SOME ASPECTS OF SMALLHOLDER RUBBER PRODUCTION

IN SOUTH SUMATRA, INDONESIA: A PRODUCTION FUNCTION APPROACH

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DECLARATION

Except where otherwise indicated, this sub-thesis is my own work.

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ABSTRACT

This study attempts to highlight and quantify the major factors affecting yields on small rubber farms in Kabupaten LIOT and MURA, South Sumatra, and to indicate the adjustments which should be made to secure a better performance.

The input-output data obtained from a 1977/1978 survey of smallholder rubber farms in South Sumatra is the basis of this study. An unrestricted form of the Cobb-Douglas production function is fitted to LIOT and MURA data separately. The function is estimated by two different techniques, Ordinary Least Square and Linear Programming. The function estimated by the first approach is interpreted as the average production function, and expresses the output level which an average farm can obtain from a given set of inputs. The function estimated by the second approach is interpreted as the best or frontier production function, which expresses the maximum output level that can be obtained by only the most efficient farms from the combination of factors at the existing state of technical knowledge. The major findings with regard to the production coefficients are as follows:

(1) There are decreasing returns to scale in the production of Kabupaten LIOT and increasing returns to scale in the production of Kabupaten MURA.

(2) For both regions, the frontier function has shifted neutrally outwards from the average function.

In general for all holdings, the number of trees in tapping per hectare seems to be an important positive influence on yield. Too deep a tapping cut appears to have substantial negative effects, especially with younger trees, whilst for older trees increasing the number of cuts and maintaining the tapping panels in good condition seems to be a big advantage.

The estimated production functions are used to calculate the technical efficiency of the individual farms. For each region, two different ratings of technical efficiency are derived from the average and the frontier production functions. The efficiency ratings are calculated as the ratios of observed output to the level of output estimated from the production functions. From this part of the analysis it is found that there is no significant difference in the efficiency ratings that are derived from the average or the frontier production functions.

On the basis of average production function, the marginal productivities of factors of production are calculated for both the regions separately.

An attempt is made to examine the factors which explain the difference between the maximum possible yield and the actual yield of both regions. The results show that in LIOT, girth is the factor responsible for reducing the extent of yield variation from the maximum possible yield, whereas depth of cut and age of trees are factors significantly widening farmer yield gap. For Kabupaten MURA, the number of cuts, condition of the tapping panel, depth of cut and education are the factors responsible for reducing the extent of yield variation from the maximum possible yield, whereas years since tapping commenced and farm size are contributing more to the difference.

Apart from their much higher rubber yields, the frontier farms in Kabupaten LIOT have bigger girthed trees and more trees in tapping. In Kabupaten MURA, they have a larger productive area surveyed, younger trees and apply more labour in maintenance.

Size of farm may well have an important influence on technical efficiency and yield, but this facet must be investigated further.

It is considered that many of the less technically efficient farms could be encouraged to improve their position if greater assistance could be given to them by extension services.

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GLOSSARY

Adat	Tradition: Custom
Alang-Alang	A sedge grass (Imperata Cylindrica)
Dusun	Village
Kabupaten	Regency or District
Kecamatan	Sub-district
Kotamadya	Municipality
Ladang	(Unirrigated) arable land, field
Marga	Village administrative district. Within any marga will be found a number of dusuns (villages)

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The main aim of this study is to establish the economic and technical conditions of the rubber small-holding industry in the province of South Sumatra. The purpose of doing this is to provide a guide for smallholding research by the Research Institute for Estate Crops, Bogor.

Most of the present attention of the Research Institute is being directed to developing new trees and to planting, exploitation, and processing methods suited to the relatively capital intensive industry on estates. Little attention is being given to the problems of smallholdings, although these units cover most of the planted rubber area in Indonesia. In 1975 this sector occupied approximately 81 per cent of the total area under rubber cultivation (Table 1.1). In addition little economic analysis of either estate or smallholding data has been undertaken so far.

TABLE 1.1

AREA AND PRODUCTION OF ESTATE AND SMALLHOLDERS RUBBER IN INDONESIA 1966-1975

Year	Area ('000 ha)				Production (Metric Tons)			
	Estate	Small-holder	% of Total	Total	Estate	Small-holder	% of Total	Total
1966	476.7	1626.3	77.33	2103.0	222.384	527.862	70.36	750.246
1967	455.3	1617.0	78.03	2072.3	200.565	500.272	71.38	700.837
1968	508.9	1689.7	76.85	2198.6	206.133	531.216	72.04	737.349
1969	418.7	1771.4	80.88	2190.1	230.100	553.826	70.65	783.926
1970	488.1	1822.1	78.87	2310.2	238.123	571.014	70.57	809.137
1971	575.3	1811.3	79.21	2286.6	238.382	547.027	69.65	785.409
1972	465.3	1840.5	79.82	2305.8	236.588	567.327	70.57	803.915
1973	455.1	1863.3	80.37	2318.4	246.541	597.925	70.81	844.466
1974	439.6	1865.6	80.93	2306.2	248.742	589.874	70.34	838.616
1975	428.2	1868.1	81.35	2296.3	243.853	536.234	68.74	780.087

Source: Balai Penelitian Perkebunan Bogor dan Biro Pusat Statistik, 1977.

An obstacle to the planned improvement of the Indonesia smallholding rubber industry is lack of information; either about inputs used or about the outputs secured from them. Some data is available from clonal and yield trials, and from experiments to investigate other specific aspects like tapping, but such work never records more than a few economic factors and has been mainly concentrated on large estates.

Current government policies towards the improvement of the rubber smallholdings are concentrated on Project Management Units. These are restricted areas where integrated and capital-intensive attempts are made to achieve development through new planting and replanting with high yielding budgrafts, through application of fertilizers and agrocides and through provision of better processing facilities and extension services. It is believed that serious attention should be given to the alternative approach of trying to provide government assistance on a much broader scale, dispersing it much more widely across the huge areas of small individually owned smallholdings.

It is not at present clear which of these two approaches is preferable in terms of generating the greatest economic product from the scarce resources available. It is clear, however, that whatever policies are followed should be based, so far as is possible, on a knowledge of the economic and social relationships of the existing situation of smallholdings, and on experiments to determine how best to deploy the scarce resources at hand so as to achieve improvement. To gather such knowledge and to conduct such experiments is a major function of the Rubber Research Institute. Gathering knowledge of the economic and social relationship for South Sumatra is the limited goal of the present study.

1.2 Objectives of the Present Study

The Province of South Sumatra is one of the largest rubber growing areas in Indonesia. In 1973, of 1,863,300 hectares smallholder rubber in Indonesia, about 491,700 hectares (about 26 per cent) were planted in this province. Its gross production was 159,500 tons, about 27 per cent of the total smallholder rubber production in this country (Tables 1.1 and 2.5). The present study has been undertaken in this province based on the consideration that the province of South Sumatra is the most important rubber producing area in Indonesia.

From the data collected during the survey, it is aimed to achieve two main purposes:

(1) To quantify the relationship between yield/growth and important influences on yield/growth such as types of planting material, density of planting, number of tapping days, and degree of maintenance.

(2) To support this with more general information on the economy of the more progressive farmers in the province of South Sumatra.

In respect to the first objective, a production function is derived for smallholder rubber in the province of South Sumatra. The procedure is:

(a) To relate yield per hectare to individual factors at a time;

(b) To fit the same functional form of Cobb-Douglas type production function by the Least Square and Linear Programming methods;

(c) To estimate the technical efficiency of individual farms relative to the average and the frontier production function respectively;

(d) To estimate the marginal productivity of factors production;

(e) To examine the factors inducing the difference between the maximum possible yield and the actual yield among the sample farms.

In respect to the second objective, some further information which helps to interpret the production function relationship is presented.

For the purpose of the thesis only data from Kabupaten LIOT and Kabupaten MURA is used and analysed. Those two _kabupatens_ are the most important rubber producing areas in the province. Of 491,700 hectares of smallholder rubber in the province, about 216,000 hectares (40.4 per cent) are planted in these two _kabupatens_ (Table 2.5). The locations of these two _kabupatens_ are indicated in Figure 1.1.

A rubber farmer in this province usually plants rubber at the same time as opening up and working on _ladang_ (shifting cultivation). The rubber is usually planted in the first or second year and it is kept free of weeds during this time and during succeeding food crops. The farmers then move on to clear another plot and simply forget the rubber trees until they are mature enough to be tapped (9-12 years old). By this method, the rubber trees are not cultivated intensively and are subsequently left uncared for during their unproductive period, when cultivation has shifted to another plot. According to the shifting cultivation, a rubber farmer in this province usually has a mix of productive rubber area, immature rubber areas and _ladangs_.

The total sample of farms in the survey comprise 250 productive rubber areas and 250 _ladangs_ with young rubber. A 'productive area' is defined as an area of yielding rubber trees tapped for at least two years, but not more than 20 years. Usually data for a given farm are collected for either a productive rubber area or a _ladang_, but not both. A '_ladang_ and young rubber area' is defined as a _ladang_ planted with rubber trees not more than three years old, and still planted with other crops. Usually this means that the _ladang_ will not have been opened for more than three years; with the pepper-growing areas, however, the _ladangs_ may have been planted with pepper for 5-6 years prior to establishment of young rubber trees. For the

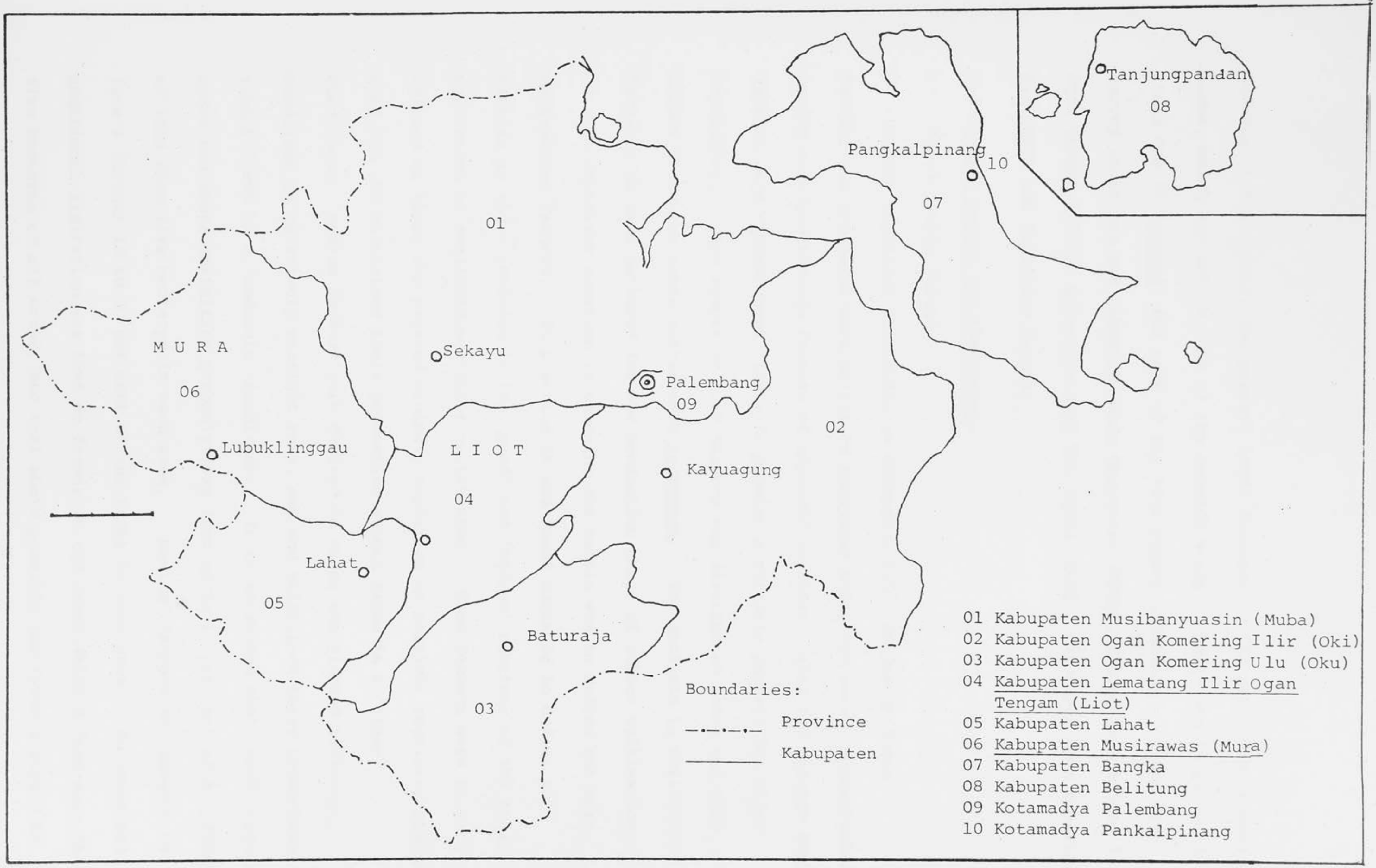


Figure 1.1 South Sumatra (Indicating the Locations of the Kabupatens LIOT and MURA)

purpose of the thesis, the present study focussed on the productive rubber areas, which are only a part of the broader study. There are 50 productive areas and 50 ladangs for each of the five survey locations. These five survey locations are Kabupaten Musi Banyuasin (MUBA), Kabupaten Lematang Ilir Ogan Tengah (LIOT), Kabupaten Musi Ulu Rawas (MURA), Kabupaten Ogan Komering Ulu (OKU) and Kabupaten Bangka.

1.3 Sample Design and the Survey

1.3.1 Sample Design

Within Kecamatan Prabumulih in Kabupaten LIOT, Kecamatan Muara Kelingi and Kecamatan Mura Beliti in Kabupaten MURA, the survey concentrated on the more progressive farmers of improved holdings. This was because such farmers were thought most likely to provide a suitable pattern for wider improvement. The sample of such farmers was distributed among the main rubber producing areas within each kecamatan. The analysis in this thesis focusses on data gathered for the production phase of rubber cultivation.

An important question in choosing the sample was to define the more progressive farmers. In practice it was found suitable to define such farmers as those included in the 'good' and 'medium' sections of the total population of smallholding rubber cultivation. Good farmers were in turn defined as those who planted ordinary seedlings in straight regularly spaced rows and who maintained their productive rubber farms in a 'clean' condition. Medium farmers were defined as those who planted ordinary seedlings in relatively straight rows, and who maintained their productive rubber farms in a 'moderate' condition. It is estimated that 'good' farmers under the above definition probably form from up to 15 per cent of all farms of less than five hectares in each area. 'Medium' farmers are thought to form a further 15 to 30 per cent of the farms in each area. An important additional limitation was that no farmer in the sample should farm more than five hectares of all crops, and that where possible the farmers should be owner-operators whose farm work was done either by themselves or by the members of their families. This limitation was considered vital, in that frequently 'progressive' farmers under the definition above were the richest members of each community; they farmed 10 or more hectares in total, and had substantial trading activities. Such people were obviously not subject to the same limitations of resources that characterised the vast majority of rubber farmers. The major characteristics of sample farms of Kabupaten LIOT and Kabupaten MURA can be seen in Table 1.2, which is discussed further in section 2.7.

In line with the search for progressive farmers some progressive 'margas' were selected from each kecamatan. These locations were selected in relatively progressive areas. All were quite close to big towns and had been influenced to varying degrees by extension work or the presence of estates. The margas considered to be most progressive in the Kecamatan Prabumulih Kabupaten LIOT were margas Rambang Kapak Tengah I, Rambang Kapak Tengah II and Lubai Suku II; in the Kecamatau Muara Kelingi and Kecamatan Muara Beliti Kabupaten MURA were margas Proatin XI and Talang Pumpung Kepungut respectively. From each marga 3 to 7 villages/dusuns (depending on the size of the marga and number of smallholders in each dusun) were selected.

As already indicated, the analysis in this thesis is focussed on the 'productive area' of each sample holding. From the data collected on the productive rubber area, it is aimed to give a comprehensive picture of technical conditions and relationships pertinent to the selected block of trees. As far as possible it covers the major inputs. It includes such specific features as the topography of the land; the number of trees in tapping, dry and not yet tapped; the detailed utilization of labour on production and processing activities; and particulars of fertilizer, weedicide, etc., applied to the area. Information is also recorded on the quality of

TABLE 1.2

AVERAGE CHARACTERISTICS OF SAMPLE FARMS OF KABUPATENS LIOT AND MURA

VARIABLE		AVERAGE					F-Stat.[a)]
		LIOT		MURA		ALL	
y	Yield (kg/ha/day)	3.8587	(2.5455)	5.6666	(3.0399)	4.7804	10.562*
X1	Trees in tapping/ha (tree)	479.1234	(232.3089)	302.9602	(110.4297)	389.3152	24.218*
X2	Number of years since tapping (year)	4.2200	(3.6605)	12.9231	(12.6005)	8.6569	19.134*
X4	Number of cuts (half spiral)	1.3200	(0.6833)	1.4231	(0.4989)	1.3725	0.761
X7	Harvesting labour (hour/day)	6.0728	(3.5735)	4.1285	(3.0955)	5.0816	8.646*
X8	Age of farmer (year)	43.3600	(15.4573)	39.9615	(10.1111)	41.6275	1.740
X9	Education (year)	4.5200	(2.8229)	3.9615	(2.0860)	4.2353	1.298
X10	Experience (year)	21.0800	(13.6349)	18.7692	(9.6723)	19.9020	0.981
X11	Farm size[b)] (ha)	2.0024	(0.9484)	2.5771	(1.3932)	2.2954	5.885**
X12	Age of trees (year)	13.2400	(4.8342)	23.4615	(14.0384)	18.4510	23.787*
X13	The girth[c)] (cm)	48.5000	(9.1009)	68.2692	(22.2103)	58.5784	34.097*
X14	Total trees/ha (tree)	647.6942	(288.3024)	408.1131	(129.8299)	525.5548	29.663*
X17	Depth of cut (mm)	5.8000	(0.9897)	6.3462	(0.9264)	6.0784	8.285*
X20	Immature trees/ha (tree)	108.2901	(120.8220)	48.5220	(43.2653)	77.8201	11.231
X21	Maintenance Labour (manday /year)	16.1634	(29.6108)	5.6903	(10.7532)	10.8242	5.722**

Notes:
a) F-Statistics testing for differences between two regions
Figures in brackets are standard deviations.
b) The total area of land under productive rubber
c) At a height of 150 cms from ground level
* Significant at the 0.1 per cent level
** Significant at the 2 per cent level

the farming activities, ranging from the relative cleanliness of the holding to the condition of the tapping panels and cuts, and the growth of rubber trees (which is a direct reflection of the standard of farming) (see function 3.1, page 33).

The socio-economic data collected cover details of the farmer's family, including education, work experience and full particulars of living costs.

A total sample of 102 productive rubber areas on 102 rubber farms are analysed in this study. This comprises 50 farms in Kabupaten LIOT and 52 farms in Kabupaten MURA.

The samples of productive areas in each kecamatan are distributed in approximate proportion to the tapped area of small holding rubber in each rubber growing village. The distribution of the sample farms are presented in Table 1.3.

TABLE 1.3

THE DISTRIBUTION OF THE SAMPLE FARMS IN

KABUPATEN LIOT AND KABUPATEN MURA

Kabupaten	Kecamatan	Marga	No. of Dusun	No. of Sample
LIOT	Prabumulih	Lubai Suku II	3	15
		Rambang Kapak Tengah I	7	20
		Rambang Kapak Tengah II	4	15
			14	50
MURA	Muara Kelingi	Proatin XI	5	26
	Muara Beliti	Talang Pumpung Kepungut	6	26
			11	52

These tapped areas were only known very roughly indeed, and were obtained by reference to the personal knowledge of local Dinas Perkebunan officers and other local government officials. The method of distributing the sample was therefore extremely approximate.

The actual choice of sample farms from within each rubber-growing village was the responsibility of the enumerators, and considerable flexibility was permitted. As far as possible, enumerators endeavoured to construct a list of progressive farmers within each rubber-growing village, and to select productive areas at random from this list. There are great practical difficulties in this procedure, however, in that no official listing of farms may be available. Usually any list has to be established by reference both to local government officials and the more informative farmers.

1.3.2 The Questionnaires and Enumerators

The questionnaires used covered technical and socio-economic aspects in two separate sections. Details of the data collected in the survey are given in the sample Recording Forms which are presented as Appendices 1A and 1B. Data was secured for 'productive areas' of rubber (Part I) and for socio-economic aspects (Part III); Part II of the questionnaire was used for ladangs.

To avoid irrelevant questions and answers, the questionnaires were pre-tested by enumerating a certain number of smallholders in the areas concerned. Appropriate changes were then made.

Some of the data in the questionnaires were obtained by direct enumeration of the farms, and some such as the area of the block, number of trees, the girth and production of rubber on the day of the interview, by direct observation, and measurement on the part of the enumerator. Other information is collected by direct and careful questioning of the farmer concerned. To gather information on each productive area took about 4 hours.

The enumerators were 2 staff of the Dinas Perkebunan of South Sumatra

Province and 1 research assistant from the Socio-Economic Division of the Research Institute for Estate Crops, Bogor. All were briefed on the survey techniques as well as the actual meaning of each question before the survey was begun. An extensive period of pre-testing and practice took place. Prior to the visits, information was sent to the smallholders selected. The information advised them of the dates of the visit and also sought their co-operation.

1.3.3 Field Work and Data Collection

The survey of the five kabupatens was done during the 24 months of 1977 and 1978. The survey of the two kabupatens selected for this thesis was done during August to December, 1977.

The main difficulty encountered collecting data from the smallholders was their lack of input and output records. Thus, most of the time smallholders had to estimate all the required information, such as their monthly rubber production and incomes. Annual production was estimated based on their average daily production and their average number of tapping days in a week and average number of tapping months in a year. Another difficulty encountered was the lack of understanding and misinterpretation of certain questions asked. Although this may have been reduced as the enumerators were given proper training, some deficiencies in the data collected might still be expected to remain. It was not possible for the smallholders to estimate their average monthly production and average monthly number of tapping days with great accuracy as rubber yield varies with days and seasons of the year. Annual production estimates based on the data can only be very approximate.

CHAPTER 2

DESCRIPTION OF THE PROVINCE OF SOUTH SUMATRA

2.1 Location and Administration

The Province of South Sumatra (Figures 2.1 and 2.2) is divided into eight kabupatens and two kotamadyas, and comprises the south-eastern part of South Sumatra island, together with Bangka and Belitung island off the east coast in the South Chinese Ocean. It lies 1^{o} to 4^{o} latitude south and longtitude 102^{o} to 108^{o} east. Its boundaries are as follows: to the North is Jambi Province, to the South is Lampung Province, to the East is the Selat Karimata and to the West is Bengkulu Province.

The total area of the South Sumatra province is about 109,254 square kilometres (Table 2.2). There are 85 Kecamatans, 263 Margas, and 1,936 dusuns or villages. A marga is not yet included as an official administrative unit, but this adat institution is becoming increasingly important in practical administration and development.

The greater part of the province is composed of a very large plain which is often swampy. This swampy area is largely that marked as 'timber' in Figure 2.4. The swampy area runs from the north-eastern coast to the south, reaching a width of about 100 kilometres from the coast. The rest is composed of undulating dry land area, most of it under cover of alang-alang grass (Imperata cylindrica),and secondary forest. In the western region, there is a mountain range that runs straight from north to south called Bukit Barisan.

2.2 Climate

The Province of South Sumatra corresponds to the Schmidt-Ferguson type A climate : Tropical Rainforest. Table 2.1 and Figure 2.3 show the rainfall figures and monthly maps of this province. The data show that the average rainfall is 2522 mm per year, with relatively high rainfall throughout the year, and no pronounced dry season. The highest rainfall

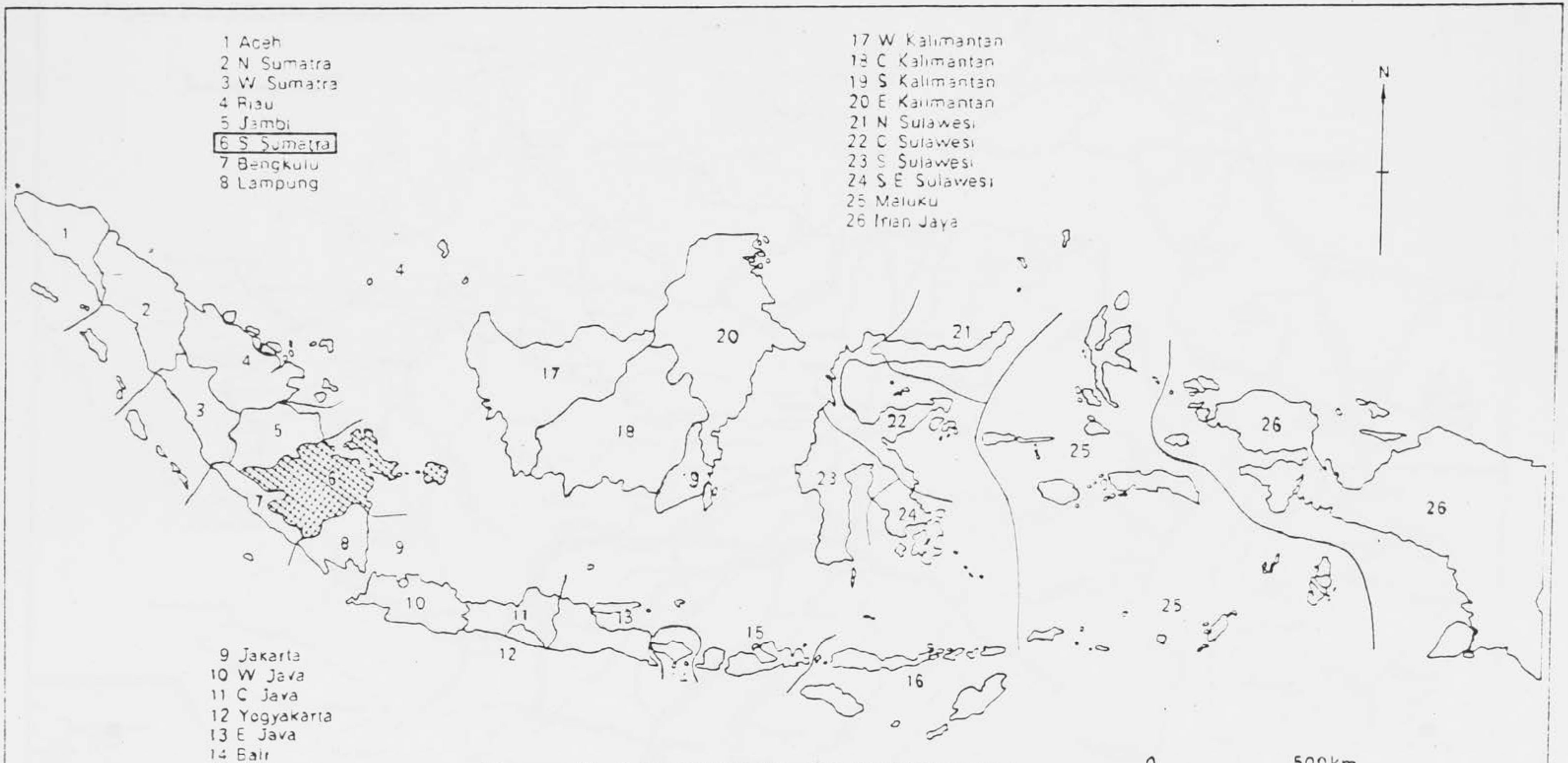


Figure 2.1 REPUBLIC OF INDONESIA

(Indicating the Location of the Province of South Sumatra)

Department of Human Geography, The Australian National University.

Source: Rachman 1978.

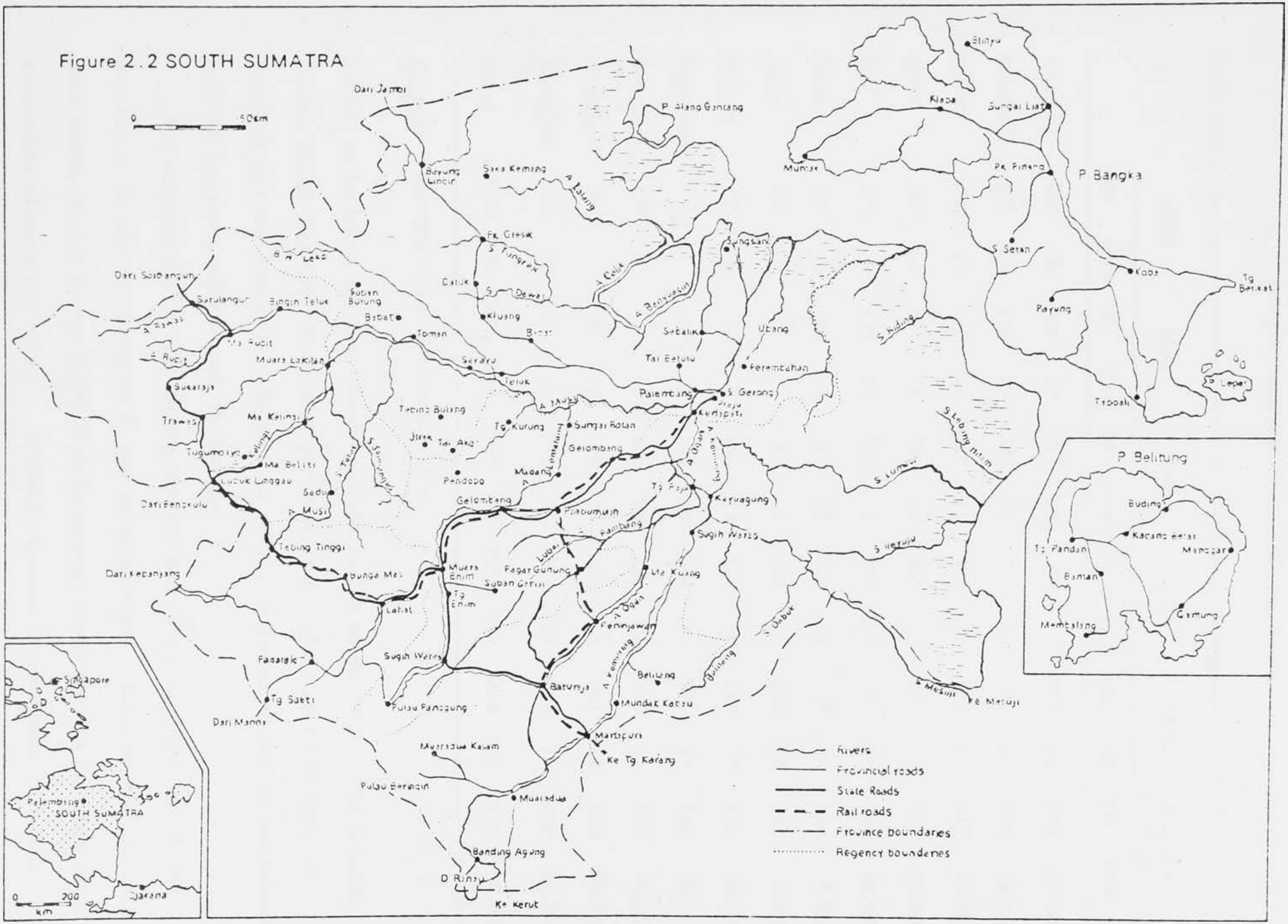


Figure 2.2 SOUTH SUMATRA

Source: Based on Panitia Penyusunan Repelita II Propinsi Sumatra Selatan 1973. From Rachman 1978.

TABLE 2.1

RAINFALL AND RAINY DAYS BY MONTH IN THE PROVINCE

OF SOUTH SUMATRA 1971-1975 (mm/days)

	1971		1972		1973		1974		1975		Average 1971-1975	
	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
January	326	16	348	17	221	13	94	8	270	14	252	13.60
February	187	11	229	13	291	13	258	13	187	10	230	12.00
March	266	13	312	15	267	14	170	12	218	11	245	13.00
April	367	12	275	14	292	18	260	12	267	13	292	13.80
May	175	9	234	11	304	14	269	13	160	10	228	11.40
June	138	8	68	5	237	13	230	8	97	6	154	8.00
July	111	7	22	1	61	5	188	11	158	10	108	6.80
August	97	8	31	3	266	14	122	6	140	9	131	8.00
September	116	7	29	2	297	18	184	11	181	11	161	9.80
October	229	12	70	5	280	15	214	12	194	11	197	11.00
November	286	15	155	10	199	14	248	14	264	15	230	13.60
December	336	17	307	14	272	16	264	17	274	15	290	15.80
Total	2634	135	2080	110	2987	167	2501	137	2410	135	2522	136.80

Source: BAPPEDA Sumatra Selatan, 1976.

