysis of the total farming system will provide important conclusions for the smallholders in PNG's Rubber Industry.

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APPENDIX 2

CAPE RODNEY LAND SETTLEMENT SCHEME

POINTS FOR CONSIDERATION: SETTLER SELECTION CRITERIA

Criteria		Points
1. Age		
	26 - 35	5
	36 - 40	3
	20 - 25	1
	under 20 or over 40	0
2. Political - place of birth for husband or wife.		
	- original land owner	10

NB: a. First preference for original landowner on equal pts.

b. A minimum of 30% of the blocks must be allocated to Abau District people.

c. A minimum of 60% of the blocks must be allocated to South Coast Region people.

3. Marital Status	Married	5
	Widower/Widow	4
	Single	3

plus 2 points for each person over 4 years
plus 1 point for each child under 4 years.

NB: MAX^{m} — 15

4. Health

   a. Mental Fitness - pass/fail criteria

   b. Physical Fitness - If applicant unfit, reduce points by 4.

5. Agricultural background

- Plantation/cash cropping experience

a.	Rubber	10
b.	Other	5
-	Subsistence Gardening	3
-	Fisherman & Others	1

APPENDIX 2 (CONT)

Criteria		Points	
6. Potential of present village land holdings for agricultural development.			
	- inadequate and/or unsuitable	10	
	- adequate but for subsistence only (disputed, inaccessible)	7	
	- adequate suitable	0	
7. Previous lease holdings	- Son or daughter of current settler	10	
	- No other leases	5	
	- Previous abandoned/forfeited	0	
	- Currently leasing one or more blocks	Disqualified	
8. Financial Status -	- Present savings or resources (trade store/PMV)	5	
	- Nil resources	3	
	- Substantial savings or resources	0	
	- Current Large Loan Debtor	Disqualified	
		Husband	Wife/Adult Dependent
9. Langauges Spoken	- English, Motu Pidgin	0-4	0-4
	- Motu and Pidgin	0-3	0-3
	- Motu only	0-2	0-2
	- Pidgin	0-1	0-1
	- Tok ples only	0-0	0-0
	Max^{m} 8 points		
10. Education qualifications	- Standard 6 and above	3	3
	- Nil to Standard 6	5	5
	Max^{m} 10 points		
11. Criminal History	- No Convictions	5	
	- Minor convictions	1	
	- Habitual Offender or one major conviction	Disqualified	
12. Marital History	- To be considered by 'Board' in light of disruption to other settlers. If evidence of poor history -	Disqualified	
13. Employment History	- Good history	5	
	- No history	3	
	- Poor history	0	

Name and Address of last employer ....

14. Previous Bank Loan History	- Successful	5	
	- Nil	3	
	- Unsuccessful	0	
15. 'Board's' Impressions/Opinion	- Graded	12 - 0	

(i.e. Apparent motivation, reasons for application).

