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RESOURCE ALLOCATION FOR SMALL SCALE FARMERS OF THE STAR GRASS ZONE IN EMBU DISTRICT, KENYA: A LINEAR PROGRAMMING APPROACH

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A Thesis Submitted in Partial
Fulfilment for the Degree of
Master of Science at the
University of Nairobi

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I hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

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A B S T R A C T

The main objectives of this study are to identify the factors which most constrain agricultural production on the small scale farms in the star grass zone of Embu district, and investigate different enterprise combinations to show how farmers' income can be increased after satisfying their household food requirements by a reallocation of resources.

The study tests the following hypotheses i) there are opportunities for farmers of the star grass zone of Embu district to increase farm income by using different enterprise mixes; ii) Coffee production is most profitable to farmers than all other enterprises in a situation where there is adequate labour availability and iii) milk production is most profitable than all the enterprises considered in the star grass zone of Embu district when there is sufficient land available and labour is in short supply.

Chapter 1 presents the background information in the agricultural areas of Embu district, the study area in particular and the characteristics of the small farm problems there. Chapter 2 reviews studies conducted in Kenya using the linear-programming technique in the contest of small farms. Chapter 3 presents the objectives of the study and methodology of investigation employed. Chapter 4 presents the findings of this study. The conclusions and recommendations are given in Chapter 5.

A survey of 40 farmers in Gaturi location in Embu district was conducted. The principal tool of analysis is linear programming model.

With optimal enterprise combinations farm income can be increased by 28%, 31%, and 27%, on small, medium and large sized farms respectively. Land and working capital shortage limit production on the small sized farms. On the medium sized farms further production is hampered by shortage of labour and working capital while on the large farms production is critically constrained by shortage of labour. The profitability of coffee production depends on the availability of labour. Milk production in the star grass zone of Embu district is most profitable than all enterprises when there is sufficient land and critical labour shortage.

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I owe many debts of gratitude to the people and organizations who assisted me during this work. One of these is to the German Academic Exchange Service (DAAD) which offered me the scholarship that enabled me to undertake this work. Thanks are also due to the International Livestock Centre for Africa (ILCA) administration, who responded promptly and favourably to my requests for financial assistance during the field data collection and typing facilities at every stage of this work.

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Chapter One

INTRODUCTION

Agriculture in Kenya is the foundation of the country's economy. Its monetary contribution to total Gross Domestic Product at current prices in 1979 amounted to about 30 percent.[1] Approximately 80 percent of the total employment is generated from the agricultural sector. Its foreign exchange earnings have also been the basis of the country's industrial development. The agricultural sector comprises both small and large farms with the former contributing 56 percent of the gross marketed production, and supporting about 75 percent of the total population.[2]

The total population of Kenya recorded as 13 million in the 1979 census is one of the fastest growing in the world with a rate of 3.9 percent increase per annum.[3] This rate of increase will substantially reduce the area of land available per capita for food production and require increased yields per hectare if Kenya is to remain self sufficient in food production.

> High rates of population increase necessitates growth in agricultural production. In 1965, Kenya had about 0.78 hectare of high potential land equivalents per person. Within twenty years it will be no more than 0.2 ha. The easy expansion of output in the 1960's when extensive areas of high potential land were transferred from grazing to arable use, is no longer possible. There has been a slowing down of the growth of agricultural output from the

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1 Republic of Kenya: Economic Survey 1980, Central Bureau of Statistics, Ministry of Planning and Community Affairs. Government Printers, Nairobi, 1980, p.12.

2 Republic of Kenya: Economic Survey 1979, Central Bureau of Statistics, Ministry of Planning and Community Affairs. Government Printers, Nairobi, 1979, pp.94-95.

3 Republic of Kenya: Economic Survey 1980, Op.cit., p.193.

> First to the Third plans and accelarating rate of population growth requires major changes in these output trends, otherwise per capita growth could become negative during the Fourth plan period.[1]

It should be emphasized that a prosperous agricultural sector is an asset to the whole economy in that it provides a growing market for the goods and services produced by the industrial sector, as well as producing the food and primary materials on which successful growth in the industrial sector largely depends.

As pointed out above the small scale farming sector contributes 56 percent of the gross marketed agricultural product and supports about 75 percent of the total population. 76 percent of the total agricultural labour inputs occurs on small holder farms, thus showing their importance in the country's economy.[2]

To improve the income levels of smallholder farmers and increase food production it is necessary to understand the production systems, discover the factors constraining production and then, with this knowledge devise a strategy for more efficient use of the scarce resources. In part this will involve an evaluation of different enterprise combinations as different combinations have different eventualities for the use of scarce resource.

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[1] Republic of Kenya, Development Plan 1979-83, Op.cit, p.208.

[2] Republic of Kenya, Economic Survey 1979, Op. cit., pp.94-95.

> There is still potential for considerably higher production in rural areas. The resources of land and labour are under-utilized. The higher potential land is now almost completely occupied but it can provide opportunities which lead to greater production and further employment.[1]

The aim of this study, therefore, is to explore the above general problems in the small scale farm sector, and to investigate specifically how efficiently resources are being used among enterprises. To demonstrate how small holder farmers can increase their farm income by a reallocation of scarce resources among enterprises within the existing farming conditions, the study uses a linear programming approach and lays its emphasis on Gaturi location in Embu district of Kenya.

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[1] Republic of Kenya, Development Plan 1979-83, Op.cit., p.207.

1.1 Embu District.

Embu district has a total land area of 2871 square kilometres (sq.km) with 3 divisions, 10 locations and 60 sublocations. The divisions of the district are Embu, Siakago and Gachoka. The location of the district in Kenya is shown in Fig. 1.

The most noticeable physiographic features of the district are Mt. Kenya in the north, a range of hills in the south west and River Tana in the west. The district can be devided into five distinct agro-ecological zones as shown in the following table.

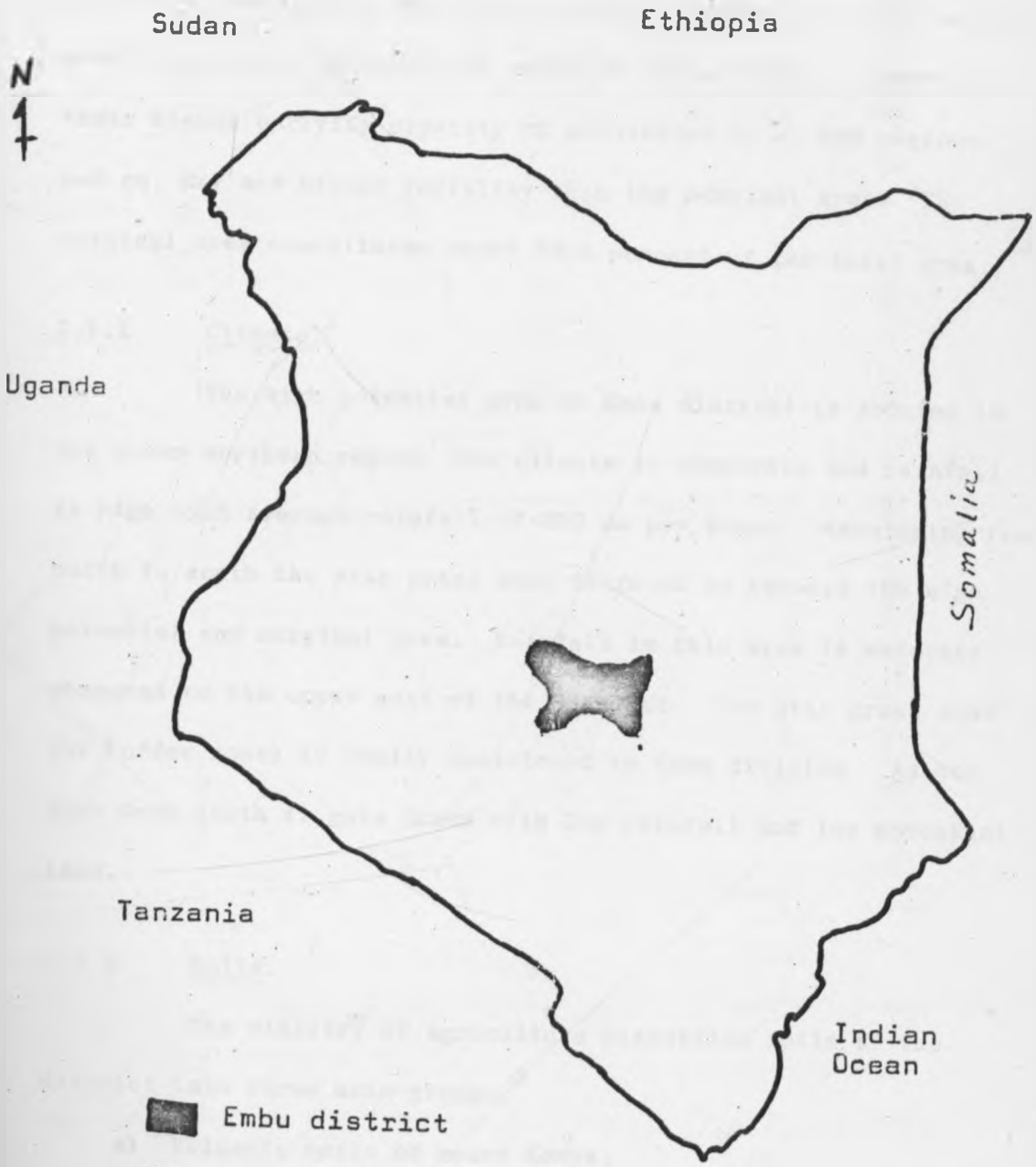
Table 1: Agro-Ecological Zones of Embu District, 1978.

Zone	Type of land	Area (Ha.)	Cultivable Area (%)
II	High potential (Tea/Coffee zone or Kikuyu grass zone)	20,843	15.9
III	Medium potential (Coffee zone or Star grass zone)	28,254	21.6
IV	Marginal area	81,842	62.6
	Subtotal	130,939	100
V	Range zone	118,261	
I + VI	(non agricultural)	37,900	
	Total	287,100	

Source: Ministry of Agriculture. Embu District Coffee Rehabilitation Project General data, 1978.

As shown in Table 1 Embu district has areas of all the major agro-ecological zones, varying from higher potential area to non agricultural zone.

In Embu district only zones II, III and IV are cultivable. Zone V is only suitable for grazing of livestock. Zone I is forest area while zone VI is the most driest area which cannot



Source: Kenya Atlas, 1970.

Figure 1: Location of Embu district in Kenya.

be used for either crop or livestock husbandry.

The high potential area constitutes about 15.9 percent of the total cultivable area in the district, while the medium potential area constitutes about 21.6 percent. These two zones are the most significant agricultural areas in the district, because of their higher carrying capacity of population (i.e. 250 persons per sq. km) and higher fertility than the marginal area. The marginal area constitutes about 62.9 percent of the total area.

1.1.1 Climate.[1]

The high potential area of Embu district is located in the upper northern region, the climate is temperate and rainfall is high with average rainfall of 800 mm per annum. Stretching from north to south the star grass zone is found in between the high potential and marginal area. Rainfall in this area is moderate compared to the upper part of the district. The star grass zone (or Coffee zone) is wholly positioned in Embu division. As one goes deep south it gets drier with low rainfall and low potential land.

1.1.2 Soils.

The ministry of agriculture classifies soils of the district into three main groups.[2]

a) Volcanic soils of mount Kenya,

b) The soils derived from metamorphic rock and

c) Black cotton soils.

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[1] Republic of Kenya, Embu District Development Plan 1974-78. Nairobi, 1974, p.3.

[2] Ministry of Agriculture, District Agricultural Gazette - Embu District. 1963-64, pp.1-3.

The soil of Zone I is poor light powdery soil. In Zone II (tea/ coffee zone or Kikuyu grass zone) the soil is light brown clay loam, with high contents of phosphorus and nitrogen.

Zone III (star grass zone or coffee zone) has red to brown clay loam soil which are also high in phosphorus and nitrogen.

1.1.3 Natural Vegetation[1]

In Zone I the vegetation normally consists of bracken and Truimtetta bush. Here, Pennisetum Cladistunm (Kikuyu grass) does not thrive except in conditions of local fertility.

Zone II has a large area of bracken and bush interpersed with patches of poor arable and patches of grazing dominated by Kikuyu grass.

In Zone III the area under cultivation are characterized by shrubby bush including Vernonian and Weddelia. Here, star grass is the most dominating type of grass.

1.1.4 Land Use[2]

In the northern tip of the district, Mount Kenya with its forests is the major Kenyan timber resource. Here, due to its high altitude and unfavourable climatic conditions there is no crop production or livestock husbandry.

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[1] Ministry of Agriculture, District Agricultural Gazette - Embu District, Op. Cit., p.2.

[2] Republic of Kenya, Embu District Development Plan, Op.Cit., p.3.

Below Zone I lies a strip of the high potential area of the district. The tea and coffee zone, also called the Kikuyu grass zone, is quite fertile and with a high carrying capacity of persons. In this zone the main cash crops are tea and coffee. Pyrethrum is grown as a cash crop by few farmers in the northern tip of this zone. The typical subsistence crops are maize, potatoes, bananas and beans. This zone is suitable for dairy production and farmers keep mainly grade cows and few crossbred[1] cows.

The star grass zone (coffee zone) is heavily populated and productive zone in the whole district. Here, the main cash crop is coffee. The subsistence crops are maize, beans, bananas and potatoes. Few farmers keep grade dairy cow. Most farmers keep either local zebu cows or crossbred dairy cows.

In the marginal area of Embu district the main cash crop is cotton. Few farmers grow tobacco as cash crop. Here, the subsistence crops are maize, sorghum, pigeon peas and beans.

The range zone (Zone V) is found in the southern part of the district. Here, cropping is not possible and livestock keeping is the most practised activity.

The southern tip of the district which is very dry and not suitable for growing crops or for keeping livestock.

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[1] Crossbred cattle refers to the crosses between local zebu and grade cattle.

1.1.5 Settlement Patterns.[1]

Population densities are highest in the high potential area. Overall, the district is populated in the northern region at about 250 persons per sq. km., and sparsely populated in the lower southern region with about 40 to 50 persons per sq. km. Most of the people (about 70%) live in Zone II, III and IV. About 90 percent of the population in Embu district is rural. The inhabitants are mainly Embians, Mbere and Akamba. There is quite a considerable flow of permanent immigrants from the surrounding districts, mainly from Machakos and Kirinyaga district.

The reduction in the size of land holdings as the result of high population pressure in the high potential area has caused migration southwards.

Table 2. Human Population (Rural) of Embu District.

District/ Division	Year	Population (Persons)	Total Area (Sq. kms)	Density (persons)
	1969	174,934	2,871	62
Embu	1974	212,955	"	74
District	1977	232,698	"	82
	1979	246,864	"	86
Increase from 1969-1979 (%)		41.1	-	38.7
	1969	101,368	462	220
Embu	1974	123,425	"	267
Division	1977	134,764	"	292
(Coffee Area)	1979	142,969	"	309
Increase from 1969-1979 (%)		41.03	-	40.5

Source: Ministry of Agriculture, Embu District Coffee Rehabilitation Project General Data, May 1978.

[1] Republic of Kenya, Embu District Development Plan, Op.cit, P.3.

As shown by Table 2, the coffee area is becoming more densely populated. In 1969 the density of human population in the coffee zone was about 220 persons per sq. km. This figure increased to about 309 persons per sq. km in 1979. This showed a growth of 47.5% in a decade in the coffee area.

1.2 Problem Identification.

Like in other parts of the country, increasing population growth is becoming a major problem in the farming sector of Embu district. This problem is aggravated particularly in the star grass zone (or coffee zone) as a consequence of immigration of investors from the high potential area around Mount Kenya who find that land is not available for purchase in sufficient quantity due to the already existing land size shrinkage in their own area. As discussed above the Star grass zone (coffee zone) is the most important agricultural area of the district.[1] This zone supports the livelihood of the majority of the population in the district. However, this zone is characterized by low yield regardless of its good potential for agricultural development.[2] There is need to make an indepth research in the Star grass zone (coffee zone) to investigate if more efficient ways of using the scarce resources can be found thus resulting increased income of the smallholder farmers.

Due to the high market prices for coffee in 1977, farmers in Embu district are giving more and more attention to the production of coffee and plots under coffee trees are expanding.

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1 Ministry of Agriculture, District Agricultural Gazette, Op.cit., p.4.

2 Republic of Kenya, Embu District Development Plan 1974-78, Op.cit., p.3.

The area under coffee increased by 5.6% from 4890 ha in 1977 to 5164.7 ha in 1978. Due to the coffee rush, there has been a scramble for seedlings available in the nurseries. This prompted illegal seedling selling and importation of seedlings from the neighbouring district. Seedling theft was also reported. More than 2,127,323 seedlings were planted in 1978 as compared to 76,647 seedlings in 1977.[1]

Due to the high population growth, land is in short supply. Moreover, coffee is a high labour demanding crop compared to other enterprises like growing cereals or keeping dairy cows. However, a greater portion of the available land and labour are being alloted to coffee production. This land is worthy of more detailed study.

To investigate these problems this study concentrates on the star grass zone of the district and on Gaturi location in particular.

1.3 Area of Study: Gaturi

Gaturi, one of 10 locations in Embu district, is the study area selected. Gaturi lies in Embu division between Ngandiri location in the west, Mbeta location in the south and Kagaari location in the East (see Figure 2). About 97 percent of the area of Gaturi is positioned in the star grass zone. About 3 percent of the area in the northern fridge lies in the Kikuyu grass zone.

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[1] Republic of Kenya. Ministry of Agriculture, Embu District Annual Report, District Agricultural office, P.O. Box 32, Embu, 1978, p.14.

Source: Survey of Kenya, 1973.

Figure 2: Location of the study area in Embu district.

The star grass zone in Gaturi is homogeneous and is representative of the star grass zone of the district. Its representativeness of the star grass zone of the district is also expressed by its high population density, land shortages and low yields in agricultural production. All of the farms in Gaturi are small scale farms, and there is not any large scale farm. The location is highly accessible with plenty of road network.

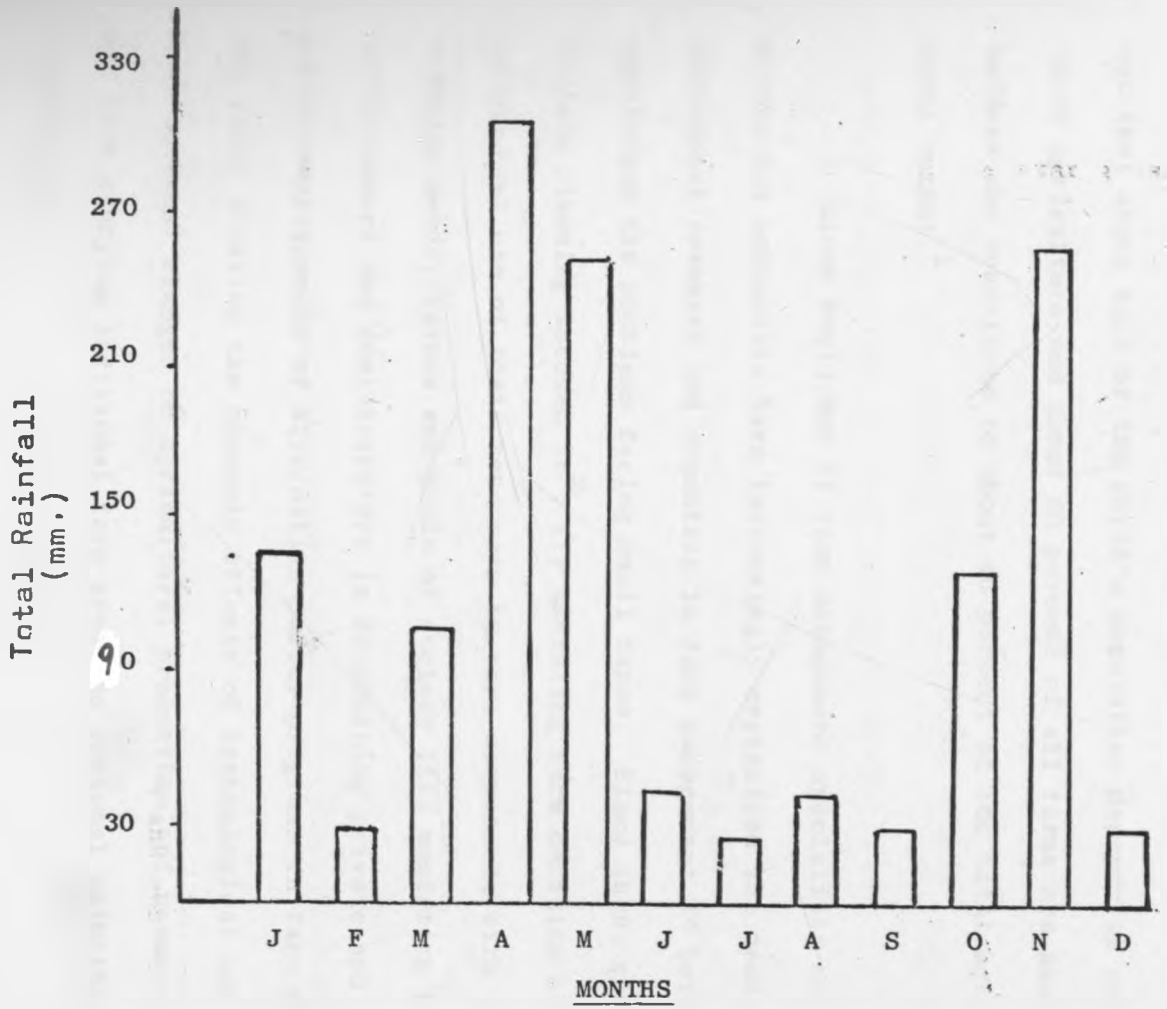
1.3.1 Soils

The soils of the star grass zone of Gaturi location is red to brown clay loam soil with high contents of phosphorus and nitrogen as discussed previously under the soils of the district.

1.3.2 Climate

Gaturi has a temperate climate. Rainfall is generally moderate and fairly reliable. The rainfall is distributed over two seasons the heavier "long rains" from March to May, and the lighter "short rains" of October and November.

As shown in Figure 2, in 1979, the Embu rainfall recording Station, situated in the star grass zone about 2 kilometres from Gaturi location recorded the highest rainfall in April and May during the "long rains" and in October and November during the "short rains".



Source: Embu Rainfall Recording Station

Figure 3: Distribution of Rainfall by month in the star grass zone of Embu District, 1979.

Chapter Two

LITERATURE REVIEW OF STUDIES ON SMALL HOLDER AGRICULTURE USING LINEAR PROGRAMMING TECHNIQUE IN KENYA.