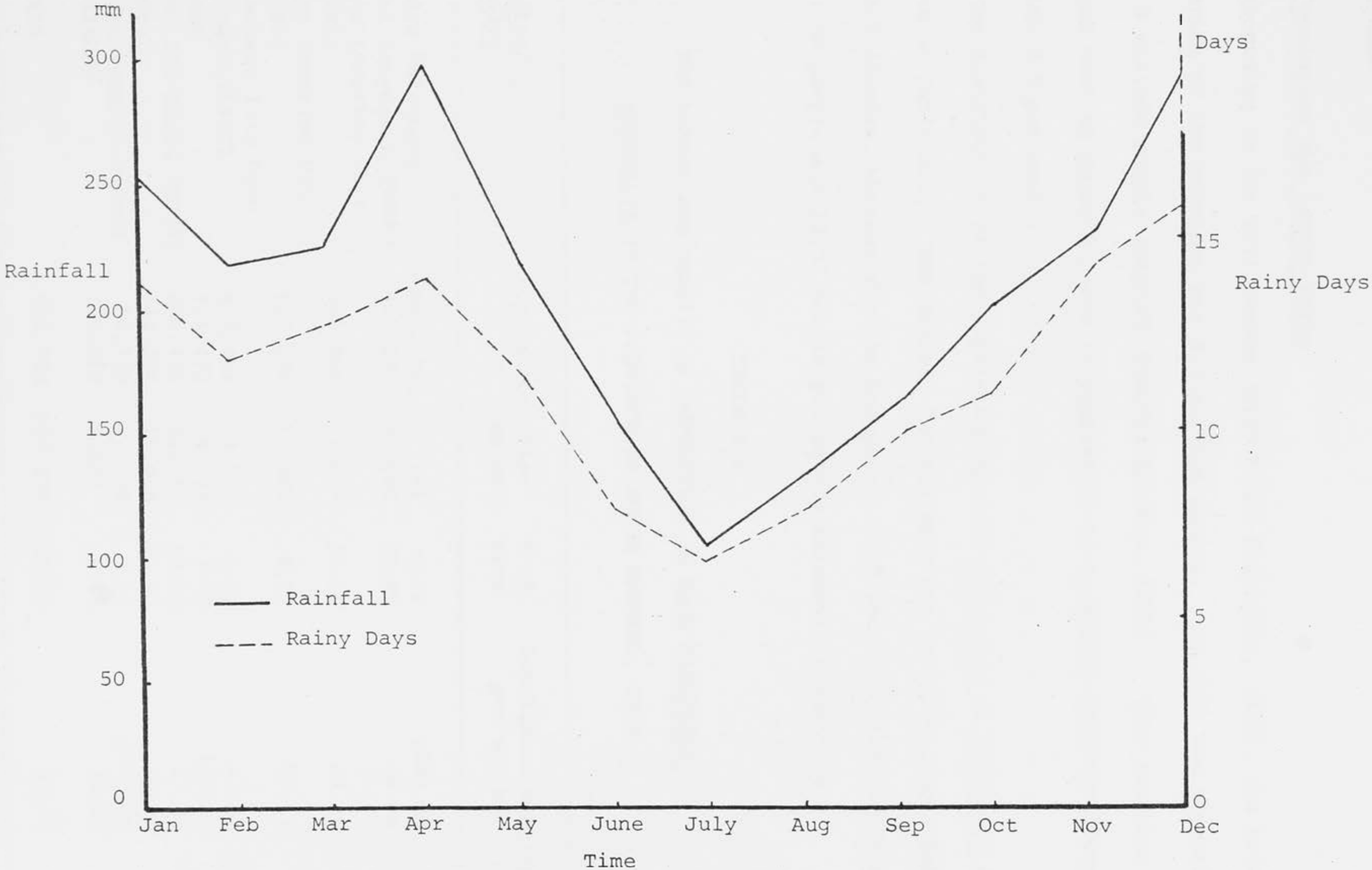
is 292 mm in April and the lowest rainfall is 108 mm in July. The average actual rainy days are 136.80 days per year, the highest is 15.80 days in December and the lowest is 6.80 days in July. November to May is the wetter half of the year, with a peak in January.

The temperature is warm during the day but chilly at night and in the morning. In the rainy season it can be quite high. Based on the climatic data above, it can be concluded that in general South Sumatra Province has a favourable climate for rubber. Climatic factors unfavourable to rubber

FIGURE 2.3

THE AVERAGE ACTUAL RAINFALL AND RAINY DAYS BY MONTH IN

THE PROVINCE OF SOUTH SUMATRA 1971-1975



production are few, namely the occasional restriction of tapping in very wet periods.

2.3 Population and Labour Force

According to the 1971 census (Biro Pusat Statistik, 1974), the total population of the province was 3.4 million people. In 1975 the population was 3.9 million people (Bappeda Sumatra Selatan, 1976). This increase of 12.8 per cent in about 4 years is equivalent to an annual increase (compounded) of about 3.5 per cent.

The distribution of the population in each kabupaten or kotamadya can be seen in Table 2.2. The density for the province is 35.74 people per square kilometre, whereas for the kabupatens LIOT and MURA, the densities are 43.08 people and 13.32 people per square kilometre respectively.

TABLE 2.2

THE NUMBER AND DENSITY OF POPULATION IN EACH KABUPATEN/ KOTAMADYA IN THE PROVINCE OF SOUTH SUMATRA, 1975

Kabupaten/ Kotamadya	Population	Size (sq.km.)	% of size	Population Density per sq. km.
1. Kodya Palembang	661,006	244	0.22	2709.04
2. Musi Banyuasin (MUBA)	427,191	25,664	23.46	16.64
3. Ogan Komering Ilir (OKI)	505,468	21,658	19.81	23.34
4. Ogan Komering Ulu (OKU)	615,276	10,408	9.52	59.11
5. Lematang Ilir Ogan Tengah (LIOT)	412,469	9,575	8.83	43.08
6. Lahat	421,472	4,034	3.69	104.48
7. Musi Ulu Rawas (MURA)	286,476	21,513	19.68	13.32
8. Bangka	344,476	11,614	10.62	29.66
9. Kodya Pangkal Pinang	84,738	32	0.03	2648.06
10. Belitung	146,212	4,532	4.14	32.26
Total	3,904,784	109.254	100.00	35.74

Source: BAPPEDA Sumatra Selatan, 1976.

The composition of the labour force in each economic sector by kabupaten/kotamadya can be seen in Table 2.3. The data show that the total labour force in 1971 was 1,226,000 people or about 30.6 per cent of the total population. The greater part of the labour force (69.30 per cent) is engaged in the agricultural sector.

TABLE 2.3

THE COMPOSITION OF LABOUR FORCE IN EACH ECONOMIC SECTOR BY KABUPATEN IN THE PROVINCE OF SOUTH SUMATRA, 1971

('00 persons)

Kabupaten/ Kotamadya	Agriculture Hunting etc.	Mining & Quarrying	Manufacturing	Services	Activities not Adequately Defined	Total
1. Kodya Palembang	195	62	202	1,079	140	1,678
2. Musi Banyuasin (MUBA)	331	5	13	110	58	1,517
3. Ogan Komering Ilir (OKI)	1,555	0	70	231	41	1,897
4. Ogan Komering Ulu (OKU)	1,579	0	18	208	39	1,843
5. Liot Muara Enim	1,220	40	14	185	70	1,529
6. Lahat	1,180	1	6	142	73	1,402
7. Musi Ulu Rawas (MURA)	569	1	15	125	133	843
8. Bangka	733	40	42	164	37	1,016
9. Kodya Pangkal Pinang	19	22	12	110	24	187
10. Belitung	115	90	34	86	22	347
Total	8,496	261	426	2,440	637	12,260
Per Cent	69.30	2.13	3.47	19.90	5.60	100.00

Source: Biro Pusat Statistik, 1974.

2.4 Major Towns

The capital city of the kabupatens and kotamadyas are the major towns of the province. There are also a number of kecamatan towns which could be considered to be major towns.[1] (Table 2.4).

TABLE 2.4

MAJOR TOWNS WITH DISTANCES FROM PALEMBANG

Major Towns	Distance from Palembang (km)		
	Road	Rail	River
Palembang, South Sumatra Province Capital	-	-	-
Sekayu, MUBA Kabupaten Capital	126	178	-
Kayuagung, OKI Kabupaten Capital	76	65	-
Baturaja, OKU Kabupaten Capital	200	173	-
Muara Erim, LIOT Kabupaten Capital	185	151	273
Prabumulih, Prabumulih Kecamatan Capital	90	90	-
Lahat, Lahat Kabupaten Capital	225	190	-
Pagaralam, Pagaralam Kecamatan Capital	295	-	-
Lubuk Linggan, MURA Kabupaten Capital	330	305	-
Pangkal Pining, Bangka Kabupaten Capital	-	-	-
Tanjung Pandan, Belitung Kabupaten Capital	-	-	-

Source: Rachman, 1978

Palembang city is the centre of almost all the activities in the province. It is the capital city of the province, the centre of trade and industrial activities and transportation. In Palembang large scale manufacturing has been established such as the crumb rubber plants, the tyre plant and oil refinery, a spinning plant, a fertilizer and a propylene manufacturing plant.

1 All discussions on the general descriptions of the major towns are based mainly on Rachman (1978).

The capital city of the Kabupaten Musi Bannyuasin is Sekayu. It can be reached from Palembang by river and road. This town is surrounded by a large number of rubber producing areas such as the kecamatans of Pangkalan Balai, Babat Toman, Sungai Lilin and Talang Kelapa. Even the rubber from some kecamatans in the kabupaten of MURA passes through Sekayu on its way to Palembang by river.

Kayuagung is the capital city of Kabupaten OKI. The surrounding areas produce rice, rubber and handicrafts. However, since the areas are close to Palembang, most of the products flow directly to Palembang rather than to Kayuagung.

Baturaja is the capital of Kabupaten OKU. It has a crumb rubber plant. The hinterland produces rice, coffee and rubber (Martapura, Pengangdonan).

Muara Enim is the capital of Kabupaten LIOT; however, this town essentially serves as a transit town for transportation of agricultural products from the interior. The surrounding areas of Muara Enim town also produce rubber.

Tanjung Enim is the capital of a kecamatan. It is a coal mining town and is expected to utilise the coal as a raw material in establishing an electric power station.

Prabumulih is also the capital of a kecamatan; however, it has a strategic location, at the junction of land transportation from Palembang to Lampung in the south and to Lubuk Linggau in the west. The state oil company (P.N. Pertamina) established one of its processing units there, and the surrounding area also produces rubber.

Lahat is the capital of Kabupaten Lahat. This city essentially serves as a transit town for the transportation of agricultural products from the kecamatan of Pagaralam, the single most important coffee and vegetable producing area in the province. The areas surrounding Lahat produce rubber and fruits.

Lubuk Linggau is the capital of Kabupaten MURA. It is located at the junction of three routes: Bengkulu to the west, Jambi to the north and Palembang to the east. This town is the end of the rail from Palembang. The hinterland produces rubber such as Muara Rupit, Muara Kelingi, Muara Lakitan and Muara Beliti.

Pangkal Pinang is the capital city of Kabupaten Bangka (Island). Bangha Island is a well known tin ore and white pepper producer. Tanjung Pandan is the capital of Kabupaten Belitung (Island). Belitung Island is also well known as a tin ore producer. These islands also produce rubber, particularly sheet rubber. Panghal Pinang and Tanjung Pandan are connected to Palembang by air and sea.

2.5 Transportation

The Province of South Sumatra has three modes of transportation, road, river and rail.[2]

Rivers have an important role in transportation for the South Sumatra province. There are many rivers, the best known of them being the Musi River. The capital of the province, Palembang, is located beside the Musi River about 80 kilomentres from the eastern coast. River transportation is influenced by the occurrence of the dry and wet seasons. In the dry season only about 305 kilometres of the Musi River can be used for transportation by barge, while in the wet season it rises to 450 kilometres. River transportation is usually used to carry the raw rubber and timber from the interior to the Kabupaten cities or to Palembang. On the other hand, it is also usually used to ship essential supplies and manufactured goods from Palembang to the interior. River transport is preferable since it is generally less expensive than road or rail transport. There are numbers of areas producing rubber and timber connected with Palembang by river only,

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2 All discussions on the general descriptions of the transportation are based mainly on Rachman (1978).

particularly in the swampy areas, where the establishment of roads is very costly.

The road transportation system is very useful for moving people and carrying goods within the province, particularly where river and rail transport is not available. The state road connects Palembang with the province of Lampung, passing through Prabumulih, Muara Enim, Baturaja and Martapura. It also connects Palembang with the province of Jambi, passing through Prabumulih and Muara Enim.

Rail transport still plays an important role in the economy of South Sumatra. Rail connects Palembang with the province of Lampung in the south, passing through Prabumulih, Baturaja and Martapura. To the west, the railway connects Palembang with Lubuk Linggau, passing through Prabumulih, Muara Enim, Lahat and Tebing Tinggi. The main use of train transport is, in particular, to haul large tonnages of goods, either manufactured goods from Palembang to the interior, or agricultural commodities from the interior to Palembang. This is particularly true for Baturaja, where rubber produced by the crumb rubber factory is conveyed by train from there to Palembang.

Each kabupaten capital can be reached by bus, or by boat. Pangkal Pinang and Tanjung Pandan (in Belitung island) can be reached by plane. Some of the kabupaten and kecamatan capitals are also linked by train, e.g., Muara Enim, Lahat, Lubuk Linggau and Baturaja.

The main export gate is the port of Boom Baru, Palembang. The exporters of agricultural commodities such as rubber, pepper and coffee, however, seem to have difficulty in shipping arrangements facing the uncertainties of the shipping schedules. In particular the shipping frequency to the United States and Europe is limited. This is understandable, as the large ships are worried about the risk of getting stranded owing to the shallowness of the river, and it takes about 6 hours to reach the port from the mouth of the river, which is only 80 kilometres away.

2.6 General Features of Rubber Production

Table 2.5 shows the 1973 data on the smallholder rubber area and production in each kabupaten of this province. It shows that the kabupaten of Musi Banyuasin (MUBA), Musi Ulu Rawas (MURA) and Lematang Ilir Ogan Tengah (LIOT) are the most important rubber producing areas of the province. About 331,000 hectares (70 per cent) are planted in these three kabupatens. The locations of the main rubber smallholder areas are indicated in Figure 2.4.

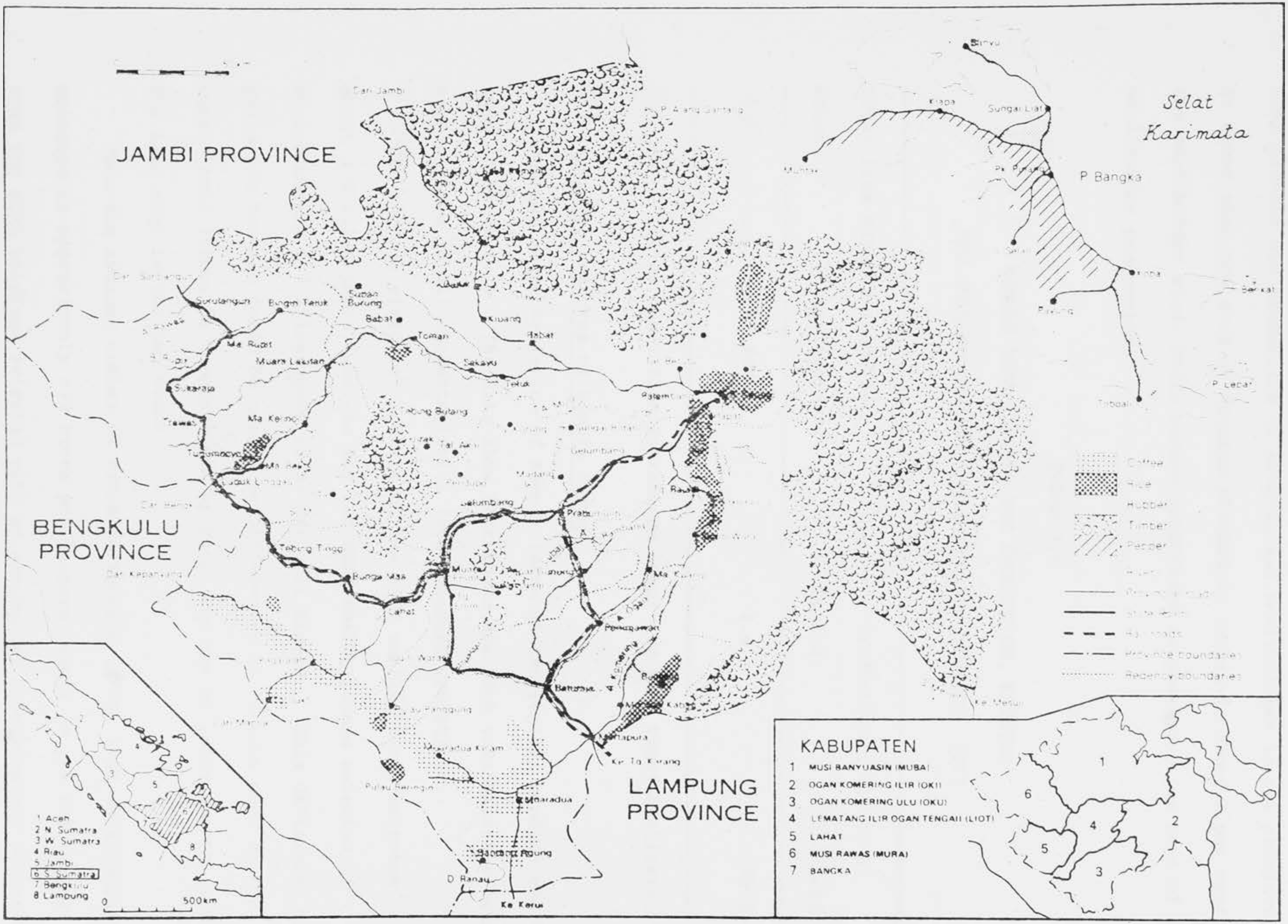
TABLE 2.5

AREA PLANTED AND PRODUCTION OF SMALLHOLDER RUBBER IN SOUTH SUMATRA BY KABUPATEN, 1973

Kabupaten	Area Planted ('000 ha)	Production ('000 tons)
Musi Banyuasin (MUBA)	115.4	35.4
Musi Ulu Rawas (MURA)	107.1	40.6
Lahat	21.2	8.5
Lematang Ilir Ogan Tengah (LIOT)	108.9	20.9
Ogan Komering Ilir (OKI)	49.3	18.9
Ogan Komering Ulu (OKU)	42.9	20.5
Bangka	45.0	14.2
Belitung	1.9	0.5
Total	491.7	159.5

Source: Dinas Perkebunan Rakyat Dati I Sumatra Selatan, 1974 p.39.

The area and production of estate rubber amounts to only a small fraction of the smallholder area and production Table 2.6 compares the total



<u>Source:</u> Rachman 1978

area planted and production of estates and smallholders in the province. It shows that the area of estates planted to rubber is about 1 per cent of the smallholder area, while estate production is about 1.6 per cent of smallholder production.

TABLE 2.6

RUBBER AREA PLANTED AND PRODUCTION, ESTATES AND SMALLHOLDERS IN SOUTH SUMATRA PROVINCE, 1973

Total Area Planted ('000 ha)		Production ('000 tons)	
Estate	Smallholder	Estate	Smallholder
4.8	484.5	2.4	149.2

Source: Balai Penelitian Perkebunan Bogor dan Biro Pusat Statistik,1977.

2.7 Specific Features of Sample Farms

Average characteristics of sample farms of two regions studied can be seen in Table 1.2. The data show that there are high variabilities between sample farms in all characteristics (see standard deviations).

The average yield per hectare of the LIOT smallholdings selected is about 3.7 kilogrammes, whereas for the MURA smallholdings selected of approximately 5.7 kilogrammes or 54 per cent higher. This difference of yield per hectare could be caused by differences in factors such as the total trees (trees in tapping) per hectare, the age of trees (girth) and the farm size in the two areas.

Thus the average number of trees in tapping of the LIOT smallholdings selected is approximtely 479 trees per hectare, about 58 per cent higher than the MURA holdings selected with an average of approximately 303 trees. The average number of total trees of the LIOT holdings selected is approx- imately 648 trees, about 59 per cent higher than the MURA holdings selected with an average of only 408 trees per hectare.

Those data show that the average number total trees per hectare of the LIOT holdings selected is much higher than the optimum number of total trees per hectare (about 370-435 trees) suggested by Barlow and Lim (1967) (See page 35). The LIOT farmers selected are constrained by their smaller farm size and thus tend to maximise output per hectare by planting more rubber trees per hectare. They will tap more rubber trees per hectare when the opportunity cost is lower or when the price of rubber increases.

The lower average yield per hectare of the LIOT holdings might be caused by the high density of rubber trees per hectare. Experiments in Malaysia have established that planting density is negatively related to yield per tree and positively to yield per hectare. This is because the decrease in yield per tree is more than offset by the overall increase in yield because of an increase in the number of trees per hectare (Sepien, 1978). Decrease in yield per tree associated with high density is due to greater competition for plant nutrients, poor girthing, over shading, high incidence pests and diseases, and also a higher proportion of immature trees. From Table 1.2 can be seen that the average number of immature trees of the LIOT holdings is approximately 108 trees, about 120 per cent higher than the MURA holdings, which have an average of only 49 trees per hectare.

All the 50 LIOT holdings selected have been between 1 to 8 years in tapping, with an average of approximately 4 years. Rubber yield per hectare of this region could be expected to be lower than the average yield of the MURA holdings, with an average number of years since tapping is about 13 years, as yield increases with age initially.

The average girth of trees of the MURA holdings is about 68 centimetres, with an average age of approximately 23 years. The average age of trees in the LIOT holdings is about 13 years with an average girth of approx-imately 48 centimetres, which is smaller than the average girth of Kabupaten

MURA. In general, the bigger girth of the tree will produce more latex per tree than the smaller one. So, the lower yield per tree of the LIOT holdings is also caused by the smaller average girth of the trees, consequently reduced rubber yields per hectare.

Usually it can be expected that small farmers will produce more rubber per hectare than farmers with bigger areas. But from Table 1.2 can be seen that the bigger farmers of Kabupaten MURA with an average farm size of about 2.6 hectares, produce more rubber per hectare than farmers with an average farm size of only 2.0 hectares from Kabupaten LIOT. The months of record may also affect the difference of yield per hectare between two regions studied. The LIOT holdings selected were recorded during the period of August-October, 1977, and for the MURA holdings during the period of November-December, 1977. To know this seasonality effect on rubber yields, a further detailed study should be undertaken.

From the data we discussed above, it can be concluded that the number of trees in tapping per hectare is one of the most dominant factors which caused the difference of yield per hectare between these two regions studied.

The number of cuts of both regions studied varies from 1 to 2, with an average of 1.3 and 1.4 cuts for LIOT and MURA respectively. The average depth of cut of the LIOT holdings selected is about 5.8 millimetres and for the MURA approximately 6.3 millimetres. Both the number of cuts and the depth of cut will increase as rubber trees become older.

The LIOT smallholders used an average of approximately 6 hours of harvesting labour daily. This is about 50 per cent more than the average of approximately 4 hours on the MURA smallholdings selected. This is due to a higher number of trees in tapping on the LIOT smallholdings than MURA.

The average age of the LIOT farmers is about 43.4 years, who on average spent about 4.5 years in school, whereas the MURA farmers are approximately 40 years, and spent approximately 4 years in school. They differ slightly between the LIOT and the MURA smallholders selected.

On average, it was found that all the LIOT farmers selected had approximately 21 years of experience in rubber farming and provided maintenance labour about 16.2 man days per year. The average experience of the MURA farmers selected was approximately 18.8 years and provided maintenance labour of about 5.7 man days per year. The LIOT farmers selected provided longer time for maintenance labour because of their younger trees.

CHAPTER 3

RUBBER PRODUCTION VARIABLES AND THEIR SPECIFICATION

3.1 The Process of Rubber Production in South Sumatra

For the purpose of this study it is necessary first to know in detail the fundamental logic of the rubber production process, and only then is it possible to select an appropriate function to fit the data collected during the field survey.

In the establishment of a rubber holding, the first stage is the tedious and expensive process of clearing the jungle in the case of new planting or clearing the old rubber trees in the case of replanting. After clearing the ground, the young plants can be planted out. The planting material used by smallholders usually consists of unimproved low yielding varieties grown from unselected seeds collected in adjoining areas. The land will often have been opened for dry land, rice, cassava, maize or pineapple. Rubber, therefore, is not always the main reason for opening up the land. The rubber is usually planted in the first or second year and it is kept free of weeds during succeeding food crops. There are rarely grown for more than three successive years. The smallholders then move on to clear another plot and simply forget the trees until they are mature enough to be tapped (about 9-12 years old). Further weeding of the rubber is minimal. The use of fertilizer and insecticides is negligible, because the smallholder cannot afford to buy them. Under the traditional shifting cultivation system, the land around the villages was used first, and then abandoned in the cultivation cycle; this land is now covered by *alang-alang* grass (*Imperata cylindrica*). The farmers tended to move further and further away from the village in search of new land, so that today the rubber trees may be located up to 15 km from the village.

The number of trees in tapping is about 450 trees per hectare. Sometimes rubber trees of varying ages can be found on a single holding.

Some trees may have grown by themselves and may never have been thinned out. This type of cultivation is commonly known as 'jungle rubber' and the number of rubber trees can at extremes reach up to 1500 trees per hectare. In such cases, well over half the trees would be small and untapped.

The tapping systems do not follow recommended scientific methods. On average the smallholders tap their rubber trees 4 days per week. Bark consumption is usually great, and bark is also damaged due to multiple cuts. As a result, bark damage is common and bark renewal is generally poor. Tapping is done usually from six to ten o'clock in the morning in order to take advantage of the high turgor pressure within the trees which enhances latex flow. The latex is collected after the smallholders have rested for about half an hour. On average, a smallholder works a total of approximately five hours daily on rubber production and processing.

The physical output produced by tapping rubber trees are latex and scrap. The sum of latex and scrap homogenised into a dry latex equivalent will be called output. Most of smallholders in this province processed their latex and scrap into slab rubber before selling it to the rubber dealers. The process of producing slabs is very simple. The mixture of latex, scrap, bark, field lump, and earth rubber is poured into a hole dug in the ground. If a box is used, it is always made watertight and lubricated with clay. The coagulation is then performed with formic acid, most often with alum or gadung (a root preparation). The next day, the coagulated slabs are removed from the box (or the hole) and almost always stocked in a water pool near the house. This soaking keeps slabs very wet and maintains a high weight.

The rubber output as considered here does not only depend on harvesting activities but also on other factors. These include planting materials, types of soil, planting distances (trees tapped), tapping systems, age of the trees, environmental conditions and the interaction of these factors.

These are listed in detail below.

This description shows the complex nature of the production process and demonstrates the difficulty of capturing this process within some mathematical expression. Some inputs are in the nature of investments which grow over time e.g. the trees; others may be continuous inputs e.g. labour. Some inputs are amenable to decisions, but others are environmental; some are quantitative and others qualitative.

3.2 Input Factors in Rubber Production

The physical annual output from smallholder rubber production is believed to be basically influenced by the following factors (Table 3.1).

(1) Controllable (decision) Variables. These are endogenous variables under the control of the farmer.

(a) Point - Input Factors: lagged values of the annual inputs applied in the previous years. These are the inputs whose effect is felt during the whole life of the trees. They are not under the immediate control of the farmer, but were originally controllable in the sense that they were applied as part of a long term decision-making process.

X Rubber trees

Z Farm size

V Planting materials.

These variables are also 'essential' in the sense that in their absence rubber production could not take place.

(b) Multi-Point Input Factors: These are annual inputs under the immediate control of the farmer and changeable at any time. There are essential and 'supplementary' inputs, the latter being inputs that assist but are not essential to production.

Essential inputs:

P Harvesting labour

H Tapping system.

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*		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	

<u>Notes</u>: * Binary variable. <u>Source</u>: Sepien, 1978

Supplementary inputs:

F Maintenance labour, including weeding by hand, fertilizer, yield stimulant, pesticides and weedicides, other chemicals.

M Management factors, including technical knowledge, organisation, entrepreneurship, etc.

(2) Uncontrollable (state) Variables: These are completely exogenous variables, both current and lagged, which cannot be controlled by the farmer.

A Age of trees

S Soil types

T Topography

C Climatic factors.

Mathematically, and the relationship between rubber output and the abovementioned inputs might be expressed as:

$$Y = f\ (X,Z,V,P,H,F,M,A,S,T,C). \tag{3.1}$$

where Y is the output of rubber from the farm. The output of rubber is made up of slab rubber. All of these variables will be discussed in more detail in the next section. Equation (3.1) is a production function which may be estimated in several alternative functional forms.

The analysis in this thesis is carried out under the assumption that the same functional relation applies to all farms investigated. A complete specification of variables is impossible because of specification error. Consequently the 'true' production function is not known. Perhaps, a close substitute could be estimated, and 2 functional forms which seem to fit the data quite well are used in this study.

The most common specification error is the omission of the relevant variables. If the omitted input variables are positively correlated with the included ones, then there will be a tendency for one or more of the coefficients of the included variables to be biased upwards. The converse is true in the case of a negative correlation between included and omitted variables (Griliches, 1957).

In rubber production, it is important to distinguish between essential inputs and supplementary inputs. The inclusion of supplementary inputs in the process of production may increase rubber output significantly. These inputs are classified in Table 3.1.

In this study all those controllable variables and some of uncontrollable variables, including age of trees and topography are quantified.

3.3 Output

In this study, we consider only one product from the farms, the output of rubber from a productive parcel of land on which our survey was focussed. The output of other crops is not included in the production function. Output is in the form of slab rubber produced by the farmer from this parcel. In this study it is measured in terms of the total weight of dry rubber produced in kilogrammes per hectare on the day of the survey (Y). The dry rubber content analysis of slab rubber samples had been done by Bakrie & Brothers Laboratory in Palembang. Annual productions were estimated based on the average number of tapping days in a week and average number of tapping months in a year of each region.

With regard to the homogeneity of the output, there could be different grades of slab rubber produced. Only limited information was available on this, and it could not be incorporated in this measure of yield. In the smallholder situation in South Sumatra, poor processing methods were employed and only the lower grades of slab rubber were normally produced. It was assumed that there was very little difference in the quality of output from different farms in the area studied.

There is no difference between the gross and net output of slab rubber, because everything produced is marketed.

The average daily outputs of holdings in the two study areas are shown in Table 1.2.

3.4 Controllable Variables

3.4.1 Point Input Factors

3.4.1.1 Rubber Trees

Rubber trees, one of the essential variables, are defined here in terms of density (number of trees) per hectare which varies with planting distance.

Planting density experiments in Malaysia have shown that low densities result in a higher yield per tree but a relatively lower yield per acre, and vice versa (Westgarth and Buttery, 1965). The decrease in yield per tree which is associated with high density is due to the greater competition for plant nutrients, poor girthing, high incidence of pest and diseases, over shading and also a higher proportion of immature trees. Under estate conditions, about 310 trees per hectare are a fair optimum, while a density of 370 to 435 trees was considered appropriate for smallholdings (Barlow and Lim, 1967).

The number of trees in tapping varies among holdings due mainly to differences in the initial number of trees planted per hectare and to the age of the stand. During the early stages of tapping, the number of trees tapped per hectare is usually less than the number of trees in that hectare. Those trees which are not yet mature do not contribute anything to the output of rubber, and may in fact depress the yield of trees already in tapping. It is the actual number of trees in tapping or in production that most affects the output.

The number of trees in tapping, the number of immature trees, and the number of dry trees (dryness of the tapping panels) planted per hectare were recorded in the study. Not all the trees will come into maturity and be ready for tapping at the same time during the first few years of tapping.

Even in old stands there still exists a small proportion of trees not in tapping, due mainly to physiological disturbance causing dryness of the tapping panels, either temporarily or permanently.

In this study we consider the number of trees in tapping per hectare (X_1), the number of immature trees per hectare (X_{20}), and the total number of trees planted per hectare (X_{14}) as the independent variables which may affect output. The values of these inputs are given in Table 1.2.

3.4.1.2 Farm Size

This is defined here as the total area of land under productive rubber on a given farm, including both the parcel surveyed and other numbered parcels (X_{11}) (Table 1.2).

Both the size and quality of land should be considered. The latter will be discussed in a separate section.

As far as size is concerned, a farmer with a smaller farm might be encouraged to be technically less efficient than one with a bigger holding, because he might use more input factors to produce the same quantity of output. Rubber smallholders who operate smaller holdings may tend to use more of almost all inputs, especially labour, to produce a kilogramme of rubber, than those operating bigger holdings. Owing to the greater labour use per unit area on smaller holdings, it can be expected that small farmers will produce more rubber per hectare than farmers with bigger areas. Accordingly farmers with smaller areas can be expected to plant relatively more trees per hectare.

3.4.1.3 Planting Materials

Rubber trees are broadly categorised into clones (budgrafted or budded trees), clonal seedling and unselected or ordinary seedlings. Clones are rubber varieties selected through breeding and vegetative propagation. Clonal seedlings are rubber trees grown from seeds selected from clones. Ordinary seedlings are unselected rubber trees, grown from seeds or seedlings found anywhere at all. Thus they produce the lowest yield, about 400 to 500 kilogrammes per hectare per year, compared to the clones and clonal seedlings which have a considerably higher yield potential. A planting material is a variable for which technical progress is embodied in the relevant vintage. Hence different types of planting material of a given clone or clonal seedling can be very different in yielding capacity. In this study we use a dummy variable to assess the effect of planting materials in the production function. The dummy variable is given a value of one corresponding to all farmers who planted clonal seedlings, and zero otherwise. Almost all farmers selected in our two study areas planted unselected seedlings (Table 3.2).