110 points

	VARIABLE	ALL FARMERS (50)					D_3-DOM ETHNIC GROUP (6)					D_4-DOMARA ETHNIC GROUP (5)				
		Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum
a.	Output (kg of Dry Rubber)	545.2	1545.2	934930	32	4800	981.33	455.34	207330	366	1629	1476	810.42	656780	340	2287
b.	Number of Trees in Tapping	799.5	799.5	331830	63	2916	486.83	324.93	105580	63	1003	728.80	214.24	45898	393	908
c.	Year Since Tapping Commenced (years)	8.14	2.42	5.84	1	13	6.33	3.20	10.27	1	9	8.20	3.03	9.20	3.00	11
d.	Harvesting Labour (hours/day)	3.01	0.91	0.83	1	5	2.75	1.37	1.88	1	4.5	3.30	0.97	0.95	2.50	5.00
e.	Age of Farmer (years)	46.98	14.70	216.06	23	79	46.67	7.94	63.07	38	59	39.80	12.28	150.70	25	59
f.	Experience of Farmer (years)	15.22	5.22	27.28	3	29	18.83	4.07	16.57	1.5	24	12.20	6.14	37.70	3.00	19
g.	Total Farm Size (hectares)	11.07	2.46	6.03	6	17	10.05	1.53	2.33	8.09	12.55	10.16	2.88	8.29	6.23	13.75
h.	Age of Trees (years)	15.3	1.28	1.64	13	17	15.83	0.98	0.97	15	17	16.40	0.89	0.80	15	17
i.	Girth Size (cms)	89.6	8.78	77.06	75	112	91.67	7.53	56.67	85	105	95	9.85	97	88	112
j.	Total Number of Trees	330.3	821.24	674440	363	4415	704.83	201.95	40785	363	924	1175	364.61	132940	725	1548
k.	Condition of Farm	2.12	0.69	0.48	1	3	2	0	0	2	2	2.00	1.00	1.00	1.00	3.00
l.	Depth of Cut (mm)	5.06	1.00	1.00	4	7	5.33	1.03	1.07	4	7	5.40	0.89	0.80	4.00	6.00
m.	Condition of Tapping Panel	2.34	0.59	0.35	1	3	2.83	0.41	0.17	2	3	2.20	0.45	0.20	2.00	3.00
n.	Maintenance Labour (man-days/year)	40.32	16.44	270.24	12	78	43.13	10.94	119.64	29.25	58.5	37.55	24.52	601.33	13.50	78
o.	Service Flow of Capital (K)	47.28	30.36	922	6	152	24.17	14.76	217.77	6	49	49.60	48.70	2371.	20.0	135.00
p.	Area Under Productive Rubber (ha)	2.00	1.44	2.07	0.16	7.29	1.22	0.81	0.66	0.16	2.51	1.82	0.54	0.29	0.98	2.27
q.	Total Income (K)	590.20	376.17	141500	6	1787	370.50	180.36	32530	130	630	535.20	324.33	105.210	82	889
r,	Total Number of Tapping Days	116.5	49.6	2461	5	200	116.67	21.52	463.07	93	147	103.80	63.31	4007.70	45	192
s.	Harvesting Labour (man-days/year)	44.74	26.38	695.7	1.88	125	40.20	19.15	366.77	11.63	55.5	39.35	20.48	419.58	19.88	72
a/p	Output/hectare	890.58	494.53	244560	40.37	2287.5	1119	677.22	458630	450	2287.5	792.75	423.88	179680	346.94	1297.60
q/b	Income/tapped tree	0.84	0.46	0.21	0.04	2.06	1.03	0.60	0.36	0.43	2.06	0.71	0.44	0.19	0.21	1.18
a/b	Output/tapped tree	2.23	1.25	1.55	0.10	5.81	2.81	1.72	2.97	1.13	5.81	1.98	1.06	1.13	0.87	3.25
q/d	Income/hour of tapping	7.46	5.30	28.04	0.22	27.74	4.43	1.72	2.95	2.55	6.49	8.84	7.67	58.86	0.80	21.36
a/s	Output/man-day of Harvesting Labour	41.99	35.35	1249.2	4.72	191.07	27.23	10.25	105.03	13.69	40.21	47.03	27.40	750.82	4.72	81.32
a/n	Output/man-day of Maintenance Labour	44.61	32.91	1083.1	0.68	169.41	23.44	10.53	110.93	9.38	35.51	58.55	64.01	4097.70	11.33	169.41
q/o	Income/Unit of Capital Expenditure	14.67	8.46	71.56	0.15	38.75	17.22	5.32	28.29	10.67	24.00	16.73	15.51	240.64	2.93	38.75
a/n	Output/Tapping Day	14.58	10.55	111.35	1.77	59.71	8.07	2.48	6.5	3.94	11.02	21.12	18.08	326.77	1.77	50.82