2.1 Introduction.

The extent of the small farm problem is vast and the need to promote the development of small farms in less developed countries is widely being recognized. Wharton (1969) has pointed out that about half of the world's population depends on subsistence agriculture and about 60 percent of all farms are smallholders who contribute to about 40 percent of the total agricultural output.[1]

Since World War II farm management specialists and production economists have increasingly emphasized the need for additional research and education in farm management to better understand the problems facing small farms. Since then, research in farm planning focused in[2]: (i) assisting farm decision makers in the best use of their resources in ways compatible with the changing needs, values and goals of society (ii) assisting public policy makers and administrators in determining private and public consequences of alternative policy programs in farm resource use (iii) studying the economic effects of technological and institutional changes on agricultural production and resource use and (iv) studying individual farm area and regional adjustments in resource use.

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1 C.R. Wharton, Subsistence Agriculture and Economic Development, 2nd edition, Aldine Publishing Company, Chicago, 1970, p.7.

2 H.R. Jensen, "Farm Management and Production Economics, 1946-70". A Survey of Agricultural Economics Literature, Vol. I, University of Minnesota Press, North Central Publishing Company, St. Paul U.S.A., 1977, pp.3-73.

In the post World War II period some of the essential tools of analysis, developed to study the farm firm are mathematical programming, (i.e. Static and dynamic linear programming, quadratic programming) simulation, production function analysis, gaming, network analysis etc.[1]

The 1950's can be considered a development period for mathematical programming. Frederick Waugh (1951) following World War II set the stage for the far-reaching developments in mathematical programming that took place in farm management and production economics. Further developments in linear programming as analytical techniques appeared in the mid 1950's, Boles (1955), Swanson (1955), Barbar, Tinter and Heady (1955), Candler (1957), Coutu (1957) etc.[2]

2.2 Studies in Kenya.

In Kenya a pioneer study using linear programming to analyse resource use on smallholder agriculture was made by Clayton in 1963.[3] He illustrated how farm productivity can be increased by efficient combination of resources on small scale farms. Clayton carried out the investigation by studying the economic organization of selected model farms from the different agro-ecological zone in Nyeri district. After he prepared alternative plans for the model farms, he came out with the conclusion that on family farms the main limitation to increased production was a shortage of labour and that land was not so

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1 H.R. Jensen, Op.cit, pp.3-75.

2 Ibid.

3 E.S. Clayton, Economic Planning In Peasant Agriculture, Wye College, University of London, 1963.

limiting. This is a reverse case commonly experienced in peasant agriculture. Clayton's study area was a high potential area of Kenya. If his study was updated the conclusion may be different as this is now an area of higher population density than 1963 and it may now be that land shortage would be the most limiting factor of production and not labour. However, the validity of this statement calls for further investigation. Clayton also concluded that the restrictions caused by a limited labour supply arose because the farming systems he studied included high value cash crops such as coffee, tea and pyrethrum which are more labour demanding than food crops. In Clayton's study, as a result of labour shortage farm families could not operate on all available land. It would be profitable for small scale farmers to leave some of their land uncropped if they were not able to hire casual labourers. Therefore, in his analysis, where he assumed hired labour was available farm incomes increased substantially.

One possible shortcoming of Clayton's study is that the data he used were generated from farm holdings which were already well planned by the Ministry of Agriculture and therefore, may be unrealistic in portraying the situations of the small farms of his study area. It would have been more appropriate if he had used data from representative sampled farms.

Another study which used linear programming technique to investigate resource use on small scale farms in Kenya is

that of Heyer (1966).[1] She made an input-output study of 16 small scale farms and concluded that labour and land are the most limiting factors of agricultural production. The supply of working capital was relatively not so important. She also found that farmers in Massii location increased expected incomes when they cultivated less cotton than the amount advised by the agricultural agents at that time. A critical analysis which was not emphasized by her study is a price sensitivity analysis of prices of at least the major crops. She could have at least varied the price of cotton and showed the stability of the plans she prepared, and suggested at what price it would have been most profitable to produce cotton.

Odero Ogwel and Clayton (1973)[2] used a linear programming model in their study of A Regional Programming Approach to Agricultural Sector Analysis. This study took place in Nyeri district where they covered all the divisions of the district. Their analysis showed that there were opportunities to increase farm income by expanding the tea production and improving dairying which would call for expanded domestic and external markets. In this study they concluded that arable crop production was relatively unprofitable. The optimal plans they prepared provided a small marketable surplus of potatoes but maize and beans remained generally at subsistence levels of production. This study clearly demonstrated the suitability of a linear programming model in portraying the peasant farming situations.

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[1] J. Heyer "Agricultural Development and Peasant Farming in Kenya". Unpublished Ph.D. Thesis, University of London, 1966.

[2] L. Odero Ogwel and E. Clayton, A Regional Programming Approach to Agricultural Sector Analysis, Wye College, University of London, 1973, pp.73-84.

Another linear programming study was made of smallholder agricultural situations by Ateng (1977).[1] His study was in Makueni location in Machakos district. After presenting a series of optimal plans for different farming technology he concluded that ox-cultivation methods gave the highest expected net returns.

All the above discussed studies in Kenya using linear programming techniques showed the applicability of the technique to analyse the small scale farming situation.

In using an LP model to study smallholder farming situations it is relevant that the most limiting factors of agricultural production should be carefully identified. Wilde et al (1967)[2] referring to resource utilization and maximization on returns on East African small holdings stated that where rainfall is more evenly distributed and both climate and soils are such as to permit greater flexibility in the timing of agricultural operations or a greater choice of crops and livestock, the fluctuation in labour requirements is much less great. The most important point to be considered is that the labour bottleneck may result not only from an absolute shortage of labour and the efficiency with which it is utilized, but also from the prevailing systems of

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[1] B.A. Ateng, "Linear Programming. An Application to the Identification of the Best Existing Farming Strategy for Peasant Farmers in Kenya". Unpublished M.A.Thesis, Dept. of Economics, University of Nairobi, 1977.

[2] John C. de Wilde, P.F.M. McLoughlin, André Guinard, Thayer Schudder and Robert Maubuche, Experience with Agricultural Development In Tropical Africa, Vol. I, Johns Hopkins Press, Baltimore, Maryland, 1967, pp.71-94.

values which may make farmers unwilling to put in more labour even though an outside observer might conclude that available labour resources could be more fully utilized. In all situations it is important to identify what bottlenecks exist and how they might be eliminated.

Once it is recognized at what rate and what results farm resources are actually being used throughout the agricultural season it is then easier to consider how new methods and new crops or combinations of crops can be introduced. To achieve this goal a thorough study of the existing farming system is required.

CHAPTER THREE

OBJECTIVES AND METHODOLOGY OF INVESTIGATION

3.1. Objectives of the Study

The overall objectives of this study are to identify the factors which most constrain agricultural production in the star grass zone of Embu district and investigate different enterprise combinations on small scale farms to show how farmers' income can be increased by a reallocation of resources.

Specifically, the study addresses the following questions:

a) To what extent are farmers in the star grass zone maximizing expected incomes in giving more attention to the production of coffee? Under what conditions does coffee compete for the available scarce resources on farms with the production of milk from dairy cow and cereals?

b) What is the effect on the income of farmers if the available land area for cultivation was to be increased?

c) How should family labour be deployed in the different enterprises and what use can be made of hired casual labour in the farming sector of the star grass zone? How does increasing the available family labour change optimal enterprise combinations on farms and the magnitude of farmers income?

d) What is the effect of the supply of working capital on the optimal enterprise combinations?

To address these questions the present organization, and operational systems of the farms were examined. After gaining an understanding into the existing farm organizational systems

of the star grass zone, farm plans were developed to investigate various combinations of the resources available for agricultural production. These farm plans can be used as guidelines by district extension officers to advise farmers on farm organization.

3.2 Hypothesis

The study attempts to test the following three hypotheseses:

i) Within the existing farm organization in the star grass zone farming income is seriously limited by the physical constraints of land, labour and working capital. There are opportunities for farmers of the star grass zone to increase the income from farming operations by using a different enterprise mix.

ii) Coffee production is more profitable to farmers of the star grass zone of Embu district than milk production or food crop production in a situation where there is adequate labour availablity.

iii) Milk production from dairy cows is more profitable than the other enterprises produced in the star grass zone where there is sufficient land available and labour is in short supply.

3.3 Sampling Design

The sampling of farms for study was preceded by a reconnaisance survey with the assistance of the district "Technical Assistant" over a period of three days. Informal interviews were held at this time with ten farmers to gain on overview of the general farming situation in the district. A homogeneous

and representative administrative Location of the star grass zone in Embu district was selected for study in consultation with the district agricultural officer. The Location selected was Gaturi.

The decision was taken to concentrate the survey in this one location which reflects the characteristic of the zone in mind. This approach is supported by Upton (1973). He states:

> although it is probably true to say that every farm is unique in certain respects, there are many similarities between large numbers of farms over quite large areas. In any one such 'type of farming area' or 'land-use zone', the same basic foods and often the same cash crops are grown by particularly all the farmers, methods of production are broadly similar and so are attitudes, customs and social institutions. Thus, although there may be variations in farm sizes, and in some of the minor crops grown and livestock kept, the same basic system of farming is found over the whole area [1]

Information in farm size and farm type in the star grass zone in Gaturi location was obtained from land registrar office of Embu district. Using this information the following procedure was followed to select sample farms. Farms were stratified based on farm sizes. In the process of stratification three farm classes were selected. These were a) small farms of less than 3 hectares, b) medium sized farms ranging from 3 to 6 hectares, and c) large farms of more than 6 hectares.

A random sample of farms were selected from each of these strata with the sample size proportional to the fraction of number of farms in the whole population.

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[1] M. Upton, Farm Management in Africa. The Principles of Production and Planning, Oxford University Press, London, 1973. p.99.

Table 3: Distribution Patterns of Farms and Sample Size by Farm Type in Gaturi, Embu, 1979.

Farm type	Farm Size (ha)	Total No. of farms[1]	% of total farms[2]	Sample size[2]	% of total sample
Small	less than 3.0	1440	60	24	60
Medium	3.0 - 6.0	720	30	12	30
Large	Over 6.0	240	10	4	10
TOTAL		2400	100	40	10

Source: [1] Embu Land Registrar Office, 1974.
[2] Own calculation.

In the sample of 40 farms 24 farms were from small farm class and 12 and 4 farms were from the medium and large farms respectively.

The statistical manipulation for the distribution of the sample farm sizes selected shows that with 95% confidence level the population mean farm size (μ) lies between $\bar{x}$ - 2.42 and $\bar{x}$ + 2.42.

3.4 Type of Data Collected.

Structured questionnaires were used to collect data from the farmers in the sample. The questionnaires were pretested prior to the actual data collection. Two enumerators, familiar with the study area and fluent in the local language were engaged to assist the author in conducting the field interviews. The district agricultural "Technical Assistant" also assisted in the field work. The data collections were made between the end of October 1979 and the beginning of January 1980.

The major data collected were as follows:

a) The size of holdings.

b) Capital assets and use of credit.

c) Type of crop grown in both the short rain and the long rain periods.

d) Type and quantity of inputs used on the crops grown.

e) Crop yields in kilogram.

f) Amount and timing of labour used by the major field operations, e.g. preparing land, planting, weeding, fertilizing, harvesting, etc.

g) Family size and supply of family labour and the use of casual labour.

h) Market access and transportation costs.

i) The use and productivity of livestock.

The data collection sheets used are presented in Appendix 9.

3.5 Limitation of the Data.

All those selected participated willingly in the survey. However, only 10 farmers kept any records and much of the data collected depended upon the recollections of farmers. A particular problem was encountered in the determination of plot sizes and the levels of inputs and outputs. Whenever practicable the interviews included crosschecks to minimize inconsistencies in their responses.

The other limitation of the data was that the survey took place in less than three months, and the data collected were from one short survey. As the result of this, data collected on labour were bound to be unreliable.

The major part of the data used in this study pertaining to livestock production, especially dairy husbandry, were acquired from farmers who kept records.

3.6 Plot Measurement Procedures.

As noted above some respondents had problems providing information about the plot sizes used during the previous cropping seasons. In these cases farmers were requested to actually demarcate the plots they used during the previous seasons. These plots were measured and checked against their estimates as recorded in the interviews.

In measuring the plots the following procedures were followed. A sketch map of the respective plot to be measured was drawn on paper and each plot was divided into triangles. Irregularities in plot shape were smoothed out by a give and take process, leaving as near as possible an equal crop area outside the measuring lines as taken inside the lines. After measuring the length of each side of the triangles by pacing, the area of the respective triangle was measured using the following formula:

$$\sqrt{S(S-a)\ (S-b)\ (S-c)}$$ [1]

Where a, b and c are the lengths of the sides of each triangle and $S = \frac{a + b + c}{2}$.

Then, area of all triangles is added up to obtain the area of the whole plot.

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[1] M. Upton, Op.cit., p.223

More difficulty was encountered in estimating the areas of crops when they were mixed. To avoid this complication each crop mixture was treated as a single enterprise.

3.7 Analytical Techniques Used in the Study

3.7.1. Survey Analysis

The data collected were compiled and analysed to acquire the necessary overall information about the study area. In compiling and analysing of the data, the mean, percentages, cross tabulation and frequency distribution were used for the respective characteristics of the data.

3.7.2 Linear Programming

In this study linear programming (LP) is the main tool of analysis. Linear programming is a mathematical tool for solving minimization and maximization problems.

In this study the concern is to determine the gross margin maximizing combination of activities on farms in a setting of limited resources.

Net revenue maximization is the customary assumption about the objectives of farmers as regards their selection of enterprises. This is a normative model of economic behaviour. Linear programming is closely related to comparative budgeting in that it is based in many of the same assumptions and requires the same basic data although normally in a much more detailed form. It is claimed by the proponents of linear programming that it has one decided advantage. In comparative budgeting we have to select a certain number of possible programmes and budget these separately.

The number of programmes which can be selected is limited by the manpower and time available, and it is seldom that more than three or four combinations are compared. The strength of the linear programming technique is that provided the basic data are adequate, and the basic assumptions of linearity are not violated, the unique profit-maximizing enterprise combination is identified.

The advantage of LP technique over budgeting in the planning of the agricultural firm is described by Renborg as follows:

> It is a long step indeed from the labourious calculations possible plans for intuitively chosen alternatives as the old budgeting method to the rapid and elegant performance of an electronic computer as it seeks its way to the optimal plan for a farm by the linear programming procedure.[1]

Mathematical programming methods have been widely advocated and used, in looking for ways of modelling small farmers' production decisions. Even though a linear programming approach has not been without its critics, it is evident that many researchers have found the technique well suited to planning small scale agriculture.[2]

Low (1978) argue that the strength of LP lies in its ability to handle a large number of interrelated variables and thus to cope with peasant farming systems which are characterized by high degree of interdependence between production and consumption, consumption and investment, investment and resource

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1 Ulf Renborg, Studies on the Planning Environment of the Agricultural Firm. Department of Agricultural Economics, Agricultural College of Sweden, Uppsala Sweden, 1962, p.6.

2 J.B. Hardaker, "A review of some Farm Management Research Methods for Small Farm Development in LDCS", Journal of Agricultural Economics, Vol. XXX, No. 3, Sept. 1979, pp.315-320.

availability and social and cultural constraints. He continues to argue that despite the data problems, appropriately specified LP models can make a significant contribution to the understanding and development of peasant farming systems.[1]

The major advantage of the linear programming technique can be summarized as follows:

i) compared with other methods in planning it can help to handle complex cases in a more comprehensive and realistic manner.

ii) It enables to find the optimum combination of the enterprise for given resources.

iii) It enables to frame the best farm plan from alternative strategies i.e. by identifying under-employed resources and limiting resources in order of importance.

In this study a single-period linear programming model is used instead of multi-period linear programming model. This is because of the limitation on data. The basic difference in the two programming models is that, in a single-period linear programming problem, the task is to allocate the scarce resources to different activities in a manner to optimize the linear objective function in static condition. In a multi-period programming model the objective is to find an optimal policy of allocating resources (making decisions) at each stage of a multi-stage decision process, with an optimum overall program in relation to the interdependence of stages.

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1 A.R.C. Low, "Linear Programming and the Study of Peasant Farming Situations", JAE, May 1978, pp.189-190.

3.7.3 Analytical Framework

The mathematical structure of the linear programming model that is used in this study to explore the possibilities of optimizing farm return is as follows:

i) maximize

$$Z = C_1X_1 + C_2X_2 + \ldots\ldots + C_nX_n$$

subject to:

$$a_{11}X_1 + a_{12}X_2 + \ldots\ldots + a_{1n}X_n \leq b_1$$

.

.

.

$$a_{m1}X_1 + a_{m2}X_2 \ldots\ldots + a_{mn}X_n \leq b_m$$

where:

Z = Total objective function to be optimized

C_n = net return per hectare of n^{th} activity

X_n = Hectarage under n^{th} crop or livestock

b_m = Availability (or constraints) of the m^{th} resource

a_{mn} = Per hectare requirement of m^{th} resource of n^{th} activity.

ii) $X_n \geq 0$ for all values of n

This is the non-negative condition of the LP model, whereby no activity should enter the solution at a negative value.

iii) $\sum_{f=1}^{4} e_f X_f \geq H$

This is the minimum requirement condition of the four specified food crops per household (H) that must be fulfilled before the maximization of the objective function by the LP programme takes place.

where:

e_f = the number of units of food requirement e that are contributed by activity f.

3.7.4. The Assumption of the Model Used.

The suitability of LP to planning the farm firm is in contest of the following assumptions:

i) The assumptions of linearity are that there is linear relationship between activities and resources. This implies that there is constant resource productivity and constant returns to scale. The linearity assumption underlying the standard programming model has been of concern to farm management and production economists. Some economists attempted to extend or improve programming techniques by examining several procedures for solving programming problems when economies of scale exist. Candler and Manning (1961)[1] described a modified simplex procedure for linear programming problems with one or two input coefficients displaying decreasing average costs.

ii) The other assumption of an LP model which is of concern is that given any activity levels ($X_1, X_2 ---- X_n$) the total usage of resource by the different activities must equal to the total quantity of resources used by each activity for all the resources. This implies that there is not any interaction among the activities of the resources. Authors like Heyer (1966)[2] argue that complementarityof activities in a peasant farming

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[1] W. Candler and R. Manning. "A modified Simplex Procedure for Problems with Decreasing Average Costs." J. Farm Econ. 43859-875, Nov. 1961.

[2] J. Heyer, op. cit., pp. 59-60.

situation is not a major problem. The complementarity of two crops in a crop mixture with respect to labour and land are dealt by treating the crop mixtures as one activity rather than two. This is the approach employed in this study whenever mixed crops are grown.

Complementarity in the crop rotation can be dealt by treating a crop rotation as a composite activity or by permitting one crop in a rotation to enter as an input for another crop whose yield is increased by the existence of the first relational crop.[1] However, in this study the problems of complementarity of activities arising as a consequence of crop rotation was not solved in the model used. This is because of a) absence of a well defined rotational system practised by farmers in Gaturi, and b) limitation of data in the variation of yield arising from crop rotational operation.

iii) The continuity assumption permits a variable to take on any value (integer or non-integer) in the optimal solution. This may pose a problem in modelling production situations where integer solutions are more appropriate. Here, if the solution gives a non-integer value to an enterprise which should be integer, the non-integer variables are merely rounded to integer values. In this study this is the technique used to overcome this linear programming problem whenever it exists. This problem can also be overcome by the use of integer and mixed integer programming technique.

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[1] J. Heyer, Op.cit., p.60 .

iv) The deterministic assumption of linear programming is that all the parameters of the model (the a_{mn}, X_n, C_n values) are known constants. LP models are usually formulated in order to select some future course of action. Therefore, the parameters used should be based on a prediction of future conditions, which inevitably introduces degree of uncertainity. For this reason it is usually important to conduct a thorough sensivity analysis after finding the linear programming solution with the assumed parameter values.

v) There are a finite number of activities and restraints.

3.7.5 Parametric Programming

As explained above one assumption of the LP model is that all the parameters of the model (the a_{mn}, X_n. and C_n) are known constants. Actually, the parameter values used in the model normally are based on a prediction of future conditions. For these reasons it is important to perform a sensitivity analysis to investigate the effect on the optimal solution if the parameters take on other values. Therefore after solving for the optimum farm plans the resource vectors were varied parametrically to evaluate their importance in determining the optimum enterprise mixes. In particular the labour and land resources for each model farm were varied parametrically as this two types of resources were expected to be important determinants of the farm plan.

These analyses helped to provide answers to the following types of questions:

i) How would changing one or more resources affect the optimum combination of activities and the value of the objective function?

ii) How great is the profitability of activities which entered the plan over those which did not?

iii) How would changes in price relationship of activities affect the optimal solution?

3.8 The Model Farms

A model farm was built for each size group of farms and the aggregate holdings of all the sample farms. In total four model farms were developed.

These are:

i) Model I for farms less than 3.0 hectares (small farm model)

ii) Model II farm portraying farm group ranging in size from 3.0 hectares to 6.0 hectares (medium farm model)

iii) Model III farm presenting farm group which are over 6.0 hectares (large farm model).

iv) Model IV (aggregate holding model) was built for all the holdings in the 40 sample studied.

3.9 Construction of the LP matrix used in the Study[1]

This major section represents details of the method used to construct the matrices.

3.9.1. Land

The mean available arable land was calculated to

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[1] See Appendices 8A to 8D.

determine the levels at which lard is to be constrained in each model. The values were calculated after allowing for all the waste land and the area under the homestead. The mean land area available for cultivation in Model I is 1.64 hectares, while in Model II, Model III and in model IV the areas available for cultivation are .3.25 ha., 6.1 ha and 2.57 ha. respectively.

Since crops are grown in two seasons in the area of study the available land is classified as long rain and short rain land. The matrices are constructed in such a way that some enterprises demand only one season land, while some need land for two seasons.

3.9.2 Labour

The supply of family labour is a constraint on the farming system. The monthly supply of family labour was estimated as was the labour required each month by each enterprise. This was done on a per hectare basis for crops to be grown and a per head basis for livestock.

To make different comparisons between different types of labour it is necessary to express days and hours in terms of common denominator (i.e. man-days and man-hours respectively). In the models built for this study man-days are used in the quantification of labour. Following Norman's (1972)[1] assumption that physical labour productivity shows initially a positive correlation and then a negative correlation with increase in age, variation was made by age group in the standardization of labour.

1 D.W. Norman, An Economic Survey of Three Villages in Zaria Province, vol. I, Text, Samaru miscellaneous paper 37, Inst.Agric.Res., Ahmadu Bello University, 1972, p. 17.

However, the other assumption of Norman that the physical labour productivity of women is lower than that of men does not hold true in the star grass zone of Embu district. Zaria Province in Nigeria where Norman conducted his studies is a moslem dominated area. Norman states "... wives in Moslem Societies are kept in partial or compete seclusion, precludes them from participating in farm work." Since this is not the case in Gaturi location where adult females equally participate in farm work with adult males differentiation was not made by sex when standardizing labour in this study[1].

Labour is standardized into adult-equivalent using the weights as presented in Table 4.