TABLE 3.2

SOME IMPORTANT CHARACTERISTICS OF SURVEY FARMS OF KABUPATEN LIOT AND KABUPATEN MURA

Variable	Percentage of All Farms	
	LIOT	MURA
Planting Materials		
Unselected seeds	94	90
Selected seeds	6	10
Topography[a)]		
Flat	66	50
Undulating	34	48
Hilly	-	2
Level of Farmer's Skills and Ability[b)]		
Excellent	-	-
Good	48	54
Average	44	42
Poor	8	4

Notes: a) The grouping is simply based on a visual inspection of the holdings by interviewer.

b) The grouping is based on general estimate of his skills and ability of the farmer by interviewer.

3.4.2 Multi Point Input Factors

3.4.2.1 Harvesting Labour

The most important labour input on mature rubber is in tapping the trees, collecting the latex, processing the latex, and transporting the output to the buyer. Depending on holding siz:, overall, a smallholder works a total of approximately five and a half ours daily on rubber production.

Rubber is a labour intensive crop. Currently there seems to be no effective practical way in which tapping rubber trees could be conveniently mechanized although new tapping instruments which somewhat reduce the labour input are being developed.

Some of the harvesting activities, particularly tapping, require considerable skill. To obtain a high yield, a tapper should cut as close as he can without wounding the cambium. At the same time, he should maintain the correct slope of cut so as to bleed as many latex vessels as possible and shave the right thickness of bark.

A rubber tree is never tapped more than once a day. Within limits, the more days the tree is tapped, the greater is the output, but beyond about 15 days of tapping per month rapidly diminishing output responses to further tapping inputs may be expected. A particular tapper may tap a given area every alternate day. However, this is not strictly adhered to because tapping cannot be satisfactorily carried out during rainy days. The number of days the trees are tapped depends both on the tapping system adopted, and on the interference of rainy days.

In this study the quantity of labour supplied in tapping was recorded as the number of working hours per tapping day, the average number of tapping days per week, either in the wet season or in the dry season and also the number of tapping months per year. The number of tapping hours per day is limited mainly by the time during which 'turgor pressure' in the bark is sufficiently high.

This study uses harvesting labour (X_7) as the independent variable which may affect rubber yield. This activity includes tapping and collecting per tapping day in hours per hectare, but does not include processing and transportation labour, which does not affect yield directly. The average value of this input can be seen in Table 1.2

3.4.2.2 Tapping System

Tapping refers to the method of harvesting of rubber trees, being a function of the length of cut (tapping panel) and frequency of tapping A S/2,D/2 tapping system refers to a half spiral cut tapped once in two days, whilst S/1, D/4 is a full spiral cut tapped every four days. The S/2, D/2 tapping system is considered the norm under estate conditions and is arbitrarily assigned a 100 per cent tapping intensity.

There are several types of tapping systems. Ideally, the type adopted should take into account the long run yield without interfering with the growth of the tree; the rate of bark consumption should not be faster than the rate of normal bark renewal. The appropriate tapping system to use varies with the actual situation in each case, because rubber trees of different ages, planting materials, and life history, react differently to different tapping systems.

Most rubber smallholders in Indonesia use several half spiral cuts at each tapping. Usually there are about 4 tapping days per week.

In this study the average number of half spiral cut per tree (X_4) is examined as a variable which may affect rubber yield and reflects the degree of tapping intensity.

The most active latex vessels are concentrated close to the cambium in the soft bark. The outer bark with the characteristic 'stone cells' contain the less efficient, sparsely distributed, and discontinuous latex vessels. The best yields are obtained by tapping as deep as possible without injuring the cambium. Tapping to a depth of within 1 mm of the cambium should therefore be satisfactory. The best tappers do this without injuring the cambium. The absence of these injuries on tapping panels is not always a sign of good tapping, however, as this may be due to too shallow tapping which gives reduced yields.

The depth of cut (X_{17}) and tapping panel condition (X_{19} = dummy) are used as independent variables which can be expected to affect rubber yields. As a dummy variable X_{19} is given a value of one, corresponding to all farms which have tapping panels in good condition and zero otherwise.

Both budded and seedling trees can be regarded as tapable when they have attained a girth of 50 cm (20 inches) at a height of 90 cm (3 feet) measured from ground level in the case of seedling trees and from the highest point of the union in the case of budgrafts. An increase in the girth at which tapping commences will result in a loss of crop due to the postponement of tapping, but yield per tapping will be higher. In general, other factors being equal, a tree which has been tapped previously will give a higher yield than one which has not.

In this study we also use the girth (X_{13}) as an independent variable which may affect yields.

The average values of these inputs (X_{13} and X_{17}) are given in Table 1.2.

3.4.2.3 Maintenance Labour

Maintenance labour is one of the supplementary inputs which includes hand slashing and weeding. Other supplementary inputs are fertilizer, yield stimulant, pesticides and weedicides and other chemicals. Supplementary inputs are very important in estates, but in the case of smallholders, very few of them use any of these inputs, except weeding labour occasionally.

Maintenance labour has only a long term effect on output. If maintenance labour was in use at the time of the survey, it is assumed that it has been used continuously and would be expected to affect output.

There were no farmers investigated in our two study areas who used these inputs other than hand slashing weeding, probably because of their low incomes, smallholding size, lack of knowledge on the benefits of those inputs, and uneconomic returns obtained. Due to their low incomes, the farmers have no savings which could be used for productive investment. Therefore this study did not include those inputs.

Maintenance labour in this study comprises family or hired labour used for manual weeding or slashing. For the majority of the holdings studied, maintenance was confined to slashing the undergrowth between the rows. Hand slashing weeding is done at irregular intervals, whenever the smallholders are free. Usually, this is performed to enhance access to tapping rather than to improve the productivity of the trees.

No attempt is made to correct the maintenance labour for quality differences, e.g. by age or sex. It is also assumed that there are no quality differences between family and hired labour.

Maintenance labour ($P_m = X_{21}$) is measured in terms of 7 hour mandays. The seven hour manday was selected based on the average effective working hours per day in those areas surveyed. This was calculated by using the formula (3.2) below, which was based on the data collected in the survey:

$$P_m = \sum_{j=1}^{n} \sum_{i=1}^{4} W_{ij} \cdot \frac{1}{7} \qquad (3.2)$$

where, W_{ij} is the number of hours of family or hired labour j spent on maintenance activity i during the year.

$j = 1, 2, \ldots n$, is the number of family and hired members involved in maintenance operations.

$i = 1, 2, \ldots 4$, is the number of maintenance operations, manual weeding or slashing.

$\frac{1}{7}$ is a factor to convert hours in 7 hour mandays equivalent.

The average value of this input can be seen in Table 1.2.

3.4.2.4 Management Factors

Management may be defined as the force within the firm that directs resource use after interpreting the wants, needs and desires of those owning or controlling production resources (Shaudys and Nodland, 1968). Production resources, such as land, labour and capital will not yield output unless they are organised and co-ordinated by someone who makes the necessary decisions (Upton, 1976).

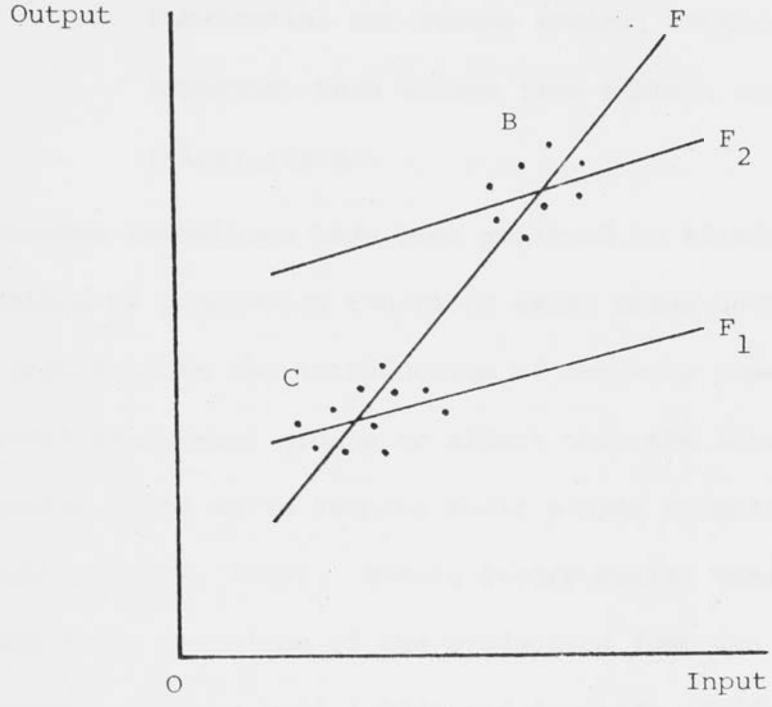
On a rubber smallholding as a small farm, these decisions are usually made and carried out by the individual smallholder himself. This is in contrast to the estate sector where an estate is controlled and run by various levels of decision-makers. A rubber smallholder, however, is an entrepreneur, a manager and a labourer. He generally performs all three functions himself, usually with the help of his family.

With respect to production function studies, where the effects of management are not explicitly included, the estimated function may suffer from what is referred to as management bias (Hoch, 1962; Mundlak, 1961; and Massell, 1967). The problem of management bias arises if both inputs and outputs are functionally related to a farmer's management ability (Etherington, 1973). Griliches (1957) has shown that, if a farmer's management ability is positively correlated to the input factors, its exclusion from the function can result in an upward bias of the estimated coefficients of the included variables, and a downward bias will exist for those variables with a negative relationship.

Figure 3.1 illustrates the effect of management bias. There are a series of observations B and C, on two types of managers, good and bad, who use production functions F_2 and F_1 respectively (F_2 and F_1 are linear in logs). Assume that the better farmers used more inputs, which is usually true (Timmer, 1970) and obtained more output. Then, in the absence of information about which observations pertain to good managers, and which to bad, the fitted function would be F rather than the two separate functions F_2 and F_1 which do discriminate between classes of management.

FIGURE 3.1

THE EFFECT OF MANAGEMENT BIAS



To illustrate with the case of rubber production:

Some of the factors believed to be associated with management in rubber production are:

(a) The farmer's educational level: formal education could be expected to influence a farmer's success as well as his method and ability in making decisions. In this study the smallholders' educational status is measured by the number of years of formal schooling he completed.

(b) His experience and technical knowledge on rubber cultivation: a smallholder who has more experience and better technical knowledge is expected to maintain a better standard of holding management and thus obtain higher yields.

(c) His age: it is believed that older farmers are more cautious of any changes from routine or taking risk. On the other hand, age will have a close relationship with experience.

(d) General condition of his holding: such features as presence or absence of weed (cleanliness), incidence of pests and diseases, conditions of tapping panels can be taken as an indication of management ability.

(e) Substantial non rubber income, especially where this is more important than income from rubber, may have a negative effect rubber yields.

Various techniques have been employed to eliminate management bias in the estimation of production functions using cross-section data. The most commonly used technique is the introduction of zero-one dummy variables to represent the different management groups to affect only the intercepts of the different regression lines while keeping their slopes constant, F_1 and F_2 (Figure 3.1; Mundlak and Hoch, 1965). Models incorporating management to affect both the intercept and the slope of the production function have been employed by various researchers such as Doll (1974) and Hopcraft (1974).

The management standard has always been difficult to define and to measure. Muller (1974) used factors such as education, age and experience, and production knowledge to measure the impact of management on production. Muggen (1969) points out that the human factor in farming is very important. He presents results of some previous studies which show the importance of the human factor. There appears to be a relationship between human factors such as ability, biography, motivations and management process on the one hand and farm management on the other. He concludes that farmers may have identical resources in all respects, but with differing levels of technological knowledge will have different levels of production.

There are many stages in the cultivation of rubber, during each of which it is possible for the farmer not to achieve technical efficiency. Any bad practice at any stage in the life of the plant could have a resultant adverse effect on yield. The importance of the management input during the establishment period of the tree is often not appreciated by smallholders.

Some of the factors believed to be associated with management in rubber production were recorded in the survey and are used as independent variables (proxies) which may affect rubber yields. They are:

Smallholder's age	(X_8)
Smallholder's years of schooling	(X_9)
Smallholder's experience on rubber cultivation	(X_{10})
Cleanliness of the farm (as assessed by the enumerator)	(X_{16} = dummy)
Other income	(D_2 = dummy)

The dummy variable X_{16} is given a value of one corresponding to all farms which are clean, and zero otherwise. D_2 is given a value of one corresponding to all farmers having other income greater than or equal RP 100,000 (US$ 165) per year.[1]

The management practices (farmer's skills and ability) of the farmers studied were grouped into: (1) excellent; (2) good; (3) average and (4) poor. The grouping was based on the quality of the smallholder's management and practices which were observed during the inspection of his holding (Table 3.2).

Management practices accounted for in the grading were the general cleanliness of the holding from weeds, alang-alang (imperata cylindrica) and brushwood, cleanliness of the tapping panels, cups, processing equipment (coagulating boxes or pans), depth of cut, wounding of the cambium, presence of pests and diseases and the quality of products.

Since some differences were still suspected, however, in this study management practices are used as a dummy variable. This variable is given a value one corresponding to all farmers who have good skills and ability and zero otherwise.

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1. The value of RP 100,000 was calculated based on the assumption that the average holding size of smallholders rubber in Indonesia is 2 hectares (Saad and Baharsjah, 1976), the average yield is about 500 kg/ha/year, and the average price of slab rubber is RP 100 - per kg dry rubber content.

3.5 Uncontrollable Variables

These are the variables, both current and lagged, which are beyond the control of the smallholder. Those of particular interest in the current study are age of trees, soil type, topography and climatic factors.

3.5.1 Age of Trees

Once the trees are planted, the age of the trees is beyond the control of the smallholder, except insofar as he may decide to replant or crown bud the particular block. This is unlikely to be an economic decision during the most productive phase of the trees (about years 2-12 of tapping), and is not a possibility considered here. Trees of different ages respond differently to various input factors and yield differently. Generally, rubber yield can be expected to rise during the early years of tapping, remain relatively stable for a short period, and then begin to decline rather sharply. Sometimes the age of rubber trees within a holding is different. This is the case where different portions of the holding have been planted in different years, which usually occurs when a holding is too big for the owner to complete establishment during a single year. But in parcels of about one to two hectares, the age of the trees usually does not differ significantly.

There was no information on the difference in the age of rubber trees within a holding in this survey. For further analysis, it is assumed that there was no difference in the age of mature trees within each individual parcel.

In this study, the number of years in tapping (X_2) and the number of years since planting (X_{12}) are used as independent variables which may affect rubber yields. The average values of these inputs can be seen in Table 1.2.

3.5.2 Soil Type

Different soil types will affect the level of nutrients available to the trees and also will affect the ability of the trees to absorb fertilizer. Soils with different chemical and physical properties have different fertilizer requirements both in terms of quantity and type. For the purposes of this study a soil sample of each farm observed was taken, and soil fertility was classified as good, average and below average. From the soil analysis results, there are no significantly different soil types among farm samples within each region. Differences between regions are hard to quantify.

Since some differences were still suspected, however, in this study soil fertility (X_{15}) is used as a dummy variable. This was determined by the interviewer based on his observation on the field and the interview and also based on the interviewer's technical knowledge and experience. This variable is given a value one corresponding to all farms which have a good soil fertility and zero otherwise.

3.5.3 Topography

The effect of the topography of the land could change the number of trees per hectare in an area and also reduce the speed and ease of movement of the tapper during harvesting.

Teo (1976) pointed out that steep topography may reduce the number of trees per hectare. Lim (1976) has suggested that smallholders are likely to carry out only minimum maintenance if their holdings are hilly. Sepien (1978) studied the variance analysis results and showed that differences among the average yield on farms of various topography are not significant.

For the purpose of this study, holdings observed were grouped into three topographical catagories: (1) flat slope; (2) undulating; and (3) hilly. The grouping was simply based on a visual inspection of the holdings.

From the Table 3.2 it can be seen that most of the farms studied belong to the first and second topographical categories. It is assumed that topography does not affect rubber yields.

3.5.4 Climatic Factors

Climatic conditions have a substantial effect on yields. Rainfall influences the quality and quantity of rubber produced, the loss of tapping days during the year, late tapping, early collection or a total loss of a day's crop due to inability to collect the latex as a result of heavy rain. High rainfall tends to increase the latex flows compared to low rainfall.

Rainfall figures and monthly maps of South Sumatra are presented in Table 2.1. There were no rainfall records available from all the holdings in each region. It is assumed that rainfall did not differ significantly between regions.

Wind damage is another important factor in areas subject to regular strong winds and storms. A high wind velocity can damage branches and trunks of rubber trees in the holdings; the number of trees available for tapping is consequently reduced and rubber yield is decreased. It is assumed that all the holdings investigated are exposed to the same general wind conditions.

Rachman (1978), based on the climatic data he collected, concluded that in general the province of South Sumatra has a favourable climate for rubber. All the holdings studied are assumed to have similar climatic conditions.

CHAPTER 4

VARIABLE AVERAGES AND CORRELATIONS

4.1 Variable Averages

An analysis of data from sample farms in Kabupaten LIOT and Kabupaten MURA (Table 1.2) shows that average values of most variables included in the present study were significantly different between those two regions. Based on this result, it could be expected that the level of the independent variables affecting the rubber yields of both regions would be different.

These differences in average values were discussed earlier in Chapter 2.

4.2 Simple Correlations Between Variables

Simple correlation between the variables included in the production function provides an immediate picture of the relationship between them. The correlation coefficient indicates the degree to which variation in one variable is associated with the variation in another.

Significant correlation between two variables does not necessarily imply that one is casually related to the other, two variables may move together because a third variable influences both. On the other hand, lack of correlation does not necessarily mean that variables are not associated with each other. The association may be non-linear or marked by variations in other variables. To clarify the position, a partial correlation is often calculated. A partial correlation coefficient measures the relationship between any two variables, when all other variables connected with those two are kept constant.

The prime interest in this section is to explain the significant correlation between variables which are later examined in the production function analysis. Table 4.1 shows the results of the simple correlation matrix of dependent variable and all the independent variables selected in the production function of Kabupaten MURA. The simple correlation matrix between variables of Kabupaten LIOT is presented in Appendix Table 4.2. The specification discussions of all these variables have been presented in Chapter 3. Partial correlation coefficients were not calculated owing to lack of time.

Table 4.1 shows that there is a strong positive correlation between yield (Y) and number of trees in tapping (X_1), (r_{YX1} = 0.4515*) and also between (Y) and total trees (X_{14}), (r_{YX14} = 0.3471***). The number of total trees is highly correlated with number of trees in tapping (r_{X1X14} = 0.8333*) which, in turn, is also highly correlated with harvesting labour (X_7), ($r_{X1\ X7}$ = 0.5314*). There is also a strong positive correlation between harvesting labour and yield (r_{YX7} = 0.4197**). These results indicate that a higher yield can be expected, the higher the number of trees in tapping (and total trees). We also conclude that the greater the number of trees in tapping, the greater the amount of labour spent in harvesting (assuming that the skill of the tapper is the same). The relationship over time is affected by other factors such as age of trees; after reaching an optimum number of trees in tapping or total trees, the rubber yield will decrease.

Yield (Y) and number of years since commencing tapping commenced (X_2) are negatively correlated (r_{YX2} = -0.3268***), indicating that the yield will decrease over time since commencement. Years since tapping commenced is highly correlated with age of trees (X_{12}), (r_{X2X12} = 0.9186*) which, in turn, is negatively correlated with yield. Generally, rubber yield can be expected to rise during the early years of tapping, remain relatively stable for a short period, and then begin to decline rather sharply as rubber trees become older. The average age of trees and the number of years since tapping for the MURA farms are 23.5 and 12.9 years respectively (Table 1.2), showing that the average rubber yield of this region is in the declining period.

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* = significant at the 0.1% level
** = significant at the 1% level
*** = significant at the 2% level

TABLE 4.1

THE CORRELATION MATRIX OF DEPENDENT AND ALL INDEPENDENT VARIABLES TESTED IN THE PRODUCTION FUNCTION OF KABUPATEN MURA

	Variable	Y	D_2	X_1	X_2	X_4	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}
Y	Yield, kg/ha/day	1.0000	-0.0317	0.4515*	-0.3268***	0.0726	0.4197**	0.0517	0.1404	0.0932	-0.1648	-0.2640^{++}	0.0440	0.3471***	0.0397	-0.2554^{++}	0.0480	0.3641**	0.0961	0.0817
D_2	Other income (dummy)		1.0000	0.0243	0.0552	0.0120	-0.1069	-0.0323	-0.0650	-0.1910	-0.0574	0.0573	-0.0934	-0.1493	0.1670	-0.1999	-0.1261	0.0401	-0.1729	-0.2389
X_1	Trees in tapping/ha			1.0000	-0.0530	-0.1133	0.5314*	0.1529	0.0532	0.1298	-0.0712	-0.1687	-0.1367	0.8333*	-0.0231	0.2590^{++}	-0.1792	0.0931	0.1580	0.0507
X_2	Years since tapping commenced, year				1.0000	0.5043*	0.1344	-0.0571	0.0708	-0.0653	-0.1035	0.9186*	0.3031^{+}	-0.1049	-0.1124	-0.0303	-0.0201	-0.5811*	-0.5822*	0.0028
X_4	Number of cuts					1.0000	0.0972	-0.0481	0.0646	-0.0532	-0.0347	0.5377*	0.1659	-0.1623	-0.1910	-0.3377***	0.0186	-0.5198*	-0.5335*	0.0681
X_7	Harvesting labour, hour/ha/day						1.0000	0.0900	0.0521	0.1197	-0.1393	0.1533	0.1720	0.5641*	-0.1017	0.0038	-0.1884	0.0828	-0.0068	0.2144
X_8	Age of farmer, year							1.0000	-0.6069*	0.8239*	0.0740	0.0312	-0.1523	0.1320	0.2198	0.0272	0.0214	0.0874	0.1186	0.0484
X_9	Education, year								1.0000	-0.5007*	0.0780	0.0024	0.3524***	0.0942	-0.0863	0.1254	-0.0417	-0.1656	0.0070	0.1236
X_{10}	Experience, year									1.0000	-0.0584	-0.0222	-0.1114	0.1132	0.0937	0.0384	0.0447	0.0054	0.1369	0.0204
X_{11}	Farm size, ha										1.0000	-0.1365	-0.2937^{+}	0.0449	0.1370	-0.0314	-0.0278	0.1420	0.1864	-0.0310
X_{12}	Age of trees, year											1.0000	0.3981**	-0.1930	-0.1003	-0.0990	0.0499	-0.4798*	-0.6130*	-0.0025
X_{13}	Girth, cm												1.0000	0.1495	-0.1009	0.0174	-0.0131	-0.1552	-0.2090	0.0231
X_{14}	Total trees/ha													1.0000	-0.0657	0.3072^{+}	-0.2489	-0.0734	0.3011^{+}	0.0041
X_{15}	Soil fertility (dummy)														1.0000	-0.0976	0.1286	0.1752	0.0147	0.0701
X_{16}	Cleanliness of the holdings (dummy)															1.0000	-0.2371	0.1417	0.0796	0.1842
X_{17}	Depth of cut, mm																1.0000	-0.1089	-0.0515	-0.1067
X_{19}	Condition of Tapping panel (dummy)																	1.0000	0.2956^{+}	-0.0667
X_{20}	Immature Trees/ha																		1.0000	-0.0991
X_{21}	Maintenance Labour, manday /year																			1.0000

Notes:
* highly significant (0.1%)
** significant at the 1% level
*** significant at the 2% level
+ significant at the 5% level
++ significant at the 10% level

The positive correlation between (Y) and the condition of the tapping panel (X_{19}), (r_{YX19} = 0.3641**) indicates that the yield could be expected to increase from the better tapping panel of the trees. A good tapper will tap his rubber trees as deep as possible without injuring the cambium, because the most active latex vessels are concentrated close to the cambium in the soft bark. On the other hand the condition of the tapping panel is negatively correlated with the number of years since tapping ($r_{X2\ X19}$ = -0.5811*) and also with number of cuts (X_4), ($r_{X4\ X19}$ = -0.5198*). These relationships indicate that a poorer tapping panel condition occurs over time, as the number of cuts increase since tapping.

Years since tapping (X_2) is positively correlated with number of cuts (X_4), ($r_{X2\ X4}$ = 0.5043*), indicating that the number of cuts increases with years since tapping. Rubber yield will decline as rubber trees become older. In their attempts to maintain the same level of production, farmers tapped their older trees more intensively. A similar interpretation can be made for the positive correlation between number of cut and age of trees ($r_{x4\ X12}$ = 0.5377*). On the other hand there is a negative correlation between (X_4) and (X_{16}) and also between (X_4) and (X_{19}), ($r_{X4\ X19}$ = -0.5198*), indicating that a lesser number of cuts could be expected from the better conditions of farms (cleanliness) and the condition of the tapping panel of the trees.

The strong negative correlation between age of trees (X_{12}) and tapping panel (X_{19}), ($r_{X12\ X19}$ = -0.4798*) indicates that the older trees usually have a poorer tapping panel.

The negative correlation between (Y) and the assessed cleanliness of the productive area (X_{16}), (r_{YX16} = -0.2554^{++}) indicates that the yield decreases as standards of maintenance increase. This relationship is

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* = significant at the 0.1% level.
++ = significant at the 10% level.

unexpected. It is perhaps due to some errors in measurements. Or it can perhaps be explained by differences in the technique of rubber cultivation. Clean weeding on the holding may expose the land to soil erosion. This may cause leaching of soil nutrients with consequent negative effects on rubber yields. There is also a lack of relationship of yield with maintenance labour (X_{21}), ($r_{Y\ X21} = 0.0817$). On the other hand there is a positive correlation between number of trees in tapping (X_1) and the assessed cleanliness of the productive area ($r_{X1\ X16} = 0.2590^{++}$), indicating that the cleaner farms are associated with more trees in tapping. This may be because the purpose of weeding for most farmers is only to create paths for the rubber tappers to pass along to facilitate tapping.

The age of the farmer (X_8) is highly negatively correlated with education (X_9), ($r_{X8\ X9} = -0.6069^{*}$) but positively correlated with experience (X_{10}), ($r_{X8\ X10} = 0.8239^{*}$) indicating that the older farmers usually have a lower education, whilst naturally having more experience on rubber cultivation. Most of the older farmers were born before World War II when there were no proper facilities for schooling.

The positive correlation between (X_9) and the girth (X_{13}), ($r_{X9\ X13} = 0.3524^{***}$), indicates the bigger girth of the trees could be expected from more educated farmers.

The negative correlation between farm size (X_{11}) and the girth (X_{13}), ($r_{X11\ X13} = -0.2937^{+}$) indicates the smaller (younger) trees could be expected from the larger farms, although this is to some extent connected with age of trees ($r_{X11\ X12} = 0.1365$).

The age of trees (X_{12}) is strongly negatively correlated with the number of immature trees (X_{20}), ($r_{X12\ X20} = -0.6130^{*}$) and on the other hand (X_{20}) is

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* significant at the 0.1% level.
*** significant at the 2% level.
++ significant at the 10% level.
\+ significant at the 5% level.

positively correlated with the total number of trees (X_{14}). This indicates that the greater the number of immature trees the smaller the number of older rubber trees.

4.3 Simple Correlations at LIOT

The simple correlation matrix of yield and all independent variables tested in the production function of Kabupaten LIOT (Appendix Table 4.2) has a similar pattern of relationship as the one for Kabupaten MURA. There are some differences in the degree of significance. But there is a different relationship between experience (X_{10}) and farm size (X_{11}), ($r_{X10\ X11}$ = 0.3282***), indicating that the more experienced farmers could be expected from the larger farms. For Kabupaten MURA the relationship between these two variables is negative but not significant ($r_{X10\ X11} = -0.0584$).

There are also some relationships of variables at LIOT which were not significant for Kabupaten MURA. The soil fertility (X_{15}) and maintenance labour (X_{21}) are positively correlated ($r_{X15\ X21}$ = 0.3776**), indicating perhaps that the better soil fertility of the holdings results from higher maintenance labour.

The age of the farmer (X_8) and his experience (X_{10}) are positively correlated ($r_{X8\ X10}$ = 0.4401^{++}) indicating that the older farmers usually have more experience.

On the other hand the number of trees in tapping (X_1) is negatively correlated with farm size (X_{11}), ($r_{X1\ X11}$ = -0.3669**) indicating that the larger farmers usually have less number of trees in tapping per hectare.

Now that we have discussed the significance of the relationship between the various variables, we are in a better position to go on to production function analysis.

** significant at the 1% level.
*** significant at the 2% level.
++ significant at the 10% level.

CHAPTER 5

THEORETICAL ASPECTS OF PRODUCTION FUNCTIONS

This Chapter is devoted to the theoretical discussion of the average and frontier production functions. The first part of this chapter deals with the properties of the Least Square Method, the Cobb-Douglas production function, the Transcendental production function and the Appropriate Properties of a Rubber Production Function. The second part of the chapter deals with a framework for the better understanding of efficiency and then discusses the estimation of a frontier function. Finally, the construction of an efficiency measurement of the individual farm relative to the estimated frontier is discussed.

5.1 The Production Functions

A production function is a mathematical expression describing the technical relationship between input resources and product outputs. A specific algebraic formulation cannot be stipulated because different outputs vary in the form of this response to different biological and mechanical processes and the environmental conditions obtaining during the production process. Various functional forms have been discussed in detail by Heady and Dillon (1961).

An average production function indicates the average physical output levels obtainable from each possible input combination. In other words, the output level indicates the level obtainable by the average farm under stipulated inputs. The best function, on the other hand, indicates the output level that can be achieved by the best farm only.

In agriculture, the possibility of inputs being either complementary factors of production with variable proportions or fully substitutable, is high. To each of these two categories, two types of production functions can be associated - Transcendental and Cobb-Douglas respectively, of which, the transcendental function incorporates all the three stages of production, while the Cobb-Douglas explains only the important second stage of production assuming perfect competition.

Some other forms, such as CES functional form could have been chosen for the purpose, but with more than two factors of production, the CES function becomes quite complicated and it is not possible to estimate using a linear programming method.

5.2 Average Production Function

The Cobb-Douglas function in its best-known form is:

$$Y_j = \beta_o \prod_{i=1}^{m} X_{ij}^{\beta_i} \qquad (5.1)$$

where,

Y_j = output of farm j (j = 1, 2, ..., n)

X_{ij} = amount of factor i used by farm j

β_i = parameter associated with the i^{th} factor-use X_i (i = 1,2, ...,m)

β_o = the efficiency parameter.

It is always assumed in estimating production functions empirically, that discrepancies exist between estimated and actual values. These are referred to as 'disturbances' in the theory of estimation.

> "In any empirical application we must of course specify .... the properties of the random disturbance terms that must be added to allow for the effect of all variables ignored in the analysis." Cramer (1969).

In order to estimate (5.1) from the sample, the error term is introduced as:

$$Y_j = \beta_o \prod_{i=j}^{m} X_{ij}^{\beta_i} U_j \qquad (5.2)$$

where,

U_j = the stochastic error term.

A useful characteristic of the non-linear form (5.2) is that it becomes linear in the logarithms of the variables, which is a necessary condition for the regression technique.

Thus, (5.2) can be written in log linear form as:

$$y_j = \beta_o + \sum_{i=1}^{m} \beta_i x_{ij} + u_j \qquad (5.3)$$

where,

$$y_j = \log_e (Y_j)$$

$$x_{ij} = \log_e (X_{ij})$$

$$\beta_o = \log_e (\beta_o)$$

$$u_j = \log_e (U_j)$$

Equation (5.3) now expresses the exact linear relationship between the variable y_j and the explanatory variables $x_1, x_2, \ldots\ldots, x_m$. Here, the error term u_j may represent either the net effect of the variables not included in the equation, or errors of observation and measurement in different input factors, or there may be a basic and unpredictable element of randomness (weather).

The parameters β_i s (i = 0, 1, 2, ..., m) and the error distribution are unknown and the problem is to obtain the estimates of these unknowns. The procedure adopted to estimate these unknown parameters is the method of least square, (usually called OLS). Now the sample estimates of (5.3) would be given by

$$\hat{y}_j = \hat{\beta}_o + \sum_{i=1}^{m} \hat{\beta}_i x_{ij} + u_j \qquad (5.4)$$

where,

$\hat{\beta}_i$ (i = 0,1,2, ..., m) are the least squares estimates of β_i s.

The least square method has been well discussed in detail by many authors in many econometric text books, e.g. Dhrymes (1970), Johnston (1972), Koutsoyiannis (1977). It is therefore proposed here to mention briefly some of its properties.

5.2.1 Properties of the Least Squares Procedure

The attractive statistical properties of the single equation least squares method are the facility of estimation and the fact that ordinary least squares provides the best linear unbiased estimator of the parameters of (5.3) when the following assumptions about u are made:

(a) The expected value of u on each occasion is equal to zero i.e. $E(u_i) = 0$

(b) U is independent of time so that there is no serial correlation among disturbances i.e., $E_{i \neq j}(u_i u_j) = 0$ but $E_{i=j}(u_i u_j) = \sigma^2$

(c) If x_i 's are considered as random variables, then they have independent joint distribution with u i.e. $E(x_i u_i) = 0$

(d) u is distributed normally as $N(0, \sigma^2)$.