APPENDIX 3.1

Average Statistics for Variables by Ethnic, Locational and Farmer Status Groups

	VARIABLE	D_5-NEW GUINEA ETHNIC GROUP (6)					D_6-KEREMA ETHNIC GROUP (14)					D_7-IANU ETHNIC GROUP (11)				
		Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum
a.	Output (kg of Dry Rubber)	1160.2	632.6	400180	32	1933	1449.1	597.20	356650	305	2145	1177.60	590.90	349170	44	1904
b.	Number of Trees in Tapping	663.67	384.36	147730	160	1222	697.29	342.08	117020	372	1479	670.45	378.98	143630	226	1603
c.	Year Since Tapping Commenced (years)	6.67	2.58	6.67	3	10	9.07	1.59	2.53	7	13	7.01	2.43	5.89	1	10
d.	Harvesting Labour (hours/day)	2.92	0.58	0.34	2.5	4	2.86	0.97	0.94	1	4	3.09	0.49	0.24	2.5	4
e.	Age of Farmer (years)	37.83	16.56	274.17	23	70	53.36	14.91	222.25	23	70	47.27	15.52	240.82	26	79
f.	Experience of Farmer (years)	12.17	4.45	19.77	4	17	16.07	5.57	31	5	29	15.46	5.20	27.07	4	24
g.	Total Farm Size (hectares)	13.07	2.70	7.31	9.71	17.4	11.28	2.43	5.93	8.49	15.01	11.07	2.45	5.99	6.83	15.38
h.	Age of Trees (years)	14	0.89	0.80	13	15	15.5	1.29	1.65	13	17	15.82	0.98	0.96	14	17
i.	Girth Size (cms)	81.63	4.75	22.57	77	90	87.93	8.81	77.61	75	100	94.73	8.98	80.62	85	110
j.	Total Number of Trees	1366	989.16	978440	480	3019	1176.6	517.62	267930	629	2373	1178	600.74	360890	635	2742
k.	Condition of Farm	2.67	0.52	0.27	2	3	2.07	0.75	0.53	1	3	1.82	0.60	0.36	1	3
l.	Depth of Cut (mm)	4.33	0.52	0.27	4	5	5.36	1.01	1.02	4	7	4.91	1.04	1.09	4	6
m.	Condition of Tapping Panel	2.33	0.82	0.67	1	3	2	0.56	0.31	1	3	2.27	0.47	0.22	2	3
n.	Maintenance Labour (man-days/year)	37.84	6.78	46.03	25.50	45.52	34.96	19.15	366.77	12	58.5	43.73	17.05	290.78	24	65
o.	Service Flow of Capital (K)	34.17	15.74	247.77	17	54	41.43	17.15	294.11	21	86	59.64	41.64	1735.5	15	152
p.	Area Under Productive Rubber (ha)	1.66	0.96	0.93	0.4	3.06	1.74	0.85	0.73	0.93	3.7	1.68	0.95	0.90	0.57	401
q.	Total Income (K)	456.17	249.58	62290	6.00	744.00	580.07	287.79	82822	94	1211	440.25	234.81	55137	17	728
r.	Total Number of Tapping Days	100.17	58.66	3441	5	151	112.71	49.33	2433.6	24	196	96.91	45.09	2033.3	7	170
s.	Harvesting Labour (man-days/year)	34.49	18.32	335.71	1.88	51	43.29	27.36	748.76	7.38	98	38.19	22.19	492.57	3.06	79
a/p	Output/hectare	712.59	463.88	215180	80	1333.1	896.92	460.35	211920	317.71	2152.7	835.03	546.60	298770	40.37	1986.6
q/b	Income/tapped tree	0.69	0.45	0.20	0.04	1.29	0.87	0.43	0.18	0.25	1.95	0.78	0.54	0.29	0.04	1.96
a/b	Output/tapped tree	1.78	1.16	1.35	0.20	3.34	2.24	1.15	1.32	0.80	5.38	2.09	1.38	1.90	0.10	5.00
q/d	Income/hour of tapping	5.67	3.03	9.15	0.22	8.46	9.31	6.84	46.81	1.72	27.74	5.26	2.42	5.85	0.25	8.33
a/s	Output/man-day of Harvesting Labour	31.96	10.94	119.74	17.07	43.81	54.94	58.41	3411.2	8.94	191.07	31.89	12.72	161.80	14.37	56.52
a/n	Output/man-day of Maintenance Labour	29	15.58	242.72	1.26	46.02	52.79	32.99	1088.2	7.82	119.42	32.78	20.70	428.39	0.68	70.52
q/o	Income/Unit of Capital Expenditure	14.74	11.39	129.79	0.35	30	14.36	7.17	51.45	4.37	30.28	11.27	8.52	72.59	0.15	26.05
a/n	Output/Tapping Day	11.68	1.03	1.06	4.38	7.20	16.53	14.33	205.26	3.32	59.71	12.06	4.62	21.37	6.29	21.20

APPENDIX 3.1 (CONT).