Table 4. Conversion values of People of Different Age and Sex into Adult-equivalent

Labour class	Age (years)	Adult-Equivalent
Small child	Less than 9	0.00
Large child	9-14	0.50
Female adult	15-64	1.00
Male adult	15-64	1.00
Female adult	65 or more	0.50
Male adult	65 or more	0.50

Source: adapted from Norman (1972, p.17)

In the analysis of the available labour on farms, the first consideration was the number of days per week that farm work is done. In Gaturi location farm work is done six days in a week and six and a half hours in a day. Therefore, every month

[1] See also F.M. Rukandema, Resource Availablity, Utilization and Productivity on Small Scale Farms in Kakamega District, Western Kenya, Unpublished Ph.D Thesis, University of Cornell, 1977, p.23.

consists of about 24 working days.

Calculations of the available family labour on the farm made allowance for the following factors:

i) On a significant number of days weather conditions do not permit field work to be done. Too much rainfall makes it impossible for farmers to enter field without damaging the crop. Also it is often too wet to weed or till the soil. Adjustment was done for rain-days based on rainfall data which reflected behaviour of the farming operation in the area of the study. It was assumed more than 5 mm rainfall in a 24 hour period would cause that day to be excluded from the number of work days.

ii) Official holidays

iii) Days spent to visit relatives

iv) Time spent on off-farm activities

Farmers hire casual labour only when the available family labour is fully utilized. An activity is included in the matrices to correspond to the hiring of casual labour. In Gaturi location labour is typically hired only during the peak periods of the long and short rains farming activities although the amount required on a farm is, of course, a function of the enterprise mix.

3.9.3 Working Capital.

Farm operating cash or credit is considered to be a constraint to farm production. Therefore, a row representing this capital constraint was included in the LP matrices. The value for this constraint needs to be developed to reflect

the total amount of money available to the farmer in each production period. The operating capital of the farmers own funds is separated from the borrowed money. In this way credit can then be treated as a variable cost in the matrices. In the formulation, the farmer is assumed to use his own funds until they are exhausted, and then borrows up to some limit. The operating cash row can then provide an estimate of the farmer's own funds available during each production period. An upper limit on the amount of funds the farmer borrows was set based on the results of the survey data.

3.9.4 Household Subsistence Requirements

Farm families have a subsistence requirement which must be included as a constraint in the models. This is essential as in smallhodler agriculture the subsistence requirements for food have to be met before they market produce. The basic per capita food consumption was introduced as a constraint in each of the four models.

Information provided by sample respondents was used to identify the type of basic staple food in the area of study. In Gaturi location the basic food crops are maize, beans, banana and Irish potatoes. The calorific values of these crops were computed and for each model the household subsistence requirement was calculated to be met by the four types of crops. The figure used in this study for the average calorific requirement by an adult is 2328 calories per day.[1] The basic food crops were specified in kilograms to be introduced in the matrices as constraints.

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[1] Report of a Joint FAO/WHO ad Hoc Committee, Energy and Protein Requirements, FAO, Rome, 1973. pp.79-82.

3.9.5. Activities Specified in the Models.

The major enterprises were identified in the Survey, and are incorporated in the matrices. The main activities considered in this study are the following:

1) Long rain maize, 2) short rain maize, 3) Irish Potatoes during the long rain, 4) short rain Irish potatoes, 5) long rain beans(1)[a] 6) short rain beans (1)[a] 7) long rain beans (2)[a], 8) short rain beans (2)[a], 9) long rain onions 10) short rain onions, 11) long rain maize and beans (1) interplanted 13) long rain maize and beans (2) interplanted 14) short rain maize and beans(2) interplanted 15) coffee, 16) banana, 17) banana and maize associated both during the long and short rains 18) banana and beans(1), 19) banana and beans(2), 20) Local zebu cow for milk production, 21) crossbred cow for milk production, 22) grade cow for milk production, 23) keeping ox to be sold, 24) selling maize during the long rain, 25) selling short rain maize, 26) selling long rain beans(1), 27) selling short rain beans(1),

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a) In this Study beans are classified into two types: these are Rose cocco or Canadian Wander and Mexican 142-Even though the technology employed to produce any type of beans in Gaturi location is similar, there is difference in the market prices. The price for a kilogram of Rose cocco or Canadian Wander is KSh. 2.22 while a kilogram of Mexican 142 sells for KSh. 2.0 Therefore in this study beans(1) refers to Rose cocco or Canadian Wander and beans(2) refers to Mexican 142.

28) Selling long rain beans(2), 29) selling short rain beans(2), 30) selling Irish potatoes during the long rain, 31) selling short rain Irish potatoes, 32) selling banana, 33) purchase of casual labour in each period and 34) borrow working capital.

Several transfer activities were included in the models.

2.9.6. Input-Output Coefficients

The coeffiecients (a_{ij}) used in each model are the mean values of each characteristic based on the 40 sample farms. In other words, the coefficients in each model used are the same but the variation is on the resource vectors.

All crops enterprises are presented in the models on a hectare basis. The demand for land by one unit of each livestock enterprise was based on the number of livestock units based in each and then connected to land equivalents.

Labour requirements are expressed in man-days per hectare by enterprise. The yields of crops were recorded in product pools from which they could be sold or consumed to meet subsistence needs.

The demand for working capital was calculated for each crop per hectare and for each head of livestock. This was done by computing the sum of inputs used times their respective market prices. Then these coefficients were included in each enterprise.

3.9.7 The Objective Function

For the basic food items costs of production per hectare was used in the objective function row of the matrices. This was done to enable the yields of the respective basic food crops to be transferred to the nutritional requirement rows and sell the remaining after the household food requirement is satisfied. For the rest of the enterprises gross margin calculation was done to be introduced in the objective function row. The gross margin is defined as the difference between the value of total production and the variable costs of producing each enterprise. In other words it is the net return to fixed resources. In the calculation of the gross margin the procedure followed can be presented by the following equations:

$$Gj = Xj - \sum_{i=1}^{n} Ci$$

where:

Gj = the gross margin from enterprise j

Xj = the value of output of enterprise j

Ci = cost of the variable inputs

j = 1, 2, 3,... n = no. of inputs

The prices used in this study are the local market prices in Gaturi location prevailing during the study period.

In calculating the costs of producing the different enterprise the following points were considered.

a) the costs are based on one hectare in the case of crops and one head of cattle in the case of livestock enterprises.

b) In the case of coffee and banana which are perennial crops cash flow calculation was done in order to calculate the establishing costs. Then, the establishing cost is distributed over the life of the respective crop.

c) To arrive at the total variable cost of milk production the costs considered are the annual cost of investment in each type of cow, cost of concentrate, minerals, health control and casual labour.

d) In the production of crops the variable costs considered are costs of fertilizer, seed, herbicide pesticide and casual labour.

Chapter Four

FINDINGS

In this chapter the results of the study are presented. The first part of the chapter discuses the survey results obtained from the field data collected. In the second and third parts the linear and parametric programming results are presented respectively.

4.1 Survey Results

4.1.1. Farming Systems in Gaturi

The farming systems in Gaturi can be divided into two, viz, crop and livestock systems, as illustrated with Figure 4.

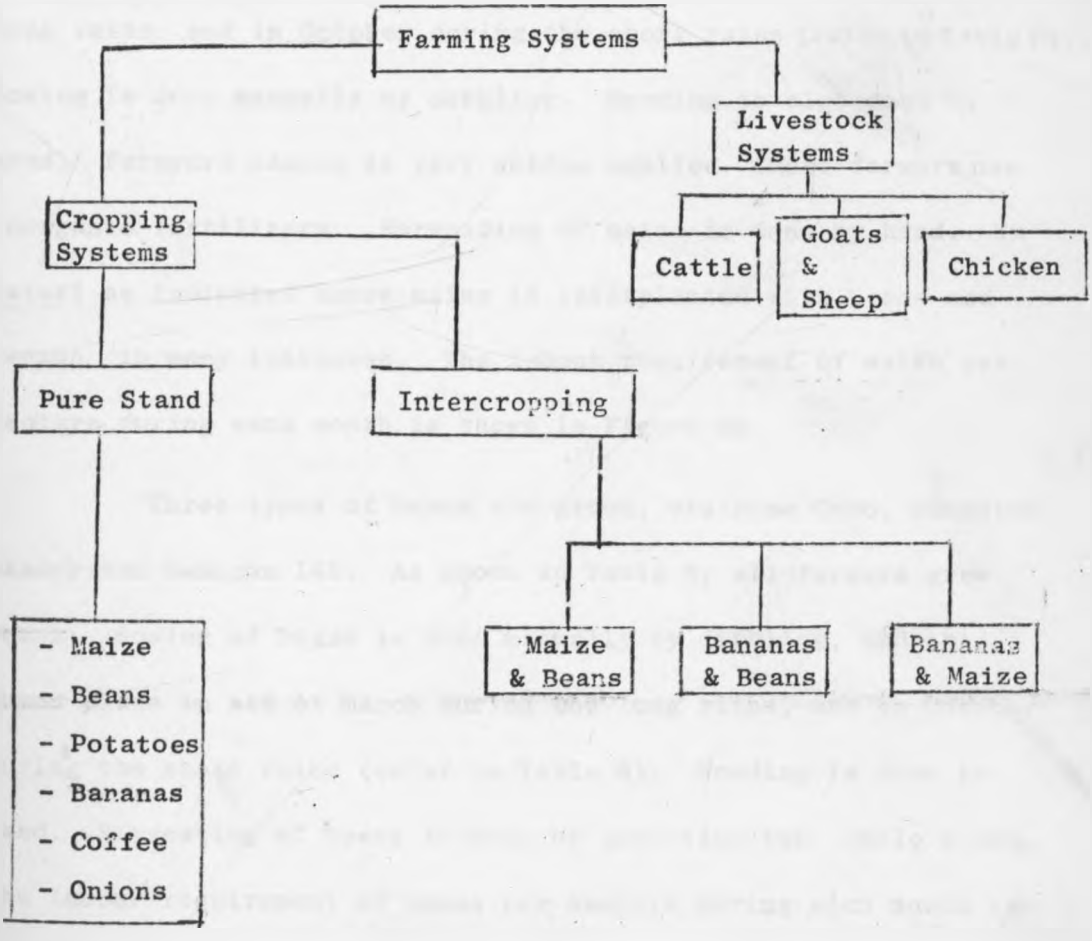


Figure 4: Farming Systems used in Gaturi

Source: Author's Observation.

(i) Crops

Two types of cropping methods are practised by farmers in Gaturi. These are pure stand cropping and intercropping. In the case of pure stand cropping crops like maize, beans, banana, potatoes and onions are grown in pure stand. On the other hand, maize and beans, banana and beans, banana and maize are grown in mixture respectively.

Maize is the main food crop in Gaturi. As shown in Table 5, all sample farmers grew maize. Maize occupied 25 per cent of all the average cultivable land during the time of the survey. The most common variety of maize grown in Gaturi is "Embu hybrids". Land preparation for maize is done by hand with the use of jembes. Sowing takes place end of March during the long rains, and in October during the short rains (refer to Table 6). Sowing is done manually by dibbling. Weeding is also done by hand. Farmyard manure is very seldom applied. Most farmers use inorganic fertilizers. Harvesting of maize is done by hand. In Gaturi as indicated above maize is interplanted with beans and banana in many instances. The labour requirement of maize per hectare during each month is shown in Figure 5A.

Three types of beans are grown, viz:Rose Coco, Canadian Wander and Mexican 142. As shown in Table 5, all farmers grew beans. Sowing of beans is done manually by dibbling, and this takes place in mid of March during the long rains, and in October during the short rains (refer to Table 6). Weeding is done by hand. Harvesting of beans is done by uprooting the whole plant. The labour requirement of beans per hectare during each month is shown in Figure 5A.

Table 5. Number of Farmers and Type of Crop Grown by Size Group of Sample Farms, in Gaturi, Embu, 1979/80.

Size Group	Small Farms	Medium Farms	Large Farms	All Holdings	
Type of Crop	No. of Farmers	No. of Farmers	No. of Farmers	Total No. of Farmers	% of total sample[1]
Maize	24	12	4	40	100
Beans	24	12	4	4o	100
Irish potatoes	20	11	4	35	87.5
Maize & beans (interplanted)	24	12	4	40	100
Banana	24	12	4	40	100
Maize & Banana (interplanted)	20	8	2	30	75
Beans & Banana (interplanted)	18	8	2	28	70
Onions	15	12	4	31	77.5
Coffee	16	12	4	32	80.0

Source: Survey data, 1979/80.

Irish potatoes are grown for home consumption and for market. As shown in Table 5, 87.5 per cent of the sample farmers grew Irish potatoes. They are a two season crop and are planted at the beginning of the rains. Planting is done by hand, and takes place in March during the long rain, and in October

[1] Percentage is based on the 40 sample farmers.

Table 6: Calendar for Major Crops Grown in Gaturi Location, Embu, 1979/80.

Type of Crop & Farming Activity	MONTHS											
	Long Rain							Short Rain				
	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan
Maize												
i) Land Preparation	X							X				
ii) Planting		X							X			
iii) Weeding			X							X		
iv) Dusting			X							X		
v) Harvesting							X					X
Beans												
i) Land Preparation	X							X				
ii) Planting		X							X			
iii) Weeding			X							X		
iv) Harvesting						X						X
Irish Potatoes												
i) Land Preparation	X							X				
ii) Planting		X							X			
iii) Weeding		X	X							X	X	
iv) Spraying		X	X							X	X	
v) Harvesting						X						X

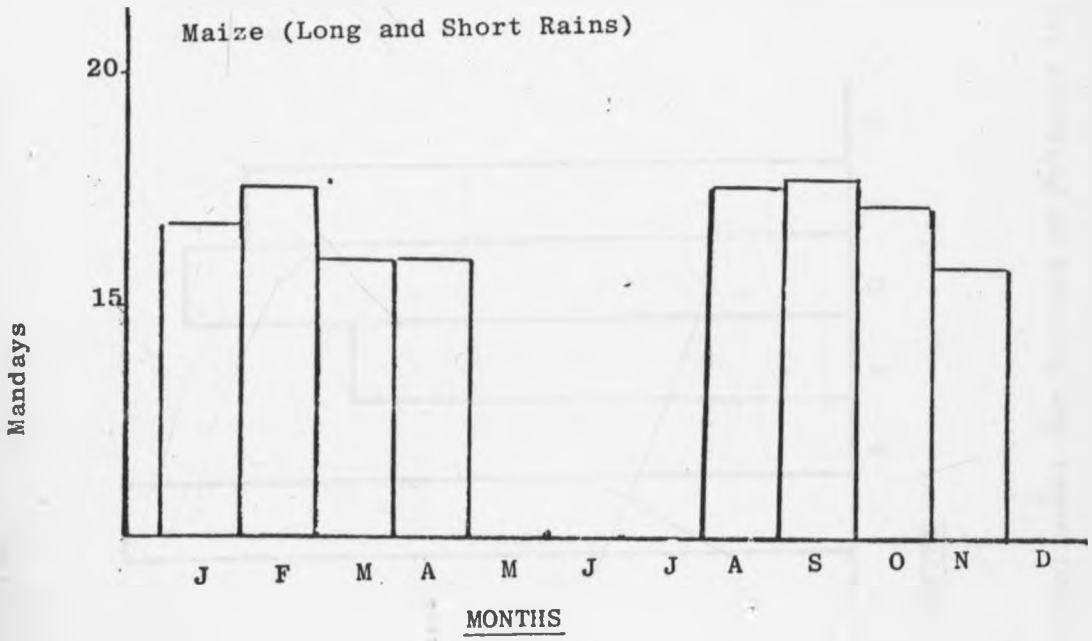
Table 6(cont'd).

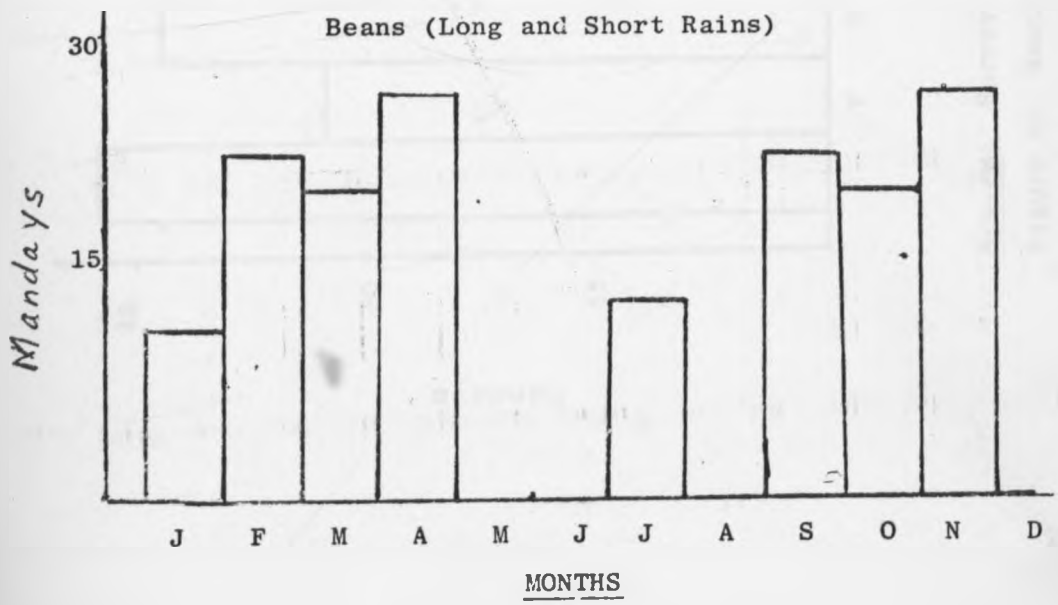
Type of Crop & Farming Activity	MONTHS											
	Long Rain							Short Rain				
	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan
Banana[1]												
i) Weeding				X						X		
ii) Harvesting		X		X		X		X		X		X
Coffee[1]												
i) Weeding	X	X	X	X	X	X	X	X	X	X	X	X
ii) Pruning	X				X							
iii) Spraying		X		X	X				X			
iv) Mulching									X	X	X	
v) Picking								X	X	X		X

Source: Survey data, 1979/80.

[1]The crop calendar for banana and coffee is at maturity stage.

X = denotes the month in which each cropping activity takes place.

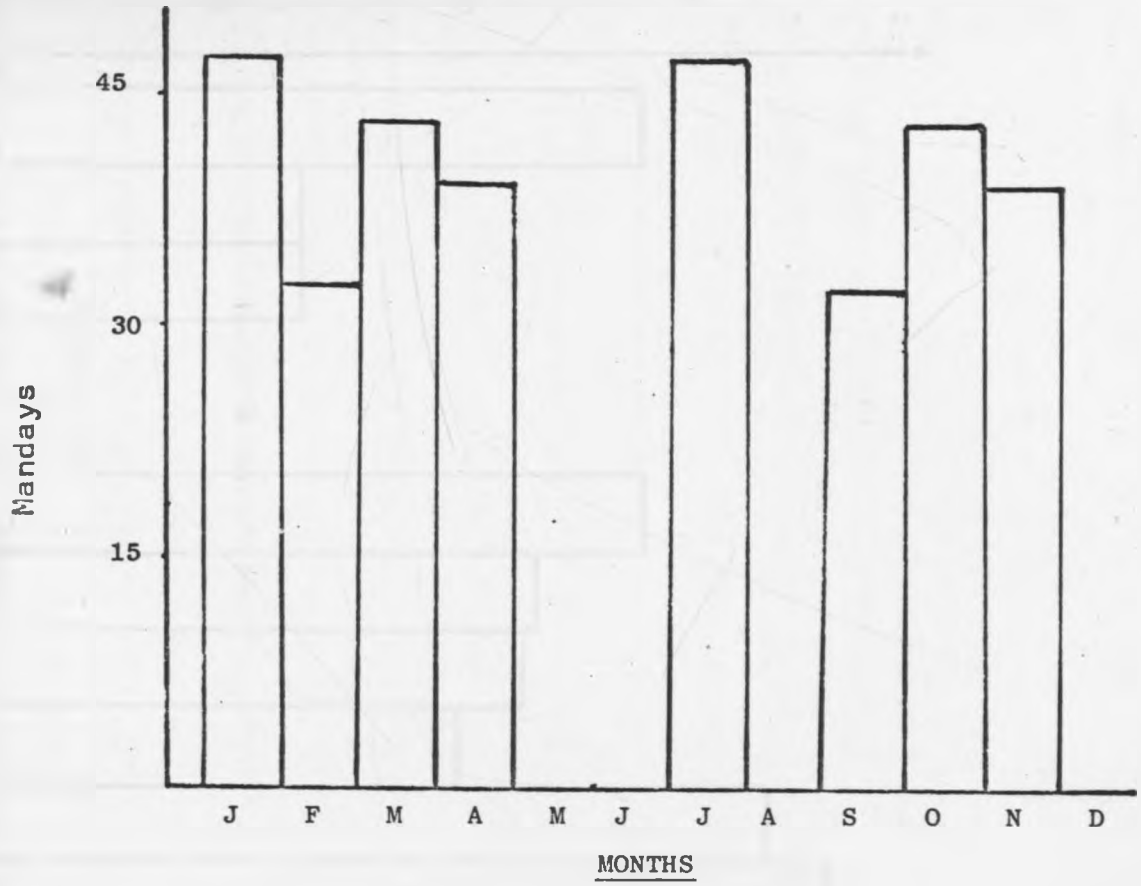




Source: Survey data, 1979

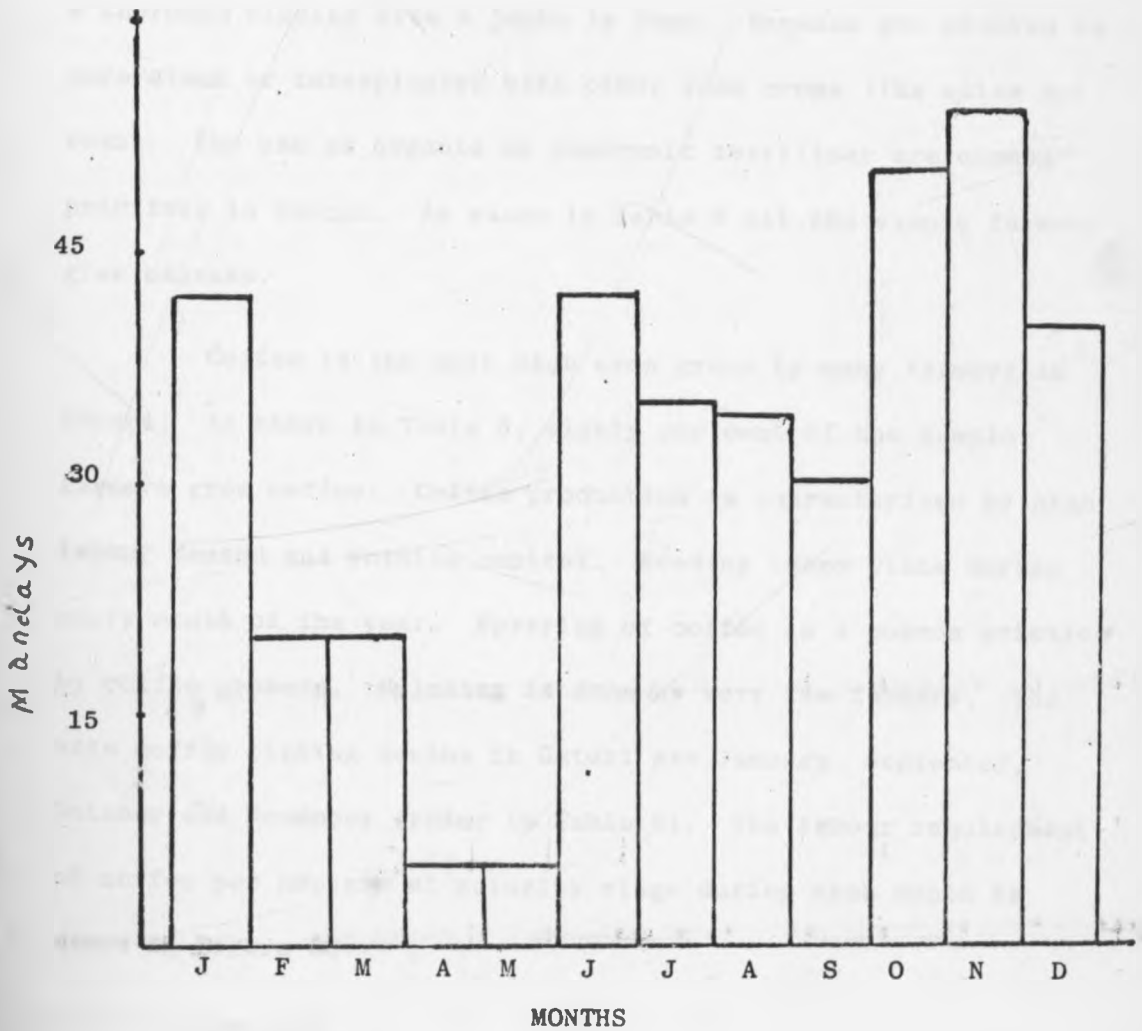
Figure 5A: Monthly Labour Requirement per Hectare of Maize and Beans in Gaturi Location, 1979/80.