With these assumptions, the method of least squares, which consists of minimising the sum of squares of the disturbances between the observed and estimated values, can be used to estimate the production parameters mentioned above.

5.2.2 Properties and Attributes of the Cobb-Douglas Production Function

General properties and attributes of this function are its ease of manipulation and interpretation and its good fit to the data. More importantly, its log linear form permits easy calculation of the 'frontier' production function by the application of a conventional linear programming package.

Some of the properties and attributes of the Cobb-Douglas function which have relevance to the present study are discussed below:

(1) The marginal product of a factor is obtained by taking the partial derivative of the function with respect to that factor, with all other input levels held constant. Thus, from equation (5.1) and ignoring the j subscript the marginal product of i^{th} factor X_j is derived as

$$MP_{X_i} = \frac{\partial Y}{\partial X_i}$$
$$= \beta_i \beta_o X_1^{\beta_1} X_2^{\beta_2} \ldots X_i^{\beta_i - 1} \ldots X_m^{\beta_m}$$
$$= \beta_i \frac{Y}{X_i} \qquad (5.5)$$

(2) The coefficients β_i (i = 1,2, ..., m) are the output elasticities of the respective factors of production, each of which remains constant throughout the production surface.

The output elasticity of the i^{th} factor X_i is given by

$$\eta_{YX_i} = \frac{X_i}{Y} \quad \frac{\partial Y}{\partial X_i}$$

$$= \frac{X_i}{Y} \left[\beta_i \frac{Y}{X_i} \right]$$

$$= \beta_i \qquad (5.6)$$

The production elasticity of each input indicates the expected percentage change in the gross output for a one per cent change in that input, with other input levels held constant. These are enumerated to remain constant with the entire input-output increase.

(3) The sum of the output elasticities measures (i) the degree of homogeneity of the function and (ii) the returns to scale. The returns to scale are increasing, constant or decreasing according as the sum of elasticities is greater than, equal to or less than unity. In mathematical notation, we have :

If $\sum_{i=1}^{m} \beta_i$ > 1, increasing returns to scale,

= 1, constant returns to scale,

< 1, decreasing returns to scale.

Increasing returns to scale means that if all factors of production are increased simultaneously by one per cent, gross output will increase by more than one per cent. Decreasing returns prevail if the gross output increases by less than one per cent. When the situation is such that a one per cent increase in the input factors leads to a one per cent increase in the gross output, the relationship is of constant returns to scale. It should be mentioned that though the function permits increasing, constant, or decreasing returns to scale, it allows only one of these and not a combination.

(4) From equation (5.5), we see that the marginal product changes as the input level is changed. The second derivative of (5.5) gives:

$$\frac{\partial^2 Y}{\partial X_i^2} = \beta_i \left[\beta_i - 1\right] \frac{Y}{X_i^2} \qquad (5.7)$$

The right hand side of (5.7) is negative, since $\beta_i < 1$. Thus we have diminishing marginal productivity for increasing input levels, with all other inputs held constant.

(5) Marginal productivity is often used to evaluate the allocative efficiency of individual plants, firms or industries. Under the assumption of perfect markets, the equilibrium condition is the point at which the marginal value product of each of the resources is equal to its marginal cost. The first order condition for profit maximization is that the marginal product of each factor is equal to the ratio of the price of the factor and the product. Hence, for the i^{th} factor, profit maximization occurs when

$$\begin{aligned} MP_{X_i} &= \frac{\partial Y}{\partial X_i} \\ &= \beta_i \frac{Y}{X_i} \\ &= \frac{P_{X_i}}{P_Y} \end{aligned} \qquad (5.8)$$

where,

P_{X_i} = price of the i^{th} factor

P_Y = price of the product.

Thus, under the assumption of perfect competition, equation (5.8) could be used to examine the extent of resource misallocation of a particular firm in the production process. In other words, the difference between the marginal productivity of a factor and its opportunity cost measures the degree of allocative inefficiency of the firm under consideration.

(6) Inspite of the many attractive properties of the Cobb-Douglas function, there are a few drawbacks. One of the most limiting characteristics is that the function assumes a constant and unitary elasticity of substitution between the input factor. Nevertheless, as long as we keep the limitations of this functional form clearly in mind, we can always exercise the necessary caution in interpreting its results.

5.2.3 Measurement of Technical Efficiency

Equation (5.4) represents the average production function. The estimate obtained from this function indicates the average output level (on the log form) which an average farm could obtain from a given set of inputs. The efficiency level of each farm relative to the average farm is measured by the ratio of the actual observed output to the output predicted from the average production function.

The average technical efficiency index/rating

$$= \frac{Y_j}{\hat{Y}_j}$$

$$= \text{Antilog of } (y_j - \hat{y}_j) \qquad (5.9)$$

where, y_j is the log of the observed output of the j^{th} farm and $\hat{y}_j$ is the estimated output level given by (5.4).

5.2.4 General Properties of the Transcendental Function

The transcendental (TRANS) function is a production function combining characteristics of the power and exponential function. This function can exhibit non constant elasticity, i.e. increasing, decreasing, and negative marginal returns, singularly, in pairs, or all three simultaneously.

The general form of the function is :

$$Y = CX_1^{a_1} e^{b_1X_1} X_2^{a_2} e^{b_2X_2} \ldots\ldots X_n^{a_n} e^{b_nX_n}$$

in which Y is the total output (dependent variable), $X_1, X_2, \ldots, X_n$ are the quantities of inputs (independent variables), e is the base of natural logarithms and C, $a_1, \ldots, a_n, b_1, \ldots, b_n$ are parameters.

The appropriate function for rubber production is the following, modified form of the TRANS production function (Sepien, 1978) :

$$Y = C \prod_{i\varepsilon A}^{n} X_i^{a_i} e^{\alpha_i X_i} \prod_{i\varepsilon B}^{n} X_i^{b_i} e^{\beta_i X_i} .U \qquad (5.10)$$

where, A and B are sets of essential and supplementary inputs,

Y is output

X_i is the i^{th} input, and

U represents the error difference which is referred to as the disturbance term on the residuals, and

$i = 1, 2, \ldots, n$

If $b_i = 0$ for i in set B and $a_i > 0$ for i in set A, equation (5.10) is reduced to :

$$Y = C \prod_{i\varepsilon A}^{n} X_i^{a_i} e^{\alpha_i X_i} \prod_{i\varepsilon B}^{n} e^{\beta_i X_i} .U \qquad (5.11)$$

This means that for :

(i) $i\varepsilon A$: any $X_i = 0$, $Y = 0$

(ii) $i\varepsilon B$: all $X_i = 0$, $Y = C \prod_{i\varepsilon A}^{n} X_i^{a_i} e^{\alpha_i X_i} > 0$

That is to say that A is the set of essential inputs and B is the set of supplementary inputs.

The marginal productivity of X_i of the function (5.11) in the Set A is:

$$\left.\frac{\partial Y}{\partial X_i}\right|_{i\varepsilon A} = Y\left(\frac{a_i}{X_i} + \alpha_i\right) , \qquad \left.\frac{\partial Y}{\partial X_i}\right|_{i\varepsilon B} = Y\beta_i \qquad (5.12)$$

When (5.12) is equated to zero, the maximum output is obtained when

$$X_i = \frac{-a_i}{\alpha_i}, \text{ which is a necessary condition if } \underset{i \varepsilon B}{X_i} \text{ is constrained at a constant level.} \quad (5.13)$$

The second derivative is

$$\left.\frac{\partial^2 Y}{\partial^2 X_i}\right|_{i \varepsilon A} = \left[\frac{a_i^{\,2} - a_i}{X_i^{\,2}} + \frac{2a_i\,\alpha_i}{X_i}\right] \quad (5.14)$$

$$= \frac{Ya_i}{X_i^{\,2}} < 0 \text{ output at maximum} \quad \text{(using 5.13)}$$

The X_i input corresponding to the inflection point is obtained when (5.14) is set equal to zero

$$X_i = \frac{-a_i \pm \sqrt{a_i}}{\alpha_i} \quad (5.15)$$

As the values of $\sqrt{a_i}$ in equation (5.15) can be both positive and negative, there are two inflection points. The one with a negative value of $\sqrt{a_i}$ is in the third stage of the production function (Figure 5.1(b)).

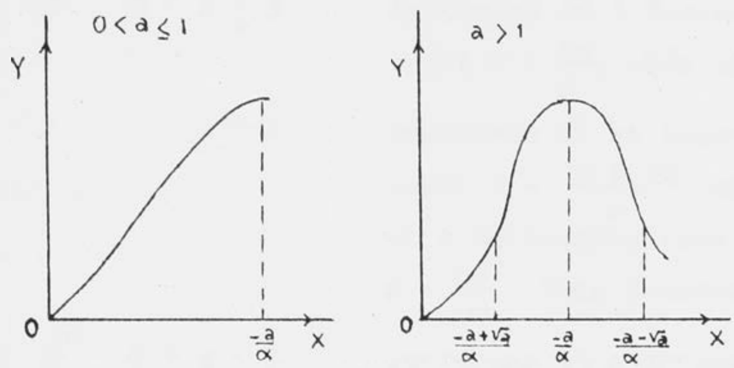
As two parameters, a_i and α_i for each X_i input in set A are estimated, the shape of a TRANS function with respect to X_i is influenced by various combinations of values of 'a_i' and α_i (Table 5.1). When the values of 'a_i' s' are positive and α_i negative, the function conforms to the production function which has all the three stages of production. The output first increases, at an increasing rate, following by a decreasing rate. Once a maximum is reached, the output decreases (Figure 5.1(b)). When $\alpha_i = 0$, the function reduces to the Cobb-Douglas type (Figures 5.1 (c), (d) and (e)).

This function provides for all the three stages of the production function, as its factors' marginal productivities can be increasing, decreasing or negative, singularly, in pairs or simultaneously. Thus it is non-homothetic.

FIGURE 5.1

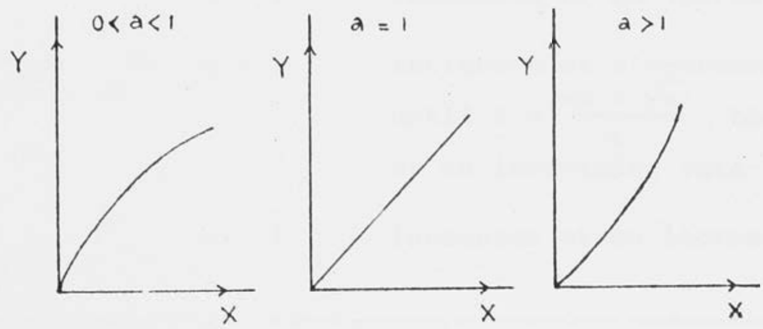
VARIOUS SHAPES OF THE TRANS FUNCTION

When $\alpha < o$



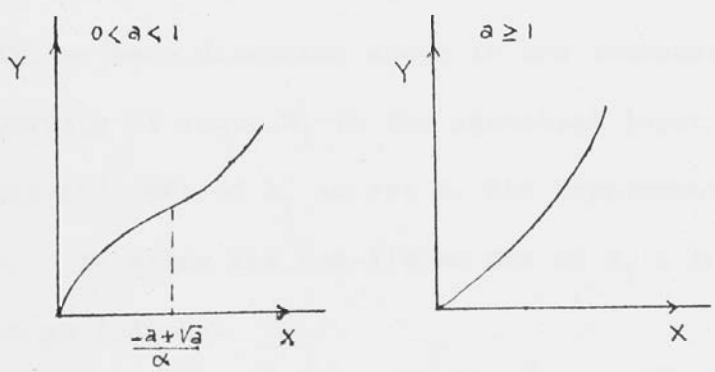
5.1(a) 5.1(b)

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



5.1(c) 5.1(d) 5.1(e)

When $\alpha > 1$



5.1(f) 5.1(g)

TABLE 5.1

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	5.1(a)
	$a > 1$	increases at an increasing rate until $Y = \frac{-a + \sqrt{a}}{\alpha}$, then increases at a decreasing rate until $X = \frac{-a}{\alpha}$, then decreases	5.1(b)
$\alpha = 0^+$	$0 < a < 1$	increases at a decreasing rate	5.1(c)
	$a = 1$	increases at a constant rate	5.1(d)
	$a < 1$	increases at an increasing rate	5.1(e)
$\alpha > 0$	$0 < a < 1$	increases at a decreasing rate until $X = \frac{-a + \sqrt{a}}{\alpha}$, then increases at an increasing rate	5.1(f)
	$a > 1$	increases at an increasing rate	5.1(g)

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

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

All we have discussed above is the increasing, decreasing, and negative productivity of input X_i in the essential input set A. But the marginal productivity (MP) of X_i in set B, the supplementary inputs, (5.10) is still linear. To allow for non-linear MPs of X_i's in set B, (5.10) may be re-written as follows:

$$Y = C \prod_{i\epsilon A}^{n} X_i^{a_i} e^{\alpha_i X_i} \prod_{i\epsilon B}^{n} e^{(\beta_i X_i + \gamma_i X_i^2)} .U \qquad (5.16)$$

The production function as expressed by equation (5.16) refers to the production function of a smallholder.

As all the smallholders studied had the same basic process of rubber production, to explain the variation in their productivity by combining the production function of each smallholder (equation 5.16) into a function which explains differences among smallholders, this is done by estimating equation (5.16) using a set of cross-sectional input and output data obtained from all the smallholders studied, and allowing for the various characteristics specific to each holding. The equation (5.16) may now be rewritten as :

$$Y_j = C_j \prod_{i \varepsilon A}^{n} X_{ij}^{a_i} e^{\alpha_i X_{ij}} \prod_{i \varepsilon B}^{n} e^{(\beta_i X_{ij} + \gamma_i X_{ij}^2)} . U_j \quad (5.17)$$

where X_{ij} is the amount of input i employed by j^{th} smallholder,

Y_j is the rubber output of j^{th} smallholder, and

C_j is the technical efficiency coefficient.

In double log linear form, this function is:

$$y_j = c_j + \sum_{i \varepsilon A}^{n} (a_i x_{ij} + \alpha_i X_{ij}) + \sum_{i \varepsilon B}^{n} (\beta_i X_{ij} + \gamma_i X_{ij}) + u_j \quad (5.18)$$

where the lower case variables denote logarithms.

5.3 Appropriate Properties of a Rubber Production Function

5.3.1 Essentiality of Inputs

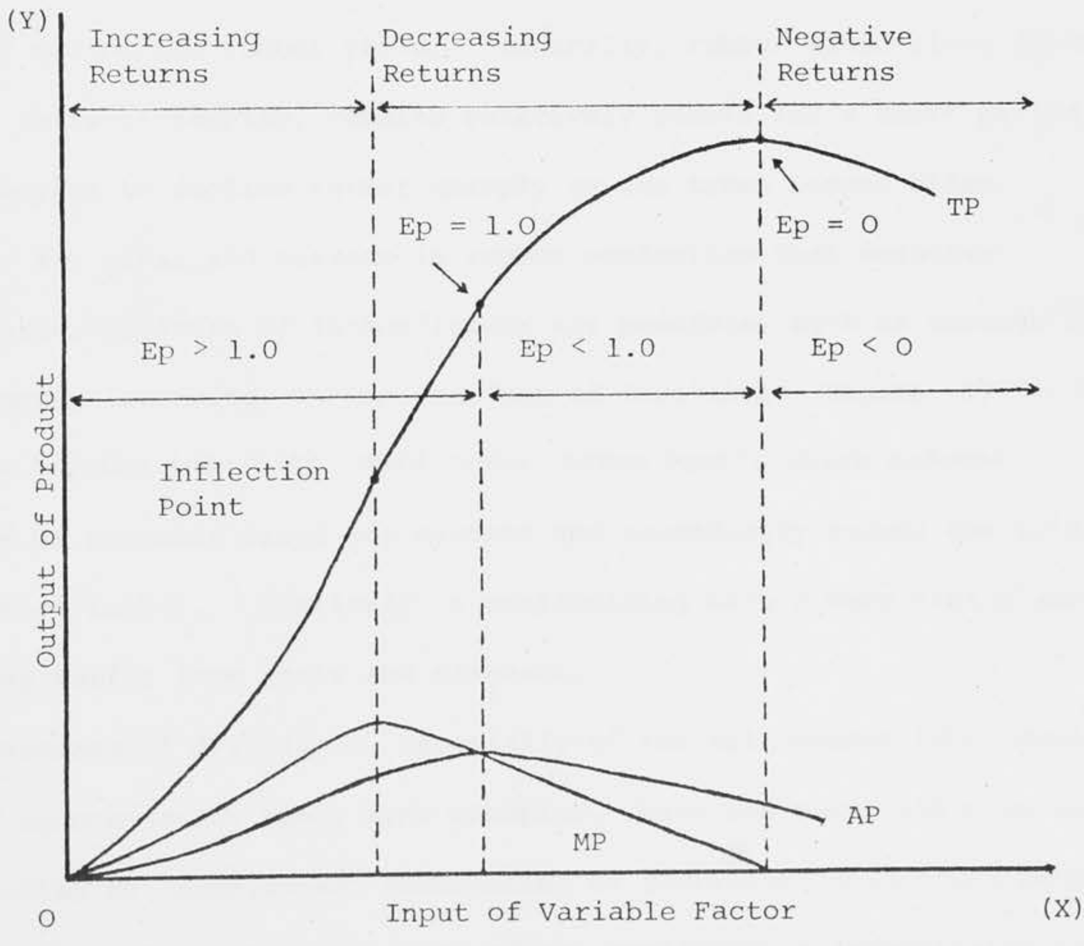
In rubber production, it is important to distinguish between essential and supplementary inputs. Essential inputs are those without which no rubber output can be attained, while the supplementary inputs are those without which rubber output can still be obtained. However the inclusion of supplementary inputs may increase rubber output significantly. The essential and supplementary input factors in rubber production were discussed earlier in Chapter 3.

5.3.2 Marginal Productivity of Inputs

The elasticity of production refers to the percentage change in output accompanying a given percentage change in input. The relationships between the total product (TP), average product (AP) and marginal productivity (MP) curves are illustrated in Figure 5.2 below. This illustration refers to a production function which includes both increasing and decreasing returns for the variable resource.

FIGURE 5.2

RELATIONSHIP OF FACTOR INPUT TO TOTAL, MARGINAL AND AVERAGE PNYSICAL PRODUCTS



The marginal product indicates the change in total product for each unit change in resource input. Accordingly as long as the MP of the variable factor is increasing, the TP must increase at an increasing rate. This is indicated by the TP curve, which is convex to the X axis as long as the MP is increasing. The TP curve reaches an inflection point, a point where the curvature reverses, as the MP attains a maximum. TP continues to increase, but at a decreasing rate as long as the MP decreases but is greater than zero. It reaches a maximum as the MP becomes zero, and then decreases as the MP becomes negative.

An appropriate rubber production function should have non-constant elasticity, i.e. increasing, decreasing and negative marginal productivity; singularly, in pairs or all three simultaneously of some inputs including rubber trees and harvesting labour (Figure 5.2). This is due to the effect of age on the rubber yield. Generally, rubber yield rises during the early years of tapping, remains relatively stable for a short period, and then begins to decline rather sharply as the trees become older.

There are clear indications in rubber production that negative marginal productivities of factor inputs are possible, such as through too high a tapping intensity, or an overdose of fertilizer (Sepien, 1978). Too high a tapping intensity could cause 'brown bast', which reduces the number of tappable trees per hectare and accordingly reduce the total dry weight of rubber. Similarly, a smallholding with a very high planting density may suffer from pests and diseases.

An overdose of fertilizer, especially of the nitrogenous type, could stimulate unnecessarily heavy tree canopies, which are susceptible to wind damage. Also an 'unbalanced' combination of fertilizer used could depress yield significantly. However, none of the smallholders investigated used fertilizer. This is due to their economic constraints. In the study area brown bast cases were commonly seen indicating that smallholders had over-tapped their rubber trees.

5.3.3 Elasticity of Substitution

The elasticity of substitution (σ) may be defined both in terms of input prices and the MRTS (Marginal Ratė of Technical Substitution).[1] In terms of the former, it is the percentage change in the factor proportion with respect to the percentage change in the factors' relative prices (Heathfield, 1971). In terms of the MRTS, elasticity of substitution is defined as the percentage change in the factor proportion in response to a percentage change in the MRTS between them, holding output constant (Griliches and Ringstad, 1971).

In the case of two inputs,the elasticity of substitution is defined as follows:

$$\alpha(X_1\ X_2) = \left. \frac{\frac{X_2}{X_1}\ d\left(\frac{X_1}{X_2}\right)}{\frac{f_1}{f_2}\ d\left(\frac{f_2}{f_1}\right)} \right|_{Y\ =\ \text{constant}}$$

where $f_1 = \partial F/\partial X_i$ is the marginal productivity of the i^{th} factor.

Since we have assumed that inputs of rubber trees (X) and labour (L) can be varied continuously, the combination of these inputs represent points on a smooth curve, joining all the combinations of rubber trees and labour, which give equal level of output (Figure 5.3). It may also be known as an iso-quantity curve or 'isoquant' (I).

All the homothetic functions have a constant elasticity of substitution among factors along the linear expansion path (OP or OQ) (Figure 5.3) which must hold true for each and every pair of factors. In other words, the MRTS depends only on the input proportion but not on the scale of production. Some examples of homothetic functions are the Cobb-Douglas function which has

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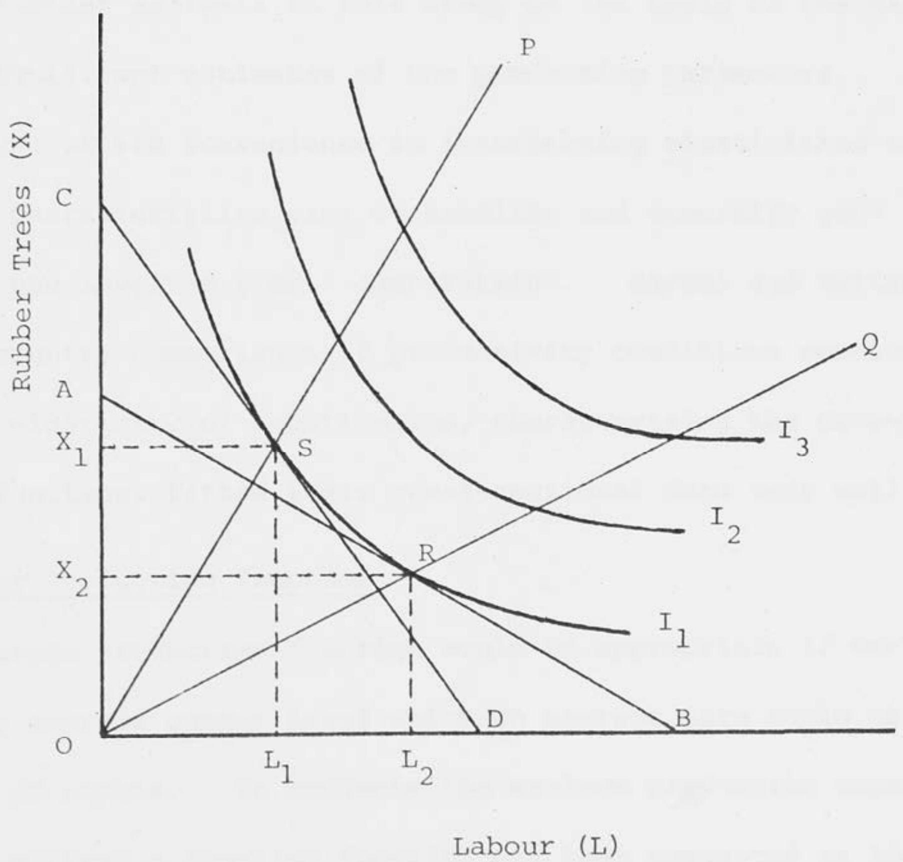
1 The MRTS tell us in what proportion the two inputs are capable of replacing (substituting) one another, if we insist the product quantity is unchanged (Frisch, 1965).

$\sigma = 1$, the CES function where σ can be any number (constant throughout) and the Input-Output model where $\sigma = o$.

Although we do not have a clear knowledge of MRTS in a rubber production function, some evidence seems to indicate that it is variable with scales of operation (non-homothetic). For example, it has been well established that large estates use a different resource combination from the smallholdings. The estates tend to be less labour intensive than the smallholdings.

FIGURE 5.3

GENERAL ILLUSTRATION OF ISOQUANTS FOR RUBBER TREES AND LABOUR IN RUBBER PRODUCTION



It has been indicated that an appropriate function for this study should be non-homothetic and have variable elasticity of substitution among factors.

The Cobb-Douglas function type has been used in rubber production studies by Teo (1976) in Sri Lanka, Lim (1976) in Malaysia and Whitlam (1976) in Papua New Guinea. The transcendental production function has been used in rubber production function studies by Sepien (1978) in Malaysia.

5.4 The Function Selected for this Study

After considering the desirable properties which have been discussed in the former sections, the Cobb-Douglas and the transcendental production functions were given a preliminary trial in this study. The estimated functional parameters are presented in Appendix Tables 5.2 to 5.5.

Of these two forms of production function, the Cobb-Douglas form was chosen for further analysis in this study on the basis of the maximum number of significant estimates of the production parameters. It was also chosen because of its convenience in interpreting elasticities of production, its primary characteristics, ease of handling and generally good fit and because its use involves simple computations. Hayami and Ruttan (1971), with inter-country comparisons of productivity conditions concluded that the unitary elasticity of substitution, characterizing the Cobb-Douglas production function, fitted their cross-sectional data very well.

5.5 Frontier Production Function

The average production function would be appropriate if one wished to estimate the average output level which an average farm could obtain from a given set of inputs. To estimate the maximum productive capacity of an industry or a firm, a frontier function has been suggested as the most appropriate form. The frontier is defined as expressing the maximum product obtainable from the combination of factors production with a given state of technical knowledge (Carlson, 1956).

The maximum possible yield function defined above, is the production function underlying what may be considered as the best practice techniques among a given group of farmers. Hence, it is not necessarily the same as the production function of the experimental results obtained by highly qualified scientists in the research stations. With the level of technology known to sample farmers, our interest is to find out the highest yield obtained using the best practice technique at field level. The production function showing such yield is called 'frontier production function' in the literature. This function may be estimated by linear or quadratic programming techniques.

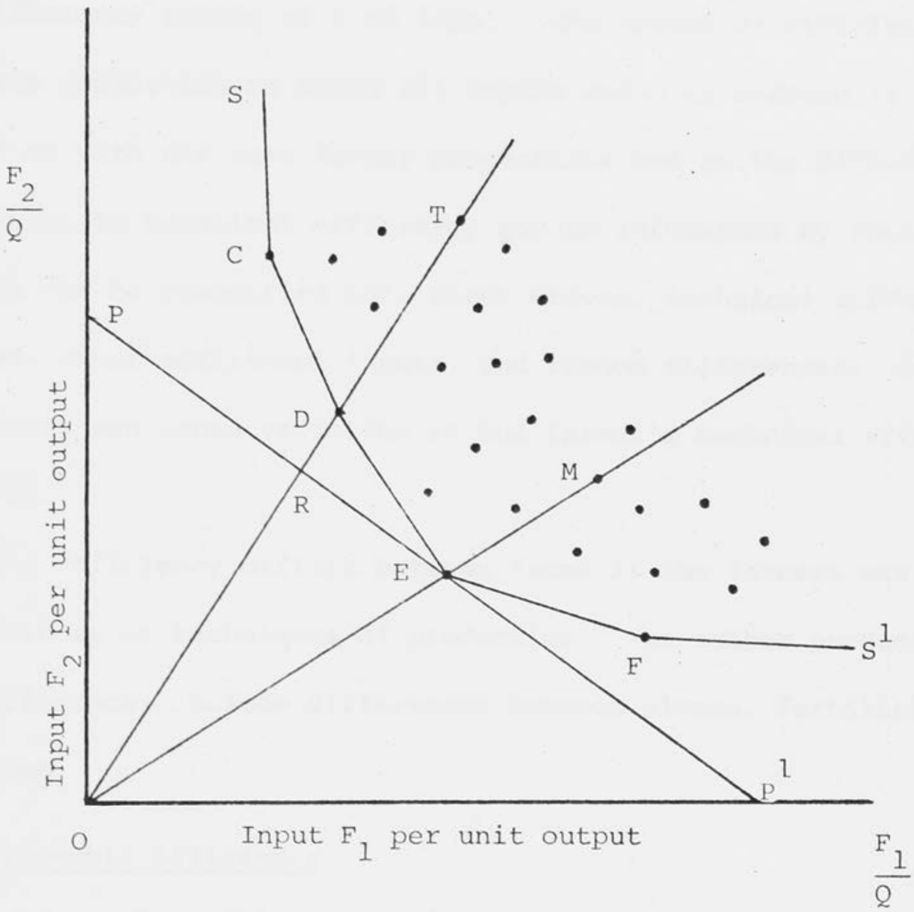
5.5.1 Review of Previous Studies

In 1957, Farrel pioneered the method of estimating an efficient production function. He illustrated the application of his method on the aggregated agricultural data of the 48 States of the United States. Since then, further studies on efficiency measures have been carried out. Some of the studies that focus on technical efficiency are those of Solow (1959), Mundlak (1961), Nerlove (1965), Seitz (1970) and Timmer (1970). Those focussing on price efficiency are by Hopper (1965), Yotopoulos (1967), and Yotopoulos and Lau (1973).

Farrell's approach is directed towards the estimation of an efficient production function from observations of inputs and output of a number of firms. For simplicity, his approach is illustrated in Figure 5.4 for the two inputs, one output case. Under the assumption of constant returns to scale, the production function can be specified in the form of a unit isoquant. Each observation represents the input combination used by a single firm to produce one unit of output. There will be as many dots in the diagram as the number of firms under consideration. Given the assumptions that the isoquant is convex to the origin and nowhere has a positive slope, the curve SS^1 is the locus of points indicating the minimum

FIGURE 5.4

TECHNICAL AND PRICE EFFICIENCY



quantities of the factors of production required to produce one unit of output with varying factor proportions. This curve thus represents the frontier and no observation lies between this curve and the origin, O, which means no firm could produce a unit output with a combination of inputs that lie to the south-west of the estimated frontier.

Farrell constructed the efficiency index for the individual firms with respect to this frontier. All those firms which operate at the production frontier are said to be 100 per cent technically efficient. All those above SS^1 are technically inefficient. In this context the firms represented by the points C. D. E. and F. in the figure are 100 per cent technically efficient, for they all lie on the frontier but those represented by T or M are inefficient as they lie interior to the frontier. The degree of technical inefficiency of the firm T is defined as the ratio of the distance between the origin and the point D to the distance between the origin and the point T, i.e. $\frac{OD}{OT}$. On this basis, all firms will have a technical efficiency rating of 1 or less. The technical efficiency index represents the proportion to which all inputs could be reduced if production were carried on with the same factor proportions but at the efficiency level.

Differences in technical efficiency may be influenced by various factors which can be classified into three groups, technical differences between farms, other additional inputs, and random differences; and any of these factors can cause variation in the farmer's technical efficiency (Timmer, 1970).

Technical efficiency differs between farms if the farmers use different types of machinery or techniques of production. In rubber production, technical differences include differences between clones, fertilizers, and tapping systems.

5.5.2 Economic Efficiency

To be economically efficient, a farmer must also be price efficient, apart from being technically efficient .This is the other component of overall economic efficiency. Price efficiency is the choice of the current proportions of input factors with respect to their price in order to minimise the total cost of production. To be price efficient, a farmer should choose a combination of inputs along the isocost line PP^1 whose slope represents the ratio of prices of inputs F_1 and F_2 (Figure 5.4). Although D is 100 per cent technically efficient, it is not price efficient because the cost of production at D is more than at E. The price efficiency at D is $\frac{OR \times 100}{OD}$ per cent, which is less than 100 per cent. Firm E is both technical and price efficient and thus economically efficient as the isocost line PP^1 is at tangent with the efficient unit isoquant SS^1 at E.

Technical efficiency is measured in relation to those firms at the frontier, whereas price efficiency is measured in relation to the isocost line. The product of these two separate efficiences $\frac{OR}{OT} = \frac{OD}{OT} \times \frac{OR}{OD}$ measures the economic efficiency of the firm at T.

Since technical efficiency (using the Farrell technique) is measured in relation to those firms on the frontier, any additional observations may sometimes reduce but cannot increase the estimated technical efficiency of a given firm. On the other hand, the price efficiency is comparatively more sensitive to additional observations and also to errors in factor prices. From Figure 5.4, it is clear that the price efficiency of T depends on (i) the slope of the isoquant SS^1 at E, (ii) its curvature between D and E, and (iii) the slope of the isocost line PP^1. Introduction of new observations is most likely to change the slope of SS^1 and also the curvature between D and E, while the errors in factor prices is likely to change the slope of PP^1. Thus it is probable that the estimated price efficiency may be more unstable than the estimated technical efficiency. Farrell (1957) recommends the use of the measure of price efficiency only in cases where many observations and accurate price information are available. In this study the lack of adequate input price data on a farm by farm basis precluded the analysis of price efficiency.