	VARIABLE	D_8-AROMA ETHNIC GROUP (4)					D_9-WESTERN ETHNIC DUMMY GROUP (4)					D_{10}-MOREGUINA LOCATIONAL DUMMY GROUP (9)				
		Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum
a.	Output (kg of Dry Rubber)	2323.7	806.90	651090	1561	3229	3624	1404.6	1972900	1726	4800	2764.40	1382.20	1910500	676	4800
b.	Number of Trees in Tapping	1426	1169.30	1367300	315	2916	1646.7	867.4	752370	669	2621	1535.90	892.60	796740	315	2916
c.	Year Since Tapping Commenced (years)	9.25	2.22	4.92	6	11	9.25	0.96	0.92	8.00	10.00	9.67	0.87	0.75	8.00	1100
d.	Harvesting Labour (hours/day)	2.75	0.65	0.42	2	3.5	3.75	1.44	2.08	2.5	5.00	3.39	1.05	1.11	2.50	5.00
e.	Age of Farmer (years)	54.25	20.34	413.58	24	68	39.75	1.71	2.92	38.00	42.00	46.33	1596.10	254.75	24.	69
f.	Experience of Farmer (years)	15	6.63	44	10	24	14.75	1.50	2.25	14.00	17.00	15.22	4.27	18.19	10	24
g.	Total Farm Size (hectares)	9.73	2.99	8.95	6	12.15	11.34	1.62	2.62	8.91	12.15	11.62	1.75	3.07	8.62	14.17
h.	Age of Trees (years)	14.25	1.26	1.58	13	16	14.00	0	0	14.00	14.00	14.89	1.36	1.86	14	17
i.	Girth Size (cms)	85.25	8.18	66.92	75	95	87.50	2.65	7.00	84.00	90.00	91.33	8.15	66.50	84.00	100.00
j.	Total Number of Trees	2293.7	1591.6	2533100	886	4415	2402.70	671.76	451250	1525	3000	2299.10	1080.50	1167500	886	4415
k.	Condition of Farm	2.75	0.50	0.25	2	3	2.00	0.82	0.67	1.00	3.00	2.44	0.73	0.53	1.00	3.00
l.	Depth of Cut (mm)	4.75	1.50	2.25	4	7	5.00	0.82	0.67	4.00	6.00	5.11	1.05	1.11	4.00	7.00
m.	Condition of Tapping Panel	3	0	0	3	3	2.50	0.58	0.33	2.00	3.00	2.67	0.50	0.25	2.00	3.00
n.	Maintenance Labour (man-days/year)	47.44	16.96	287.77	27	66.75	45.50	13.00	169.00	39.00	65.00	49.64	13.95	194.61	27	66.75
o.	Service Flow of Capital (K)	66.50	22.75	517.67	41	89	66.00	21.23	450.67	42.00	90.00	69.67	19.50	380.25	41	90
p.	Area Under Productive Rubber (ha)	3.57	2.92	8.54	0.79	7.29	4.12	2.17	4.70	1.67	6.55	3.84	2.23	4.98	0.79	7.29
q.	Total Income (K)	865.5	308.25	950150	546	1160	1362	509.41	259500	367	1787	1029.10	527.30	278040	190	1787
r,	Total Number of Tapping Days	155.50	8.74	76.33	143	162	184.5	21.76	473.67	153	200	155.89	44.88	2014.40	50	200
s.	Harvesting Labour (man-days/year)	53.58	13.91	193.36	40.25	70.88	87.89	38.73	1500.10	47.81	125	68.69	34.54	1193.10	15.63	125
a/p	Output/hectare	1018.7	685.23	469530	380.38	1975.9	939.61	166.86	278410	732.82	1109.10	864.78	491.20	241280	359.57	1975.90
q/b	Income/tapped tree	0.93	0.59	0.34	0.38	1.73	0.89	0.17	0.03	0.68	1.04	0.79	0.44	0.19	0.25	1.73
a/b	Output/tapped tree	2.55	1.72	2.96	0.95	4.96	2.35	0.42	0.17	1.83	2.77	2.16	1.23	1.52	0.90	4.96
q/d	Income/hour of tapping	8.42	0.74	0.55	7.62	9.26	11.59	7.11	50.57	4.12	20.59	8.96	5.37	28.83	2.56	20.59
a/s	Output/man-day of Harvesting Labour	43.07	8.73	76.28	34.93	55.20	54.28	30.90	1592.30	13.81	100.39	46.39	26.55	705.07	13.81	100.39
a/n	Output/man-day of Maintenance Labour	49.70	6.88	47.31	41.24	57.82	81.22	33.05	1092	44.26	123.08	58.96	31.96	1021.70	11.56	123.08
q/o	Income/Unit of Capital Expenditure	13.00	0.91	0.83	12.20	14.15	20.31	3.12	9.73	16.07	22.84	14.83	6.40	40.99	2.92	22.84
a/n	Output/Tapping Day	14.87	4.88	23.86	10.76	20.70	20.32	9.50	90.25	8.63	31.37	17.49	6.94	48.10	8.63	31.37