Irish Potatoes (Long and Short Rains)



Source: Survey data, 1979.

Figure 5B: Monthly Labour Requirement per Hectare of Potatoes in Gaturi Location 1979/80.



Source: Survey data, 1979

Figure 5c: Monthly Labour requirement per Hectare of Coffee (at maturity stage) in Gaturi Location, 1979/80.

during the short rain (refer to Table 6). The use of organic or inorganic fertilizer by farmers in the area is very rare. Potatoes are harvested by hand. Jembes are the implements usually used for harvesting. The labour requirement of potatoes during each month is shown in Figure 5B.

Bananas are usually grown as subsistence crops. Few farmers grow bananas to earn cash by selling in the local markets. Land preparation for bananas is done by hand, whereby all perennial grasses are eradicated. On soils where there is no couch grass a thorough digging with a jembe is done. Bananas are planted in pure stand or interplanted with other food crops like maize and beans. The use of organic or inorganic fertilizer are common practices in Gaturi. As shown in Table 5 all the sample farmers grew bananas.

Coffee is the main cash crop grown by many farmers in Gaturi. As shown in Table 5, eighty per cent of the sample farmers grew coffee. Coffee production is characterized by high labour demand and working capital. Weeding takes place during every month of the year. Spraying of coffee is a common practice by coffee growers. Mulching is done by very few farmers. The main coffee picking months in Gaturi are January, September, October and November (refer to Table 6). The labour requirement of coffee per hectare at maturity stage during each month is shown in Figure 5C.

(ii) Livestock

Along with crops livestock husbandry is an important activity in Gaturi.

In the study area 8 per cent of the sample farmers kept grade cattle. The type of grade cattle kept according to descending order of preference by farmers are: Guernsey, Friesian, Ayshire and Jersey. Farmers are not interested in keeping grade cattle in Gature because of two major reasons. The first reason being the high mortality rates (estimated at about 15 per cent per year) and the second reason is their high purchase price. At the time of the survey a grade heifer costed approximately KSh.2000.00.

The most preferable type of cattle, kept by farmers in Gaturi are crossbred cows. They have higher milk yields than the indigenous Zebu type and lower mortality rates than the grade cattle as the result of their adaptability to the area. Farmers estimated annual mortality rates of around 5 per cent for mature crossbred cows. Furthermore, they can be bred from the indigenous herd with artificial insimination, the facilities for which are becoming more readily available. Thus the cost of acquiring them is substantially less than the high costs of grade cows.

Bulls and oxen are kept on open grazing with the rest of the cattle and in 92 percent of cases these animals were the local Zebu type. Oxen are used mainly for transportation. In the study area oxen are not used for ploughing. Livestock like goat and sheep have not much economic significance in Gaturi.

Few farmers grow napier grass as fodder crop which is usually planted at the bottom of a farm as a ley pasture to counter erosion. Star grass is the most common grass type fed to livestock. Usually, livestock are allowed to directly graze on the latter type of grass. Cut and carry forage feeding is not a common practice in Gaturi location. Concentrate feeds

are fed only to grade and crossbred milking cows. The feed is acquired by farmers from Kenya Farmers Association (KFA) at a price of KShs. 74.50 per bag[1] at the time of the survey. The price ratio of concentrate feed to the farm gate milk price was approximately 1:1.75 at the time of the survey. A kilogram of milk sold for KShs. 1.85 in Gaturi local market.

There is no farmers' dairy cooperative in Gaturi location. Farmers do not sell the milk they produce to Kenya Cremeries Cooperatives (KCC) and there are no milk collection centres in the whole district. Farmers sell the milk they produce to neighbouring farmers or to consumers in local markets.

As mentioned above farmers have become aware of the need to increase production by upgrading their local Zebu cow. The governments Artificial Insemination (A.I.) service covers the whole of Embu division. Farmers have built crushes for the A.I. service along the roadside. They pay KSh. 1.00 per cow for maximum of four series of inseminations. If three repeat artificial inseminations are made for any cow the farmer is advised to deliver the cows for clinical check-up to the district veterinary officer.

Ninety eight percent of the sample farmers, who usually would not like to risk a loan from credit institutions like AFC (Agricultural Finance Cooperation) to purchase grade heifers prefer the artificial insemination service, which costs little.

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[1] A bag of concentrate weighs 70 kg.

The artificial insemination service provides semen from sires of Guernsey, Friesian, Ayrshire and Jersey breeds. Farmers can choose the breed used with their cows. If they do not indicate a preference the artificial insemination technicians select a breed for them. This happens in only few cases.

There are nine dips in Gaturi location. Livestock are dipped twice a week, and farmers are required to pay KSh. 0.50 per head per dipping. In 1978 approximately 75 percent of the cattle in Gaturi were dipped regularly as compared to 82 percent of the cattle for the district as a whole.[1]

4.1.2. Land

The average size of land holding in Gaturi location is 2.79 ha. Sixty per cent of the farms are less than 3.0 ha. with an average land holding size of 1.76 ha. Thirty percent of the farms are between 3.0 ha. and 6.0 ha. with an average land holding size of 3.47 ha. Only 10 percent of the farms are over 6 ha., and they have an average size of 6.94 ha. Details of land holding distribution pattern of the sample farmers are shown in Table 7. At the time of the survey (1979/80) the price of land in Gaturi location was reported to be in the range of KSh. 20,000 to KSh. 25,000 per hectare.

Within the existing farming system annual crops occupy 41.22 per cent of the available land, area occupied by pasture and tree crops constitutes to 25.1 per cent and 25.8 per cent of the total available land respectively. The area used for homestead amounts to 7.52 per cent on the average. Details of the average land use pattern are presented in Table 8.

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[1] Republic of Kenya, Ministry of Agriculture, Embu District Annual Report 1978, Embu, 1978, p.42.

Table 7: Distribution of Sizes of Land holdings of Sample Farms in Gaturi, 1979/80.

Farm Sizes (ha)	No. of Holding in Sample	Percentage of sample
0-1	6	15.0
1.01-2	9	22.5
2.01-3	9	22.5
3.01-4	6	15.0
4.01-5	4	10.0
5.01-6	2	5.0
6.01-7	3	7.5
7.01-8	1	2.5
Total	40	100

Source: Survey data, 1979/80.

Table 8: Pattern of Land Use on Sample Farms in Gaturi, Embu, 1979/80.

Type of use	Total (ha.)	Average (ha.)	Per cent
Annual Crop	46.0	1.15	41.22
Grass	28.0	0.7	25.1
Tree crops	28.8	0.72	25.8
Homestead	8.4	0.21	7.52
Waste Land	0.49	0.01	0.36
Total	111.6	2.79	100.00

Source: Survey data, 1979/80

All land in Gaturi location is registered. In Gaturi 99 per cent of the farmers are owner-operators. Eighty per cent of the sample acquired their land through inheritance, while the remaining 20 per cent obtained land by purchase. Sixty per cent of the latter type of land owners are immigrants from the Kikuyu grass zone.

4.1.3 Labour

The survey took account of the available family and hired casual labour. Hired casual labour is only used when family labour is fully utilized. There are peak periods of labour occuring mainly for land preparation, planting, weeding and harvesting. Farmers reported hiring most casual labour during the coffee picking periods. The cost of casual labour was reported as KSh. 10.00 per day. Casual labourers are required to work for six and a half hours per day to earn this wage.

Table 9 presents details of the family composition and estimated family labour supply for each of the three classes of farms. In the survey area, males were 47.2 per cent of the whole population. The size of household in Gaturi was 8.3 persons at the time of the survey. The average number of adults in a family is 3.7 persons. The number of adults constitute to 43.4%, 44.9% and 51.5% of the total family size in small, medium and large farms respectively. In Gaturi location adults working in farm full time are 2.2 persons on the average per holding, while those not working in farm full time are 1.5 persons. On the small farms an average of 2.0 adults are available per farm

while in medium sized farms 2.5 adults are available. On large farms 2.75 adults comprise the family labour supply for the farm operations. School age children work in farms only during school holidays, in April, August and December.

Table 9. Mean Family Labour Availaibility by Farm Holding by Size Group of Sample Farms, in Gaturi, Embu, 1979/80.

Size of holdings	Less than 3.0 ha.		3.0 - 6.0ha.		Over 6.0ha.		All Holdings in Sample	
Family member	No.	%	No.	%	No.	%	No.	%
Adult males[1]	1.7	20.5	1.75	20.9	1.75	21.2	1.7	20.5
Adult Females[1]	1.9	22.9	2.0	24:0	2.5	30.3	2.0	24.1
Total adults[1]	3.6	43.4	3.75	44.9	4.25	51.5	3.7	44.6
9-14 years[1]	3.0	36.1	3.1	37.1	2.5	30.3	3.0	36.1
Less than 9 years[1]	1.7	20.5	1.5	18.0	1.5	18.2	1.6	19.3
Family size	8.3	100	8.35	100	8.25	100	8.3	100
Adult members not working on Farm full time								
Adutl employed off-Farm[2]	0.5	13.9	-	-	-	-	0.3	8.1
Adult in school[2]	0.4	11.1	0.5	31.3	0.5	11.8	0.45	12.2
Too old[2]	0.7	19.4	0.75	20.0	1.0	23.5	0.75	20.2
Total adults not working on farm (full time)[2]	1.6	44.4	1.25	33.3	1.5	35.3	1.5	40.5
Adults working on Farm (Full time)[2]	2.0	55.6	2.5	66.7	2.75	64.7	2.2	59.5
Total Adults	3.6	100	3.75	100	4.25	100	3.7	100
Children in school[3]	4.0	85.1	3.8	82.6	3.0	75.0	3.8	82.6
Children not in school[3]	0.7	14.9	0.8	17.4	1.0	25.0	0.8	17.4
Total children	4.7	100	4.6	100	4.0	100	4.6	100

Source: Survey data, 1979/80

[1] In computing percentages, family size was used as base.
[2] Percentage based on total adults in the holding.
[3] Percentages based on total children in the holding.

4.1.4. Capital

The main type of capital available on the farms are, farm land, working capital, livestock and implements.

The main type of farm implements used by farmers are pangas, forked jembes, jembes, clippers, milking utensils, wheel barrow, spraying pumps and ox-carts.

As shown in Table 10 the number of farm implements owned by farmers increases as the size of holding increases.

Table 10: Average Number of Farm Implements and Values Used by Farm Holding by Size of Sample Farms, in Gaturi, Embu, 1979/80

Size of holding	Small farms (0-3.01)		Medium farms (3.01-6.0ha)		Large Farms (over 6ha)		All Holdings[1]	
	No.	value (Ksh)[2]	No.	value (Ksh)[2]	No.	value (Ksh)[2]	No.	value (Ksh)[2]
Pangas	1.45	30.0	3.0	60.0	6.0	150.0	2.37	51.0
Forked jembes	1.29	50.0	3.4	155.5	6.3	250.0	2.43	85.4
Jembes	1.0	24.0	3.0	54.0	7.0	160.0	2.2	30.6
Ox-cart	0.2	28.0	0.6	90.0	1.2	140.0	0.42	578.0
Wheel barrow	-	-	0.56	165.2	1.6	400.0	0.33	89.6
Bicycle	0.19	232	0.61	518.2	1.4	850.0	0.44	380.0
Milking utensils	0.43	78.0	3.2	384.0	6.4	740.0	1.22	236.0
Clippers	0.37	8.55	2.64	42.24	8.4	58.8	1.1	23.7
Spraying pumps	0.25	199.5	1.0	296.0	1.6	600.0	0.61	268.5
Total		902.1		2575.2		4608.8		1742.8

Source: Survey data, 1979/80.

[1] For values of implements under all holdings weighted averages were used.
[2] The values of farm implements are estimations by sample farmers.

On the small farms the value of implements per hectare of cultivable land area is equal to KSh. 550.00 while on the medium and large farm it amounted to Ksh. 792.4 per ha. and KSh. 754 per ha respectively. Thus the medium farms have the highest value of implements per hectare of cultivable area.

As shown in Table 11 the value of land and related investment in the small farms amounted to KSh. 25,000 per hectare at the time of the survey. On the medium and large farms land and related investments were valued at KSh. 29,677 and Ksh. 25,689 per hectare repsectively.

Table 11. Mean Value of Land and Related Investment by Farm Holding by Size Group of Sample Farms, in Gaturi, Embu, 1979/80.

Specifications	Small Farms	Medium Farms	Large Farms	All holdings
	(Ksh.)[2]	(KSh)[2]	(KSh)[2]	(KSh.)[2]
Land	35,200	69,400	138,800	55,820
Building	7,200	14,000	18,000	10,320
Fence/hedges	100	500	800	290
Tree Crops	890	16,400	16,000	7,054
Annual crops (in the field)	890	1,000	1,200	954
Livestock	600	1,000	2,600	920
Livestock shed	-	680	880	292
Total	44,880	102,980	178,280	75,650
per hectare of holdings	25,500	29,677	25,689	27,115

Source: Survey data, 1979/80.

[1] For investment values under all holdings weighted averages were used.

[2] The values of investment in the above various capital are estimations by sample farmers.

4.2 Linear Programming Results

The first part of this section analyses the maximum levels of gross margin obtainable and the optimum level of enterprise combinations if family labour alone was to be used on the model farms. The second and third parts show the changes that occur in the plans prepared as the result of hiring casual labour to support the family labour and borrowing working capital respecitively. Then, comparison of the existing and optimal plans are made for each model farm. Finally, the results of price sensitivity analysis are presented.

4.2.1 Family Labour Use

i) Small Farms

When family labour alone is used on the small famrs the optimal enterprise combination is presented in the table below and in Figure 10.

Table 12: Optimal Enterprise Combination on the Small Farms When Family Labour Alone is Used

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Beans (2)	-	0.13
Irish potatoes	0.16	0.13
Onion	0.03	-
Maize and beans (1) (interplanted)	0.61	0.50
Maize and beans (2) (interplanted)	0.43	0.5
Banana	0.13	0.13
Banana and maize	0.28	0.28
Total	1.64	1.64

Source: Computer Print Out

As shown in Table 12 when only family labour is used on the small farms the most profitable enterprises are the production of food crops. Since the total available land size for cultivation is only 1.64 ha., most of it is used to grow food crops for household subsistence. The main cash earning crops are maize, beans, Irish potatoes and onion. The maximum gross margin attainable from the sale of these crops amounted to KSh. 1124.0 per farm.

With the use of family labour alone on the small farms further agricultural production is constrained by shortage of land, labour and working capital. The marginal value product of these limiting resources is shown in the table below.

Table 13: Marginal Value Product of Limiting Resources in the Optimal Plan on the Small Farms When Family Labour Alone is Used

Resource	Unit	MVP (KSh)
Land	Hectare	1495.0
March family labour	Manday	27.0
September family labour	"	46.0
November family labour	"	58.0
Operating capital	Shilling	1.96

Source: Computer Print Out.

The marginal value product is the extra revenue which results from increasing the quantity of an input by one unit, all other input quantities remaining constant. When family

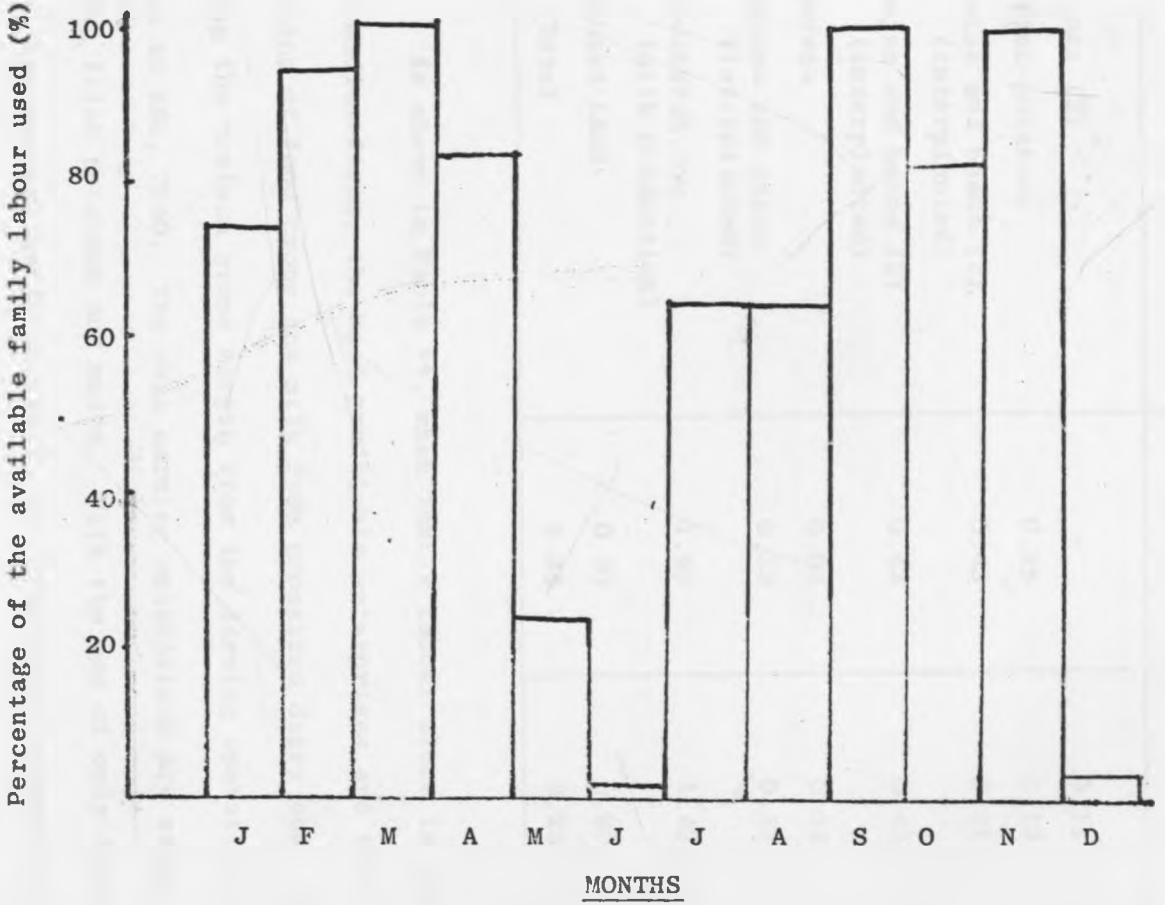
labour alone is used, the marginal value product of land per hectare is equal to KSh. 1495.00. This value is much less than the price of a hectare in Gaturi which is KSh. 22500.00. If one assumes the scarcity of capital available to farmers and sets the capital cost to buy one hectare of land at 10% interest rate per annum, this amounts to KSh. 2250.00 per annum. This value is higher than the marginal value product of a hectare of land which is equal to KSh. 1495.00. In other words an investment in a hectare of land brings a return of 6.6% per annum compared to 10% interest rate per annum of capital (see also pp.68 and 71). In Gaturi land is not available to farmers to acquire in sufficient quantities at 6.6% interest rate per annum.

On the small farms the most limiting labour periods are during land preparation, planting, weeding and harvesting. As shown in Table 11 an increase of family labour by one more man-day during March, September and November would increase the farm gross margin by KSh. 27.0, KSh. 46.0 and KSh. 58.0 respectively. The level of family labour use by month in the small farms is shown in Figure 6.

Production of coffee on the small farm is limited by shortage of September and November family labour, which are coffee picking months. Milk production from dairy cows on small farms is constrained due to shortage of land, and the production of food crops compete for the available land.

ii) Medium Farms

When family labour alone is used on the medium farms the optimal enterprise combination is presented in the table below (Also see Figure 10).



Source: Computer Print Out

Figure 6: Level of Family Labour Use by Month on the Small Farm model.

Table 14. Optimal Enterprise Combination on the Medium Farms When only Family Labour Alone is Used

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Beans (2)	-	0.11
Irish potatoes	0.25	0.13
Maize and beans (1) (interplanted)	0.43	0.51
Maize and beans (2) (interplanted)	0.43	0.46
Banana	0.02	0.02
Banana and Maize (interplanted)	0.33	0.33
Crossbred cow (milk production)	1.49	1.49
Unused Land	0.30	0.20
Total	3.25	3.25

As shown in Table 14, when family labour alone is used on the medium farms, the most profitable enterprises are the production of food crops and milk from crossbred dairy cow. By so doing the maximum gross margin from the farming operation amounts to KSh. 7550. The cash earning enterprises are sales of milk, Irish potatoes and maize. With the use of only family labour, the production of coffee is not profitable because of its high labour demand. Shortage of labour during coffee picking in September and November hampered the production of coffee.

Since labour supply is the most limiting factor of production it would be most profitable for farmers to concentrate on enterprises which demand little labour. In this respect, the production of food crops and milk from crossbred cow is

the most profitable. When only family labour is used the limited supply of labour does not permit all the available land area to be cultivated.