Prior to 1957, most of the production functions were fitted by regression methods. All the functions so fitted are, in a sense, the average production functions. In this light, Farrell's approach of estimating the efficient production function through the use of the efficient isoquant can be considered a pioneering work in production studies. Though this approach seems to generate a function that corresponds to the theoretical ideal production function, it is not completely free from criticism.

Nerlove (1965) and Bressler (1967) criticised Farrell's method because it utilises only the "marginal" observations and operates in an input-output space under the assumption of constant returns to scale which raised a number of theoretical and operational difficulties.

In 1968 Aigner and Chu developed a mathematical programming method which is more general. This is a modified and improved version of Farrell's method of estimating the frontier function and the assumption of constant returns to scale need not be made. By applying the techniques of linear programming to cross-section data on firms, the Aigner and Chu method may produce the frontier function by controlling the disturbance term to be of one sign only. The assumptions embodied in this approach are (i) that the disturbances are of one sign, i.e., the observed points in the production space lie on or below the frontier only, (ii) that errors of measurement in all variables are negligible and (iii) that all the differences in technical efficiency are included in the disturbance term. The analysis in this study uses the Aigner and Chu method.

5.5.3 Estimation Procedure

The Cobb-Douglas model in general form, linear in logarithm, given by equation (5.3), can be written as

$$y_j = \sum_{i=o}^{m} \beta_i \; x_{ij} + u_j \tag{5.19}$$

where one column of x_i is a vector of ones to allow for an intercept.

To make this a frontier function all u_j must be constrained to one side of the estimated production surface. Thus, the production function (5.3) should be estimated such that :

$$\sum_{i=o}^{m} \hat{\beta}_i \; x_{ij} = \hat{y}_j \geqslant y_j \tag{5.20}$$

where,

β_i, x_{ij} and y_j are as defined in the first section.

Here, it should be recognised that only the "efficient" farms satisfy the final equality - all others have a smaller actual output than would be achieved if they, too, were efficient by the standards of the estimated production function.

Since the error terms are assumed to lie only on one side of the frontier, the linear programming method can be used to estimate the desired frontier by considering the linear sum of errors as its objective function. As the data are subject to observation errors, our aim is to estimate the frontier function by minimising the sum of residuals as a linear loss function,

i.e., minimise

$$\sum_{j=i}^{n} u_j = \sum_{j=i}^{n} \sum_{i=o} \hat{\beta}_i \; x_{ij} - \sum_{j=1}^{n} y_j \qquad (5.21)$$

subject to

$$\sum_{i=o}^{m} \beta_i \, x_{ij} \geqslant y_j$$

and $$\beta_i \geqslant 0 \qquad (5.22)$$

For any particular data set $-\sum_{j=1}^{n} y_j$ is a constant, and hence can be dropped from the equation (5.21). Minimising (5.21) is the same as minimising

$$\sum_{j=1}^{n} \sum_{i=o}^{m} \hat{\beta}_i \; x_{ij} \qquad (5.23)$$

Dividing (5.22) by n farms, the number of observations, the objective function becomes :

$$\sum_{i=o}^{m} \hat{\beta}_i \; \bar{x}_i$$

$$= \hat{\beta}_o + \hat{\beta}_1 \bar{x}_1 + \hat{\beta}_2 \bar{x}_2 + \ldots\ldots\ldots + \hat{\beta}_m \; \bar{x}_m \qquad (5.24)$$

where,

$$\bar{x}_i = \frac{1}{n} \sum_{j=1}^{n} x_{ij}$$

and $$\bar{x}_o = 1$$

The problem then is to minimise the objective function

$$\hat{\beta}_o + \hat{\beta}_1 \bar{x}_1 + \hat{\beta}_2 \bar{x}_2 + \ldots\ldots\ldots + \hat{\beta}_m \bar{x}_m \qquad (5.25)$$

subject to the linear constraints

$$
\begin{array}{l}
\hat{\beta}_o + \hat{\beta}_1 x_{11} + \hat{\beta}_2 x_{21} + \ldots\ldots\ldots + \hat{\beta}_m x_{m1} \geqslant y_1 \\
\hat{\beta}_o + \hat{\beta}_1 x_{12} + \hat{\beta}_2 x_{22} + \ldots\ldots\ldots + \hat{\beta}_m x_{m2} \geqslant y_2 \\
\ldots \quad \ldots \quad \ldots \qquad \ldots \qquad \ldots \quad \ldots \\
\hat{\beta}_o + \hat{\beta}_1 x_{ij} + \hat{\beta}_2 x_{2j} + \ldots\ldots\ldots + \hat{\beta}_m x_{mj} \geqslant y_j \\
\ldots \quad \ldots \quad \ldots \qquad \ldots \qquad \ldots \quad \ldots \\
\hat{\beta}_o + \hat{\beta}_1 x_{1n} + \hat{\beta}_2 x_{2n} + \ldots\ldots\ldots + \hat{\beta}_m x_{mn} \geqslant y_n
\end{array}
\tag{5.26}
$$

and

$$\hat{\beta}_i \geqslant 0$$

Here, $\hat{\beta}_i$ s are the estimated parameters obtained by using linear programming technique. The estimate obtained from either equation indicates the output level (in the log form) which only the efficient farms can obtain from a given set of inputs.

5.5.4 Measurement of Technical Efficiency

Technical efficiency refers to the maximum quantity of output that can be achieved from a given set of inputs; the greater the output given the inputs, the higher the level of efficiency. The efficiency level of each farm relative to the best farm or the frontier efficiency rating is measured by the ratio of the actual observed output to the output predicted from the frontier function.

Once the frontier function is estimated, the efficiency index is calculated relative to this frontier.

The index of technical efficiency :

$$\frac{Y_j}{\hat{Y}_j} = \text{Antilog of } (y_j - \hat{y}_j) \tag{5.27}$$

where,

y_j is the log of the observed output of the j^{th} farm, and

$\hat{y}_j$ is the estimated output level from the frontier function.

CHAPTER 6

EMPIRICALLY ESTIMATED PRODUCTION FUNCTIONS

In this chapter, an analytical discussion of the empirically estimated production functions is presented. The first part deals with the statistical interpretation of the average and the second part with that of the frontier estimates.

6.1 Average Production Function

Two production functions were estimated by fitting a Cobb-Douglas functional form to 50 sample farms of Kabupaten LIOT, and 52 sample farms of Kabupaten MURA. Step wise regression analysis was performed using Y as a dependent variable and a selection of the above independent variables : X_1, X_2, ..., X21.

6.1.1 Production Elasticities

The best fit of the estimated coefficients and related statistics are summarized in Tables 6.1 and 6.2. The results show that a certain number of independent variables included are dropped completely from those two average production functions because they do not increase the goodness of fit. The average production function of Kabupaten LIOT appears to be different with the average production function of Kabupaten MURA.

In the case of Kabupaten LIOT (Table 6.1) the production coefficients for number of trees in tapping and the girth were positive and significant at the 1 per cent level. On the other hand the estimated coefficients of age of trees and depth of cut were negative and significant at the 1 per cent level.

The production elasticities of each input indicate the expected percentage increase (or decrease) in the output as a result of a one per cent increase in that input, with other input level held constant.

TABLE 6.1

THE ESTIMATED PARAMETERS AND RELATED STATISTICS OF AVERAGE PRODUCTION FUNCTION IN KABUPATEN LIOT

	Variable	Parameter
X1	Trees in tapping/ha.	0.8647*
		(0.1341)
X8	Age of farmer, year	-0.2575
		(0.1637)
X12	Age of trees, year	-0.3593**
		(0.1642)
X13	The Girth, cm	0.8552*
		(0.2987)
X17	Depth of cut, mm	-0.7565*
		(0.2525)
α	Constant	1.0416
$\bar{R}^2$		0.5780
R^2		0.6210
F		14.4177*
N	Number of cases	50

Notes: Figures in brackets are standard errors of estimates

* Significant at the 1% level in this and subsequent tables

** Significant at the 5% level

TABLE 6.2

THE ESTIMATED PARAMETERS AND RELATED STATISTICS OF AVERAGE PRODUCTION FUNCTION IN KABUPATEN MURA

	Variable	Parameter
X1	Trees in tapping/ha.	0.6002*
		(0.1071)
X2	Years since tapping, year	-0.0979**
		(0.0490)
X4	Number of cuts	0.4918*
		(0.1485)
X9	Education, year	0.2967*
		(0.0815)
X10	Experience, year	0.1333**
		(0.0672)
X11	Farm Size, ha.	-0.1865*
		(0.0610)
X16	Cleanliness (=dummy)	-0.5997*
		(0.1316)
X19	Tapping panel (=dummy)	0.5833*
		(0.1182)
D2	Other income (=dummy)	-0.0925
		(0.0834)
α	Constant	2.8268
$\bar{R}^2$		0.6699
R^2		0.7281
F		12.5001*
N	Number of cases	52

Notes: Figures in brackets are standard errors of estimates.

The results show that a 1 per cent increase in the number of trees in tapping and the girth could be expected to increase the output/yield by 0.86 and 0.83 per cent respectively. On the other hand, a 1 per cent increase in the age of trees and depth of cut could be expected to decrease the yield by 0.36 and 0.76 per cent respectively. A similar interpretation holds for age of farmer.

The coefficient of multiple correlation (R^2) measures the degree of goodness of fit of the production function and thus indicates the extent to which the input variables as a group contribute in explaining the output variations. In quantitative terms, we may say that the closer the R^2 is to unity, the better the model explains the data. As can be seen from Table 6.1 the value of R^2 is 0.62. The included factors explain 62 per cent of variations in the yield. The unexplained part of the variability in the yield is due to other input factors which have not been taken into account.

The F statistic was used to test the overall significance of the fitted functions. The F value of 14.4177 was significant at the 1 per cent level of significance; thus the null hypothesis that the input factors, as a whole, have no influence on the yield was rejected.

The simple correlation coefficient between the variables included in the production function indicates the degree of collinearity between them. Such coefficients are presented in Tables 6.3 and 6.4. These coefficients provide sufficient evidence to believe that mullticollinearity is not a problem for these estimated functions. Heady and Dillon (1961, p.136) have suggested that the highly correlated variables be omitted, that is, when the correlation coefficients are greater than 0.8.

In the case of Kabupaten MURA (Table 6.2), the coefficients of trees in tapping, number of cut, education and the condition of tapping panel were positive and significantly different from zero at the 1 per cent probability

TABLE 6.3

THE SIMPLE CORRELATION COEFFICIENTS BETWEEN SELECTED VARIABLES OF KABUPATEN LIOT

		Y	X_1	X_8	X_{12}	X_{13}	X_{17}
Y	Yield, kg/ha/day	1.0000	0.6822*	-0.2953+	-0.1600	0.2275	-0.1898
X_1	Trees in tapping/ha		1.0000	-0.2371	-0.0809	0.0416	0.0118
X_8	Age of farmer, year			1.0000	-0.0674	-0.2037	-0.1714
X_{12}	Age of trees, year				1.0000	0.2669++	-0.0649
X_{13}	Girth, cm					1.0000	0.1803
X_{17}	The depth of cut, mm						1.0000

* significant at the 0.1 per cent level

\+ significant at the 5 per cent level

++ significant at the 10 per cent level

TABLE 6.4

THE SIMPLE CORRELATION COEFFICIENTS BETWEEN SELECTED VARIABLES OF KABUPATEN MURA

		Y	D_2	X_1	X_2	X_4	X_9	X_{10}	X_{11}	X_{16}	X_{19}
Y	Yield, kg/ha/day	1.0000	-0.0317	0.4515*	-0.3268***	0.0726	0.1404	0.0932	-01648	-0.2554++	0.3641**
D_2	Other income (dummy)		1.0000	0.0243	0.0552	0.0120	-0.0650	-0.1910	-0.0574	-0.1999	0.0401
X_1	Trees in tapping/ha			1.0000	-0.0530	-0.1133	0.0532	0.1298	-0.0712	0.2590++	0.0931
X_2	Years since tapping commenced, year				1.0000	0.5043*	-0.0708	-0.0653	-0.1035	-0.0304	-0.5811*
X_4	Number of cuts					1.0000	0.0646	-0.0532	-0.0347	-0.3377***	-0.5198*
X_9	Education, year						1.0000	-0.5007*	0.0780	0.1254	-0.1656
X_{10}	Experience, year							1.0000	-0.0583	0.0384	0.0054
X_{11}	Farm Size, ha								1.0000	-0.0314	0.1420
X_{16}	Cleanliness (dummy)									1.0000	0.1417
X_{19}	Tapping Panel (dummy)										1.0000

* significant at the 0.1 per cent level
** significant at the 1 per cent level
*** significant at the 2 per cent level
++ significant at the 10 per cent level

level and those of farm size and cleanliness of holding were negative and significant at the 1 per cent level. The coefficient of number of years since tapping was negative and significant at the 5 per cent level, but the coefficient of experience was positive and significant at the 5 per cent level.

Thus, a 1 per cent increase in number of trees in tapping increases yield by 0.60 per cent, and a 1 per cent increase in number of cuts increase yield by 0.49 per cent. A similar interpretation holds for education, experience and the condition of the tapping panel.

On the other hand, a 1 per cent increase in the numbers of years since tapping decreases yield by 0.10 per cent, a 1 per cent increase in farm size decreases yield by 0.19 per cent and a 1 per cent increase in cleanliness of holding decreases yield by 0.60 per cent.

All these estimates indicate that yield could be expected to increase by increasing the number of trees in tapping, education, experience, and by improving the condition of the tapping panel. Yield is also positively correlated with the number of cuts. This was not anticipated. Maybe it can be explained by looking at the average age of the rubber trees in this region. Table 1.2 shows that the average age of rubber trees of the MURA farms selected is quite high, about 23.50 years. At this age, increasing the number of cuts can within limits be expected to increase yield, especially if tapping panels are maintained in a good condition.

The results further show that the estimates of the coefficients of number of years since tapping, farm size and cleanliness are negative. This indicates that output would decrease if these inputs are increased. The negative cleanliness coefficient is also unexpected. As noted earlier, weeding or slashing continually to make it easier for tappers to move, may expose the holding to soil erosion. It may cause leaching of soil nutrients and have negative effects on rubber yields.

Table 6.2 shows that the value of R^2 is 0.73; thus the included factors explain 73 per cent variations in the yield. The F value of 12.5001 is significant at the 1 per cent level; thus the null hypothesis that the input factors, as a whole, have no influence on the yield is rejected.

6.1.2 Returns to Scale

Both the functions presented in Tables 6.1 and 6.2 were estimated from the unrestricted form of the Cobb-Doublas production function. The estimated regression coefficients are, therefore, the production elasticities, and their sum measures the returns to scale.

In the function of Kabupaten LIOT, the production elasticities add up to 0.35, while in the function of Kabupaten MURA, they add up to 1.24. These sums indicate that if all five factors of production of Kabupaten LIOT were to increase simultaneously by one per cent, the gross output of rubber would increase by only 0.35 per cent (decreasing returns to scale). In the case of Kabupaten MURA, the sum indicates that if all six factors of production (not including the dummy variables) were to increase simultaneously by one per cent, the gross output of rubber would increase by 1.24 per cent (increasing returns to scale).

6.2 Frontier Production Function

The next stage is to examine the frontier production function, which was estimated using the Cobb-Douglas production function (Tables 6.1 and 6.2) from the same variables as the average production function discussed above. The only exception is that the dummy variables were not included in the average production function of Kabupaten MURA.

6.2.1 Frontier Coefficients

Tables 6.5 and 6.6 present the coefficients of the production functions estimated by these two methods. Equations (Ia), (Ib) and (IIa), (IIb), (IIc) in those tables represent the results obtained by fitting the

Cobb-Douglas production functions. Equations (I) and (II) are the average estimates in respect of Kabupaten LIOT and Kabupaten MURA which are presented here for the purpose of comparison.

Equation (Ia), labelled LP_{100} is a deterministic frontier function of Kabupaten LIOT estimated from the same set of data used in equation (I) (Table 6.5). With the exception of the coefficients of age of farmer, age of trees, depth of cut and the intercept which are dropped completely from the frontier, the rest of the estimated coefficients are similar with those of the average function. That means all those variables which are dropped from the frontier function are non-constraining variables. They do not immediately constrain rubber yields of frontier farms.

TABLE 6.5

THE ESTIMATES OF THE AVERAGE AND FRONTIER COEFFICIENTS OF KABUPATEN LIOT

	Variable	Equation		
		OLS_{100} (I)	LP_{100} (Ia)	LP_{98} (Ib)
α	Constant	1.0416	-	2.8552
X_1	Trees in tapping/ha	0.8647	0.8399	0.7062
X_8	Age of farmer, year	-0.2575	-	-
X_{12}	Age of trees, year	-0.3593	-	-
X_{13}	Girth, cm	0.8352	0.5417	-
X_{17}	Depth of cut, mm	-0.7565	-	-
$\bar{R}^2$		0.5780		
R^2		0.6210		
N		50	50	49

Notes: OLS - Ordinary Least Square
LP - Linear Programming
The estimates parameters of OLS_{98} are similar to those of OLS_{100}.

It is possible that the 'efficient' farms have been measured as efficient simply because of errors of observation or because of other problems. Timmer (1970) has suggested that in order to overcome any possible bias due to data problems, some of the efficient farms might be discarded from the data set, and the rest of the observations used to determine the frontier.

The equation (Ib) (LP_{98}) reports what happens as the first 2 per cent of the 'efficient' farms (one observation) from equation (Ia) are removed from the data file. With 2 per cent of the observations removed, almost all of the coefficients are dropped completely from the frontier, except the intercept and the coefficient of the trees in tapping, which looked similar with that of equations (I) and (Ia), indicating that the coefficients seem to have stabilised. The intercepts, however, are very different. The antilog of the intercept of the frontier function is 513.26 per cent higher than that of the average function (I).

Comparing the average function (I) with the frontier function (Ib), there is a fall of 22.55 per cent in the coefficient of the number of trees in tapping. The differences between the two functions could safely be considered to be insignificant[1]. This suggests that the differences between the frontier and average production function are concentrated in the constant term.

Brown (1966) divided technological change into two categories: neutral and non-neutral.

> "A neutral change alters the production function but does not affect the marginal rate of substitution. A non-neutral change does affect the marginal rate of substitution."

In accordance with this definition, the frontier function for rubber of Kabupaten LIOT seems to have shifted neutrally upward from the average function.

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1 However, no formal tests of significance are available which could be used to check this statement.

Equation (IIa) presents the results of a deterministic frontier function estimated from the same data set as used in equation (II) of Kabupaten MURA (Table 6.6). Equations (IIb) and (IIc) (LP_{98} and LP_{96}) are the probabilistic frontiers estimated by removing 2 per cent and 4 per cent of the 'efficient' farms from equation (IIa). The results are given by equation (IIc). With the exception of the coefficients of years since tapping, number of cut, experience and farm size which are dropped completely from the frontier, the rest of the coefficients are similar to those of equation (II), indicating that stabilization of the coefficients seems to have occurred.

When compared to the average function (II), the frontier function (IIc) indicates almost no change in the coefficient of number of trees in tapping (a rise of 1.21 per cent), but a fall of 43.35 per cent in the education coefficient. The differences could safely be considered to be insignificant[2]. The intercepts, however, are different. The antilog of the intercept of the frontier is 38.86 per cent higher than that of the average function. This is as might be expected.

The difference in technological change between the average and the frontier for rubber production of Kabupaten MURA also appears to be neutral, similar to that of Kabupaten LIOT.

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2 There are no formal tests of significance with which this assertion can be checked.

TABLE 6.6

THE ESTIMATES OF THE AVERAGE AND FRONTIER COEFFICIENTS

OF KABUPATEN MURA

	Variable	Equation			
		OLS_{100} (II)	LP_{100} (IIa)	LP_{98} (IIb)	LP_{96} (IIc)
α	Constant	3.7768	1.5486	4.0245	4.1051
X_1	Trees in tapping/ha	0.5350*	1.0596	0.5633	0.5415
		(0.1414)			
X_2	Years since tapping commenced, year	-0.2377*	-	-	-
		(0.0590)			
X_4	Number of cuts	0.5181*	-	0.0381	-
		(0.1804)			
X_9	Education, year	0.1656	0.0373	0.0425	0.0905
		(0.1057)			
X_{10}	Experience, year	0.0771	-	-	-
		(0.0874)			
X_{11}	Farm Size, ha	-0.1362	-	-0.0072	-
		(0.0823)			
$\bar{R}^2$		0.3848			
R^2		0.4572			
N		52	52	51	50

Notes: OLS - Ordinary Least Square

LP - Linear Programming.

The estimates parameters of OLS_{98} and OLS_{96} are similar with OLS_{100}

Figures in brackets are standard errors of estimates.

CHAPTER 7

TECHNICAL EFFICIENCY OF THE FARMERS

Estimations using fitted production functions can enable one to judge one farm's performance relative to that of another when different factor-amounts and proportions are used. Two different vectors of technical efficiency for each region are generated from the production function results of Tables 6.5 and 6.6. A comparative analysis of the efficiency vector derived from the average production function and the efficiency vector derived from the frontier production function is presented for the two regions separately.

7.1 Efficiency Ratings

The technical efficiency ratings of the average and the frontier functions are the ratios of the actual output to the calculated average output or calculated frontier output respectively.

Technical efficiency ratings were calculated using equation (5.9) for the average production function and equation (5.27) for the frontier production function. The resulting efficiency factors are presented in Tables 7.1 and 7.2 along with rankings of each vector. The farm with the highest efficiency was assigned rank 1; tied efficiencies were assigned the average of tied ranks.

Columns 2 and 4 of Table 7.1 present the efficiency ratings for Kabupaten LIOT. These are derived from equation (I) and (Ib) of Table 6.5. Table 7.2 presents the efficiency ratings for Kabupaten MURA. These are derived from equation (II) and (IIc) of Table 6.6.

7.2 Technical Efficiency

Setting the average efficiency level equal to unity, the estimated efficiency ratings in rubber production of Kabupaten LIOT varied from a minimum of 0.3252 to a maximum of 1.8735. These values suggest that the best farm could produce 87 per cent higher output of rubber than the average farm which, in turn, could attain 68 per cent more output than the

TABLE 7.1

TECHNICAL EFFICIENCY IN RUBBER PRODUCTION

OF KABUPATEN LIOT

Farm No.	AVERAGE FUNCTION Efficiency Rating	AVERAGE FUNCTION Rank	FRONTIER FUNCTION Efficiency Rating	FRONTIER FUNCTION Rank
1	.7023	40.0	.3810	35.0
2	.9391	31.0	.4698	21.0
3	1.2564	15.0	.4968	17.0
4	1.1509	17.0	.6005	10.0
5	.9047	35.0	.4334	30.0
6	1.3126	13.0	.4317	31.0
7	.6275	47.0	.3037	43.0
8	.9540	26.0	.4353	29.0
9	1.3401	11.0	.4799	18.0
10	1.0440	23.0	.3587	37.0
11	1.6270	5.0	.6383	7.0
12	1.6132	6.0	.6109	9.0
13	.3252	50.0	.1403	49.0
14	1.1194	19.0	.7305	5.0
15	.9527	27.0	.4623	24.0
16	1.3582	10.0	.7588	4.0
17	1.6910	4.0	-	-
18	.5994	48.0	.3689	36.0
19	1.4426	7.0	.6357	8.0
20	1.4141	8.0	.5984	11.0
21	.9054	34.0	.4953	19.0
22	1.2846	14.0	.8353	3.0
23	1.8735	1.0	1.0000	1.5
24	.9484	29.0	.4617	25.0
25	.6731	44.0	.1850	47.0
26	.9241	33.0	.5138	14.0
27	1.7560	3.0	.4604	26.0
28	1.0804	20.0	.3814	35.0
29	.7240	39.0	.2328	46.0
30	1.0507	22.0	.4229	32.0
31	.8489	37.0	.5002	16.0
32	.9474	30.0	.5027	15.0
33	.8878	36.0	.5953	12.0
34	1.3995	9.0	.7239	6.0
35	1.0408	24.0	.5142	13.0
36	.6898	42.0	.3189	42.0
37	1.0600	21.0	.4640	22.0
38	1.2343	16.0	.4113	33.0
39	.5990	49.0	.2412	45.0
40	1.7935	2.0	1.0000	1.5
41	.6365	46.0	.2958	44.0
42	.9313	32.0	.4596	27.0
43	1.1234	18.0	.4707	20.0
44	1.0038	25.0	.3317	40.0

(Continued)

TABLE 7.1 (Continued)

Farm No.	AVERAGE FUNCTION		FRONTIER FUNCTION	
	Efficiency Rating	Rank	Efficiency Rating	Rank
45	.6959	41.0	.3544	38.0
46	.8464	38.0	.3830	34.0
47	.9493	28.0	.3296	41.0
48	.6387	45.0	.3435	39.0
49	1.3374	12.0	.4519	28.0
50	.6747	43.0	.1794	48.0

TABLE 7.2

TECHNICAL EFFICIENCY IN RUBBER PRODUCTION

OF KABUPATEN MURA

Farm No.	AVERAGE FUNCTION		FRONTIER FUNCTION	
	Efficiency Rating	Rank	Efficiency Rating	Rank
1	.5596	49.0	.3064	45.0
2	1.1920	20.0	.8842	11.0
3	1.5197	6.0	.9244	8.0
4	.8332	40.0	.7093	21.0
5	1.6941	3.0	.7910	16.0
6	1.3821	11.0	.9264	7.0
7	.6296	46.0	.4249	40.0
8	1.1962	19.0	.8061	14.0
9	.7904	41.0	.8512	13.0
10	1.4957	7.0	.8890	10.0
11	1.6175	5.0	-	-
12	.9378	29.0	.4883	34.0
13	1.4542	9.0	-	-
14	.8654	35.0	.7221	20.0
15	1.1486	22.0	.9999	2.0
16	1.7037	1.0	.9437	5.0
17	1.1977	18.0	.9685	4.0
18	.8608	36.0	.8085	12.0
19	.9196	31.0	.5405	30.0
20	1.4347	10.0	.9997	2.0
21	1.4860	8.0	.7967	15.0
22	.9834	27.0	.4670	39.0
23	.4769	51.0	.3749	42.0
24	.8833	32.0	.4682	38.0
25	.8378	38.0	.4818	35.0
26	.7763	42.0	.5510	32.0
27	.6345	45.0	.2837	48.0
28	.8819	33.0	.3538	43.0
29	1.1767	21.0	.6213	25.0
30	1.2968	16.0	.7328	18.0
31	1.2982	15.0	.6895	22.0
32	1.0442	25.0	.5526	29.0
33	.9474	28.0	.6445	23.0
34	.3796	52.0	.2699	49.0
35	.8457	37.0	.5776	27.0
36	1.3570	13.0	.9432	6.0
37	1.1324	23.0	.5611	28.0
38	1.2560	17.0	.7253	19.0
39	1.3085	14.0	.5390	31.0
40	.4923	50.0	.2511	50.0
41	1.3540	12.0	.9998	2.0
42	.7760	43.0	.4027	41.0
43	1.1168	24.0	.6379	24.0
44	.6190	47.0	.2951	46.0
45	.7718	44.0	.3183	44.0
46	.5931	48.0	.2869	47.0

(Continued)

TABLE 7.2 (Continued)

Farm No	AVERAGE FUNCTION		FRONTIER FUNCTION	
	Efficiency Rating	Rank	Efficiency Rating	Rank
47	1.6924	4.0	.9063	9.0
48	.8359	39.0	.4783	36.0
49	.8703	35.0	.6053	26.0
50	.9885	26.0	.4710	37.0
51	1.7016	2.0	.7342	17.0
52	.9207	30.0	.5050	33.0

worst farm. The worst farm was producing only 32 per cent of the average output.

As regards the frontier function (N=49), the efficiency ratings varied from 0.1403 to 1.0000. There are two farms which had the highest efficiency level of 1.0000. Altogether, about 6 per cent of the farms had a measured technical efficiency within 20 per cent of the frontier function; about 34 per cent of the farms, inclusive of the two most efficient farms, were operating within 50 per cent of the frontier. The least efficient farm (Farm No. 13 in Table 7.1) had efficiency level of only 0.1403, which suggests that given the same level of inputs, the most efficient farm could produce 86 per cent more output of rubber than the least efficient farm.

In the case of Kabupaten MURA, the efficiency ratings in relation to the average function varied from a minimum of 0.3796 to a maximum of 1.7037. These values indicate that the best farms could obtain 70 per cent more output than the average farm which, in turn, could produce 62 per cent more output than the worst farm. The worst farm was producing only 38 per cent of the average.

The frontier efficiency ratings (N=50) reveal that three farms were found to have operated exactly on the frontier. The estimated efficiency ratings varied from a minimum of 0.2551 to a maximum of 0.9999. The efficiency rating further suggested that 24 per cent of farms, inclusive of the three most efficient farms, had technical efficiency within 20 per cent of the frontier function, and about 66 per cent of the farms were operating within 50 per cent of the frontier. The least efficient farm (Farm No. 40 in Table 7.2) was, however, about 75 per cent away from the frontier. For a given set of inputs, therefore, the least efficient farm produced 75 per cent less output of rubber than the most efficient farm.

7.3 Comparison of the Efficiency Ratings from the Average and the Frontier Production Functions

The use of two different methods to generate estimates of technical efficiency invites comparison to see if any relationship exists between these two efficiency vectors. With a view to examining the relationship between those two efficiency vectors, the Spearmen rank correlation coefficient (r_s) between the corresponding sets of ranking was calculated. A t-test was then used for testing the significance of r_s. The calculated value of the t-statistic and the related statistics for the two regions are shown in Table 7.3.

From Table 7.3, it is evident that the calculated value of t for the two regions is highly significant at all plausible levels of significance.

TABLE 7.3

TEST STATISTICS BETWEEN AVERAGE AND FRONTIER EFFICIENCY RATINGS

	Region	
	LIOT	MURA
Spearman rank correlation coefficient	0.74	0.84
Value of t-statistics	8.04	10.81
Degrees of freedom	47	48
No of observation	49	50

Therefore the null hypothesis of zero correlation between these two sets of efficiency ratings is rejected in favour of the alternative hypothesis that there exists a relationship between the two. The Spearman correlation coefficient further suggests the presence of a strongly positive correlation between the two sets of rankings. Furthermore, the frontier ratings were plotted against the average ratings for both the regions separately.