APPENDIX 3.1 (CONT).

	VARIABLE	D_{11}-IANU LOCATIONAL DUMMY GROUP (13)					D_{12}-BOMGUINA LOCATIONAL DUMMY GROUP (8)					D_{13}-MANABO LOCATIONAL DUMMY GROUP (20)				
		Mean	Standard Derivation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum
a.	Output (kg of Dry Rubber)	1176.90	652.86	426230	32	2002	1085.90	423.19	186790	366	1629	1419.70	605.27	366360	305	2287
b.	Number of Trees in Tapping	574.85	302.17	91308	160	1222	553.37	329.97	108880	63	1006	712.60	312.52	97671	383	1603
c.	Year Since Tapping Commenced (years)	7.54	2.79	7.77	1.00	11.00	6.13	2.75	7.55	1.00	9.00	8.65	1.93	3.71	3.00	13
d.	Harvesting Labour (hours/day)	3.08	0.57	0.33	2.00	4.00	2.75	1.17	1.36	1.00	4.50	2.90	0.93	0.86	1.00	5.00
e.	Age of Farmer (years)	50	17.38	302.17	23	79	44.13	8.24	67.84	35	59	46.45	14.97	223.94	23	70
f.	Experience of Farmer (years)	14	5.35	28.67	4.00	24	17.50	4.24	18	13	24	15.10	5.89	34.73	3.00	29
g.	Total Farm Size (hectares)	10.67	2.69	7.21	6.00	15.38	10.91	2.20	4.83	8.09	14.98	11.16	2.77	7.65	6.23	17.40
h.	Age of Trees (years)	15.31	1.18	1.40	13	17	15.25	1.39	1.93	13	17	15.50	1.32	1.74	13	17
i.	Girth Size (cms)	90.62	8.59	73.42	75	110	88.50	8.67	75.14	78	105	88.60	9.64	92.99	75	112
j.	Total Number of Trees	1119.50	659.65	435140	480	3019	809.50	421.62	177760	363	1747	123980	556.42	309600	629	2742
k.	Condition of Farm	2.08	0.64	0.41	1.00	3.00	2.25	0.46	0.21	2.00	3.00	1.95	0.76	0.58	1.00	3.00
l.	Depth of Cut (mm)	4.77	0.93	0.86	4.00	6.00	5.13	0.99	0.98	4.00	7.00	5.20	1.06	1.12	4.00	7.00
m.	Condition of Tapping Panel	2.15	0.55	0.31	1.00	3.00	2.88	0.35	0.13	2.00	3.00	2.10	0.55	0.31	1.00	3.00
n.	Maintenance Labour (man-days/year)	40.44	14.99	224.57	24	65	41.91	9.52	80.71	29.25	58.50	35.40	19.29	372.04	12	78
o.	Service Flow of Capital (K)	52.08	40.03	1602.40	15	152	26	15.07	227.14	6.00	49	42.60	25.60	655.09	20	135
p.	Area Under Productive Rubber (ha)	1.44	0.76	0.57	0.40	3.06	1.39	0.83	0.68	0.16	2.52	1.78	0.78	0.61	0.96	4.01
q.	Total Income (K)	445.23	246.10	60563	6.00	728	416.62	176.38	31109	130	630	556.35	280.40	78623	82	1211
r,	Total Number of Tapping Days	101.38	56.59	3202.90	5.00	176	117.87	19.90	395.84	93	147	108.00	48.59	2361.40	24	196
s.	Harvesting Labour (man-days/year)	38.35	23.48	551.29	1.88	79	40.70	16.88	284.88	11.63	55.50	39.73	22.49	505.72	7.38	98
a/p	Output/hectare	919.01	651.07	423890	40.37	2152.70	1045.3	602.55	363060	450	2287.50	821.81	334.22	111700	317.71	1338.10
q/b	Income/tapped tree	0.86	0.62	0.38	0.04	1.96	0.98	0.53	0.28	0.43	2.06	0.79	0.34	0.12	0.21	1.29
a/b	Output/tapped tree	2.30	1.63	2.67	0.10	5.38	2.63	1.53	2.35	1.13	5.81	2.06	0.84	0.70	0.80	3.34
q/d	Income/hour of tapping	5.31	2.63	6.90	0.22	8.33	5.08	2.04	4.15	2.55	8.46	9.13	6.69	44.71	0.80	27.74
a/s	Output/man-day of Harvesting Labour	30.27	11.94	142.53	14.37	56.52	29.17	10.50	110.17	13.69	43.81	52.76	50	2499.60	4.72	191.07
a/n	Output/man-day of Maintenance Labour	32.71	20.50	420.26	0.68	70.52	26.74	10.87	118.25	9.38	39.07	53.05	40.62	1650.10	7.82	169.41
q/o	Income/Unit of Capital Expenditure	11.79	8.43	71	0.15	26.05	18.29	6.69	44.72	10.67	30	15.02	9.73	94.64	2.93	38.75
a/n	Output/Tapping Day	11.40	4.54	20.66	6.29	21.20	8.99	2.89	8.37	3.94	13.69	17.57	14.74	217.29	1.77	59.71