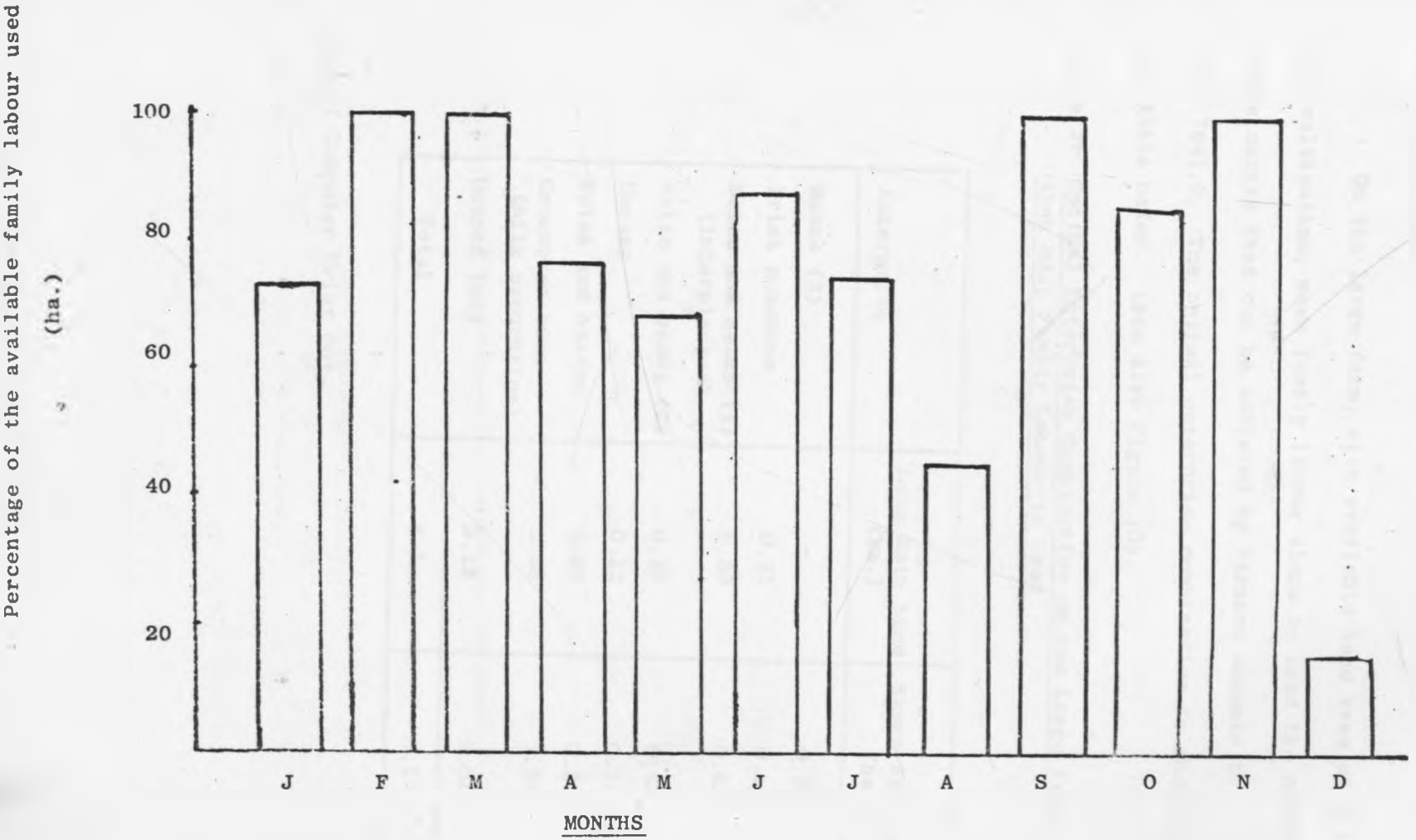
The marginal value product of the limiting resources is shown in the table below.

Table 15: Marginal Value Product of Limiting Resources in the Optimal Plan On the Medium Farms When Family Labour Alone is Used

Resource	Unit	MVP (KSh.)
February Family Labour	Manday	24.77
March Family Labour	"	132.1
September Family Labour	"	809.1
November Family Labour	"	28.0

Source: Computer Print Out.

Table 15 shows the most limiting factor of production to be labour during land preparation and weeding. If February, March, September and November family labour supply is increased by the manday each the objective function in the optimal plan would increase by KSh 24.77, KSh. 132.1, KSh.809.1 and KSh 28 respectively. These values indicate that it would be profitable to hire casual labour during the peak months on the medium farms. In Gaturi the cost of hiring one man equivalent casual labour per day is Ksh. 10.0. The daily wage of casual labour is much less than the marginal value product of labour. Therefore, the gross margin attainable from the farming operation on the medium farms can be increased by hiring casual labour during the peak periods.



Source: Computer

Figure 7: Level of Family Labour Use by Month on the Medium Farm model.

The level of family labour use on the medium farms is presented in Figure 7.

iii) Large Farms

On the large farm, with available land area of 6.1 ha. for cultivation, when family labour alone is used the maximum gross margin that can be achieved by farmers amounts to Ksh. 7641.0. The optimal enterprise combination is shown in the table below. (see also Figure 10).

Table 16: Optimal Enterprise Combination on the Large Farm When only Family Labour is Used

Enterprise	Long Rain Land (ha.)	Short Rain Land (ha.)
Beans (2)	-	0.24
Irish potatoes	0.31	0.18
Maize and beans (1) (interplanted)	0.53	0.62
Maize and beans (2)	0.52	0.43
Banana	0.11	0.11
Maize and banana	0.25	0.25
Crossbred cows (milk production)	1.26	1.26
Unused land	3.12	3.01
Total	6.1	6.1

Source: Computer Print Out.

As shown in Table 16 the most profitable enterprises to produce are food crops and milk from crossbred dairy cows. If only family labour is to be employed it would not be as profitable to grow coffee due to its high labour usage.

Since the family labour cannot take care of the whole available land area for cultivation it would be profitable to leave 51.14% and 49.3% of the land during the long and short rains respectively unused.

The following table shows the marginal value product of the limiting resources in the optimal plan.

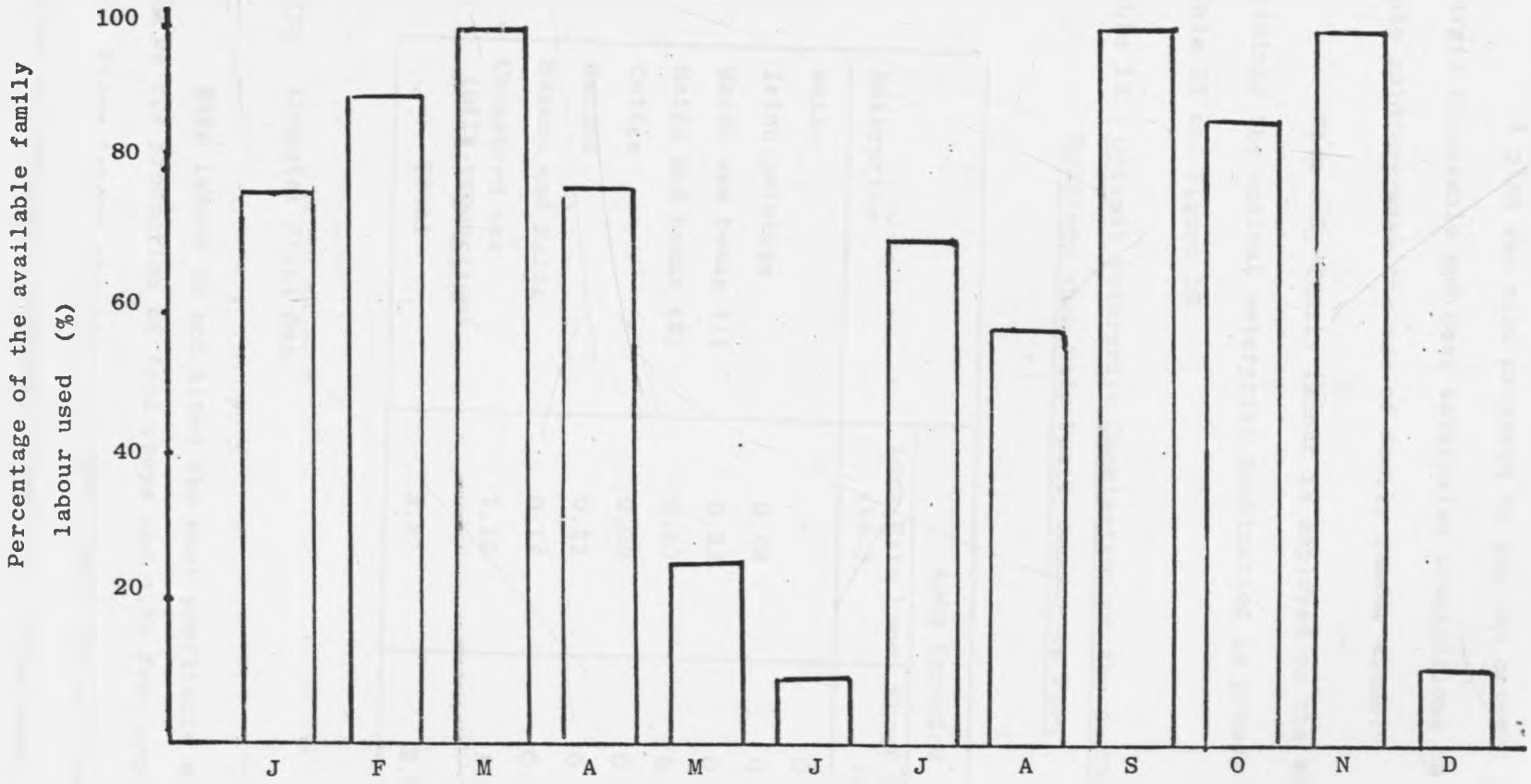
Table 17. Marginal Value Product of Limiting Resources in the Optimal Plan on the Large Farm When Only Family Labour is Used

Resource	Unit	MVP (KSh.)
March family labour	manday	150.6
September family labour	"	790.2
November family labour		27.0

Source: Computer Print Out.

The most limiting labour months are March, September and November, with marginal value product of KSh. 150.6, KSh. 790.2 and KSh. 27.0 respectively. These shadow prices indicate that it would be profitable to hire casual labour during the peak months.

The level of family labour use by month in the optimal plan is illustrated in Figure 8.



Source: Computer Print out

Figure 8: Level of Family Labour Use by Month on the Large Farm Model.

iv) Aggregate Holdings

A plan was also prepared to see the optimal gross margin obtainable and best enterprise combinations on the aggregate holdings with the use of family labour alone.

When only family labour is employed on the aggregate holdings the optimal enterprise combination is presented in Table 18 and Figure 10.

Table 18. Optimal Enterprise Combination on the Aggregate Holdings when Only Family Labour is Used

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Maize	-	0.24
Irish potatoes	0.48	0.09
Maize and beans (1)	0.32	0.35
Maize and beans (2)	0.30	0.42
Coffee	0.09	0.09
Banana	0.11	0.11
Banana and Maize	0.14	0.14
Crossbred cow (milk production)	1.13	1.13
Total	2.57	2.57

Source: Computer Print Out.

When labour is not hired the most profitable enterprise would be the production of food crops and milk from cross bred cows. Since labour shortage is a bottleneck for increased return it would be economic to produce enterprises which demand minimum labour. Therefore, if only family labour is to be used on the existing farm organization, coffee is not the main cash earning

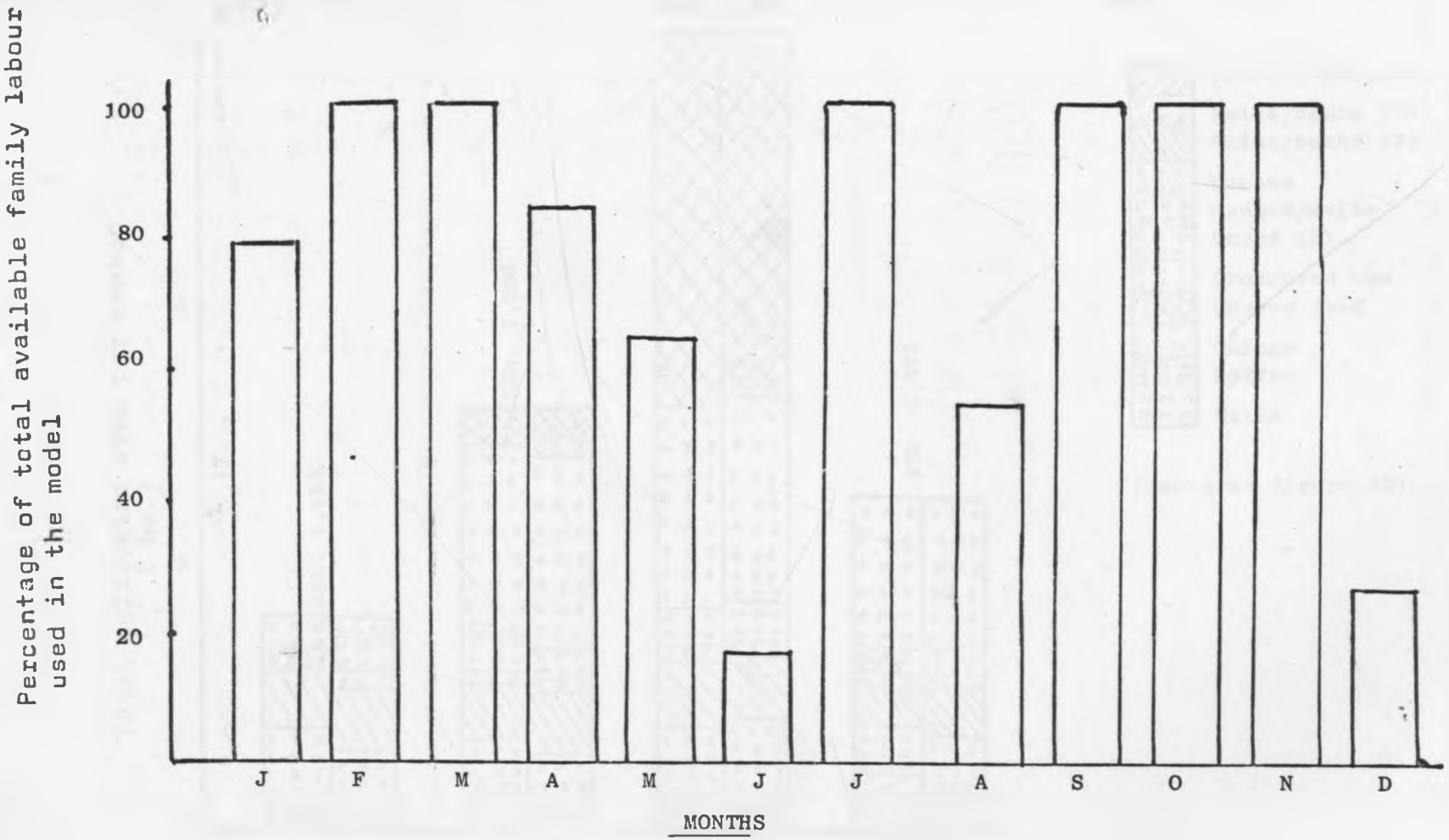
crop. As shown in Table 18 and Figure 10 a very small portion of the arable land is occupied with coffee trees. This is due to the high labour demand of coffee production that the family labour alone cannot take care of more coffee trees. For example, the labour requirement of coffee per hectare, which is at its peak during picking is four times that of maize.

Labour during land preparation, planting, weeding and harvesting of food crops and coffee picking is the most limiting factor of production.

In Gaturi the labour bottleneck for land preparation is partly contributed by the absence of any form of ox-traction or any type of mechanization used by farmers. As mentioned previously land preparation takes place by hand with the use of jembes.

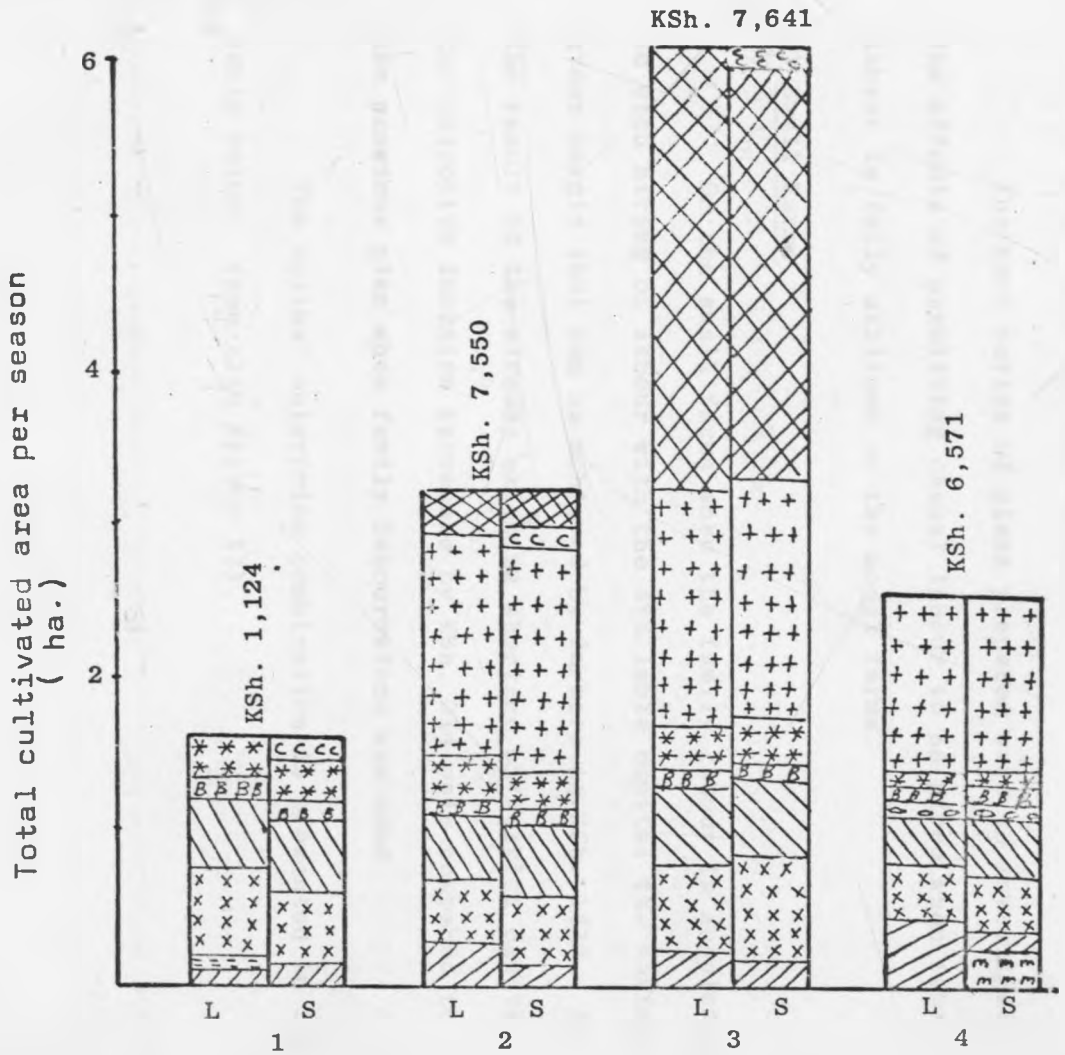
On the aggregate holdings with available land area of 2.57 ha. for cultivation, the maximum gross margin that can be achieved when only family labour is employed is equal to KSh. 6576.

The shadow prices of labour during the months of February, March, July, September and November are KSh. 65.50, KSh. 46.40, KSh. 86.62, KSh. 26.40 and KSh. 36.0 per manday respectively. These values indicate that it would be profitable for farmers in Gaturi to hire casual labourers during the above peak months. In Gaturi the cost of hiring one man-equivalent casual labour per day is KSh. 10.00. The daily wage of casual labour is much less than the marginal value product of labour. Therefore, the gross margin from the farming operation in Gaturi



Source: Computer Print out.

Figure 9: Level of Family Labour Use by Month of the Aggregate Farm model.



Key

- Irish Potatoes
- Maize/beans (1)
- Maize/beans (2)
- Banana
- Banana/maize
- Beans (2)
- Crossbred cow
- Unused land
- Onions
- Coffee
- Maize

(see also figure 10)

Source: Computer Print out.

Figure 10: Optimal Enterprise Combination and Maximum Gross Margins on Small, Medium, Large and Aggregate Farms when Family Labour Alone is Used.

can be increased by hiring casual labour during the peak periods.

On the aggregate farm model, even though land shortage is not seriously constraining production there are still possibilities for additional gross margin to be gained if land area is to be increased. This can be done by channelling most of the production of milk on the increased area of land.

The level of family labour use by month in the optimal plan is shown in Figure 9.

4.2.2 Effect of Hired Casual Labour

The next series of plans prepared were to investigate the effects of permitting casual labour to be hired when family labour is fully utilized on the model farms.

i) Small Farms

On the small farms when the family labour is supplemented with hiring of labour with the available capital the maximum gross margin that can be achieved by farmers is KSh. 1433. As the result of the already existing shortage of working capital the objective function increased by KSh. 314 only compared to the previous plan when family labour alone was used.

The optimal enterprise combination is presented in the table below. (see also Figure 11).

Table 19: Optimal Enterprise Combination with the Use of Hired Casual Labour on the Small Farms

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Irish potatoes	0.12	0.13
Maize and beans (1) (interplanted)	0.69	0.51
Maize and beans (2) (interplanted)	0.43	0.61
Coffee	0.05	0.05
Banana	0.35	0.35
Total	1.64	1.64

Source: Computer Print Out.

As shown in Table 19 the most profitable enterprises to produce are Irish potatoes, maize and beans (1) interplanted, maize and beans (2) interplanted. It would be profitable for the farmers to grow about 105 coffee trees on 0.05 hectares of land. The cash earning crops for farmers are sales of maize, beans (1) and coffee. As pointed out previously the production of milk from dairy cow is hampered by shortage of land. Food crops compete for the available land area for cultivation.

When casual labour is used on the small farms the most limiting resources are working capital and land with shadow prices of KSh. 3.7 per shilling and KSh. 4830 per hectare respectively. The shadow price of working capital indicates that it would be profitable for small farms to borrow working capital. In Gaturi the interest rate of working capital at the time of the survey was 10 per cent per annum.

ii) Medium Farms

When family labour is augmented with hired casual labour the maximum gross margin that can be obtained on the medium farm amounted to KSh. 17,891. This is an increase of KSh.10,341 compared to the previous plan when only family labour alone is used. Therefore, this shows that hired casual labour can have a great effect in raising the income of farmers on the medium farms.

The optimal enterprise combination on the medium farm when the family labour is supported with hired casual labour is presented in the table below. (see also Figure 11).

Table 20: Optimal Enterprise Combination On the Medium Farms When Hired Casual Labour is Used.