FIGURE 7.1

AVERAGE AND FRONTIER EFFICIENCY RATINGS

KABUPATEN LIOT

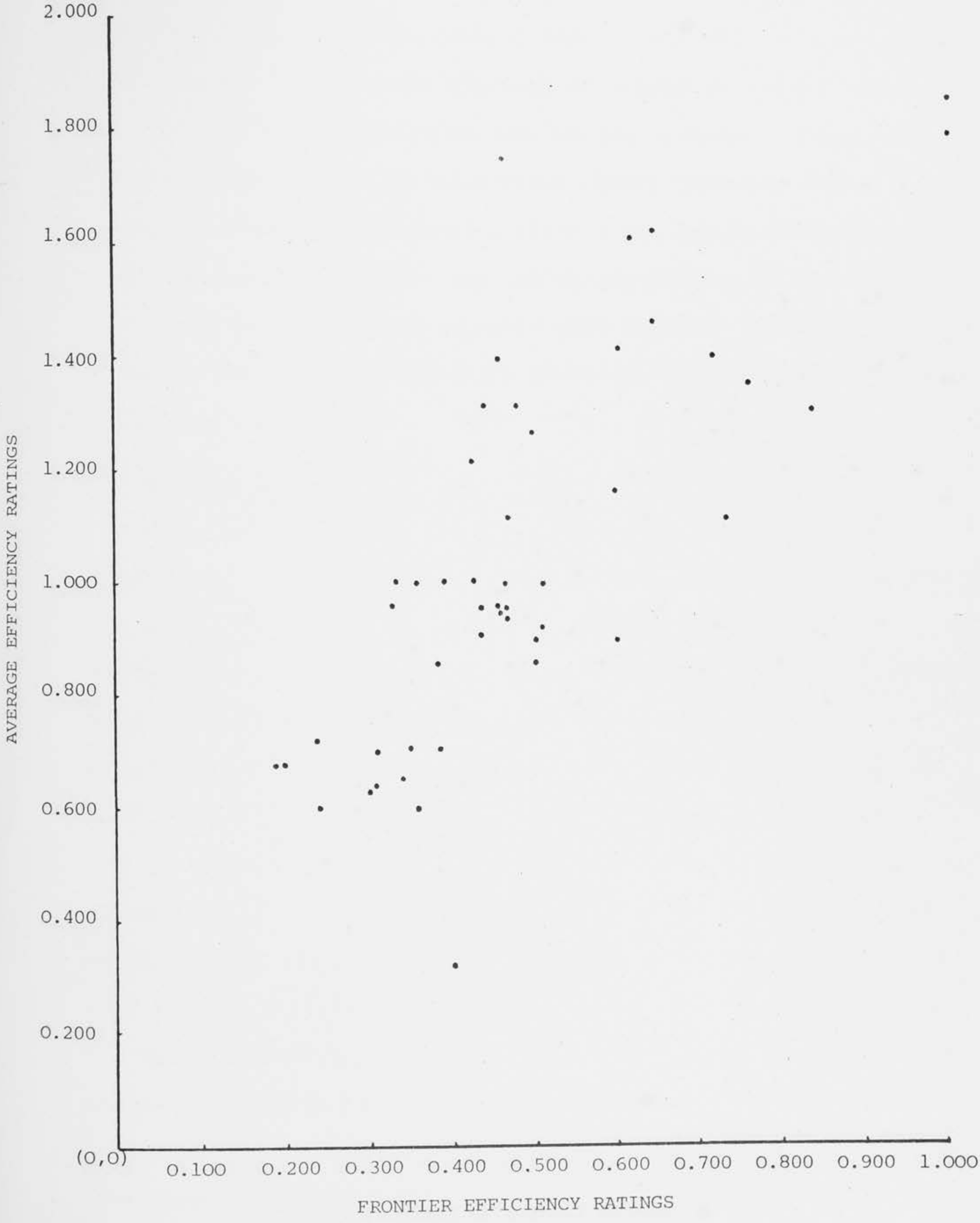
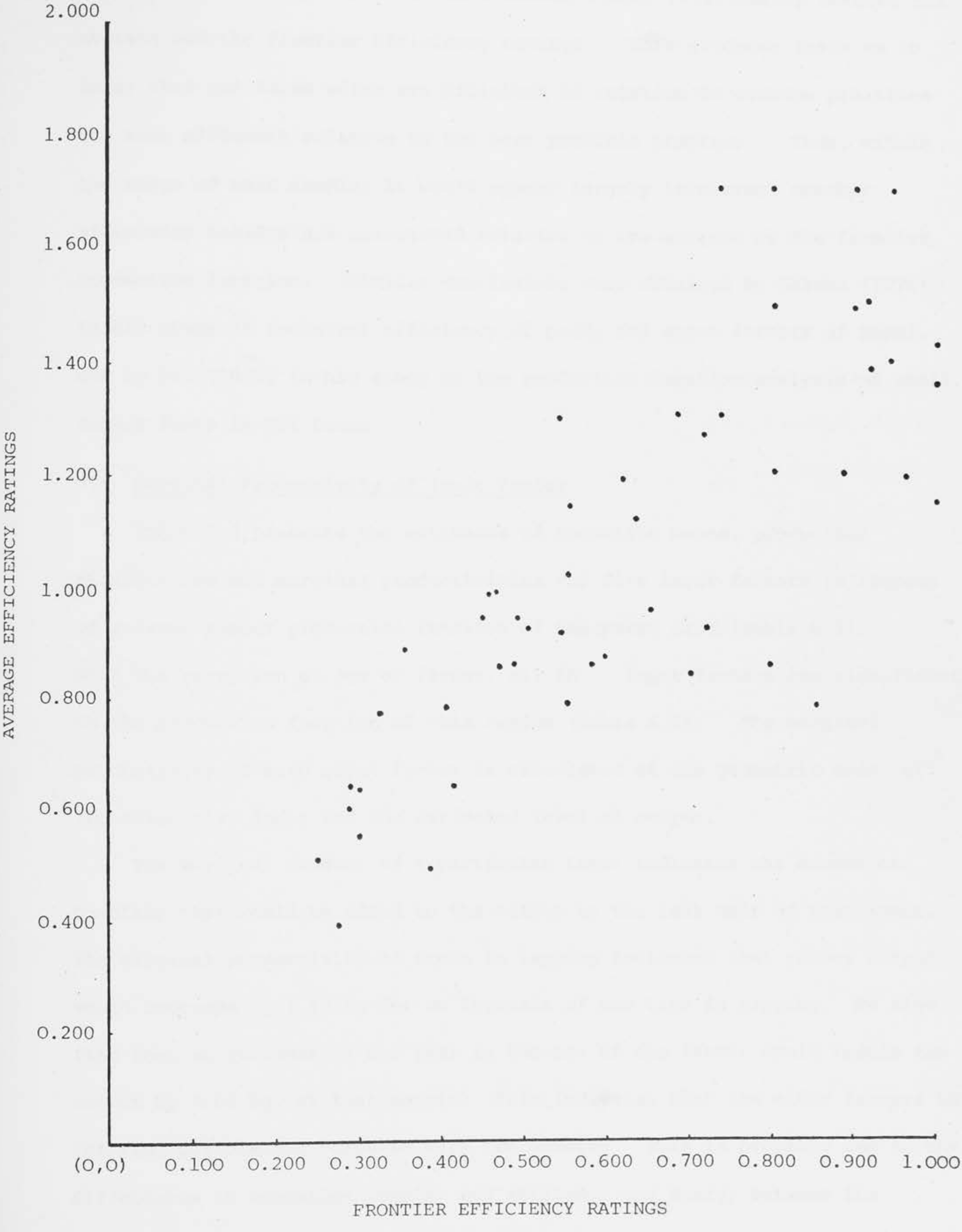


FIGURE 7.2

AVERAGE AND FRONTIER EFFICIENCY RATINGS

KABUPATEN MURA



The resulting graphs are shown in Figures 7.1 and 7.2. Both the figures clearly indicate the existence of a strong linear relationship between the average and the frontier efficiency ratings. This evidence leads us to infer that the farms which are efficient in relation to average practices are also efficient relative to the best possible practice. Thus, within the range of this sample, it would appear largely irrelevant whether efficiency ratings are calculated relative to the average or the frontier production function. Similar conclusions were obtained by Sharma (1974) in his study of technical efficiency of paddy and wheat farmers of Nepal, and by Teo (1976) in his study of the production function analysis of small rubber farms in Sri Lanka.

7.4 Marginal Productivity of Input Factor

Table 7.4 presents the estimates of geometric means, production elasticities and marginal productivities for five input factors in respect of average rubber production function of Kabupaten LIOT (Table 6.1). With the exception of age of farmer, all th input factors are significant in the production function of this region (Table 6.1). The marginal productivity of each input factor is calculated at the geometric mean of the respective input and the estimated level of output.

The marginal product of a particular input indicates the amount or quantity that would be added to the output by the last unit of that input. The marginal productivity of trees in tapping indicates that rubber output would increase by 1.12 kg for an increase of one tree in tapping. We also find that an increase of one year in the age of the farmer would reduce the output by 3.68 kg, at that margin. This indicates that the older farmers have inferior performance compared with the younger. This is probably due to the differences in education levels, and attitudes and energy between the younger and the older farmers (Appendix Table 4.2).

The marginal productivity of the age of trees as anticipated indicates that if the age of trees increases by a year, rubber output would decrease by 16.81 kg. This indicates that the average rubber yield on farms in this survey area is in the diminishing stage, even though the trees have only been tapped for about 5 years on average.

An increase of one centimetre in the girth of the trees would contribute 10.92 kg at the margin to the rubber output. Consequently, it is very important to secure good maintenance during the immature period of rubber trees to produce higher subsequent yields.

The marginal productivity of the depth of cut indicates that an increase of one millimetre in the depth of cut would reduce rubber output by 80.79 kg. This result indicates that, on average, the farmers tapped their rubber trees too deep. This has had a negative effect on rubber yield.

Table 7.5 presents the estimates of geometric means, production elasticities for six input factors (not inclusive dummy variables) in respect of average rubber production function of Kabupaten MURA (Table 6.2). All the input factors are significant in the production function of this region. The estimated production elasticities are those obtained from the function given in Table 6.2.

The marginal productivity of trees in tapping indicates that an increase of one rubber tree in tapping would contribute 1.89 kg at the margin to the rubber per year. Rubber output decreases by 7.22 kg for every increase of a year since tapping. This indicates that on average the rubber yields in the survey areas would decline as rubber trees become older. Years since tapping is highly, though not significantly, correlated with age of trees.

TABLE 7.4

GEOMETRIC MEANS, PRODUCTION ELASTICITIES AND MARGINAL PRODUCTIVITIES OF VARIOUS INPUTS IN RUBBER PRODUCTION OF KABUPATEN LIOT

	Variable					
	Estimated level of Output	Trees in Tapping	Age of Farmer	Age of Trees	Girth	Depth of Cut
	$\hat{Y}$	X_1	X_8	X_{12}	X_{13}	X_{17}
	(kg)		(year)	(Year)	(cm)	(mm)
G.M.	619.41	479.12	43.36	13.24	48.50	5.80
$\hat{\beta}_i$		0.8647	- 0.2575	- 0.3593	0.8552	- 0.7565
$MP_i = \hat{\beta}_i \frac{\hat{\bar{Y}}}{\bar{X}_i}$		1.12	- 3.68	-16.81	10.92	-80.79

G.M - Geometric Mean

$\hat{\beta}_i$ - Estimated production elasticity of the i^{th} factor

$\hat{Y}$ - Estimated level of output when each input is held at its geometric mean

MP_i - Marginal productivity of the i^{th} factor

TABLE 7.5

GEOMETRIC MEANS, PRODUCTION ELASTICITIES AND MARGINAL PRODUCTIVITIES OF VARIOUS INPUTS IN RUBBER PRODUCTION OF KABUPATEN MURA

Item	Variable						
	Estimated Level of Output $\hat{Y}$ (kg)	Trees in Tapping X_1	Years Since Tapping X_2 (year)	Number of Cuts X_4	Education X_9 (year)	Experience X_{10} (year)	Farm Size X_{11} (Ha)
G.M	953.00	302.96	12.92	1.42	3.96	18.77	2.58
$\hat{\beta}_i$		0.6002	- 0.6002	- 0.0979	0.2967	0.1333	- 0.1865
$MP_i = \hat{\beta}_i \frac{\bar{\hat{Y}}}{\bar{X}_i}$		1.89	- 7.22	330.06	71.40	6.77	-68.89

G.M - Geometric Mean

$\hat{\beta}_i$ - Estimated production elasticity of the i^{th} factor

$\hat{Y}$ - Estimated level of output when each input is held at its geometric mean

MP_i - Marginal productivity of the i^{th} factor

An increase of one cut of tapping per tree, of a year of schooling and of a year in the experience of the farmer, would increase rubber output by 330.06 kg per year, 71.40 kg per year and 6.77 kg per year respectively.

An increase of one hectare of farm size would reduce rubber output per year by 68.89 kg. This indicates that smallholders produce more rubber per hectare than farmers with bigger areas, and is in line with findings on size/productivity relationships in other crops (Khusro, 1964).

The marginal productivities discussed so far relate to the average farms of these two kabupatens studied. That is, these results indicate only the average level of the whole distribution. The marginal productivity of each input factor for each individual farm of Kabupaten LIOT and Kabupaten MURA is presented in Tables 7.6 and 7.7 respectively.

From Table 7.6, it is evident that the marginal productivity of trees in tapping in Kabupaten LIOT varied from a minimum of 0.38 kg to a maximum of 3.22 kg. The distribution of the marginal productivity of trees in tapping is shown in Table 7.8, and its graphical representation is given in Figure 7.3. For about 76 per cent of the farms, the marginal productivity to one rubber tree was greater than 0.93 kg and for fifty per cent of the farms it was greater than 1.11 kg. There are 26 farms (or more than fifty per cent) which have values with cluster at 0.80 - 1.30. In general, the marginal productivity of trees in tapping is positively related to the technical efficiency ratings.

TABLE 7.6

MARGINAL PRODUCITIVITY OF INPUT FACTORS BY INDIVIDUAL

FARM OF KABUPATEN LIOT

(kg/ha/year)

Farm No.	Marginal Productivity of				
	Trees in tapping	Age of farmer (-)	Age of trees (-)	Girth	Depth of cut (-)
1	.97	4.29	11.18	6.39	58.84
2	1.08	3.45	22.46	10.80	94.56
3	1.20	3.00	11.43	9.74	88.26
4	1.27	10.01	29.94	19.10	147.10
5	1.11	3.00	15.72	9.33	79.43
6	1.19	2.05	8.73	6.77	47.28
7	.73	2.89	12.09	5.99	47.28
8	.99	2.77	17.96	10.08	88.26
9	1.39	1.98	15.72	8.70	55.16
10	1.01	2.14	6.99	6.35	44.13
11	1.71	2.82	16.77	10.63	88.26
12	1.69	4.98	14.84	10.35	66.95
13	.39	.67	3.35	1.95	17.65
14	1.97	3.98	17.68	12.65	198.58
15	1.08	6.93	14.79	11.24	88.26
16	1.73	10.17	36.68	18.60	154.45
17	3.22	17.26	58.22	22.55	294.19
18	.93	3.08	13.97	6.50	70.61
19	1.70	2.57	20.96	11.69	105.91
20	1.42	5.01	31.44	17.40	110.32
21	1.01	7.11	31.44	19.49	158.86
22	1.45	24.72	46.57	38.67	392.26
23	2.42	12.02	50.30	27.84	211.82
24	.98	9.39	26.20	20.88	132.39
25	.50	.79	5.37	4.78	24.52
26	1.51	2.22	7.01	10.13	169.73
27	1.31	2.25	7.86	9.87	55.16
28	1.10	2.37	3.93	4.87	44.13
29	.66	2.31	4.03	4.93	28.29
30	.98	6.50	15.72	12.18	70.92
31	1.24	5.83	29.47	10.75	82.74
32	1.30	3.88	21.68	9.00	76.08
33	1.46	3.78	41.46	14.35	152.75
34	1.49	12.87	67.37	32.12	189.12
35	1.17	5.15	37.73	18.96	127.09
36	.74	2.68	25.66	12.28	75.65
37	1.23	2.82	26.95	10.69	66.19
38	1.13	1.40	15.09	8.55	52.95
39	.73	1.67	6.99	3.96	24.52
40	2.94	9.80	39.30	12.82	94.56
41	.65	3.75	12.57	7.69	56.74

(Continued)

TABLE 7.6 (Continued)

Farm No.	Marginal Productivity of				
	Trees in tapping	Age of farmer (-)	Age of trees (-)	Girth	Depth of cut (-)
42	1.21	5.01	18.86	8.27	56.74
43	1.07	3.84	27.34	15.13	95.93
44	.90	.95	15.72	7.49	44.13
45	.88	3.00	16.77	7.49	58.84
46	1.06	1.99	17.37	8.07	58.51
47	1.01	1.93	6.74	4.57	28.37
48	.86	4.51	11.23	6.52	55.16
49	1.30	2.51	11.61	7.62	45.39
50	.38	1.70	7.86	8.86	37.82

TABLE 7.7

MARGINAL PRODUCTIVITY OF INPUT FACTORS BY INDIVIDUAL

FARM OF KABUPATEN MURA

(kg/ha/year)

Farm No.	Marginal Productivity of					
	Trees in tapping	Years since tapping (-)	Number of cuts	Education	Experience	Farm size (-)
1	1.00	5.58	196.34	39.48	5.32	57.27
2	3.77	19.36	340.32	68.44	23.06	103.25
3	2.97	31.76	638.11	96.24	6.65	75.62
4	1.95	31.76	319.05	64.16	8.65	60.49
5	2.22	7.94	638.11	96.24	6.40	120.99
6	2.39	77.91	782.75	157.41	9.64	74.21
7	1.38	13.55	272.26	54.75	2.95	82.60
8	2.85	6.65	233.97	94.10	5.07	88.73
9	2.34	50.81	382.87	76.99	13.84	290.38
10	3.16	28.23	567.21	68.44	38.43	143.40
11	4.25	338.73	1701.63	342.19	30.75	2581.16
12	1.38	1.61	170.16	102.66	2.31	64.53
13	3.81	93.15	467.95	282.31	6.34	39.43
14	2.54	15.52	233.97	56.46	7.05	88.73
15	3.81	97.71	490.85	148.06	6.65	119.32
16	2.97	23.99	723.19	72.72	24.50	137.12
17	3.71	112.91	567.21	68.44	6.15	43.02
18	1.73	33.87	425.41	171.10	9.22	322.64
19	1.66	21.17	425.41	42.77	5.76	36.66
20	2.56	84.68	850.81	171.10	46.12	248.18
21	2.60	16.94	510.49	102.66	9.22	77.43
22	1.45	3.39	255.24	153.99	2.31	96.79
23	1.72	6.77	85.08	25.66	3.07	18.44
24	1.45	2.54	127.62	153.99	3.46	32.26
25	1.77	6.77	340.32	20.53	8.38	129.06
26	1.73	5.64	170.16	102.66	4.61	103.25
27	.78	2.54	127.62	25.66	69.18	19.35
28	1.04	2.17	283.60	34.22	3.84	43.02
29	2.59	1.83	170.16	34.22	7.09	57.36
30	2.59	3.85	212.70	85.55	5.49	53.77
31	3.89	1.18	127.62	30.80	11.53	96.79
32	1.73	2.82	212.70	42.77	19.22	80.66
33	1.66	10.84	272.26	109.50	5.90	63.54
34	.93	16.94	170.16	25.66	4.61	32.26
35	1.66	9.03	226.88	68.44	7.23	57.36
36	2.91	11.85	297.78	179.65	8.07	112.92
37	1.75	13.31	467.95	31.37	18.12	44.36
38	1.66	37.64	567.21	342.19	3.84	47.79
39	1.66	9.68	340.32	102.66	23.06	25.81
40	.73	5.93	148.89	89.82	1.34	14.11

(Continued)

TABLE 7.7 (Continued)

Farm No.	Marginal Productivity of					
	Trees in tapping	Years since tapping (-)	Number of cuts	Education	Exper- ience	Farm size (-)
41	2.74	25.58	449.72	90.44	17.41	97.45
42	1.13	6.16	340.32	41.06	3.42	64.53
43	1.51	13.17	595.57	119.77	6.46	225.85
44	.95	5.27	238.23	15.97	16.14	36.14
45	.67	4.84	340.32	68.44	3.69	25.81
46	.82	2.26	226.88	34.22	4.10	114.72
47	2.34	3.05	382.87	153.99	10.38	290.38
48	1.19	1.35	170.16	205.32	2.31	258.12
49	1.68	46.57	467.95	94.10	3.62	44.36
50	1.25	8.47	382.87	76.99	3.46	34.16
51	2.77	1.81	226.88	45.62	12.30	34.41
52	1.58	9.68	340.32	68.44	4.19	64.53

TABLE 7.8

DISTRIBUTION OF MARGINAL PRODUCTIVITY OF TREES IN TAPPING

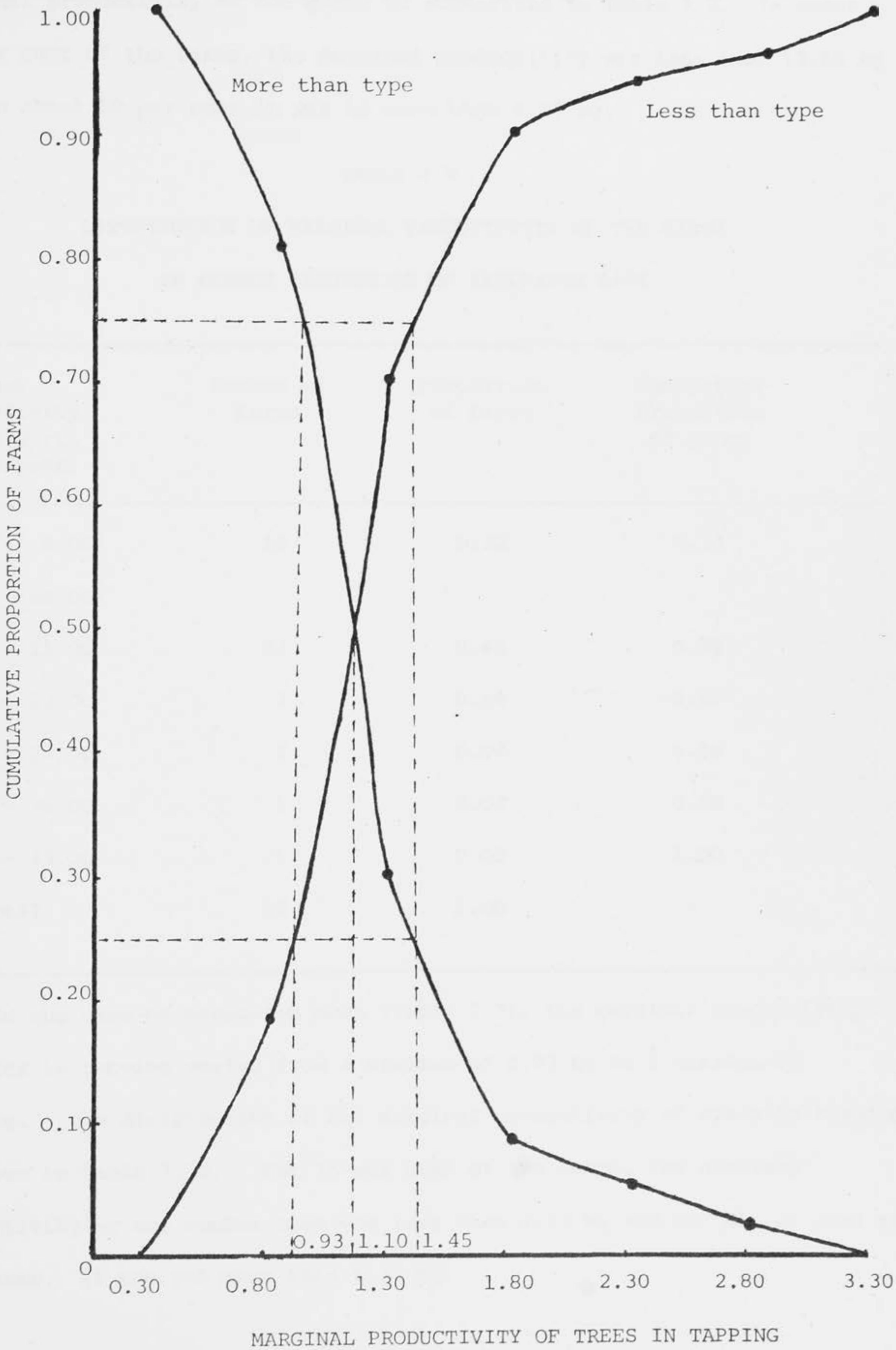
IN RUBBER PRODUCTION OF KABUPATEN LIOT

Marginal Product of Trees in Tapping (in kg/ha/year)	Number of Farms	Proportion of Farms	Cumulative Proportion of Farms (less than type)	Cumulative Proportion of Farms (more than type)
0.30 - 0.80 (≤0.80)	9	0.18	0.18	1.00
0.80 - 1.30	26	0.52	0.70	0.82
1.30 - 1.80	11	0.22	0.92	0.30
1.80 - 2.30	1	0.02	0.94	0.08
2.30 - 2.80	1	0.02	0.96	0.06
2.80 - 3.30	2	0.04	1.00	0.04
Total	50	1.00	-	-

FIGURE 7.3

MARGINAL PRODUCTIVITY OF TREES IN TAPPING

OF KABUPATEN LIOT



The productivity of an additional centimetre of girth of tree varied from a minimum of 1.95 kg to a maximum of 38.67 kg. The distribution of the marginal productivity of the girth is summarized in Table 7.9. In about 76 per cent of the farms, the marginal productivity was less than 12.65 kg and in about 50 per cent it was no more than 9.87 kg.

TABLE 7.9

DISTRIBUTION OF MARGINAL PRODUCTIVITY OF THE GIRTH IN RUBBER PRODUCTION OF KABUPATEN LIOT

Marginal Productivity of the Girth (kg/ha/year)	Number of Farms	Proportion of Farms	Cumulative Proportion of Farms
1.00 - 8.00 (≤8.00)	16	0.32	0.32
8.00 - 15.00	23	0.46	0.78
15.00 - 22.00	7	0.14	0.92
22.00 - 29.00	2	0.04	0.96
29.00 - 36.00	1	0.02	0.98
36.00 - 43.00	1	0.02	1.00
Total	50	1.00	-

In the case of Kabupaten MURA (Table 7.7), the marginal productivity of trees in tapping varied from a minimum of 0.67 kg to a maximum of 4.25 kg. The distribution of the marginal productivity of trees in tapping is shown in Table 7.10. For 75 per cent of the farms, the marginal productivity of one rubber tree was less than 2.74 kg and for 25 per cent of the farms, it was not more than 1.38 kg.

TABLE 7.10

DISTRIBUTION OF MARGINAL PRODUCTIVITY OF TREES IN

TAPPING IN RUBBER PRODUCTION OF KABUPATEN MURA

Marginal Productivity of Trees in Tapping (kg/ha/year)	Number of Farms	Proportion of Farms	Cumulative Proportion of Farms
0.65 - 1.25	10	0.19	0.19
(≤1.25)			
1.25 - 1.85	19	0.37	0.56
1.85 - 2.45	5	0.10	0.66
2.45 - 3.05	11	0.20	0.86
3.05 - 3.65	2	0.04	0.90
3.65 - 4.25	5	0.10	1.00
Total	52	1.00	-

The marginal productivity of education, varied from 15.97 kg to 342.19 kg. The distribution of the marginal productivity of education is shown in Table 7.11. For 75 per cent of the farms, the productivity of education was less than 119.77 kg, and for 25 per cent of the farms it was not more than 42.77 kg.

A similar interpretation can be made for the marginal returns to depth of cut, and experience of the farmer. The distributions of marginal productivities of depth of cut and experience are presented in Appendix Tables 7.12 and 7.13.

TABLE 7.11

DISTRIBUTION OF MARGINAL PRODUCTIVITY OF EDUCATION

IN RUBBER PRODUCTION OF KABUPATEN MURA

Marginal Productivity of Trees in Tapping (kg/ha/year	Number of Farms	Proportion of Farms	Cumulative Proportion of Farms
15.00 - 70.00 (≤70.00)	24	0.46	0.46
70.00 - 125.00	16	0.31	0.77
125.00 - 180.00	8	0.15	0.92
180.00 - 235.00	1	0.02	0.94
235.00 - 290.00	1	0.02	0.96
290.00 - 345.00	2	0.04	1.00
Total	52	1.00	-

CHAPTER 8

FACTORS RESPONSIBLE FOR THE FARMER YIELD GAP

This survey revealed that sample farmers cultivating under the same process of production varied in their performance. This implies that further realisation of the potential of the rubber cultivation is still possible. However, it should also be borne in mind that variation in performance among the participants producing under the same process of production could also happen because of differences in technique used, variations in socio-economic and biological factors including management ability or differing random elements. There may be important constraints to altering performance, which have not been taken into account in this analysis.

By estimating the frontier yield (maximum possible yield = MPY) from yield data, comparisons can be made with the production function representing the average technology of the area. A calculation of the difference between the maximum possible yield and the actual yield obtained by individual farmers, which is described as the farmer yield gap in this study, enables us to analyse some important factors acting as constraints.

It is assumed in this comparison that the yield a farmer can achieve, using the available knowledge of the technology in the study area, is the maximum possible yield, and is that obtained through use of the best practices and techniques. This implies that, if the production technology of each sample participant is raised to the best known practices and techniques available in that area, then all would be able to produce at this maximum level, given similarity in other conditions of production. This also means that a number of sample participants do not produce the greatest possible output from a given set of inputs, and are therefore not technically efficient.

The maximum possible yields were calculated with the frontier production function, using equation (Ib) in Table 6.5 and equation (IIc) in Table 6.6 for Kabupaten LIOT and Kabupaten MURA respectively. Actual farm yields, maximum possible yields and the difference between these in Kabupaten LIOT and Kabupaten MURA are given in Tables 8.1 and 8.2 respectively. These results show that in both the regions, there were considerable differences between the maximum possible yield and the actual yield of sample farms (Figure 8.1).

Identification of the major elements influencing the farmer yield gap (attempted below) could help policy makers to formulate appropriate programmes to help the farmers realise the maximum possible yield.

As a start some mean values of selected variables pertaining to the top ten frontier farms (according to the technical efficiency rating) and other farms of Kabupatens LIOT and MURA are presented in Table 8.3. Apart from their much higher yields, frontier farms in Kabupaten LIOT are characterised by more trees in tapping and bigger girthed trees. The top ten frontier farms in Kabupaten MURA are characterised by a larger productive area surveyed. They have younger trees, lower years since tapping commenced, and they apply more labour in maintenance. This evidence of larger farms is important, and seems to indicate that greater technical efficiency is associated in some way with a higher asset status. Any more detailed analysis of frontier farms in Kabupaten MURA should accordingly split the farms up into different age groups, to eliminate the effect of this vintage capital variable.

In the following analysis, it is assumed that the productivity differences could happen either from technique factors or because of various socio-economic and biological factors including management ability. An attempt is made to estimate a function of the form:

$$D = \alpha + \sum_{i=j}^{n} \beta_i \ W_i + E \qquad (8.1)$$

where D refers to the deviation of individual farmer's yield from the maximum possible yield (Tables 8.1 and 8.2) and W_i's denote variables postulated as causing these deviations. A disturbance term (E) was introduced representing errors in measurements and in observations and deviation of the specified functional form from the true one.

The results for Kabupaten LIOT (Table 8.4) show an R^2 of 0.33, significant at the 1 per cent level, which means that D in equation (8.1) is not well explained by the independent variables included. The unexplained part (67 per cent) of the variability in the yield is due to other input factors which have not been taken into account. It is interesting to note that the estimated coefficient of the girth was negative and significant at the 1 per cent level. It showed an inverse relation as might be expected. This means that an increase in the girth decreases the extent of yield variation from the maximum possible yield. The girth is strongly associated with field maintenance during immature period of rubber trees. Once the trees have been planted, field maintenance is essential to ensure healthy tree growth. This result suggests that better maintenance during immaturity is very important to increase rubber yield.

The estimated coefficients of depth of cut and age of trees were positive and significant at the 1 per cent, age of farmer was positive and significant at the 10 per cent level. These results suggest that an increase in each of these three factors increases the extent of yield variation from the maximum possible yield.