APPENDIX 3.1 (CONT).

	VARIABLE	D_{15}-LOCAL FARMERS (26)					D_{16}-NON LOCAL FARMERS (24)				
		Mean	Standard Deviation	Variance	Minimum	Maximum	Mean	Standard Deviation	Variance	Minimum	Maximum
a.	Output (kg of Dry Rubber)	1366	751.44	564660	44	3229	1739.40	1141.20	1302400	32	4800
b.	Number of Trees in Tapping	755.54	585.29	342570	63	2916	847.12	574.49	330040	160	2621
c.	Year Since Tapping Commenced (years)	7.81	2.71	7.36	1.00	11	8.50	2.04	4.17	3.00	13
d.	Harvesting Labour (hours/day)	3.00	0.85	0.72	1.00	5.00	3.02	0.99	0.99	1.00	5.00
e.	Age of Farmer (years)	46.77	14.19	201.46	24	79	47.21	15.53	241.22	23	70
f.	Experience of Farmer (years)	15.54	5.51	30.34	3.00	24	14.88	4.99	24.90	4.00	29
g.	Total Farm Size (hectares)	10.45	2.36	5.57	6.00	15.38	11.74	2.42	5.89	8.40	17.40
h.	Age of Trees (years)	15.69	1.16	1.34	13	17	14.88	1.30	1.68	13	17
i.	Girth Size (cms)	92.62	8.90	79.13	75	112	86.33	7.53	56.75	75	100
j.	Total Number of Trees	1239.90	852.46	726690	363	4415	1428.40	792.28	627700	480	3019
k.	Condition of Farm	2.04	0.66	0.44	1.00	3.00	2.21	0.72	0.52	1.00	3.00
l.	Depth of Cut (mm)	5.08	1.06	1.11	4.00	7.00	5.04	0.95	0.91	4.00	7.00
m.	Condition of Tapping Panel	2.50	0.51	0.26	2.00	3.00	2.17	0.64	0.41	1.00	3.00
n.	Maintenance Labour (man-days/year)	42.97	16.74	280.31	13.50	78	37.44	15.95	254.42	12	65
o.	Service Flow of Capital (K)	50.58	37.72	1422.70	6.00	152	43.71	19.80	392.22	17	90
p.	Area Under Productive Rubber (ha)	1.89	1.46	2.14	0.16	7.29	2.12	1.44	2.06	4.00	6.55
q.	Total Income (K)	507.85	289.74	83948	17	1160	679.42	440.73	194240	6.00	1787
r,	Total Number of Tapping Days	111.81	44.47	1978	7.00	192	121.54	55.15	3041.30	5.00	200
s.	Harvesting Labour (man-days/year)	41.25	19.75	390.13	3.06	79	48.52	32.09	1029.40	1.88	125
a/p	Output/hectare	920.69	560.18	313800	40.37	2287.5	857.95	421.65	177790	80	2152.70