Enterprise	Area Occupied	
	Long rain land (ha.)	Short Rain Land (ha.)
Irish potatoes	0.12	0.13
Maize and beans (1) (interplanted)	0.78	0.60
Maize and beans (2) (interplanted)	0.43	0.6
Coffee	1.21	1.21
Banana	0.71	0.71
Total	3.25	3.25

Source: Computer Print Out.

The most profitable enterprises to produce are Irish potatoes, maize and beans interplanted, coffee and bananas. Coffee occupies 37.2% of the cultivable area. Since the high demand

of coffee for labour is met by hiring, coffee replaces the production of milk. After satisfying the family food requirement the sale of food crops like maize, beans and bananas are cash earning for farmers.

On the medium farm when the family labour is augmented with hired casual labour further agricultural production is hampered by shortage of working capital. This shortage occured because of a) additional cost incurred in buying labour input and b) the production of more coffee trees which is capital intensive. The shadow price of working capital is equal to KSh. 3.64. This shows that an investment of one additional shilling will increase the gross margin by KSh. 3.64.

iii) Large Farms

On the large farm when the family labour is supported with hired casual labour the maximum gross margin that can be obtained amounted to KSh. 32,766. This is an increase of Ksh. 25,125 compared with the previous plan when family labour alone is used. This shows that the impact of hired casual labour is very high on the farming operation of large farms. Large farms rely for their farming operation on hired casual labour. This is because a) the land area for cultivation is so large that it cannot be wholly operated on with the family labour alone. If the family labour alone is to be employed on the whole available area the gross margin attainable will be below the potential of the existing farm organization. b) the high demand of coffee for labour cannot be met by family labour alone. Therefore, the family labour has to be supported

by casual labour.

The optimal enterprise combination on the large farms when the family labour is supported with casual labour is presented in the table below. (see also Figure 11).

Table 21: Optimal Enterprise Combination on the Large Farms When Hired Casual Labour is Used

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Maize	-	0.3
Irish potatoes	1.12	0.58
Maize and beans (1) (interplanted)	0.52	0.62
Maize and beans (2) (interplanted)	0.1	0.24
Coffee	1.49	1.49
Beans and banana	0.47	0.47
Crossbred cow (milk production)	2.4	2.4
Total	6.1	6.1

Source: Computer Print Out.

The most profitable enterprises to produce would be Irish potatoes, maize and beans (1) interplanted, maize and beans (2) interplanted, coffee and milk from about five crossbred cows.

Local Zebu cows are not included in the optimal plan because of their low milk yield. Similarly because of initial and maintenance cost and their low milk yield grade cows are not selected.

On the large farms, working capital and land are not constraints on production. The most limiting factor production

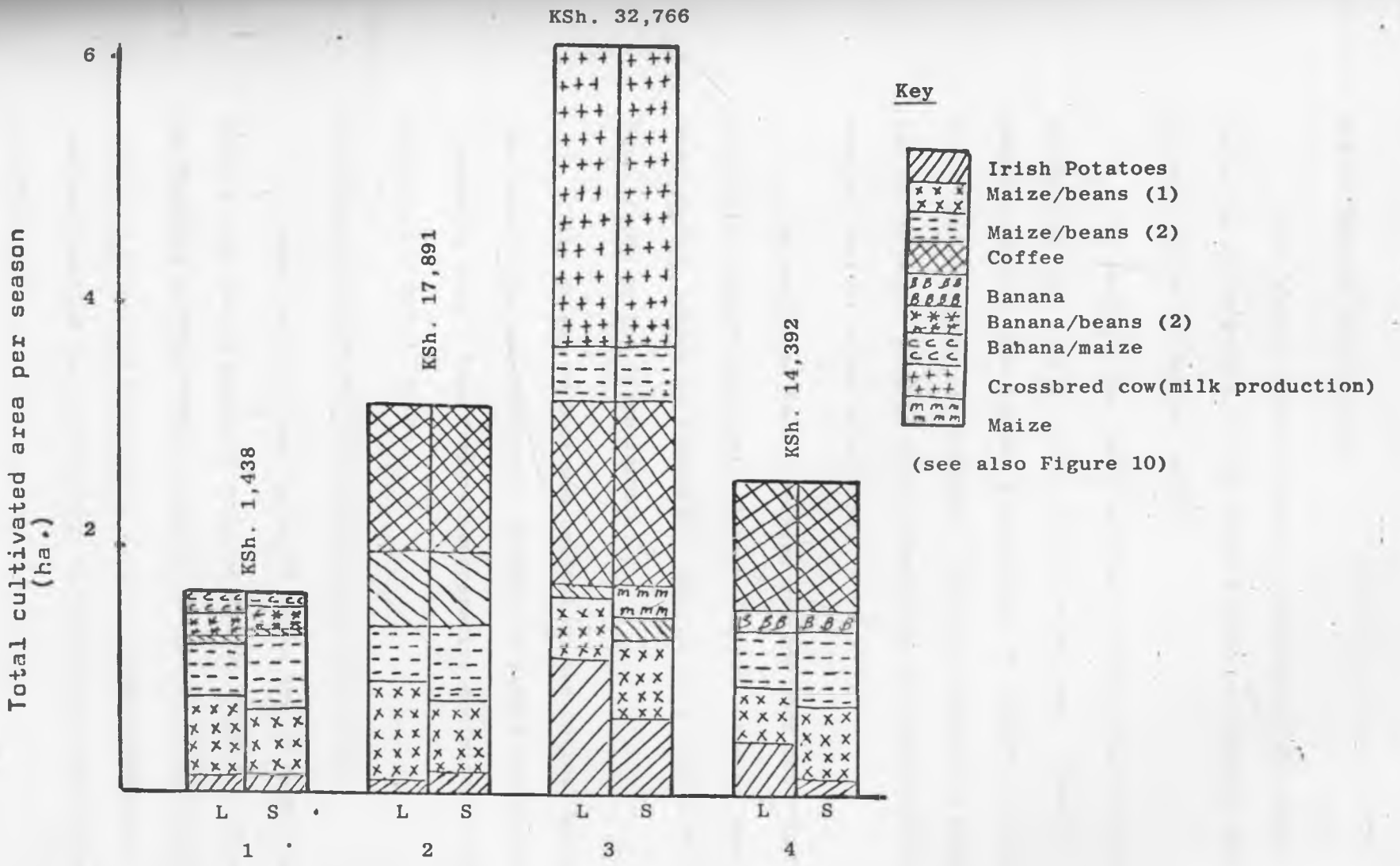
was determined to be labour, particularly during January, July, September and November. These are months for land preparation, weeding, harvesting of food crops and coffee picking. Further production of coffee is constrained by shortage of labour during the picking months of January, September and November. In Gaturi due to the high demand for casual labour by coffee growers its availability is limited for hiring.

iv) Aggregate Holdings

As shown in Figure 11, when the family labour is augmented with hired casual labour on the aggregate holdings the most profitable enterprises are Irish potatoes, maize and beans(1) interplanted, maize and beans (2) interplanted, banana and coffee. After satisfying the household food requirement the maximum gross margin that can be acquired from the farming operation is equal to KSh.14,392.

When hired labour is used on the aggregate holdings coffee replaces milk production from crossbred cows. This is because the high labour demand of coffee is met when hired casual labour is used.

In this plan the most limiting factor of production is working capital. This shortage arose as the result of additional cost incurred in hiring casual labour and producing more coffee trees which is capital intensive. The shadow price of working capital is equal to KSh. 3.60. It would be most profitable to borrow working capital at the interest rate of 10% per annum.



Source: Computer Print out.

Figure 11: Optimal Enterprise Combinations and Maximum Gross Margins on Small, Medium, Large and Aggregate Farms When Hired Casual Labour is Used.

4.2.3 Working Capital Use

When family labour alone is available on the small farms the gross margin of the optimal plan is strongly limited by constraints on working capital.

On medium sized farms working capital is not limiting production when family labour alone can be used. However, working capital does become a constraint to production when hired casual labour is available. This is principally because the extra labour permits more coffee which in turn requires working capital as an enterprise.

On the large farms, working capital does not limit production either when family labour alone is used or when hired casual labour is available. This is as a result of high farm income on the large farms.

The effect of borrowed capital on the optimal plans of the model farms was analysed. Farmers in Gaturi acquire credit facilities mainly from farmers' cooperative societies at 10% per annum interest charge.

i) Effect of Borrowed Working Capital on Small Farms

When credit is used by small farms the maximum gross margin that can be acquired amounted to KSh. 3138.56. This is an increase of KSh. 1720.6 compared to the plan when the family labour is supported with casual labour. This value shows that borrowed capital has great effect on increasing farm return on the small farms.

The following table shows the best enterprise combination on the small farms when borrowed working capital and hired

casual labour are used. (see also Figure 12).

Table 22. Optimal Enterprise Combination on the Small Farm When Borrowed Working Capital is Used

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Irish potatoes	0.47	0.13
Maize and beans (1) (interplanted)	0.43	0.60
Maize and beans (2) (interplanted)	0.43	0.60
Coffee[1]	0.09	0.09
Bananas	0.22	0.22
Total	1.64	1.64

Source: Computer Print Out.

As shown in Table 22 the main profitable enterprises to produce are food crops. It would be profitable to grow about 122 coffee trees on 0.09 ha. of land. After satisfying the family food requirement farmers can earn cash by the sale of maize, beans and Irish potatoes.

As pointed out above milk production from dairy cow is constrained by shortage of land, because the food crops compete for the available land.

When hired labour and borrowed capital are used on the small model farms the most limiting factor of production is land

[1] Equivalent to 122 coffee trees at 1350 trees per ha.

shortage. The shadow price of land per hectare is equal to KSh. 12,390. This value indicates that if land input was increased by one hectare the gross margin would increase by KSh. 12,390. At this point an attempt was made to make a comparison between the marginal value product of one hectare of land and rent of land in Gaturi location. Since land renting is not a common practice in Gaturi, this was an impossible exercise. However, the marginal value of land, which is KSh. 12,390 per hectare is much lower than the price of a hectare of land in Gaturi, which ranges between KSh. 20,000 and KSh. 25,000.

As shown above on the small farms the best plan is when hired casual labour and credit are used.

ii) Effect of Borrowed Working Capital on Medium Farms

When credit is used on the medium farms the maximum gross margin that can be achieved by farmers is KSh. 22,325. This is an increase of KSh. 4,434 compared to the previous plan when hired casual labour was used but capital was not borrowed. This increase of the objective function shows that credit has great effect on the medium farms as in the small farms.

The following table shows the best enterprise combination on the medium farms when borrowed working capital and hired casual labour are used. (see also Figure 12)

Table 23 : Best Enterprise Combination on the Medium Farms When Borrowed Working Capital is Used

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Long Rain Land (ha.)
Irish potatoes	0.62	0.14
Maize and beans (1) (interplanted)	0.44	0.77
Maize and beans (2) (interplanted)	0.25	0.4
Coffee	1.62	1.62
Bananas	0.32	0.32
Total	3.25	3.25

Source: Computer Print Out.

In this plan 49.8% of the total arable area is occupied with coffee trees and the rest is under food crops.

On the medium farms, since the labour needs of the coffee enterprise are met by hired casual labour, milk production from dairly cow is not included in the optimal plan. Any further expansion of the coffee area is constrained by the shortage of January and November labour. This is because casual labour supply during these months is limited in Gaturi as all coffee growers need to hire more.

iii) Effect of Borrowed Working Capital on Large Farms

As pointed out previously on the large farms working capital is not a constraint of production. The large farms have high farm income and enough cash in hand for their farming operation on the existing farm organization.

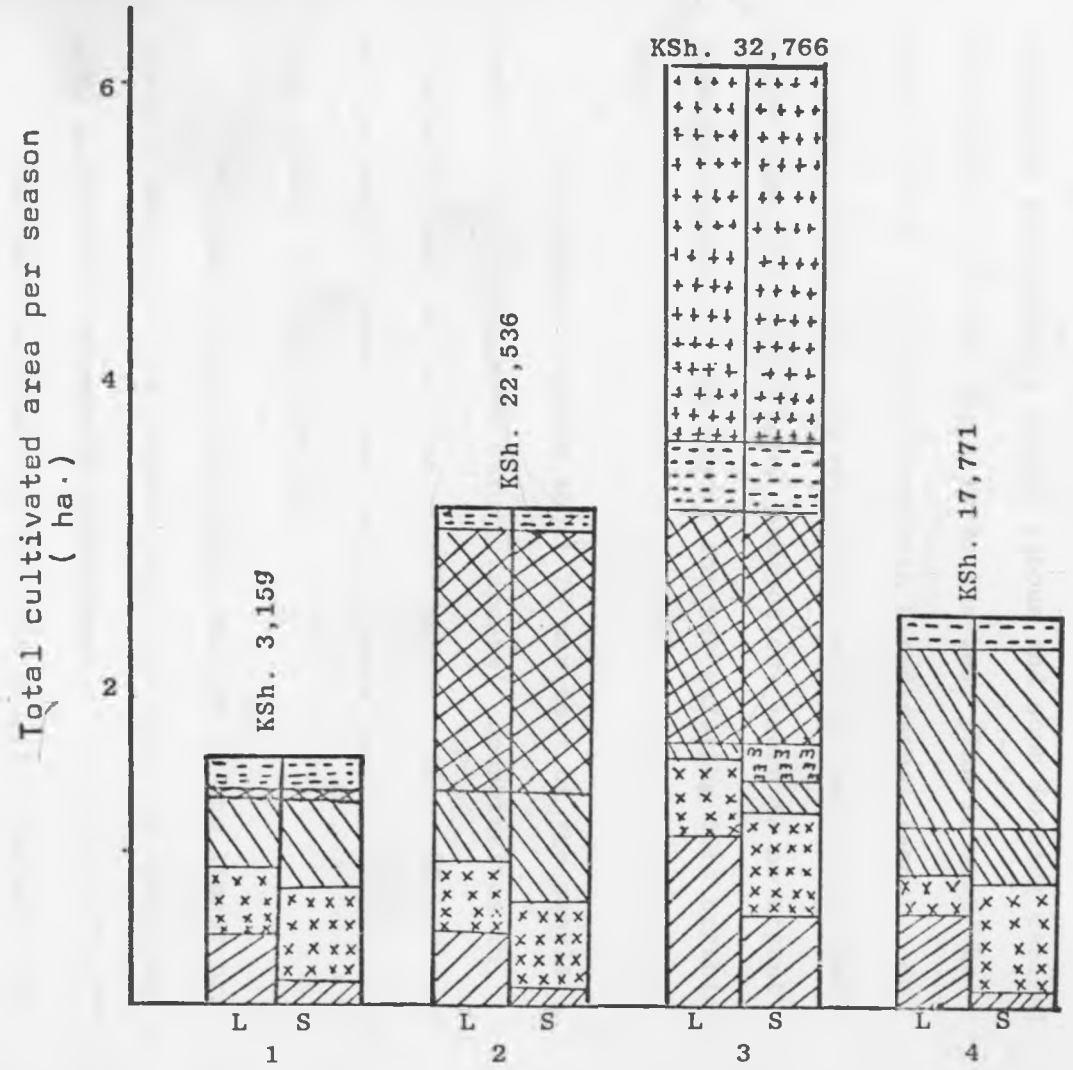
As pointed out earlier, the critical limiting factor of production on the large farms is labour. In practice it is difficult to obtain adequate hired casual labour during the months of peak labour demand in Gaturi. Since cultivable land area is in adequate supply it would be most profitable to use the major part of the land area for the production of milk from crossbred cows. Moreover, the low labour demand nature of milk production gives an advantage for more dairy cows to be kept than coffee production when labour shortage occurs.

iv) Effect of Borrowed Working Capital on the Aggregate Holdings

When only family labour is used working capital does not limit agricultural production in the aggregate holdings. This was due to the low capital demand of the enterprise which appeared in the optimal plan. However, in the latter plan, when casual labour was hired capital was a limiting factor of production. As pointed out before, this is because of i) increase in coffee production which is capital intensive and II) additional cost incurred in hiring labour.

When borrowed working capital is used on the aggregate holdings the maximum gross margin obtainable is equal to KSh. 17,771.00. This is an increase of the gross margin by about 19 per cent compared to the previous plan, when hired casual labour is used but working capital was not borrowed.

As shown in Figure 12 the most important cash earning crop is coffee. As the result of credit use the land size under coffee trees increased by 11.5 per cent compared to the previous plan, when hired casual labour is used but working capital was not borrowed.



Source: Computer Print out.

Figure 12: Optimal Plans on Small, Medium, Large and Aggregate Farms with the use of Credit and Hired Labour.

The most profitable food crops grown in the optimal plan are Irish potatoes, maize and beans (1) interplanted, maize and beans (2) interplanted, coffee and banana. (see Figure 12)

4.2.4 Comparison of Optimal and Existing Farm Plans

As shown by the above results, the highest farm gross margins in the small and medium farms are when the family labour supply is augmented by casual labour and some working capital is borrowed. On the large farms the best plan is when the family labour is supplemented with hired casual labour. On the large farms since the available working capital on farms is not limiting agricultural production, there is no urgent need for farmers to use credit for the existing farm organization.

In Gaturi location about 70 per cent of the sample farmers used credit from Gaturi farmers' cooperatives in kind or in cash at the time of the survey. About 80 per cent of the sample farmers hired casual labour for the farming operation during the peak periods.

The best plans obtained by the use of the linear programming technique are compared with the existing farm plans as used by the three strata of farm sizes.

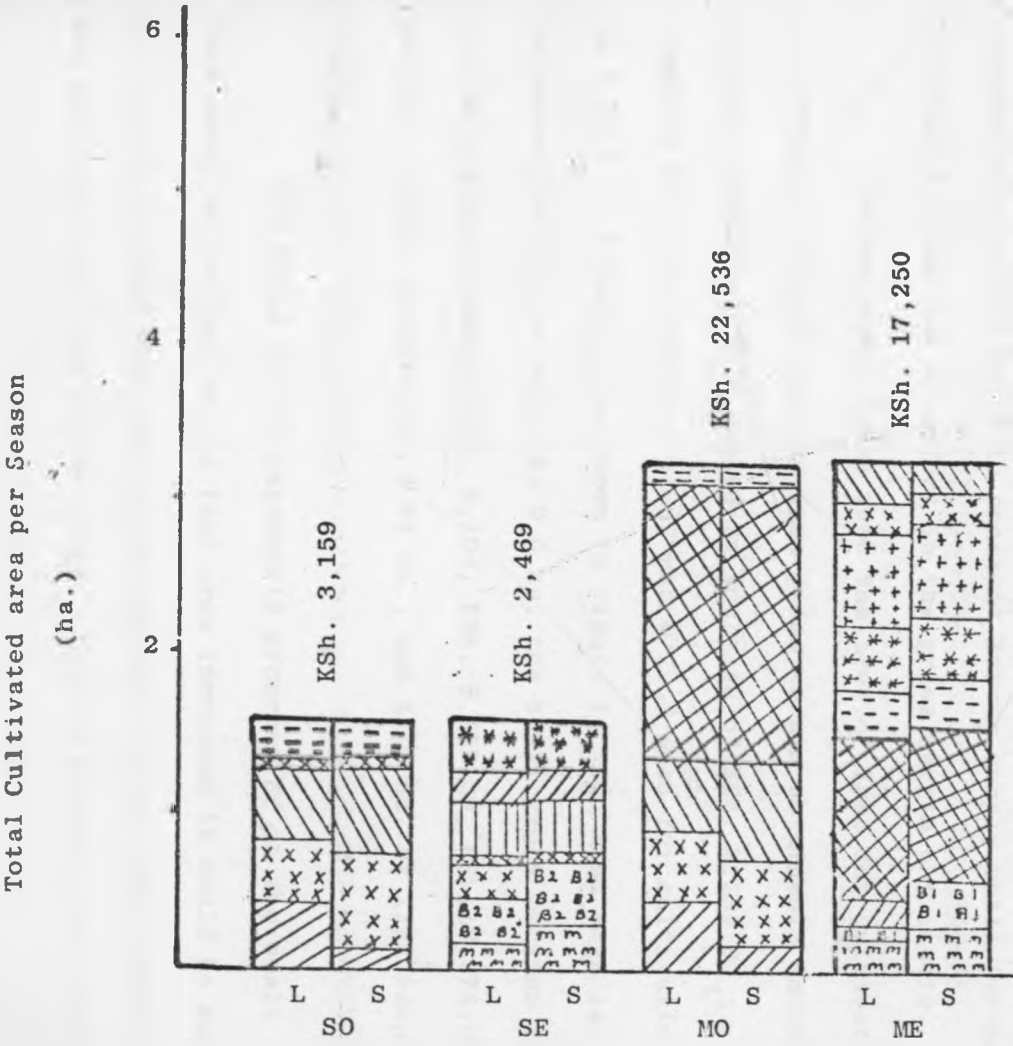
As shown in Figure 13 the farm return obtained in the optimal plan on the small farms amounts to KSh. 3,159. In the existing plan in the small farms the gross margin obtained is equal to KSh. 2,469. The optimal plan showed an increase of about 28 per cent compared to the existing plan. This indicates

that a better reorganization of farm resources among the most profitable enterprises will increase the farm gross margin substantially. (see also Appendix 2).

As illustrated in Figure 13 the maximum gross margin that can be obtained in the optimal plan for the medium farms amounted to KSh.22,536. The existing farm plan showed that farmers made KSh. 17,250 from their farming operation. The optimal plan showed that farmers can increase their farm income by about 31 per cent if resources (i.e. land, labour and working capital) are efficiently used among the most profitable enterprises (see also Appendix 3).

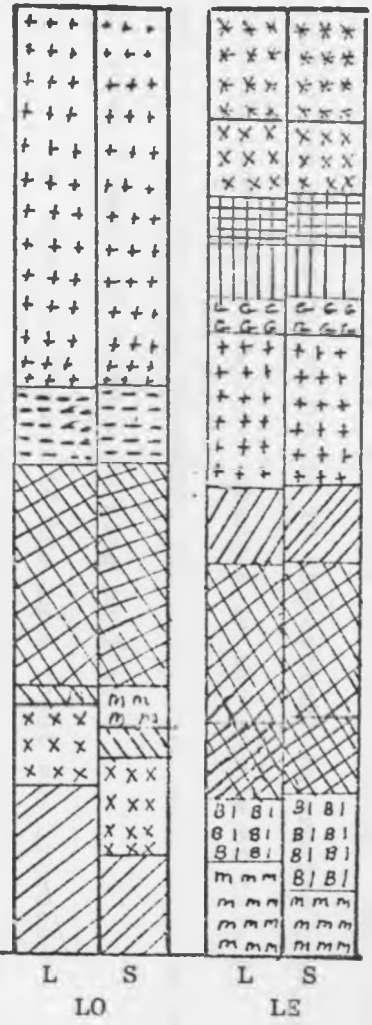
Likewise, on the large farms if resources are to be used efficiently the gross margin can reach KSh.32,766 compared to the existing farm plan, which brought a gross margin of KSh. 25,885. The optimal plan showed an increase of about 27 per cent. The optimal enterprise combination and the level of gross margin that can be achieved from the best plan for large farms is demonstrated in Figure 13 and Appendix 4.