The effect of the age of trees suggests replanting, but further research must be undertaken before suggesting a replanting or new planting programme for this region, because the data show that the average age of rubber trees was 13.24 years (Table 1.2). Whilst the sample of progressive farmers is not necessarily typical of farmers in the region as a whole, trees of this age

TABLE 8.1

ACTUAL YIELD AND ESTIMATED MAXIMUM POSSIBLE YIELD

(MPY) FOR THE SAMPLE FARMS OF KABUPATEN LIOT

(Kg/Ha/Year)

Farm No (1)	Maximum Possible Yield (MPY) (2)	Actual Yield (3)	Difference (2) - (3) (4)	% of Difference (5)
1	1224.96	466.67	758.30	162.49
2	1596.40	750.00	846.40	112.85
3	1409.09	700.00	709.09	101.30
4	1942.90	1166.67	776.24	66.53
5	1211.35	525.00	686.35	130.73
6	1013.35	437.50	575.85	131.62
7	1440.56	437.50	1003.06	229.27
8	1608.15	700.00	908.15	129.73
9	911.70	437.50	474.20	108.39
10	975.75	350.00	625.75	178.79
11	1096.74	700.00	396.74	56.68
12	1014.06	619.47	394.59	63.70
13	997.70	140.00	857.70	612.64
14	1078.08	787.50	290.58	36.90
15	1514.33	700.00	814.33	116.33
16	1614.36	1225.00	389.36	31.78
17	1443.27	1944.44	- 501.17	- 25.77
18	1265.09	466.67	798.42	171.09
19	1101.11	700.00	401.11	57.30
20	1462.30	875.00	587.30	67.12
21	2119.74	1050.00	1069.74	101.88
22	3103.91	2592.59	511.31	19.72
23	1399.62	1400.00	- 0.38	- 0.03
24	1895.13	875.00	1020.13	116.59
25	1051.12	194.44	856.68	440.58
26	873.35	448.72	424.63	94.63
27	950.35	437.50	512.85	117.22
28	917.60	350.00	567.60	162.17
29	963.94	224.36	739.59	329.64
30	1551.92	656.25	895.67	136.48
31	1311.98	656.25	655.73	99.92
32	1200.41	603.45	596.96	98.92
33	1356.77	807.69	549.08	67.98
34	2072.00	1500.00	572.00	38 13
35	1633.69	840.00	793.69	94.49
36	1567.78	500.00	1067.78	213.55
37	1131.52	525.00	606.52	115.53
38	1021.25	420.00	601.25	143.16
39	806.05	194.44	611.61	314.54
40	874.77	875.00	- 0.23	- 0.03

(Continued)

TABLE 8.1 (Continued)

Farm No (1)	Maximum Possible Yield (MPY) (2)	Actual Yield (3)	Difference (2) - (3) (4)	% of Difference (5)
41	1775.03	525.00	1250.03	238.10
42	1142.29	525.00	617.29	117.58
43	1616.31	760.87	855.44	112.43
44	1055.28	350.00	705.28	201.51
45	1316.88	466.67	850.21	182.19
46	1009.77	386.74	623.03	161.10
47	796.36	262.50	533.86	203.37
48	1273.67	437.50	836.17	191.12
49	929.35	420.00	509.35	121.27
50	1950.56	350.00	1600.56	457.30

TABLE 8.2

ACTUAL YIELD AND ESTIMATED MAXIMUM POSSIBLE YIELD

(MPY) FOR THE SAMPLE FARMS OF KABUPATEN MURA

(Kg/Ha/Year)

Farm No (1)	Maximum Possible Yield (MPY) (2)	Actual Yield (3)	Difference (2) - (3) (4)	% of Difference (5)
1	1302.82	399.23	903.59	226.33
2	1565.33	1384.00	181.33	13.10
3	1403.68	1297.50	106.17	8.18
4	1829.20	1297.50	531.70	40.98
5	1640.29	1297.50	342.79	26.42
6	1717.98	1591.60	126.38	7.94
7	1302.82	553.60	749.22	135.34
8	1180.35	951.50	228.85	24.05
9	1829.20	1557.00	272.20	17.48
10	1297.39	1153.33	144.06	12.49
11	1913.29	3460.00	-1546.71	- 44.70
12	1417.18	692.00	725.18	104.79
13	914.48	951.50	- 37.02	- 3.89
14	1317.60	951.50	366.10	38.48
15	998.21	998.08	0.13	0.01
16	1558.25	1470.50	87.75	5.98
17	1190.86	1153.33	37.53	3.25
18	2139.79	1730.00	409.79	23.69
19	1600.32	865.00	735.32	85.01
20	1730.46	1730.00	0.46	0.03
21	1302.82	1038.00	264.82	25.51
22	1111.32	519.00	592.32	114.13
23	922.86	346.00	576.86	166.72
24	1108.51	519.00	589.51	113.59
25	1436.33	692.00	744.33	107.56
26	1255.88	692.00	563.88	81.48
27	1829.20	519.00	1310.20	252.45
28	1630.11	576.67	1053.44	182.68
29	1113.72	692.00	421.72	60.94
30	1180.35	865.00	315.35	36.46
31	752.67	519.00	233.67	45.02
32	1565.33	865.00	700.33	80.96
33	1717.98	1107.20	610.78	55.16
34	1281.91	346.00	935.91	270.49
35	1597.52	922.67	674.85	73.14
36	1283.95	1211.00	72.95	6.02
37	1695.77	951.50	744.27	78.22
38	1590.15	1153.33	436.82	37.87
39	1283.95	692.00	591.95	85.54
40	1205.89	302.75	903.14	298.31

(Continued)

TABLE 8.2 (Continued)

Farm No. (1)	Maximum Possible Yield (MPY) (2)	Actual Yield (3)	Difference (2) - (3) (4)	% of Difference (5)
41	1829.20	1828.86	0.34	0.02
42	1718.56	692.00	1026.56	148.35
43	1898.38	1211.00	687.38	56.76
44	1641.34	484.40	1156.94	238.84
45	2174.31	692.00	1482.31	214.21
46	1607.88	461.33	1146.54	248.53
47	1717.98	1557.00	160.98	10.34
48	1446.89	692.00	754.89	109.09
49	1572.00	951.50	620.50	65.21
50	1652.98	778.50	874.48	112.33
51	1256.76	922.67	334.09	36.21
52	1370.42	692.00	678.42	98.04

FIGURE 8.1

PERCENTAGE DIFFERENCES BETWEEN MAXIMUM POSSIBLE YIELD AND ACTUAL YIELD AMONG SAMPLE FARMS OF KABUPATENS LIOT AND MURA

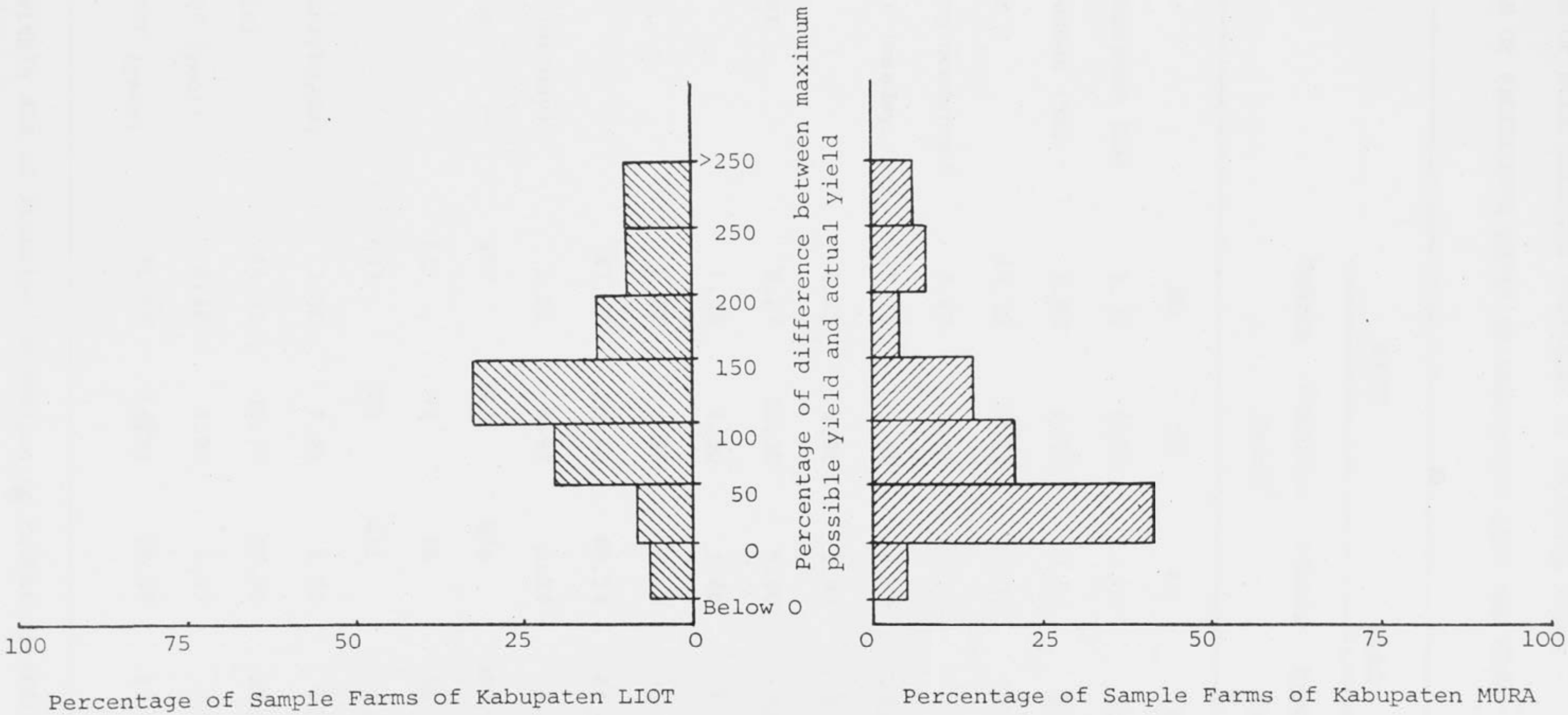


TABLE 8.3

AVERAGES OF SOME SELECTED VARIABLES OF FRONTIER FARMS

AND OTHERS OF PRODUCTIVE AREAS IN KABUPATENS LIOT AND MURA

	LIOT		MURA	
	Others	Frontier Farms[a]	Others	Frontier Farms[b]
Number of farms	40	10	42	10
Productive area observed (ha)	1.31	0.92	1.63	1.93
Total productive areas (ha)	1.99	2.05	2.54	2.73
Age of trees (year)	13.35	12.80	25.74	13.90
Years since tapping commenced	4.42	3.40	15.17	3.50
Maintenance labour (manday /yr)	17.74	9.87	4.52	10.59
Tapping days/week	4.25	4.20	3.93	3.70
Tapping months/year	9.27	10.20	9.90	10.70
Number of cuts	1.32	1.30	1.48	1.20
Depth of cut (mm)	5.87	5.50	6.28	6.60
Girth (cm)	47.42	52.80	69.24	64.20
Harvesting labour (hr/day)	5.85	6.97	4.24	3.64
Trees in tapping/ha	457	568	304	300
Immature trees/ha	117	72	46	59
Total trees/ha	633	705	411	396
Dry weight of rubber/ha/day	3.06	7.05	4.86	9.07
Age of farmer (year)	44.52	38.70	40.00	39.80
Education of farmer (year)	4.42	4.90	4.07	3.50
Experience of farmer (year)	21.77	18.30	19.07	17.50

a Top 10 farms, within 40% of frontier (according to technical efficiency rating).

b Top 10 farms, within 10% of frontier.

TABLE 8.4

THE ESTIMATED PARAMETERS OF THE FUNCTION EXPLAINING

THE DIFFERENCE BETWEEN MPY AND ACTUAL YIELD

OF KABUPATEN LIOT

	Variable	Parameter
X_1	Trees in tapping/ha	- 0.1585
		(0.1341)
X_8	Age of farmer, year	0.2575
		(0.1638)
X_{12}	Age of trees, year	0.3593**
		(0.1642)
X_{13}	The girth, cm	- 0.8352*
		(0.2987)
X_{17}	Depth of cut, mm	0.7565*
		(0.2525)
α	Constant	1.8136
$\bar{R}^2$		0.2537
R^2		0.3298
F		4.3312*
N		50.

Notes: Figures in brackets are standard error of estimates are not really old enough to be replanted.

The depth of cut suggests lack of technical knowledge. This implies that the improvement of technical knowledge of tapping amongst farmers in the survey areas is very useful. This can perhaps be done by increasing the number of farm visits by extension officers. Farm visits by officials enable them to observe the fields at various stages of production. This is important since, with their training and knowledge, they are able to identify the problems better than the farmers, even in the initial stages. Survey evidence shows that the majority of sample farmers had never met extension officials. At present the extension services department is severely under-financed, and cannot handle its duties owing to lack of manpower and transport facilities. It is also suggested to give more attention to the older farmers, which usually have lower education than the younger.

As identified earlier, the rubber yield of this region could be expected to increase by increasing the girth of the trees and number of trees in tapping.

The results for Kabupaten MURA (Table 8.5) show an R^2 of 0.54, significant at the 1 per cent level. It is interesting to note that the estimated coefficients of the number of cuts and the condition of the tapping panel were negative and significant at the 1 per cent level. The estimated coefficients of years of education and depth of cut were negative and significant at the 10 per cent level. Both of them showed an inverse relation, as might be expected.

The number of cuts, the depth of cut and the condition of the tapping panel are strongly associated with technical knowledge of the farmers in these survey areas. This implies that improvement of knowledge of the farmers concerning tapping systems is very important in this region. As was suggested for Kabupaten LIOT, this can be done by increasing the number of farm visits by extension officials and improved comprehension of the extension programme on smallholder rubber development.

There is a possibility of reducing D in equation (8.1) by increasing the education of farmers. The same relationship was also found by Bhati (1971) in his study of factors influencing productivity of padi farmers in Malaysia and Sepien (1978) in his study of technical and allocative efficiency in Malaysia rubber smallholding using a production function approach. Schwart (1958) analysed the effects of formal education on the success of farmers, and he found that formal education influenced farmers' success as well as their method and ability in making decisions. As indicated previously (Table 4.1), education is negatively correlated with age of the farmers owing to the lack of educational facilities originally available to the older farmers.

The estimated coefficients of years since tapping commenced and farm size were positive and significant at 1 per cent and 5 per cent level respectively. These results indicate that an increase in each of these variables increased the extent of yield variation from the maximum possible yield.

The results also indicate that the yield will decrease by increasing the number of years since tapping was started. The data shows that the average age of rubber trees on the farms in this region was 23.46 years (Table 1.2). Thus yields were in this declining period.

In relation to the effect of farm size (Table 8.5), rubber smallholders who operate smaller holdings may tend to use more of almost all inputs, especially labour, to produce a unit of rubber output than those operating bigger holdings. Owing to the greater labour use per unit area on smaller holdings it can be expected that small farmers will produce more rubber per hectare than farmers with bigger areas.

The same relationship between the average yield with respect to farm size as described above, has also been indicated by various independent rubber smallholding studies conducted by Barlow and Chan (1968) in Malaysia, Barlow et al (1975) in Sri Lanka and also by Sepien (1978) in Malaysia. It

TABLE 8.5

THE ESTIMATED PARAMETERS OF THE FUNCTION EXPLAINING THE DIFFERENCE BETWEEN MPY AND ACTUAL YIELD OF KABUPATEN MURA

	Variable	Parameter
X_2	Years since tapping, year	0.1590*
		(0.0575)
X_4	Number of cuts	- 0.6658*
		(0.1667)
X_7	Harvesting labour, hour/day	- 0.1459
		(0.0940)
X_9	Education, year	- 0.1465
		(0.0923)
X_{10}	Experience, year	- 0.1041
		(0.0754)
X_{11}	Farm size, ha	0.1523**
		(0.0709)
X_{14}	Total trees/ha	0.2033
		(0.1930)
X_{17}	Depth of cut, mm	- 0.4060
		(0.2416)
X_{19}	Tapping panel (dummy)	- 0.4967*
		(0.1444)
α	Constant	0.5610
$\bar{R}^2$		0.4411
R^2		0.5397
F		5.4715*
N		52.

Notes: Figures in brackets are standard errors of estimates is interesting to note that in all these studies, the relationship between yield and farm size displays a pattern similar to that of a sine function.

CHAPTER 9

SUMMARY AND CONCLUSIONS

This study attempts to highlight and quantify major factors affecting yields by using the estimation of production functions on the basis of input-output data from a 1977/1978 survey of smallholder rubber farms in Kabupaten LIOT and Kabupaten MURA of South Sumatra Province. After considering various desirable properties of the Cobb-Douglas and the Transcendental production functions, these functions were given a preliminary trial in this study. Of these two forms of production function the Cobb-Douglas form was chosen for further analysis in this study on the basis of the maximum number of significant estimates of the production parameters. The analysis was carried out under the assumption that the functional form applied to all the farms. The Cobb-Douglas production function was estimated for both regions separately.

For each region, the Cobb-Douglas production function was estimated by different techniques, namely, the Ordinary Least Square and Linear Programming. The function estimated by the first technique was interpreted as the average production function and that estimated by the second technique as the 'best' or frontier production function.

In the specification of the variables various possible sources of error are encountered. There is no annual data on output and tapping days. The annual output is calculated based on the measured daily yields per hectare (in dry rubber content) of the holding observed on one day. Average tapping days per year are calculated based on the average tapping days in a week and average number of tapping months per year. There is no hard annual data referring to other income of the farmers. This is calculated based on enumerator-response only. Quality differences in harvesting and maintenance labour such as age, sex, education level, or working experience could not be considered due to lack of information.

As a first step in the analysis, simple correlation method is employed with a view to establishing whether there is a relationship between each pair of variables included. Step wise regression analysis is performed using yield/output as dependent variable and eighteen independent variables selected.

Of the eighteen factors of production postulated as affecting rubber yields only five factors, namely, number of trees in tapping, age of farmer, age of trees, girth and depth of cut are retained in the final estimating equation of Kabupaten LIOT. Again, only nine factors, namely number of trees in tapping, years since tapping began, number of cuts, education, experience, farm size, cleanliness of holding, condition of tapping panel and other income are retained in the final estimating equation of Kabupaten MURA. Zero - one dummy variables are employed to represent different conditions of soil fertility, cleanliness of holding, condition of tapping panel and other income. The rubber output is measured as the total quantity of slab rubber in kg/ha/year in dry rubber content.

The average production function of Kabupaten LIOT is different from the average production function of Kabupaten MURA. For both regions, the production coefficients of the estimated average functions were statistically significant. The R^2 value is 0.62 for Kabupaten LIOT and 0.73 for Kabupaten MURA, and the F ratio for both of them is significant at the 1 per cent level.

The sum of production elasticities indicated decreasing returns to scale for Kabupaten LIOT and increasing returns to scale for Kabupaten MURA.

For both regions, the estimated coefficients of the frontier function appeared to be little different from those of the average functions, indicating that the frontier had shifted neutrally upward from the average function.

The estimated production functions are used to calculate the technical efficiency of the individual farms. For each region, two different vectors of technical efficiency are generated from the average and the frontier production functions. The efficiency ratings are calculated as the ratios of actual output to the level of output estimated from the production functions.

For a given set of inputs, the best farm in rubber production of

Kabupaten LIOT obtains 87 per cent more output than the average farm which, in turn, produces 68 per cent more output than the worst farm. Similarly, the best farm in rubber production of Kabupaten MURA could produce 70 per cent higher output than an average farm while the worst farm was producing 62 per cent less output than an average farm.

With a view to examining the relationship between the efficiency ratings derived from the average production function and the efficiency ratings derived from the frontier production function, the Spearman rank correlation coefficient between the corresponding sets of rankings is calculated and the test of significance is carried out. The results show that the hypothesis of no relationship between the two sets of efficiency ratings is rejected for both the regions. Furthermore the resulting graphs obtained from plotting the frontier ratings against the average ratings (Figures 7.1 and 7.2) also show the existence of a strong linear relationship between the two efficiency ratings. These results suggest that within the range of this sample, it is irrelevant whether the efficiency ratings are calculated relative to the average or the frontier function.

On the basis of the average production function, the marginal productivities of factors of production are calculated for both regions. On average the marginal productivities of trees in tapping and girth of Kabupaten LIOT were 1.12 kg and 10.92 kg per year respectively. For Kabupaten MURA the marginal productivities of trees in tapping, number of cuts, education and experience were 1.89 kg, 330.06 kg, 71.40 kg and 6.77 kg per year respectively. The marginal productivity of trees in tapping of Kabupaten MURA was higher than that of Kabupaten LIOT.

The variation in performance among the sample farms producing under the same process of production could also be because of random factors, technique factors, or because of various socio-economic and biological factors including management ability. An attempt is made to examine the factors inducing this difference between the frontier yield (maximum possible yield) and the actual yield. The maximum possible yield is calculated by using the frontier production functions. This analysis is carried out under the assumption that the productivity differences could happen either from technique factors, or because of various socio-economic and biological factors including management ability. By using regression analysis we can find out which of these independent variables are contributing more to the differences.

The results showed that the girth of trees for Kabupaten LIOT was a factor responsible for reducing the extent of yield variation from maximum possible yield, whereas depth of cut and age of trees were factors significantly widening farmer yield gap. For Kabupaten MURA, number of cuts, condition of tapping panel, depth of cut and education were factors responsible for reducing the extent of yield variation from maximum possible yield, whereas years since tapping commenced and farm size were contributing more to the differences.

As a result of these analyses it is suggested that by improving technical knowledge, especially in tapping, and by improving the educational level of the farmers, it can be expected the farmer yield gap will decline. This can be attempted by increasing the number of farm visits by extension officials.

Apart from their much higher rubber yields, the frontier farms in Kabupaten LIOT have bigger girthed trees and more number of trees in tapping. In Kabupaten MURA, the frontier farms are characterised by a larger productive area surveyed, and they have younger trees and apply more labour in maintenance.

This study serves to highlight the significance of certain factors affecting rubber yield in the two regions on which we have concentrated. For all holdings the number of trees in tapping per hectare seem to have an important positive influence on yield, and for younger stands (as in Kabupaten LIOT) a greater girth seems to be of major significance. Too deep a tapping cut appears to have substantial negative effects, especially with younger trees, whilst with older trees increasing the number of cuts and maintaining tapping panels in good condition seem to be big advantages. Size of farm (as in Kabupaten MURA) may well have important influences on technical efficiency and yield, but this facet must be investigated further.

There is some other quite considerable data which was collected in this survey which could not be presented and analysed due to time limitations.

APPENDIX 1.A

RESEARCH INSTITUTE FOR ESTATE CROPS

(Balai Penelitian Perkebunan, Bogor)

Jl Taman Kencana No. 1

BOGOR

FORM FOR RESEARCH ON SMALL-HOLDER RUBBER

IN SOUTH SUMATRA

1976/1977

(Fill in with pencil)

PART I : PRODUCTIVE FARMS

Name of Farmer : ______________________

Talang (hamlet) : ______________________

Dusun (village) : ______________________

Marga (area) : ______________________

Kecamatan : ______________________

Kabupaten : ______________________

File Number : [| | | | | | | 0 | 1] 1-9

No. of farm : Columns 1-3

Is it productive or ladang* : Column 4 (1 = productive 2 = ladang)

No. of Kecamatan : Column 5

No. of dusun : Columns 6 & 7

No. of card : Columns 8 & 9

Name of interviewer : ______________

(a)

Date : ______________ [10|11]

(a) Use numbers 1-12 beginning with October 1976 (October = 1; November = 2; and so on.)

* Ladang is land which is cultivated but not yet productive.

PART I

PRODUCTIVE FARMS

(* indicates that this should be completed by the research worker himself).

(To be completed for one block only).

Boxes for Nos.

1.1 Farmer's status

Owner	1	☐ 12
Tapper	2	
Share-cropper	3	
Tenant	4	

1.2 Area of farm in hectares ☐☐☐☐ 13-16

1.3 Distance from home to closest boundary of the farm in metres ☐☐☐☐ 17-20

1.4 Origins of the plantation: ☐ 21

Own planting	1
Owned by parents	2
Inheritance	3
Bought	4
Other (specify) ______________________	

____

1.5 Number of years since planting ☐☐ 22-23

1.6 Number of years since tapping began ☐☐ 24-25

1.7 Total number of rubber trees in the farmer's estimation:

Being tapped	☐☐☐☐ 26-29
Dry trees (brown bast or dead bark)	☐☐☐ 30-32
Small trees	☐☐☐ 33-35
Total	☐☐☐☐ 36-39

* Density of trees/ha ☐ 40

Based on sample	1
Based on counting	2

See attached sheet:

Being tapped	☐☐☐☐ 41-44
Not yet tapped	☐☐☐☐ 45-48
Dry	☐☐☐☐ 49-52
Total	☐☐☐☐ 53-56

Boxes for Nos.

1.8 *Samples of the density of trees

1.9 Distance between trees (only if laid out) m x m — [ ][ ] 57-58

3 x 3	1	4 x 5	6
3 x 4	2	4 x 6	7
3 x 5	3	5 x 5	8
3 x 6	4	Other (specify) ______________	
3 x 7	5		

____

1.10 Origins of planting material: — [ ][ ] 59-60

Unselected seeds 1
Selected seeds 2
Unselected seedlings 3
Selected seedlings 4
Clonal stump 5
Other (specify) ____________________

1.11 If selected planting materials were probably used, where were they obtained? — [ ] 61

Bureau of Plant Industry 1
Large plantation 2
Another farmer 3
Experimental farm 4
Other (specify) ____________________

What Clone? — [ ] 62
GT1, PR2, LCB3
Other (specify) _________________ — [ ] 63 [ ] 64
Why were selected seeds/seedlings used?
(specify) _________________________________
Distance from farm to place where materials were obtained (km) — [ ] 65

1.12 If selected materials were NOT used, why not? — [ ][ ] 66-67

None were available 1
It was too far to go 2
They were too expensive 3
Other (specify) _________________________

Boxes for Nos.

1.13 *Topography of the farm ☐ 68

Flat	1
Undulating	2
Hilly	3

1.14 *Type of soil ☐ 69

Latosol	1
Podsolic	2
Alluvial	3

File Number ☐☐☐☐☐☐☐[0][2] ;-9

Boxes for Nos.

* Soil Analysis ☐☐☐☐☐☐☐☐☐☐☐☐ 10-21

1.15 *Fertility of soil : ☐ 22

Good 1; Average 2; Below Average 3.

1.16 *Type of vegetation between rubber trees: ☐ 23

Alang-alang	1
Other weeds	2
Perdu (brushwood)	3
Other (specify) ________________	

____

1.17 Condition of farm ☐ 24

Well-kept	1
Reasonably well-kept	2
In bad repair	3
In very bad repair	4

1.18 Maintenance of farm (in the past 12 months)

How many times/year	Number of workers each time (on average)	Number of days each time (on average)	Number of hours/day
☐ 25	☐☐ 26 27	☐☐ 28 29	☐ 30

Workers wage (if paid labour used)

Number of workers	Rp (person) day
☐☐ 31 32	☐☐☐ 33 34 35

Total paid for piece-work (Rp) ☐☐☐☐☐ 36-40

Boxes for Nos.

Section of farm which is worked: ☐ 41

- Entire farm cleared in between the rows of trees 1
- A section of the farm cleared in between the rows of trees 2
- The perimeter of the farm cleared in between the trees 3
- Entire farm cleared only along the rows of trees 4
- A section of the farm cleared only along the rows of trees 5
- Entire farm cleared just around the base of the trees 6

1.19 Fertilizers and disease control:

	Type a)	Amount (kg)	Time of Application b)	No. of Workers	No. of days' work	No. of hours/day
Fertilizer	☐ 42	☐☐ 43 44	☐☐ 45 46	☐ 48	☐☐ 49 50	☐ 51
Disease Control	☐ 52	☐☐ 53 54	☐☐ 55 57	☐ 58	☐☐ 59 60	☐ 61

a) NPK1, Kcl 2, ZK 3, TB 4, Sulphur 5.
Other (specify) ______________________

b) January = 1; February = 2, etc.
1974 = 1, 1975 = 2, etc.

If fertilizer NOT used, why? ☐ 62 ☐ 63

None available at the market 1
No funds available 2
Other (specify) ________________

If fertilizer used, why? ☐ 64 ☐ 65

Financial help from another source was available 1
So that production would rise 2
Because own source available 3
Other (specify) ________________

1.20 Outbreaks of disease

Types of disease a)	Extent of Outbreak b)
66 ☐	☐ 67
68 ☐	☐ 69
70 ☐	☐ 71

a) Write name of disease beside the box
b) Serious, average, not serious.

Boxes for Nos.

1.21 Portion of the total area which is tapped every day ☐ 72

100% 1, 75% 2, 50% 3, 25% 4.
Other (specify) ____________________

1.22 Frequency of tapping:

No. of tapping days/week (dry season) ____________
No. of tapping days/week (wet season) ____________
No. of months in wet season per year ____________
No. of tapping days last week ____________

Average No. of tapping days per week ☐ 73
No. of tapping months per year ☐☐ 74-75

If less than 12 months used for tapping, why? ☐ 76 ☐ 77 ☐ 78

Because of work in paddy fields/ ladang	1
falling leaves	2
rest period for trees	3
production too low	4
Other (specify)	

File number ☐☐☐☐☐☐☐ 0 3 1-9

1.23 No. of trees one man can tap in one day ☐☐☐ 10-12

1.24 *Condition of tapping panels ☐ 13

Good 1; Poor 2; Very Poor 3.

1.25 *No. of tapping cuts per tree (examine 10 trees)

Maximum ☐ 14
Minimum ☐ 15
Average ☐ 16

1.26 *Types of tapping ☐ 17

S/1	1
S/2	2
V/2	3
Mixture	4
Other (specify) ____________	

1.27 *Direction of tapping ☐ 18

Towards the bottom	1
Towards the top	2
Both towards the bottom and the top	3

Boxes for Nos.

1.28 * Direction of cuts

☐ 19

High left - low right 1
High right - low left 2
Non consistent 3

1.29 *Height of cut above ground (the average of 10 trees chosen at random from the entire farm) in cm. (see enclosed sheet)

Highest cut ☐☐ 20-23
Lowest cut ☐☐ 24-27

1.30 *The cuts are found in

☐ 28

Lower cutting panel (<175 cm) 1
Higher cutting panel (>175 cm) 2
Branches 3

1.31 Bark which is being tapped:

☐ 29

Virgin bark 1
First renewal 2
Second renewal 3
No longer known 4

1.32 Have artificial stimulants ever been used?

Yes 1; No 2 ☐ 30
If yes state what type:_______________
When used (year) ☐☐ 31-32
What was the result like?
Good 1; Poor 2. ☐ 33

1.33 Amount of bark used in each cut (MM) ☐☐ 34-35

1.34 *Depth of cut, mm ☐☐ 36-37

1.35 Thickness of bark being cut

☐ 38

Thick 1
Thin 2
Very thin 3

1.36 *Circumference of trunk

(average of 30 trees chosen at random from the total area of the farm, 150 cm. from the ground), in cm.

☐☐ 39-40

Boxes for Nos.

1.37 Hour / Time } at which tapping is begun. ☐☐☐ 41-43

1.38 Amount of time needed for tapping, collecting and processing each day's crop

	Time (minute/tapping day) 1st tapper a) ( )	2nd tapper a) ( )	3rd tapper a) ( )	4th tapper ( )
From home to farm	☐☐☐ 44 - 46	☐☐ 47 48	☐☐ 49 50	☐☐ 51 52
Tapping the trees	☐☐☐ 53 - 55	☐☐☐ 56 - 58	☐☐☐ 59 - 61	☐☐☐ 62 - 64
Rest	☐☐ 65 66	☐☐ 67 68	☐☐ 69 70	☐☐ 71 72
File Number		☐☐☐☐☐☐☐ 0 4 1-9		
Collecting latex	☐☐ 10 11	☐☐ 12 13	☐☐ 14 15	☐☐ 16 17
Processing	☐☐ 18 19	☐☐ 20 21	☐☐ 22 23	☐☐ 24 25
Age of tapper in years	☐☐ 26 27	☐☐ 28 29	☐☐ 30 31	☐☐ 32 33
Sex b)	☐ 34	☐ 35	☐ 36	☐ 37
System of payment c)	☐ 38	☐ 39	☐ 40	☐ 41

a) place the tapper's name in the brackets
b) Male 1, Female 2
c) Owner 1, Family member 2, one-half 3, one-third 4 one-quarter 5.

1.39 Tools (only those which are really used)

	Number used/year (on average)	Price of one item
Tapping knife	☐ 42	☐☐☐ 43 - 45
Latex bucket	☐ 46	☐☐☐ 47 - 49
Spouts (when bought)	☐☐☐ 50 - 52	☐ 53
Other (specify) ______	☐ 54	☐☐☐ 55 - 57

Boxes for Nos.

1.40 *Latex Cup: ☐ 58

Coconut shell 1
Bamboo 2

*Condition of cups ☐ 59

Clean 1, Dirty2, Viry dirty 3.

1.41 *Spout: ☐ 60

Zinc (bought) 1
Zinc (home-made) 2
Leaf 3
Other (specify) ____________________

1.42 *Are wood-shavings mixed with the latex? ☐ 61

Yes 1, No 2.

If they are mixed in, why? ☐ 62
(Specify) ________________________

1.43 Output of tapping in one day (in litres) ☐☐ 63-64
(Calculate from the number of tins collected and their volume)

1.44 Percentage of latex obtained from total output (after removing lumps and scraps). If possible, calculate the gross weight of each. ☐☐ 65-66

1.45 Place of processing: ☐ 67

On the farm 1
At home 2
Elsewhere (specify) ________________

1.46 *Distance from farm to processing place (in metres) ☐☐ 68-71

1.47 *Type of coagulant used ☐ 72

Alum 1
Sulphuric acid 2
Formic acid 3
Other (specify) ________________________

1.48 Dose of coagulant

- Formic acid (vinegar) (kg per 100 kg produce) ☐ 73

- Alum (kg per kg) ☐ 74

Boxes for Nos.

1.49 Price of coagulant:
(Rp per unit) ☐☐☐ 75-77

Unit: kg = 1, bottle = 2, other (specify) ☐ 78

1.50 *Detailed information about slab ☐ 79

Made in wooden box 1
hole in the ground 2
Other (specify) ________________

File number ☐☐☐☐☐☐☐ 0 5 1-9

*Cleanliness of slab making tool ☐ 10

Clean	1
Dirty	2
Extremely dirty	3

Treatment of latex ☐ 11

Diluted	1
Undiluted	2

1.51 Detailed information about sheets

Processed	1	☐ 12
Trodden	2	
Lumps separated	1	☐ 13
Lumps mixed	2	
Bark included	1	☐ 14
Bark not included	2	

Method of milling
No. of times on smooth roller ☐ 15
No. of times on ribbed roller ☐ 16

Cost of milling (Rp/Kg) ☐☐☐ 17-19

1.52 State of processing instruments ☐ 20

Clean	1
Dirty	2
Very dirty	3

1.53 Additional information about the product

Measurement of daily production (date ________________)

Slabs Length ____________ Sheets Length ____________
Width ____________ Width ____________
Thickness ____________ Thickness ____________

Boxes for Nos.

Type of Product (a)	Measurement of daily product Weight Dry (kg) rubber content% (b)	Dry Weight (kg)	Condition (c)	Method of storing (d)	Frequency of sale (e)	Variation in weight of previous months daily product
	______ ______	21 - 23	24	25	26	______ ______ ______

(a) Slabs = 1, Sheet = 2, Latex = 3, Other (specify) __________

(b) (According to laboratory sample)

(c) Clean = 1, Dirty = 2, Very dirty = 3.

(d) In air = 1, in water = 2, other (specify) ______________

Type of Product (a)	At time of sale (every sale) Weight (kg)	Dry rubber content % (b)	Dry Weight difference (kg)	Sale price Rp/kg Date (c)	Price Variation last month (Rp/kg) Highest	Lowest
27	28 - 30	31 32	33 - 35	36 37 38 40	41 42	43 44

Price of transport from place of sale to market 45

(a) Slabs = 1, Sheet = 2, Latex = 3, Other (specify) ____________

(b) Of one sale (daily, weekly etc.) according to the estimate of the buyer

(c) January = 1, February = 2, etc.
1974 = 1, 1975 = 2, etc.

(d) Buyer's name and place of sale

1.54 Yearly production trend of each block 46

Increase 1
Decrease 2
Stable 3

Boxes for Nos.