q/b	Income/tapped tree	0.85	0.52	0.28	0.04	2.06	0.83	0.40	0.16	0.04	1.95
a/b	Output/tapped tree	2.31	1.41	2.00	0.10	5.81	2.15	1.05	1.11	0.20	5.38
q/d	Income/hour of tapping	6.24	3.97	1.57	0.25	2.14	8.78	6.25	39.11	0.22	27.74
a/s	Output/man-day of Harvesting Labour	35.45	16.52	272.89	4.72	81.32	49.08	47.58	2236.90	8.94	191.07
a/n	Output/man-day of Maintenance Labour	38.18	32	1024.10	0.68	169.41	51.58	33.12	1097	1.25	123.08
q/o	Income/Unit of Capital Expenditure	13.96	8.98	80.71	0.15	38.75	15.45	7.97	63.52	0.35	30.28
a/n	Output/Tapping Day	13.31	9.21	84.78	1.77	50.82	15.95	11.89	141.31	3.32	59.71

APPENDIX 3.1 (CONT).

APPENDIX 3.2

Output, Days Absent, Wet, Worked and Weekends for 1978 Data Set

Farm Number	Output	Days Absent	Days Wet	Days Work	Days Weekend	Total Days	Output/Work
1	3305	068	37	169	105	365	20
2	1706	074	24	161	105	365	11
3	1784	079	30	151	105	365	12
4	2071	081	37	144	105	365	14
5	3493	054	24	183	105	365	19
6	1820	091	24	156	105	365	12
7	2141	120	24	116	105	365	19
8	2338	121	25	115	105	365	20
9	2207	107	27	126	105	365	18
10	0118	56	18	17	36	122	7
11	2301	101	31	121	105	365	19
12	0221	39	11	16	25	91	8
13	0477	153	31	74	105	365	7
14	2200	123	28	107	105	365	21
15	3388	58	31	172	105	365	20
16	1487	105	32	134	105	365	11
17	4102	061	29	171	105	365	24
18	2641	094	24	143	105	365	18
19	0490	138	34	089	105	365	6
20	0225	040	11	036	036	122	6
21	0721	141	24	095	105	365	8
22	1353	074	24	152	105	365	11
23	0665	110	25	125	105	365	5
24	1141	134	24	102	105	365	11
25	0860	113	25	122	105	365	7
26	0827	044	10	076	054	184	11
27	0264	031	12	026	023	92	10
28	0652	188	25	096	105	365	7
29	0802	090	17	066	069	242	12
30	0264	062	62	065	062	244	4
31	1382	078	31	151	105	365	9
32	0012	031	06	006	016	059	2
33	1695	081	24	112	098	306	15
34	0959	112	25	058	079	274	17
35	0899	116	22	078	088	304	12
	50902/35=1454.34	915/35=26.14		3731/35=106.6			433/35=12.37