As shown in the optimal plans for the three strata of farm sizes there are opportunities for farmers in Gaturi location to increase their farm income by more efficient reallocation of their resource endowments (i.e. land, labour and working capital).



Source: Survey data 1979/80 and computer Print out.

Figure 13: Comparison of Optimal and Existing Plans



Key

Irish Potatoes
Maize/beans (1)
Maize/beans (2)
Coffee
Crossbred cow
Banana
Maize
Local zebu
Beans (1)
Grade cow
Beans (2)
Banana/maize
Banana/beans

(see also Figure 10)

SO = Small Farm's Optimal Plan

SE = Small Farm's Existing Plan

MO = Medium Farm's Optimal Plan

ME = Medium Farm's Existing Plan

LO = Large Farm's Optimal Plan

LE = Large Farm's Existing Plan

on Small, Medium and Large Farms.

4.3 Results of Parametric Programming

The most limiting factor of production in each farm plan was varied parametrically to determine its importance in the farm plan at different levels of supply. This would assist to determine how farmers should alleviate their resources if these altered parameters were realized.

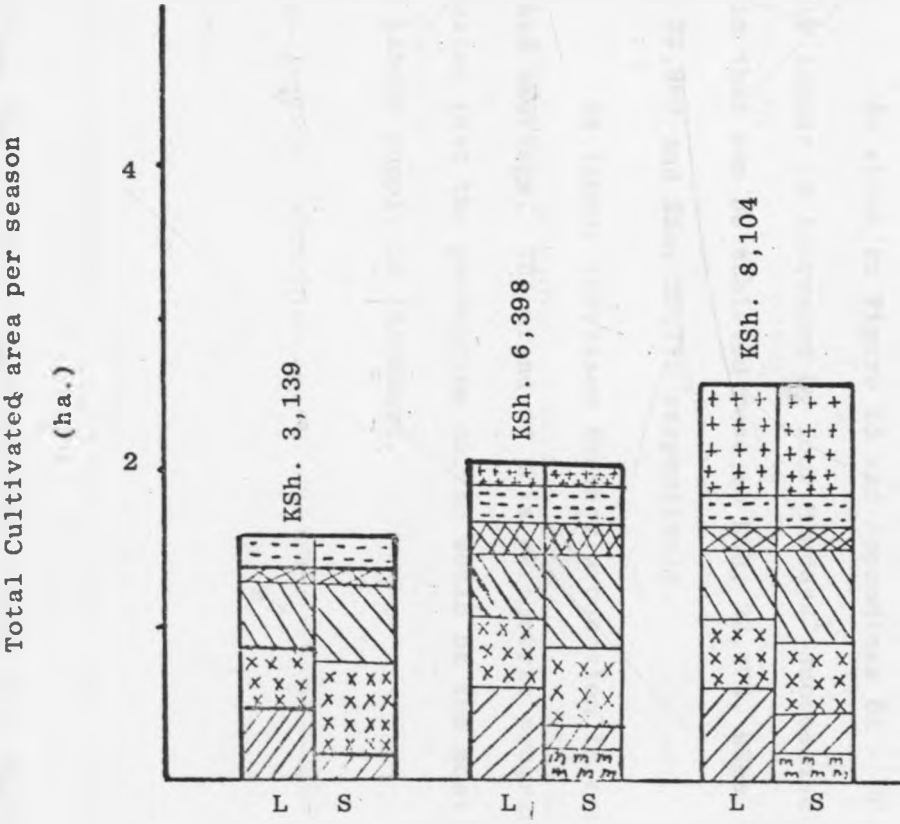
4.3.1 Effect of Change in Land Area

Land is the most limiting factor of production on the small farms with 1.64 ha. available for cultivation. This land supply was varied to determine if the optimal enterprise combination is affected by marginal changes in the supply of this resource. This was examined using the small farm model with access to hired labour and outside working capital.

As shown in Figure 14 the land input was increased successively by 0.5 ha. with constant labour supply until further increase in land has no effect in the gross margin obtainable.

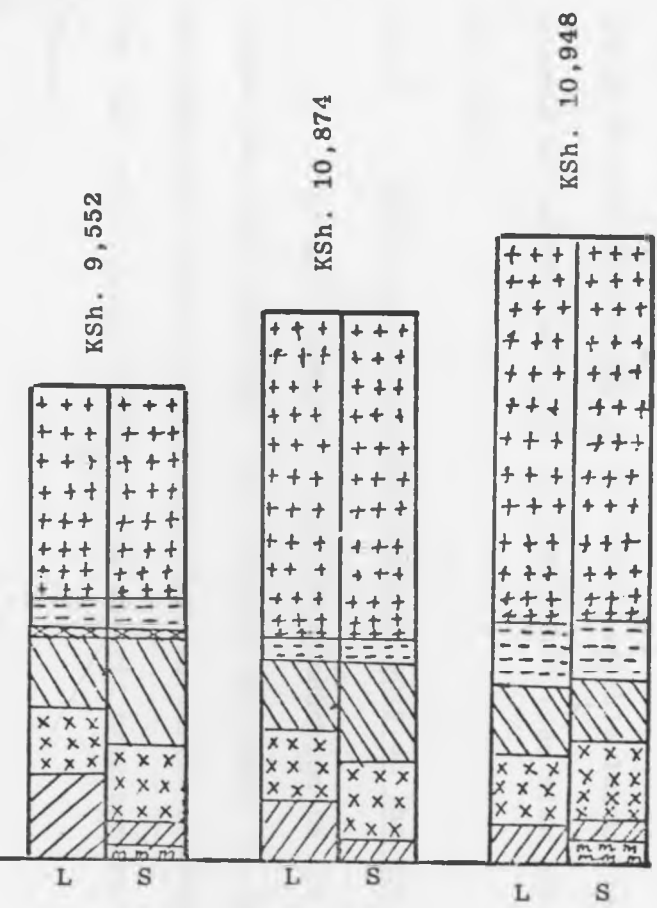
On the small farms when the area of land for cultivation is increased to 2.14 ha. the farm gross margin obtainable amounted to KSh. 6,398.00. This showed an increase of KSh. 3,239.00 compared with the previous plan, where land area for cultivation is 1.64 ha. Likewise, as shown in Figure 14 when land area is increased further in steps by 0.5 ha. the total gross margins that can be acquired reached KSh. 8,104, KSh. 9,552.00, KSh.10,874.00 and KSh. 10,948 on 3.14 ha., 3.64 ha., and 4.14 ha. of land respectively.

The trend of the parametric programming on the small farm model shows that as the land area increases it would be most profitable to keep more and more crossbred cows for milk production, and grow less and less coffee trees. This is because with constant



Source: Computer print out.

Figure 14: Optimal Plans on the Small Farms



Key

See Figure 12

as Land Size is increased by 0.5 ha. with constant Labour Input

labour availability when land area alone is kept increasing, labour becomes the critical limiting factor of production. Therefore, the labour bottleneck constrains the expansion of coffee production, which is labour intensive. On the other hand since the labour demand of milk production from crossbred cow is low, it would be more profitable to use the available labour for milk production in the increased area of land (see also Appendices 5A - 5D).

4.3.2. Effect of Increasing Labour Supply on the Medium Farms

The most limiting factor of production on the medium farms was labour shortage. To find out the impact of increasing the available labour on the maximum gross margin obtainable and the best enterprise combination, parametric programming was performed.

As shown in Figure 15 and Appendices 6A - 6C when the family labour is increased by four mandays[1] successively the gross margin that can be achieved rose to KSh. 22,470, KShs. 22,615, KSh. 22,969 and KSh. 22,776 respectively.

As labour increases further production is constrained by land shortage. The trend of this parametric programming results indicates that the production coffee would be the most profitable when labour supply is increased.

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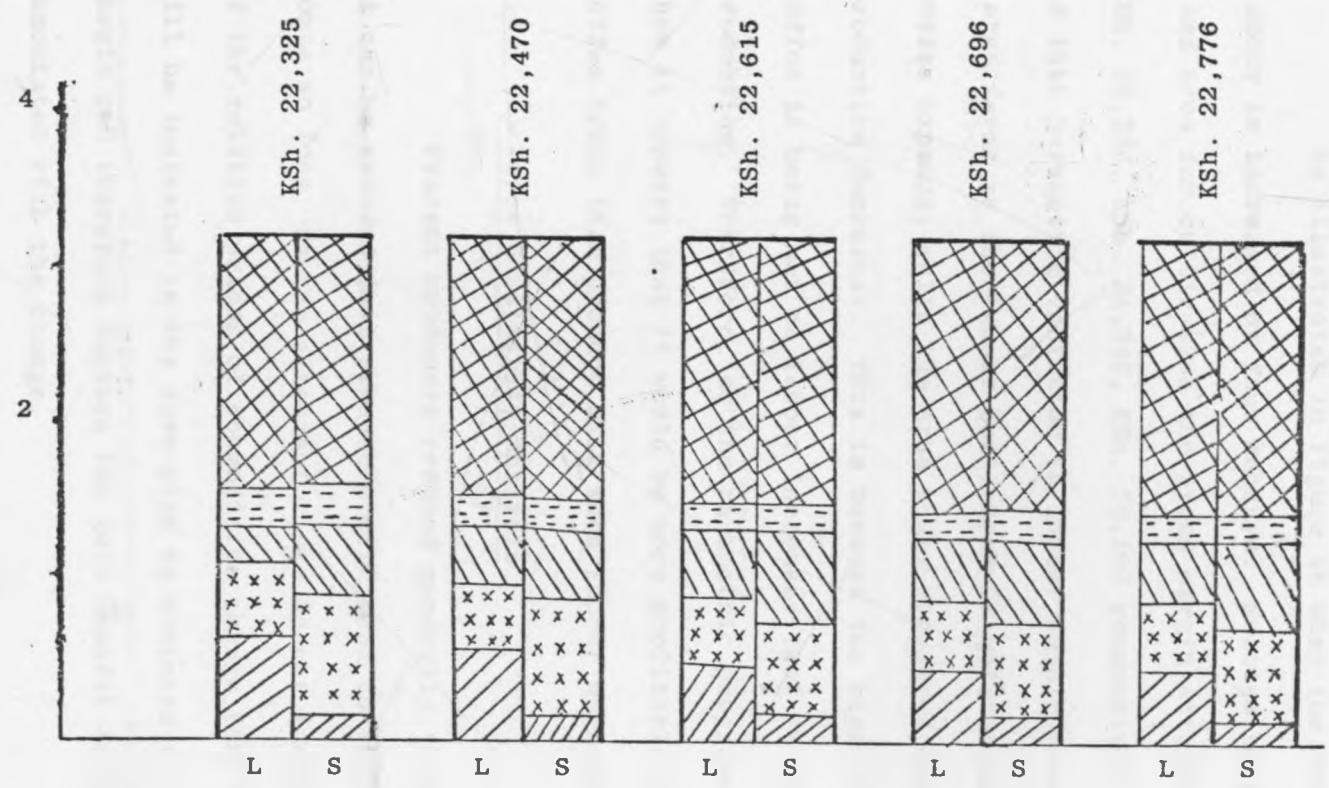
[1] It was found that to increase labour with less than four mandays does not have enough magnitude to defect.



Source: Computer Print out.

Figure 15: Optimal Plans on Medium Farms as the Available Labour is Increased by Four Mandays with Constant Land Area for Cultivation.

4.3.3. Effect of Increasing Labour Supply on Large Farms

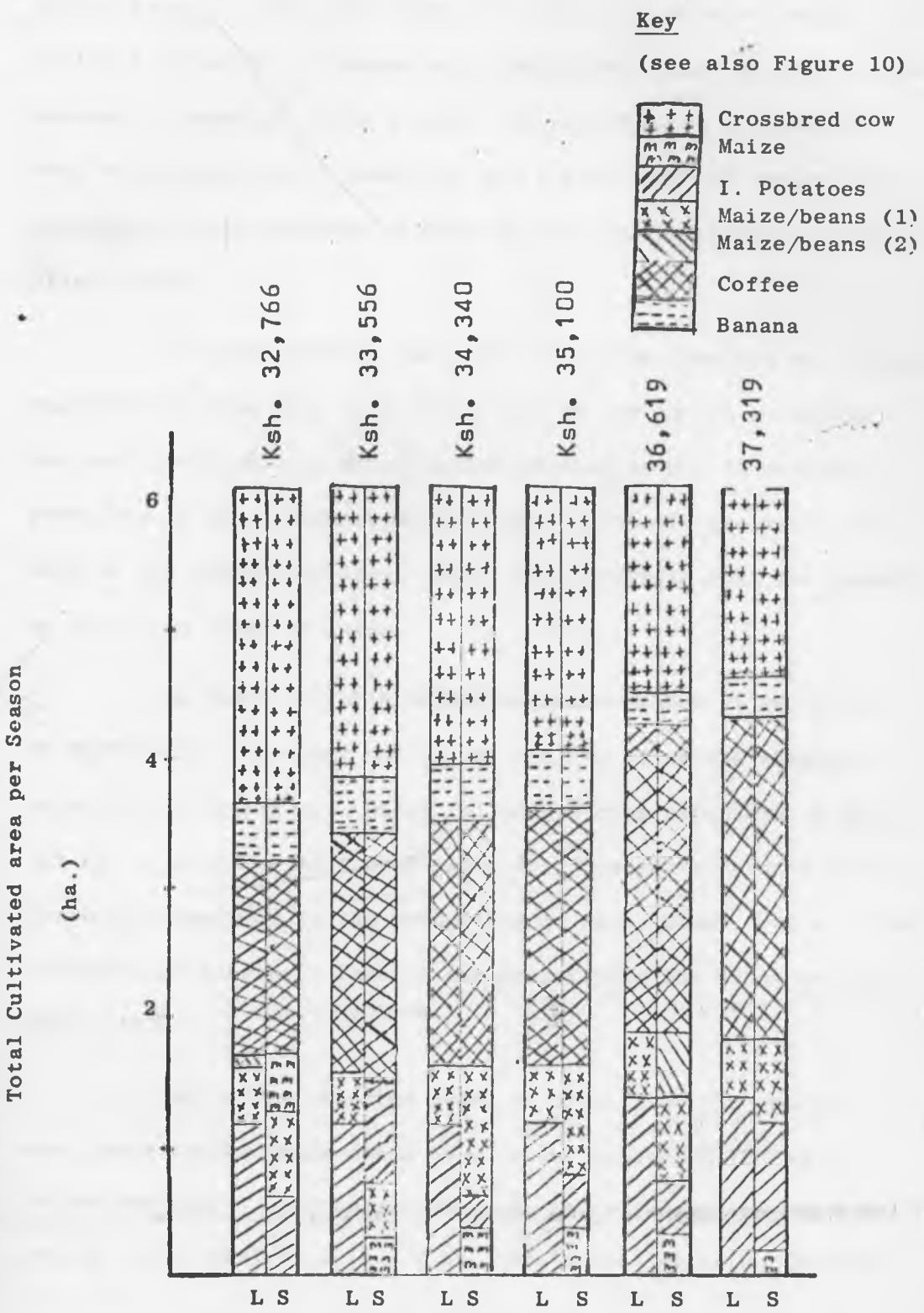
On the large farms, since labour is the most constraining factor of agricultural production variation is also made in this resource to find out the maximum objective function that can be acquired, and the best level of enterprise combination.

As illustrated in Figure 16 when the available family labour is increased by four mandays. Successively with constant land area for cultivation the gross margin attainable amounted to KSh. 33,356, KSh. 34,340, KSh. 35,100 respectively. The trend of this parametric variation in labour supply shows that on the large farms as the labour bottleneck is relaxed the area under coffee expands, while the area under crossbred cows for milk production decreases. This is because the high labour demand of coffee is being met as labour increases that it displaces milk production. Therefore, as the parametric programming results show it appears that it would be more profitable to grow more coffee trees than produce milk when labour magnitude is increased.

4.4 Price Sensitivity Analysis

Peasant producers respond generally to price changes. It can be assumed that producers will tend to increase their incomes so long as the attendant risks do not increase significantly. If the relative prices of commodities change then some changes will be indicated in the farm plan to maximize the farm gross margin and therefore capture the full benefit (minimize the loss) associated with the change.

In Gaturi coffee is the main cash earning crop grown. Its price is not determined by the domestic market demand and supply situation unlike cereal crops or milk but principally by the world coffee market.



Source: Computer Print out.

Figure 16: Optimal Plans When Family Labour is Increased by Four Mandays with Constant Land Input on the Large Farms.

In Gaturi location farmers responded to the increase of coffee price in 1977 and were induced to expand the area under coffee trees[1]. This situation calls for a price sensitivity analysis of coffee to demonstrate how farmers might react to price changes to maximize their income. Since coffee is a perennial crop which requires at least two and a half years to mature, the validity of this exercise depends on how long the price of coffee stays stable.

In this exercise the price of coffee cherries was changed successively from KSh. 1.00 to KSh. 15.00 per kg. to determine the most profitable level of coffee production and to see the stability of the plans prepared. Since coffee is the main cash crop on the medium and large farms, this analysis lays its emphasis on these two types of farms.

As shown in Table 24 in the medium Farms it would not be profitable to produce coffee for a price of coffee cherries below KSh. 2.50 per kg. Below coffee cherries price KSh. 2.50 per kg. it would be most profitable for farmers to channel their available resources to the production of milk, beans, maize, Irish potatoes and bananas. Farmers can profit from the sales of these enterprises.

For coffee cherries price of KShs. 2.50 the optimal area under coffee trees would be 0.24 ha. producing 720 kg of coffee cherries. When coffee cherries price is equl to KSh 5.00 per kg the optimal area is 1.7 ha. Regardless of price increase

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[1] See page 11 .

Table 24: Optimal Hectarage and Production Level of Coffee for Various Prices on the Medium Model Farm

Price of coffee cherries (KSh./kg)	Optimal coffee Hectarage	Optimal level of production (kg)
.0	0	0
1.5	0	0
2.0	0	0
2.5	0.24	720
3.0	0.50	1500
3.5	0.94	2820
4.0	1.11	3330
4.5	1.21	3630
5.0	1.7	5100
.	.	.
.	.	.
.	.	.
15.0	1.7	5100

Source: Computer Print Out.

beyond KSh. 5.00 it would not be profitable to increase coffee hectarage. This is because further expansion of coffee is halted by labour shortage during its picking seasons.

On the large farms it would not be profitable to produce coffee for price below KSh. 2.50 per kg. If coffee cherries price is to be set at this level it would be profitable for framers to produce milk and food crops. The optimal area under coffee trees emerge when the price is set at KSh. 6.00. Within the existing resource organization it would not be profitable to increase coffee area beyond 1.72 hectares. Labour shortage for picking coffee halts its further expansion.

Table 25: Optimal Hectarage and Production Level of Coffee for Various Prices on the Large Model Farm

Price of Coffee Cherrries (KSh/kg)	Optimal Coffee Hectarage	Optimal Level of Production (Kg)
1.0	0	0
1.5	0	0
2.0	0	0
2.5	0.2	600
3.0	0.28	840
3.5	0.34	1020
4.0	0.43	1290
4.5	1.1	3330
5.0	1.32	3960
5.5	1.60	4800
6.0	1.72	5160
.	.	.
.	.	.
15.0	1.72	5160

Source: Computer Print Out.

4. EVALUATION OF THE TECHNIQUE USED IN THE STUDY

The technique used in this study has a number of operational advantages and some shortcomings.

The LP technique used in this study has assisted to clearly identify the most limiting resources of agricultural production, and to show how farm families should allocate their resources among enterprises if their objective is to maximize farm gross margin. It also clearly demonstrates how enterprises on farm compete for scarce resources.

The technique used in this study has also some notable shortcomings. It only deals with a single objective function i.e. maximization of farm gross margin. However, in reality this might conflict with the objective of farmers where profit motive does not greatly influence farming decisions. Concerning this Clayton (1963, p.61) states:

> It may perhaps be objected that the application of this technique is irrelevant to traditional peasant societies where profit motive does not greatly influence farming decisions. But this is to misconceive the role and purpose of the technique. The results of linear programming have the same function as any other scientifically based recommendations. They are, in short extension or advisory tools. And just as it is wrong to condemn a policy recommending the adoption of ley husbandry principles (where this is technically desirable) because the peasant is ignorant of the need for fertility maintenance, so it is wrong to condemn a policy which fosters maximum farm systems when economic motivation is lacking. In both cases, it is essential to know the right direction to take even though it is difficult to achieve.

This study does not explicitly consider natural and economic risks and uncertainities of various alternatives faced by farm families.

The LP method used here does not tackle adequately the positive and negative effects of aggregation in the study area. This means it ignores consequences of aggregation effects that what is best for a given farm may not be best for the farms in the whole area if they follow the same optimizing strategy. The LP method assumes that there is always little effect on a given market if all farmers are to follow the optimal plan e.g. to buy or to rent more land or to hire more labour and grow more coffee etc. The model assumes that market prices are not affected by the quality produced and sold. In other words it does not show the interaction of supply and demand of commodities reflected in the pricing system in a given market.

The LP technique used does not explicitly consider the difference of management factors on different farms. This is also because of limitation of data and the problem of quantifying management factor in the linear programming model directly. It appears that it is not sufficient to talk in terms of quantities of labour: the efficiency, work methods, techniques, tools and implements associated with labour must also be identified. Other potential important factors not related to labour include plant population, seed varieties and soil maintenance practices. Due to limitation of time attention was not focussed on these factors at the data collection stage of this study, and this is why it has only been possible to discuss them in general terms.

Also because of lack of data of suitable quantity and quality, there has been some reluctance to apply methods like multiperiod linear programming. The model used in this study is static and time is not explicit in the formulation i.e. resources are not transferred from one period to the other.

Regardless of the shortcomings of the method used, the study has clearly met its objective subject to the assumptions made in the study.

CHAPTER FIVE

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Like other parts of the country, increasing population is becoming a major problem in the farming sector of Embu District. Due to continued shrinkage, land is becoming a limiting factor of production.

To improve the level of income of small holder farmers and food production there is need to have an insight into the production systems to discover the factors constraining production and device ways for efficient use of the factors of production viz. land, labour and capital.

The objectives of this study are to identify factors of production constraining the level of farm income from increasing, and to show how farm income can be increased by re-allocation of resources, namely, land, labour and capital among enterprises in the star grass zone of Embu district.

The study tested the following hypotheses: i) Within the existing farm organization in the star grass of Embu district farming income is serious limited by the physical constraints of land, labour and working capital. There are substantial opportunities for farmers of the study area to increase their farm income by more efficient use of resources within the existing farming system ii) Coffee production is more profitable to farmers of the study area than milk production or food crop production in a situation where there is adequate labour availability and iii) milk production from dairy cows is most profitable than all the enterprises considered in the study area in a situation where there are enough land area and extreme labour shortage.

Gaturi location where this study was carried out lies

in the star grass zone of Embu district. Gaturi is representative of the agricultural areas of the Star grass zone of Embu district.