1.55 Place of sale ☐ 47

On plantation 1
At home 2
At market 3
From boat/barge 4
Other (specify) ________________

1.56 Does the buyer provide your daily groceries? ☐ 48

Yes 1, No 2.

If yes, does the buyer offer credit? ☐ 49

Cash 1, Goods 2.

1.57 Method of transport to place of sale ☐ 50

Carried on shoulder-pole 1
Hired vehicle used 2
Sold at place of processing
or at home 3
Other (specify) ________________

1.58 Time needed to transport and sell product (hours/week) ☐☐ 51-52

1.59 Cost of transport to place of sale (Rp/kg) ☐☐ 53-54

1.60 Shrinkage from time of making to time of sale (%) ☐☐ 55-56

How many days on average between fabrication and sale of sheets/slabs ________________

1.61 Have you ever made other shapes or qualities? ☐ 57
(specify) ________________

1.62 What problems do you face in raising the quality? ☐ 58
(specify) ________________

What is your opinion of trying to improve the quality? ☐ 59
(specify) ________________

1.63 Do you own any other productive rubber trees? ☐ 60

Yes = 1 No = 2
If yes, complete the following:

Blok	Type of plant	Age of trees	First year of tapping	Area (hedara)	Dry weight per day of tapping (Dry rubber content = 100% (Kg)
	☐ 61	☐☐ 62 63	☐☐ 64 65	☐☐☐☐ 66 - 69	☐☐ 70 71

Boxes for Nos.

File number ☐☐☐☐☐☐☐06 1-9

2.	10	11 12	13 14	15 - 18	19 20
3.	21	22 23	24 25	26 - 29	30 31

Number of Trees

Blok	Being tapped	Not yet tapped	Dry
1.	32 - 35	36 - 38	39 - 41
2.	42 - 45	46 - 48	49 - 51
3.	52 - 55	56 - 58	59 - 61

(a) Selected seeds 1
Clonal 2
Unselected seeds 3
Other (specify) ____________

1.64 Do you own any fallow land? ☐ 62

Yes 1, No 2.

If not, why not? (specify) ____________ 63 64 65

If yes, why did you start it? (specify) ____________ 66 67 68

What problems did you have at the beginning? (Specify) ____________ 69 70 71

File number 1 1 07 1-9

If you own young rubber, give details here:

Blok	Type of plant	Age of plants	Area (ha)	Distance* between plants (b)	Average* circum-ference of trunk (c)	Condit-ion (d)	Is there a cover crop? (e)	How many years until mature for tapping
1.	10	11 12	13 - 16	17 18	19 20	21	22	23 24
2.	25	26 27	28 - 31	32 33	34 35	36	37	38 39
3.	40	41 42	43 - 46	47 48	49 50	51	52	53 54

(a) Selected seeds = 1, Clone = 2, Unselected seeds = 3.

(b) 3 x 3 = 1   3 x 4 = 2
3 x 5 = 3   3 x 6 = 4
3 x 7 = 5   4 x 5 = 6
4 x 6 = 7   5 x 5 = 8
Other (specify) ________________________

(c) If possible measured 150 cm above ground level
if not, 50 cm above ground level

(d) Clean=1, Quite clean = 2, Dirty = 3, Very dirty = 4

(e) Yes = 1, No = 2.

Measured 150 cm above ground level = 1
Measured 50 cm above ground level = 2   ☐ 55

☐☐☐ 56 58   ☐☐☐ 59 61

☐☐☐ 62 64   ☐☐☐ 65 67

☐☐☐ 68 70   ☐☐☐ 71 73

☐☐☐ 74 76   ☐☐☐ 77 79

File number   ☐☐☐☐☐☐☐ 0 8 1-9

☐☐☐ 10 12   ☐☐☐ 13 15

☐☐☐ 16 18   ☐☐☐ 19 21

☐☐☐ 22 24   ☐☐☐ 25 27

☐☐☐ 28 30   ☐☐☐ 31 33

☐☐☐ 34 36   ☐☐☐ 37 39

☐☐☐ 40 42   ☐☐☐ 43 45

☐☐☐ 46 48   ☐☐☐ 49 51

☐☐☐ 52 54	☐☐☐ 55 57
☐☐☐ 58 60	☐☐☐ 61 63
☐☐☐ 64 65	☐☐☐ 66 69
☐☐☐ 70 72	☐☐☐ 73 75
☐☐☐ 76 78	☐☐☐ 79 80

APPENDIX 1.B

BALAI PENELITIAN PERKEBUNAN BOGOR

(Research Institute for Estate Crops)

Jl. Taman Kencana No. 1

BOGOR

FORM FOR RESEARCH ON SMALL-HOLDER RUBBER

IN SOUTH SUMATRA

1976/1977

(Fill in with pencil)

PART III : OTHER INFORMATION

Name of Farmer : ____________________

Talang (hamlet) : ____________________

Dusun (village) : ____________________

Marga (area) : ____________________

Kecamatan : ____________________

File number [| | | | | | |3|1] 1-9

No. of farm : Columns 1-3

Is it productive
or (fallow) ladang: Column 4 (1 = productive
2 = ladang)

No. of kecamatan : Column 5

No. of dusun : Columns 6 & 7

No. of card : Columns 8 & 9

Name of interviewer : ____________________

Date [a] : ____________________ [|] 10-11

a) Use numbers 1-12 beginning with October 1976
(October = 1, November = 2, and so on).

PART III OTHER INFORMATION

3.1 Family details (for owners or active cultivators, not paid tappers)

Family member	Age	Sex (a)	Length of schooling	Final level of schooling	Years of experience in rubber	Other experience type	Other experience years (c)	Type of work on productive plantation (d)	Work on Ladang (e)
Farmer	12 13	14	15 16	17	18 19	20	21 22	23	24
Wife									
Children									
	64 65	66	67 68	69	70 71	72	73 74	75	76
File number					3 2	1-9			
	10 11	12	13 14	15	16 17	18	19 20	21	22
	62 63	64	65 66	67	68 69	70	71 72	73	74
File number					3 3	1-9			
	10 11	12	13 14	15	16 17	18	19 20	21	22
	62 63	64	65 66	67	68 69	70	71 72	73	74
File number					3 4	1-9			
Other Dependents	10 11	12	13 14	15	16 17	18	19 20	21	22
	49 50	51	52 53	54	55 56	57	58 59	60	61

(a) Male = 1, Female = 2

(b) S.D. graduate (primary school) 1
S.L.P. graduate (junior school) 2
S.L.A. graduate (senior school) 3

Also write final level beside the box.

(c) Farming = 1. Selling = 2. Other (write at side)

(d) Only tapping = 1
Only collecting = 2
Only processing = 3
Tapping and collecting = 4
Collecting and processing = 5
Tapping, collecting or processing = 6
Other (write above)
(Match this answer with 1.32)

(e) Yes = 1, No = 2

3.2 Recap of farmer's earnings from rubber and other sources for the last year, between the months of ____________ and ____________ (last 12 months)

Type of work	Area (ha)	Product (Kg)	Earnings (Rp)
Total productive rubber	☐☐☐☐ 62–65	☐☐☐☐ 66–69	☐☐☐☐☐☐ 70–75
File number		☐☐☐☐☐☐☐ 3 5	1-9
	☐☐☐☐ 10–13	☐☐☐☐ 14–17	☐☐☐☐☐☐ 18–23
Total ladang	☐☐☐☐ 52–55	☐☐☐☐ 56–60	☐☐☐☐☐☐ 61–66
File number		☐☐☐☐☐☐☐ 3 6	1-9
	☐☐☐☐ 10–13	☐☐☐☐ 14–18	☐☐☐☐☐☐ 19–24
	☐☐☐☐ 40–43	☐☐☐☐ 44–48	☐☐☐☐☐☐ 49–54
Other (specify) (a)			
☐ 55 ________	☐ 56 ________	☐☐☐☐ 57–61	☐☐☐☐☐☐ 62–67
☐ 68 ________	☐ 69 ________	☐☐☐☐ 70–74	☐☐☐☐☐☐ 75–80

(a) including all other sources of income.

File number ☐☐☐☐☐☐☐ 3 7 1-9

3.3 Living Expenses

Item	Amount (a)	Unit (b)	Sufficient for how long? (c)	Source (d)	Price Rp/un
Rice	10 12	13	14	15	16 19
Meat					
Fresh Fish					
Dried Fish					
Shrimps					
Vegetables					
Root Vegetables	65 66	67	68	69	70 73

File number 3 8 1-9

Others:					
Coffee	10 11	12	13	14	15 18
Tea					
Sugar					
Salt					
Coconut Oil					
Kerosene					
Cigarettes					
Tobacco	65 65	66	67	68	69 72

File number 3 9 1-9

Soap	10 11	12	13	14	15 18
Flour					
Milk	28 29	30	31	32	33 36

Other expenses (specify) ____________________

37	38 39	40	41	42	43 46

Clothing					
School Fees				74	75 79

File number 4 0 1-9

Other expenses (specify)

10					26 30

(a) Write name of unit beside the box

(b) Kg = 1 Box = 2

(c) Per week = 1, per month = 2, per year = 3

(d) Bought = 1, own produce = 2

3.4 Sources of information about rubber

Radio = 1 ☐ 31 ☐ 32 ☐ 33

Newspaper = 2

Friends/discussion = 3

None = 3

Other sources (specify) ________________

3.5 Do you participate in any government schemes e.g. Village Unit, G.C.C. & A.R.P.? ☐ 34

Yes = 1 No = 2

Why do you participate in these schemes? (maybe more than 1 reason) ☐ 35 ☐ 36 ☐ 37

To expand rubber plantation	1
Plans for rejuvenation	2
Because you receive help	3
Other (specify) ______________________	

Why do you NOT participate in these schemes? ☐ 38 ☐ 39 ☐ 40

No more labour available	1
No government schemes in operation	2
Dubious about the result	3
Other (specify) ______________________	

3.6 Have you ever been in contact with government instructors? ☐ 41

Often	1
Occasionally	2
Never	3
Other (specify) __________________	

Give details of this contact with the instructor

____

____

____

3.7 *Level of farmer's skills and ability (based on a general estimate of his skills and ability) ☐ 42

Excellent 1
Good 2
Average 3
Poor 4

3.8 *Level of farmer's knowledge ☐ 43

Excellent 1
Good 2
Average 3
Poor 4

3.9 Does the farmer participate in social activities/ Village development? ☐ 44

Yes = 1 No = 2

If yes, what activities is he involved with? ☐ 45 ☐ 46 ☐ 47

Development committees for roads/ school/mosque 1
Security 2
Community education/sport 3
Other (specify) ____________

If not, why not? ☐ 48 ☐ 49 ☐ 50

No time 1
Not interested 2
Often away from village 3
Other (specify) ____________

☐☐☐ 51 53 ☐☐☐ 54 56

☐☐☐ 75 77 ☐☐☐ 78 80

☐☐☐☐☐☐☐ 4 1 1-9

☐☐☐ 10 12 ☐☐☐ 13 15

☐☐☐ 76 78 ☐☐ 79 80

APPENDIX TABLE 4.2

THE CORRELATION MATRIX OF DEPENDENT AND ALL INDEPENDENT VARIABLES, TESTED IN THE PRODUCTION FUNCTION OF KABUPATEN LIOT

	Variable	Y	D_2	X_1	X_2	X_4	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{19}	X_{20}	X_{21}
Y	Yield, kg/ha/day	1.0000	0.0844	0.6822*	-0.0534	-0.1413	0.4395**	-0.2953+	0.0872	-0.3236***	-0.2911+	-0.1600	0.2275	0.5668*	0.0382	-0.0110	-0.1898	0.1548	0.2099	-0.0498
D_2	Other income (dummy)		1.0000	-0.0586	0.0549	0.1447	0.1110	-0.0750	0.2138	-0.2185	-0.0950	0.1415	0.1845	-0.1300	0.1657	-0.0375	-0.0391	-0.1067	-0.2437	0.0657
X_1	Trees in tapping/ha			1.0000	0.0334	-0.1810	0.7241*	-0.2371	-0.0065	-0.3165+	-0.3669**	-0.0809	0.0416	0.8983*	-0.0225	-0.0093	0.0118	0.2070	0.3715**	0.0619
X_2	Years since tapping commenced, year				1.0000	0.3431***	0.2109	-0.1046	0.0080	0.0855	0.0191	0.8485*	0.2919+	-0.0752	-0.2804+	-0.4545*	-0.0682	-0.4703*	-0.5967*	0.1068
X_4	Number of cuts					1.0000	-0.0532	-0.1382	0.2546++	-0.0715	-0.1241	0.2568++	0.2109	-0.1646	0.1222	-0.3290***	0.0227	-0.3787**	-0.2200	-0.0512
X_7	Harvesting labour, hour/ha/day						1.0000	-0.1682	-0.0332	-0.1592	-0.2184	0.1401	-0.0361	0.5386*	0.0306	-0.1053	-0.0510	-0.0112	0.0771	0.2468++
X_8	Age of farmer, year							1.0000	-0.6033*	0.7309*	0.4401**	-0.0674	-0.2037	-0.0753	0.2092	0.3665**	-0.1714	0.0673	0.1116	0.2501++
X_9	Education, year								1.0000	-0.5787*	-0.2253	0.0761	0.2569++	-0.1406	-0.0295	-0.2562++	0.0376	-0.1652	-0.1549	-0.0535
X_{10}	Experience, year									1.0000	0.3282***	-0.0220	-0.2327	-0.1756	0.0618	0.2125	-0.1643	0.0387	-0.2666++	0.1232
X_{11}	Farm Size, ha										1.0000	0.0775	-0.0927	-0.2413++	0.0996	0.1223	-0.1745	0.1576	-0.0488	-0.1713
X_{12}	Age of trees, year											1.0000	0.2669++	0.1782	-0.2228	-0.4933*	-0.0649	-0.5796*	-0.6045*	0.0559
X_{13}	The girth, cm												1.0000	-0.1012	0.0280	-0.1159	0.1803	-0.1604	-0.1599	0.0610
X_{14}	Total trees/ha													1.0000	-0.0722	0.0741	0.0257	0.2256	0.5724*	-0.0342
X_{15}	Soil fertility (dummy)														1.0000	0.1839	-0.0008	0.2116	0.1164	0.3776**
X_{16}	Cleanliness of the holding (dummy)															1.0000	-0.0807	0.4927*	0.2694++	0.1247
X_{17}	Depth of cut, mm																1.0000	-0.0562	0.1401	-0.0854
X_{19}	Condition of tapping panel (dummy)																	1.0000	0.4011**	-0.1093
X_{20}	Immature trees/ha																		1.0000	0.0019
X_{21}	Maintenance labour, manday /year																			1.0000

Notes:
- * highly significant (0.1%)
- ** significant at the 1% level
- *** significant at the 2% level
- \+ significant at the 5% level
- ++ significant at the 10% level

APPENDIX TABLE 5.2

THE ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION

FOR SAMPLE PARTICIPANTS IN KABUPATEN LIOT

Variable		Parameter
Ln X_1	(Number of trees in tapping/ha)	0.9862*
		(0.2006)
Ln X_2	(Number of years since tapping commenced)	-0.1178
		(0.0726)
Ln X_7	(Harvesting labour, hour/ha/day)	-0.0447
		(0.1694)
Ln X_{13}	(The girth, cm)	0.8831*
		(0.3135)
Ln X_{17}	(Depth of cut, mm)	-0.6967*
		(0.2596)
α	(Constant)	-6.8103
$\bar{R}^2$		0.5455
R^2		0.5919
F ratio		12.7620*
Number of cases		50

Notes: Figures in brackets are standard errors of estimates

* significant at the 1% level.

APPENDIX TABLE 5.3

THE ESTIMATED TRANSCENDENTAL PRODUCTION FUNCTION

FOR SAMPLE PARTICIPANTS IN KABUPATEN LIOT

Variable		Parameter
Ln X_1	(Number of trees in tapping/ha)	1.0980 (0.8204)
X_1		-0.0003 (0.0015)
Ln X_7	(Harvesting labour, hour/ha/day)	-0.3866 (0.5064)
X_7		0.0568 (0.0768)
X_2	(Number of years since tapping)	-0.0620 (0.0527)
X_2^2		0.0026 (0.0035)
X_{13}	(The girth, cm)	0.0642 (0.0643)
X_{13}^2		-0.0005 (0.0006)
X_{17}	(Depth of cut, mm)	-0.3480 (0.3676)
X_{17}^2		0.0186 (0.0358)
α	(Constant)	-5.4720
$\bar{R}^2$		0.5027
R^2		0.6042
F ratio		5.9528
Number of cases		50.

Notes: Figures in brackets are standard errors of estimates.

APPENDIX TABLE 5.4

THE ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION

FOR SAMPLE PARTICIPANTS IN KABUPATEN MURA

Variable		Parameter
Ln X_1	(Number of trees in tapping/ha)	0.3967 ***
		(0.1745)
Ln X_2	(Number of years since tapping)	-0.1824 *
		(0.0549)
Ln X_7	(Harvesting labour, hour/ha/day)	0.2310 ***
		(0.1059)
Ln X_{13}	(The girth, cm)	0.1462 O
		(0.1151)
Ln X_{17}	(Depth of cut, mm)	0.3895 O
		(0.2865)
α	(Constant)	-1.8453
$\bar{R}^2$		0.3520
R^2		0.4156
F ratio		6.5422 *
Number of cases		52

Notes: Figures in brackets are standard errors of estimates
* significant at the 1% level
*** significant at the 5% level

APPENDIX TABLE 5.5

THE ESTIMATED TRANSCENDENTAL PRODUCTION FUNCTION

FOR SAMPLE PARTICIPANTS IN KABUPATEN MURA

Variable		Parameter
Ln X_1	(Number of trees in tapping/ha)	-0.3480 (0.5943)
X_1		0.0024 (0.0022)
Ln X_7	(Harvesting labour, hour/ha/day)	0.6819 + (0.3701)
X_7		-0.0906 (0.0708)
X_2	(Number of years since tapping)	-0.0512 * (0.0164)
X_2^2		0.0009 * (0.0003)
X_{13}	(The girth, cm)	0.0067 (0.0182)
X_{13}^2		-0.0001 (0.0001)
X_{17}	(Depth of cut, mm)	0.3715) (0.3645)
X_{17}^2		-0.0214 (0.0322)
α	(Constant)	1.2780
$\bar{R}^2$		0.3955
R^2		0.5140
F Ratio		4.3371
Number of cases		52

Notes: Figures in brackets are standard errors of estimates.

* significant at the 1% level

\+ significant at the 10% level

APPENDIX TABLE 7.12

DISTRIBUTION OF MARGINAL PRODUCTIVITY OF NUMBER

OF CUT IN RUBBER PRODUCTION OF KABUPATEN MURA

Marginal Productivity of number of cuts (kg/ha/year)	Number of Farms	Proportion of Farms	Cumulative Proportion of Farms
85.00 - 355.00 (≤355.00)	31	0.59	0.59
355.00 - 625.00	15	0.29	0.88
625.00 - 895.00	5	0.10	0.98
895.00 -1165.00	-	0.00	0.98
1165.00 -1435.00	-	0.00	0.98
1435.00 -1705.00	1	0.02	1.00
Total	52	1.00	-

APPENDIX TABLE 7.13

DISTRIBUTION OF MARGINAL PRODUCTIVITY OF EXPERIENCE

OF THE FARMER IN RUBBER PRODUCTION

OF KABUPATEN MURA

Marginal Productivity of Experience (kg/ha/year)	Number of Farms	Proportion of Farms	Cumulative Proportion of Farms
1.00 - 13.00 (≤13.00)	40	0.77	0.77
13.00 - 25.00	8	0.15	0.92
25.00 - 37.00	1	0.02	0.94
37.00 - 49.00	2	0.04	0.98
49.00 - 61.00	-	0.00	0.98
61.00 - 73.00	1	0.02	1.00
Total	52	1.00	-

BIBLIOGRAPHY

ANDERSON, J.R. et al. 1977. Agricultural Decision Analysis, Iowa State University Press, Ithaca, pp. 234-57.

AIGNER, D. et al. 1977. "Formulation and Estimation of Stochastic Frontier Production Function Models", Journal of Econometrics, No. 6, pp. 21-37.

AIGNER, D.J. and CHU, S.F. 1968. "On Estimating the Industry Production Function", The American Economic Review, vol. 58, No. 4, pp. 826-39.

BALAI PENELITIAN PERKEBUNAN BOGOR dan BIRO PUSAT STATISTIK. 1976. Statistik karet 1976, Balai Peneltian Perkebunan Bogor, Bogor.

BAPPEDA SUMATRA SELATAN. 1976. Sumatra Selatan Dalam Angka Tahun 1974 dan 1975, BAPPEDA.

BARLOW, C. 1977. Cooperative work with the Balai Penelitian Perkebunan Bogor, 1966/77. A report to the Head of the Badan Penelitian dan Pengembangan Pertanian and Director of the Balai Penelitian Perkebunan Bogor. (Unpublished), Australian National University, Canberra.

__________ 1978. The Natural Rubber Industry: Its Development, Technology and Economy in Malaysia, Oxford University Press, Kuala Lumpur, Malaysia.

BARLOW, C. and CHAN, C.K. 1968. "Towards an Optimum Size of Rubber Holding", Paper delivered to RRIM Natural Rubber Conference, Kuala Lumpur.

BARLOW, C and LIM, S.C. 1967. "Effect of Density of Planting on the Growth, Yield and Economic Exploitation of Hevea Brasiliensis", Part II: The Effect on Profit, Journal of the Rubber Research Institute of Malaya, vol. 20, No. 1, pp 44-64.

BARLOW, C. et al. 1975. Some Aspects of the Economics of Smallholding Rubber in Sri Lanka, Proceedings of the International Rubber Conference, Kuala Lumpur. Vol. 3, pp.385-407.

BATTESE, G.E. and CORRA, G.S. 1977. "Estimation of a Production Frontier Model: with application to the pastoral zone of Eastern Australia", Australian Journal of Agricultural Economics, Vol. 21 No. 3, pp. 169-179.

BAUMOL, W.J. 1977. Economic Theory and Operations Analysis, Prentice-Hall, Inc., New Jersey.

BHATI, U.N. 1971. Economic Determinants of Income on Irrigated Paddy Farms in Tanjong Karang, West Malaysia, Ph.D Thesis, Australian National University.

BIRO PUSAT STATISTIK. 1974. Sensus Penduduk 1971, Penduduk, Sumatra Selatan, Seri E No. 6. (Series E No. 6, 1971 Population Census, Population Census of South Sumatra). Biro Pusat Statistik Jakarta.

BRESSLER, R.G. 1967. "The Measurement of Productive Efficiency" Ibid., pp.129-36

BROWN, M. 1966. On the Theory and Measurement of Technological Change, University Printing House, Cambridge.

CARLSON, S. 1956. A Study on the Pure Theory of Production, Kelley and Millman, New York.

CHAMBE, R. 1972. Rubber Smallholdings Situation Rehabilitation, Balai Penelitian Perkebunan Bogor, Bogor.

CHIANG, A.C. 1967. Fundamental Methods of Mathematical Economics, McGraw-Hill Book Company, New York.

CHRISTENSEN, L.R. et al. 1975. "Transcendental Logarithmic Utility Functions", The American Economic Review, Vol. 65 No. 1, pp.367-83.

COBB, C.W. and DOUGLAS, P.H. 1928. "A Theory of Production", The American Economic Review, Supplement, Vol.18, pp.139-65.

CRAMER, J.S. 1969. Empirical Econometrics, North Holland Publishing Company, London.

DHRYMES, P.J. 1970. Econometrics: Statistical Foundations and Applications. Harper & Row, Publishers, New York. Chapter 4.

DINAS PERKEBUNAN RAKYAT DAERAH TINGKAT I SUMATRA SELATAN. 1974. Laporan Tahunan Tahun 1973/74 (1973/74 Annual Report). Dinas Perkebunan Rakyat Daerah Tingkat I Sumatra Selatan, Palembang.

DOLL, J.P. 1974. "On Exact Multicollinearity and the Estimation of Cobb-Douglas Production Function", American Journal of Agricultural Economics, Vol. 56 No. 3, pp. 556-63.

DULOY, J.H. 1959. "Resource Allocation and a Fitted Production Function", Australian Journal of Agricultural Economics, Vol. 3, No. 2, December, 1959, pp. 75-85.

ETHERINGTON, D.M. 1973. "An Econometric Analysis of Smallholder Tea Production in Kenya." East African Literature Bureau, Nairobi.

FARRELL, M.J. 1957. "The Measurement of Productive Efficiency", Journal of the Royal Statistical Society, Vol. 120, Series A (General), Part 3, pp.253-90.

FERGUSON, C.E. 1975. The Neoclassical Theory of Production and Distribution, Cambridge University Press.

FRAZER, J.R. 1968. Applied Linear Programming, Prentice-Hall, Inc., New Jersey.

FRISCH, R. 1965. Theory of Production, D. Reidal Publishing Company, Dordrecht-Holland.

GRILICHES, Z. 1957. "Specification Bias in Estimates of Production Functions", Journal of Farm Economics, Vol. 39, No. 1, pp. 8-20.

GRILICHES, Z. and RINGSTAD, V. 1971. Economies of Scale and the Form of the Production Function, North Holland Publishing Company.

HALTER, A.N. et al. 1957. "A Note on the Transcendental Production Function", Journal of the Farm Economics, Vol. 39, No. 4, pp.966-74

HAYAMI, Y. and RUTTAN, V.W. 1971. Agricultural Development: An International Perspective, The John Hopkins Press, London.

HEADY, E.O. 1952 "Use and Estimation of Input-Output Relationships of Productivity Coefficients", Ibid. Vol. 34, pp.775-86.

__________ 1960. Economics of Agricultural Production and Resource Use, Prentice-Hall, Inc., Englewood Cliffs.

HEADY, E.O. and DILLON, J.L. 1961. Agricultural Production Functions, Ames, Iowa: Iowa State University Press.

HEATHFIELD, D.F. 1971. Production Functions, the Macmillan Press Ltd., London.

HENDERSON, J.M. and QUANDT, R.D. 1971. Microeconomic Theory, A Mathematical Approach, McGraw-Hill Kogakusha, Limited, Tokyo.

HOCH, I. 1958. "Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function", Econometrica, Vol.26, pp. 566-78.

__________ 1962. "Estimation of Production Function Parameters Combining Time Series and Cross Section Data", Econometrica, Vol. 30, No. 1, pp. 34-53.

HOPCRAFT, P.N. 1974. "Human Resources and Technical Skills in Agricultural Development: An Economic Evaluation of Educative Investments in Kenya's Small Farm Sector", Ph.D Thesis, Stanford University.

HOPPER, W.D. 1965. "Allocation Efficiency in a Traditional Indian Agriculture", Journal of Farm Economics, Vol. 47, pp. 611-24.

HU, TEH-WEI 1975. Econometrics: An Introductory Analysis, University Park Press, Baltimore.

JOHNSTON, J. 1972. Econometric Methods. McGraw-Hill Book Company, New York, Chapter 4 and 8.

KALIRAJAN, K.P. 1979. "An Analysis of the Performance of the High Yielding Varieties Programme for Paddy in Coimbatore District, Tamil Nadu, India." Ph.D Thesis, Australian National University.

KHUSRO, A.M. 1964. "Returns to Scale in Indian Agriculture". Indian Journal of Agricultural Economics, Vol.19, pp.51-80.

KOUTSOYIANNIS, A. 1977. Theory of Econometrics, McMillan Press Limited, London.

KRISHNA, R. 1964. "Some Production Functions for the Punjab", Indian Journal of Agricultural Economics, Vol. 19, pp.87-97.

LIM, S.C. 1976. "Land Development Schemes in Peninsular Malaysia: A Study of Benefits and Costs", Rubber Research Institute of Malaysia, Kuala Lumpur.

MALYA, M. 1962. "Linear Programming and Farm Planning", Indian Journal of Agricultural Economics, Vol. 17, No. 1, pp.206-11.

MASSELL, B.F. 1967. "Elimination of Management Bias from Production Functions Fitted to Cross-Section Data: A Model and an Application to African Agriculture", Econometrica, Vol. 35, No. 3 - 4, pp.495-508.

MEIER, G.M. 1976. Leading Issues in Economic Development, Oxford University Press, New York.

MUBYARTO 1977. Pengantar Ekonomi Pertanian, Lembaga Penelitian, Pendidikan dan Penerangan Ekonomi dan Sosial, Jakarta.

MUGGEN, G. 1969. "Human Factors and Farm Management: A Review of Literature", Review Article No. 10, World Agricultural Economics and Rural Sociology Abstracts, Vol. 11, No. 2, pp. 1-11.

MULLER, J. 1974. "On Sources of Measured Technical Efficiency: The Impact of Information", American Journal of Agricultural Economics, Vol. 56, No. 4.

MUNDLAK, Y. 1961. "Empirical Production Function Free of Management Bias", Journal of Farm Economics, Vol. 43, pp.44-56

MUNDLAK, Y AND HOCH, I. 1965. "Consequences of Alternative Specifications in Estimation of Cobb-Douglas Production Functions", Econometrica, Vol. 33, No. 4, pp.814-28.

NERLOVE, M. 1965. Estimation and Identification of Cobb-Douglas Production Functions, Rand McNally & Company, Chicago, pp. 86-100.

PEE, T.Y. and ANI BIN AROPE. 1976. Rubber Owners' Manual, Economics and Management in Production and Marketing, Rubber Research Institute of Malaysia, Kuala Lumpur.

RACHMAN, B. 1978. "Strategy for Smallholder Rubber Development in South Sumatra", Masters Thesis, Australian National University, Canberra.

ROSEGRANT, M.W. 1976. The Impact of Irrigation on the Yield of Modern Varieties, Agricultural Economics Development IRRI, Philippines, Paper No. 76-28.

SAAD, H.R. and BAHARSJAH, S. 1976. "Masalah Karet Rakyat", Konperensi Karet Nasional, Jakarta.

SCHULTZ, T.W. 1964. Transforming Traditional Agriculture, Yale University Press, New Haven.

SCHWART, R.B. 1958. "The Relation of Variation in Education to the Decision-Making of Farmers",Ph.D. Thesis, Ohio State University.

SEITZ, W.D. 1970. "The Measurement of Efficiency Relative to a Frontier Production Function", American Journal of Agriculture Economics, Vol. 52, pp.505-11.

SEPIEN, Abdullah bin. 1975. "Marketing Smallholders' Rubber in the East Coast of Peninsular Malaysia", Masters Thesis, Australian National University, Canberra.

__________ 1978. "Technical and Allocative Efficiency in Malaysian Rubber Smallholdings: A Production Function Approach", Ph.D Thesis, Australian National University.

SHARMA, S.R. 1974. "Technical Efficiency in Traditional Agriculture: An Econometric Analysis of the Rupandehi District of Nepal", Masters Thesis, Australian National University, Canberra.

SOLOW, R.M. 1957. "Technical Progress and the Aggregate Production Function", Review of Economics and Statistics. Vol. 39, pp. 312-320.

SHAUDYS, E.T. and NODLAND, T. 1968. "Biography and Performance", The Management Factor of Farming: An Evaluation and Summary of Research, Minnesota Agricultural Experiment Station, Technical Bulletin, No. 258.

SUITS, D.B. 1957. "Use of Dummy Variables in Regression Equations", American Statistical Association Journal, pp.548-51

TAHA, H.A. 1976. Operations Research: An Introduction, Macmillan Publishing Company, New York.

TEO CHOO-KIAN 1976. "Production Function Analysis of Small Rubber Farms in Sri Lanka", Masters Thesis, Australian National University, Canberra.

TIMMER, C.P. 1970. "On Measuring Technical Efficiency", Food Research Institute Study in Agricultural Economics, Trade and Development, Vol. 9, No. 2, pp.109-71.

———— 1971. "Using a Probalistic Frontier Production Function to Measure Technical Efficiency", Journal of Political Economy, Vol. 79, No. 4, pp.776-94.

UPTON, M. 1976. Agricultural Production Economics and Resource-Use, Oxford University Press, London.

———— 1979. "The Unproductive Production Function", Journal of Agricultural Economics, Vol. 30, No. 2, pp.179-193.

WESTGARTH, D.R. and BUTTERY, B.R. 1965. "The Effect of Density of Planting on Growth, Yield and Economic Exploitation of Hevea brasiliansis, Part I. The Effect on Growth and Yield", Journal of the Rubber Research Institute of Malaya, Vol. 19, No. 1, pp. 62-73.

WHITLAM, G.B. 1976. "Analysis of Some Factors Affecting Smallholder Rubber Production", Papua New Guinea Agricultural Journal, Vol. 27, Nos. 1 and 2, pp.1-10.

WONNACOTT, R.J. 1970. Econometrics, John Willey & Sons, Inc., New York.

YAMANE, T. 1970. Statistics: An Introductory Analysis, Harper & Row New York.

YOTOPOULOS, P.A. 1967. Allocative Efficiency in Economic Development. Centre of Planning and Economic Research Monograph, No. 18, Athen.

YOTOPOULOS, P.A. and LAU, L.J. 1973. "A Test for Relative Economic Efficiency: Some Further Results", The American Economic Review, Vol. 63, No. 1, pp.214-23.