For the purpose of this study 40 sample farms were selected from Gaturi with the use of random sampling technique. To avoid bias, farms were stratified into three classes according to size, then proportional random sampling technique was employed.

Survey questionnaires were prepared and administered to sample farmers for the collection of data. The main type of data collected were regarding input-output of farm enterprises in Gaturi farming situation. The data collection took place between end of October 1979 and beginning of January 1980, and the data collected were those of the previous long and short rain seasons. The limitation of the data collected was that a majority of the respondents were unable to recall some of the information pertaining to the farming operation. Since the nature of the data collected were cross-sectional it was difficult to most of the farmers to recall input-output data of enterprises. Very few farmers kept records.

In Gaturi location the two main types of farming systems practised by farmers are crop and livestock systems. In the cropping systems crops are planted either in pure stand or interplanted.

The most economic type of livestock kept by farmers are dairy cows and oxen. Livestock like goat and sheep have not much economic significance in the study area. Only 8 percent of the sample farmers kept grade dairy cows. Crossbred cattle are replacing the local zebu cows. This is as the result of the increased facilities of artificial insemination in the area.

The average size of land holding in Gaturi location was 2.79 ha. at the time of the survey. Sixty per cent of the farms were belcow 3.0 ha., 30 per cent of the farms were between 3.0 ha. and 6.0 ha. Only 10 per cent of the farms were over 6.0 ha.

In Gaturi the average family size is approcimately 8.3 persons per family. Hired casual labour is used at peak seasons i.e. during land preparation, planting, weeding, harvesting of food crops and picking of coffee. Usually, in the family farms the highest number of casual labour is hired during coffee picking.

The main type of farm tools commonly found among farmers in Gaturi are: pangas, forked jembes, jembes, secateur, milking utensils, wheel barrows, bicycles and spraying pumps.

In this study the tool of analysis is a linear programming technique. A model farm was built for each size group of farms and for the aggregate holdings of all sample farms. A linear programming technique was employed to explore the maximum gross margin that can be obtained by farmers from their farming operation, and to identify the limiting factor of production. The advantages and disadvantages of the LP technique and the assumptions underlying it are discussed in the study in full.

As commonly done to use the linear programming technique four matrices were built which were modified whenever necessary. In the matrices the proper activities as practised by Gaturi farmers were clearly identified. All the necessary constraints were set and the value of input/output coefficients were inserted under the respective activity in the matrices.

Different optimal plans were prepared with the use of a linear programming technique on each model farm with the following

major assumptions: i) when only family labour is used ii) with the use of additional hired labour iii) with the available working capital on farm iv) with restricted borrowed capital v) the effect of changing the available family labour.

5.2 Conclusions

The conclusion of this study can be summarized as follows:

a) As investigated from the four model farms, in Gaturi location the best plan emerges when the family labour is supported by hired casual labour and borrowed capital is used. The farm gross margin obtained by farmers at the time of the survey is lower than that obtained in the optimal plans of the four model farms as prepared by the linear programming technique. When hired casual labour and borrowed working capital are used the existing farm return on the small farms can be raised by 28%, while on the medium and large farms the farm revenue can be increased by 31% and 27% respectively. Therefore, this shows that farmers in Gaturi are operating below the potential of the existing farming situation. There are opportunities for farmers in Gaturi to increase their income substantially by reallocation of their resource endowments (i.e. land, labour and capital) among enterprises.

b) On the small farms the most limiting factors of agricultural production are shortage of land, working capital and labour. On the small farms the most profitable enterprises to produce are food crops and few coffee trees. Milk production from dairy cows on the small farms is hampered by shortage of land because the food crops compete for the available land. If the available land area for cultivation was to increase there

are high opportunities for the small farms to gain much more additional farm income. This can be done by channeling the available labour for milk production on the increased area of land.

c) One the medium farms the most constraining factors of production are labour and available working capital on farms. Labour shortage for coffee picking during January and November are the most critical. When the family labour is supplemented with hired casual labour and borrowed working capital the most cash earning enterprise is the production of coffee. If only family labour was to be used on the existing farm situation it would be economic to produce enterprises which demand minimum labour. In this case the production of food crop and milk production from crossbred cows would be the most profitable. If only family labour is to be employed coffee production would not be the main cash earning crop. This is because the high labour demand for coffee production cannot be met by family labour alone. Therefore, to a larger extent coffee production in Gaturi depends on the availability of hired casual labour.

d) On the large farms the most limiting factor of agricultural production is only labour. The best plan for the large farms is when the family labour is supported with hired labour. The most profitable enterprises to produce are food crops, coffee and milk from crossbred cows. Since there is high competition for hired casual labour by coffee growers in Gaturi location it would be profitable for the large farmers to leave a large portion of the available area for milk production from crossbred cows. However, as found from the parametric programming results if the labour availability was to increase coffee replaces milk production.

e) In Gaturi location the production of milk from crossbred cows is most profitable than all the enterprises produced in situations where there are enough supply of land and critical shortage of labour. Also the production of milk from crossbred cows is more profitable than from grade cows or local zebu cows. This is because of their higher adaptability in the star grass zone, their lower input cost than the grade cows, and the higher milk yield they render than the local zebu.

f) The rationality of farmers in Gaturi to concentrate more on coffee production than milk or food crop production can only be justified when there is enough hired casual labour available.

5.3 Recommendations

In Gaturi the labour bottleneck is partly contributed by the absence of ox-traction or mechanization for land preparation. As discussed in this study land preparation takes place by hand wth the use of jembes. Therefore, one possible recommendation would be that extension agents should put effort to advise and encourage farmers to use ox-ploughing or to introduce hand driven tractors.

Moreover, extension agents should encourage farmers to counter weeding of coffee and food crops with the use of mainly herbicide. This will relax the labour shortage which arises during weeding. For example, if short rain food crops are weeded with use of herbicide during the month of November, it would certainly assist to release the family labour for use in coffee picking during this month. The use of herbicide calls for enough working capital which is already lacking on the small

and medium farms, which are 90% of the sample farms in Gaturi. There is a serious need for credit by these groups of farms. Therefore, development agents should put enough effort in looking into this problem very carefully. Extension agents should encourage farmers to take credit whenever it is available. As found in this study, the marginal value product of working capital is much higher than its cost within the existing farming situations on the small and medium farms.

As found in this study production of milk competes with coffee production as cash earning enterprise under some conditions within the existing farm organization. It would be the role of extension agents to advise farmers to concentrate more on milk production from dairy cow than coffee production on farms where there is extreme labour shortage and enough land within the existing farm organization. Farmers should be made aware that coffee production is only profitable when there is enough labour available.

As discussed in this study there is not a single farmers dairy cooperative in the whole district. There is need for the government policy to look into this matter very carefully. With efficient milk marketing system, there is high possibility to induce farmers with adequate land to exercise better management level so as to increase their milk yield per cow. By so doing milk production can compete with coffee as cash earning enterprise and the maximum farm income within the farming organization can be maintained. This in turn can help to release some of the labour input spent on coffee production for further use in the production of other enterprises. However, the validity of this statement calls for a further indepth research.

On the small farms land scarcity is the most limiting factor of agricultural productions and farm income is greatly affected by the absence of this factor. Sixty per cent of the sample farmers own on the average only 1.64 ha. of land area for cultivation. One approach to overcome this serious problem would be to devise a combination of measures and policies calculated to increase the productivity of the small holding. By so doing it would be possible to increase the farm income of the small holdings. This requires an increase in the yield of foodstuffs resulting from a better farming method, thus permitting the release of some land for commercial farming.

From this study a number of problem areas warranting further in depth research can be mentioned. This study considers the study area as an independent economic entity, it fails to show the interdependence of regions and the econony as a whole, and assumes assured market for farmers if all follow the optimal plan outlined. There is a need for a type of study which considers the interdependence of regions and the economy as a whole and which further investigates the market situations. Therefore, one possible approach to this would be a regional programming sector analysis.

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APPENDIX 1

Distributional Pattern of Dips and Dipping Percentage of Livestock in Embu District, 1979

Location	Plunge Dips Constructed	Plunge Dips in Use	Spray Pumps	Dipping Percentage
Gaturi	9	9	15	75
Ngandori	8	7	10	95
Kagaari	12	12	10	95
Kyeni	8	6	5	75
Mbeti	4	4	15	85
Siakago/Gachoka	28	20	5	50
District Total	69	58	60	79%

Source: Republic of Kenya. Ministry of Agriculture, Embu District, Annual Report. 1979.

APPENDIX 2

Optimal and Existing Enterprise Combination when Hired Labour and Borrowed Working Capital is Used on the Small Model Farm (available land area = 1.64 ha.)

Enterprise	Area Occupied			
	Long Rain Land (Ha.)		Short Rain Land (Ha.)	
	Optimal	Existing	Optimal	Existing
Maize	-	0.22	-	0.31
Beans 2	-	0.3	0.1	0.41
Maize and Bean 1 (interplanted)	0.6	0.20	0.48	-
Coffee	-	0.07	-	0.07
Banana and Maize (interplanted)	0.32	0.33	0.32	0.33
Irish Potatoes	0.16	0.22	0.13	0.22
Maize and Beans 2 (interplanted)	0.43	-	0.48	-
Banana	0.13	-	0.13	-
Local zebu (Milk production)	-	0.3	-	0.3
Total	1.64	1.64	1.64	1.64

Source: Computer print out and survey data 1979/80.

APPENDIX 3

Optimal and Existing Enterprise Combination when Hired Labour and Borrowed Working Capital is Used on the Medium model Farm (available land area = 3.25 ha.)

Enterprise	Area Occupied			
	Long Rain Land (Ha.)		Short Rain Land (Ha.)	
	Optimal	Existing	Optimal	Existing
Maize		0.2		0.2
Beans 1		0.15		0.25
Irish Potatoes	0.5	0.2	0.13	0.1
Coffee	1.7	1.0	1.7	1.0
Banana	0.22	0.3	0.22	0.3
Local zebu (milk)		0.4		0.4
Cross bred (milk)		0.6		0.6
Maize and beans 1 (interplanted)	0.43	0.2	0.6	0.2
Maize and beans 2 (interplanted)	0.40	0.2	0.6	0.2
Total	3.25	3.25	3.25	3.25

Source: Survey data, 1979/80 and computer print out.

APPENDIX 4

Optimal and Existing Enterprise Combination when Hired Labour and Borrowed Working Capital is used on the Large model Farm (Available land area - 6.1 ha)

Enterprise	Area Occupied			
	Long Rain land (ha)		Short Rain land (ha)	
	Optimal	Existing	Optimal	Existing
Maize	-	0.6	0.3	0.4
Beans 1	-	0.4	-	0.6
Beans 2	-	0.5	-	0.5
Coffee	1.2	1.0	1.2	1.0
Irish Potatoes	1.2	0.5	0.69	0.5
Cross bred cow	2.4	1.0	2.4	1.0
Grade cow	-	0.4	-	0.4
Banana/maize	-	0.2	-	0.2
Banana/beans 2	-	0.3	-	0.3
Banana/beans 1	0.6	0.5	0.71	0.5
Local zebu (milk)	-	0.7	-	0.7
Maize/beans 2	0.1	-	0.2	-
Banana	0.6	-	0.6	-
Total	6.1	6.1	6.1	6.1

Source: Survey data 1979/80 and computer print out.

APPENDIX 5A

The effect of Changing Land Area on the Optimal Enterprise Combinations on the Small Farms

a) Increasing Land by 0.5 ha.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	-	0.2
Irish Potatoes	0.6	0.14
Maize and beans 1 (interplanted)	0.43	0.5
Maize and beans 2 (interplanted)	0.4	0.5
Coffee	0.21	0.21
Banana	0.20	0.20
Cross bred cow (milk production)	0.30	0.30
Total	2.14	2.14

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(Ksh.)
Land	Hectare	3411.61
March Labour	Manday	67.55
September Labour	"	48.71
November Labour	"	119.74

APPENDIX 5B

b) Increasing Land by 1.0 ha.

Enterprise	Area Occupied	
	Long Rain Land (ha.)	Short Rain Land (ha.)
Maize	-	0.18
Irish Potatoes	0.56	0.14
Maize and beans 1 (interplanted)	0.43	0.50
Maize and beans 2 (interplanted)	0.43	0.60
Coffee	0.15	0.15
Banana	0.22	0.22
Cross bred cow	0.85	0.85
Total	2.64	2.64

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(Ksh.)
Land	Hectare	3411.62
March Labour	Manday	67.55
September Labour	"	48.70
November Labour	"	119.74

APPENDIX 5C

c) Increasing Land by 1.5 ha.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Irish Potatoes	0.55	0.21
Maize and beans 1 (interplanted)	0.43	0.60
Maize and beans 2 (interplanted)	0.43	0.60
Coffee	0.06	0.06
Banana	0.22	0.22
Cross bred cows	1.45	1.45
TOTAL	3.14	3.14

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
Land	Hectare	1844.58
March Labour	Manday	80.58
September	"	274.46

APPENDIX 5D

d) Increasing Land by 2.0 ha.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Irish Potatoes	0.41	0.15
Maize and beans 1 (interplanted)	0.43	0.51
Maize and beans 2 (interplanted)	0.43	0.60
Banana	0.28	0.28
Cross bred cow	2.0	2.0
TOTAL	3.64	3.64

Marginal Value of Constraining Resources

Resources	Unit	MVP (Ksh.)
Land	Hectare	514
March Labour	Manday	134.17
September Labour	"	710.20

APPENDIX 6A

The effect of changing labour on the optimal enterprise combination on the medium farms:

a) Increasing labour by 4 Mandays

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Irish Potatoes	0.55	0.13
Maize and beans 1 (interplanted)	0.43	0.69
Maize and beans 2 (interplanted)	0.34	0.50
Coffee	1.66	1.66
Banana	0.27	0.27
TOTAL	3.25	3.25

Marginal value of constraining resources

Resources	Unit	MVP(KSh.)
Land	Hectare	11,750
July Labour	Manday	10.0
November labour	"	10.0

APPENDIX 6B

b) Increasing Labour by 8 Mandays.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Irish Potatoes	0.47	0.13
Maize and beans 1 (interplanted)	0.43	0.50
Maize and beans 2 (interplanted)	0.43	0.60
Coffee	1.70	1.70
Banana	0.22	0.22
TOTAL	3.25	3.25

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
Land	Hectare	11,750
July Labour	Manday	10.0
November Labour	"	10.0

APPENDIX 6C

c) Increasing Labour by 12 Mandays.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Irish Potatoes	0.43	0.13
Maize and beans 1 (interplanted)	0.50	0.60
Maize and beans 2 (interplanted)	0.40	0.60
Coffee	1.70	1.70
Banana	0.22	0.22
TOTAL	3.25	3.25

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
Land	Hectare	11,750
July Labour	Manday	10
November	"	10

APPENDIX 7A

The effect of changing Labour on the optimal enterprise combination on the large farms.

a) Increasing by 4 Mandays

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize and beans 1 (interplanted)	0.57	0.67
Maize	-	0.38
Maize and beans 2 (interplanted)	-	0.45
Banana	0.60	0.60
Cross bred cow (milk production)	2.31	2.31
Coffee	1.32	1.32
Irish Potatoes	1.20	0.36
TOTAL	6.1	6.1

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
January Labour	Manday	21.27
July Labour	"	58.14
November Labour	"	97.65
September Labour	"	20.32

APPENDIX 7B

b) Increasing by 8 Mandays.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	0.2	0.38
Maize and beans 1 (interplanted)	0.53	0.62
Maize and beans 2 (interplanted)	-	0.53
Banana	0.60	0.60
Cross bred cow (milk production)	2.2	2.2
Coffee	1.44	1.44
Irish Potatoes	1.13	0.33
TOTAL	6.1	6.1

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
January Labour	Manday	34.22
July Labour	"	57.0
November Labour	"	98.71

APPENDIX 7C

c) Increasing by 12 Mandays

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	-	0.48
Maize and beans 1 (interplanted)	0.50	0.62
Maize and beans 2 (interplanted)	0.20	0.44
Banana	0.60	0.60
Cross bred cow (milk production)	2.10	2.10
Coffee	1.48	1.48
Irish Potatoes	1.22	0.38
TOTAL	6.1	6.1

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
January Labour	Manday	34.22
July Labour	"	57.0
November Labour	"	98.71

APPENDIX 7D

d) Increasing by 16 Mandays

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	0.2	0.38
Maize and beans 1 (interplanted)	0.50	0.62
Maize and beans 2 (interplanted)	-	0.55
Banana	0.61	0.61
Cross bred cow (milk production)	1.99	1.99
Coffee	1.43	1.43
Irish Potatoes	1.28	0.43
TOTAL	6.1	6.1

Marginal Value Product of Constraining Resources.

Resources	Unit	MVP(KSh.)
January Labour	Manday	34.22
July Labour	"	57.0
November Labour	"	98.71

APPENDIX 7E

e) Increasing Labour by 20 Mandays.

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	0.2	0.38
Maize and beans 1 (interplanted)	0.53	0.62
Maize and beans 2 (mixture)	-	0.55
Banana	0.6	0.6
Cross bred cow (milk production)	1.89	1.89
Coffee	1.58	1.58
Irish Potatoes	1.3	0.48
TOTAL	6.1	6.1

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
January Labour	Manday	34.22
July Labour	"	57.0
November Labour	"	98.71

APPENDIX 7F

f) Increasing Labour by 24 Mandays

	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	0.2	0.38
Maize and beans 1 (mixed)	0.53	0.62
Maize and beans 2 (mixed)	-	0.54
Banana	0.6	0.6
Cross bred cow (milk production)	1.8	1.8
Coffee	1.63	1.63
Irish Potatoes	1.16	0.53
TOTAL	6.1	6.1

Marginal Value Product of Constraining Resources

Resources	Unit	MVP(KSh.)
January Labour	Manday	34.0
July Labour	"	57.0
November Labour	"	98.0

APPENDIX 7G

g) Increasing Labour by 28 Mandays

Enterprise	Area Occupied	
	Long Rain Land (ha)	Short Rain Land (ha)
Maize	0.2	0.38
Maize and beans 1 (mixed)	0.53	0.62
Maize and beans 2 (mixed)	-	0.55
Banana	0.6	0.6
Cross bred cow (milk production)	1.59	1.59
Coffee	1.73	1.72
Irish Potatoes	1.41	0.62
TOTAL	6.1	6.1

Marginal Value Product of constraining Resources.

Resources	Unit	MVP(KSh.)
January Labour	Manday	24.20
July Labour	"	37.0
November Labour	"	58.70

APPENDIX 8A

LP Matrix - Small Farm Model, Gaturi Location, Embu, Kenya, 1979.

Constraints	Produce long Rains Maize	Produce short Rains Maize	Produce long Rain Bean(1)	Produce short Rain Bean(1)	Produce long Rain Bean(2)	Produce short Rain Bean(2)	Produce Long Rain I. Potatoes	Produce Short Rain I. Potatoes	Long Rain Onion	Short Rain Onion	Produce long Rain Maize/ Beans(1)	produce short rain maize/ Beans(1)	Produce Long Rain maize/ Beans(2)	Produce short Rain maize/ Bean(2)	Coffee Cherries	Produce Banana	Produce Banana/ maize	Produce Banana/ Beans1	Produce Banana/ Beans 2	local zebu cow	Cross bred Milk)	Grade cow (Milk)	Ox	sell short rain maize	sell short rain maize	sell long rain beans(1)	sell short rain beans(1)	sell long rain beans(2)	sell short rain beans(2)	sell long rain I.potatoes	sell short rain I.potatoes	sell bana-na	buy cre-dit	Hire long rain labour	Hire short rain labour	Maize Trans-sfer	Beans Trans-sfer	Irish potatoes Trans-sfer	Banana Trans-sfer	RHS
Obj fn	-230	-170	-60	-52	-67	-49	-2200	-2200	4200	4200	-130	-110	-123	-100	12000	-102	-105	-106	-108	858	3200	3605	820	0.83	0.93	2.83	2.13	2.0	2.0	2.0	2.0	10.0	-8.0	-10.0	-10.0	0	0	0	0	
Long Rain Land	a	1			1		1		1		1		1		1	1	1	1	1	0.5	2.7	2.8	0.65																		3.75
Short Rain Land	a		1			1		1		1		1		1	1					0.5	2.7	2.8	0.65																		3.75
January Labour	a		20		11		11		48		32		22		22	42	20	32	31	31	1.0	2.0	3.4	2.41										-1						45.4
February Labour	a	22		22		23		33		32		22		22			20	32	31	31	1.0	2.0	3.4	2.41									-1							45.4
March Labour	a	18		26		21		44		53		25		25			20	29	34	34	1.0	2.0	3.4	2.41										-1						45.4
April Labour	a	18		26		26		39		50		24		24				27	28	28	1.0	2.0	3.4	2.41																54.0
May Labour	a															42	26	21	21	21	1.0	2.0	3.4	2.41																54.0
June Labour	a			12		12		48		50		12		13		40		9	9	21	21	1.0	2.0	3.4	2.41																54.0
July Labour	a											28		28		39						2.0	3.4	2.41																43.8
August Labour	a	22														39						2.0	3.4	2.41																43.8
September Labour	a			22		23		33		32		22		22		20		9	9	9	9	2.0	3.4	2.41																43.8
October Labour	a			26		21		44		53		25		25		20		29	34	34	34	2.0	3.4	2.41																45.4
November Labour	a			26		21		39		50		24		24				27	28	28	28	2.0	3.4	2.41																54.0
December Labour	a			26		26		39		50		24		24		54	21	21				2.0	3.4	2.41																54.0
working capital	a	230	170	60	52	67	49	2200	2200	710	710	-1900	110	-1900	100	2100	102	105	106	106	182	3200	3605	820																3400
Long Rain maize Yield	a	-2760											-810		-710			-520							1															0
Short Rain maize Yield	a		-889									-417		-420					-288							1														0
Long Rain Beans(1) Yield	a			-800									-360		-310												1													0
Short Rain Beans(1) Yield	a				-355															-290								1											0
Long Rain Beans(2) Yield	a					-547																							1										0
Short Rain Beans(2) Yield	a						-378																							1									0
Long Rain Irish Potatoes Yields	a							-50																							1								0
Short Rain Irish Potatoes Yield	a								-45																							1							0
Banana yield	a																-340	-430	-425														1						0
Maize subsistence	a																																	1					300.0
Beans subsistence	a																																		1				180.0
I. Potatoes subsistence	a																																			1			90.0
Banana subsistence	a																																				1		120.0
Hired labour long rain	a																																					1	10.0
Hired labour short rain	a																																						30.0
Credit	a																																						3000.0

APPENDIX 8B

LP Matrix - Medium Farm model, Gaturi Location, Embu, Kenya, 1979

Constraints	Produce long Rains Maize	Produce short Rains Maize	Produce Long Rain Bean(1)	Produce short Rain Bean(1)	Produce long Rain Bean(2)	Prgduce short Rain Bean(2)	Produce Long Rain I. Potatoes	Produce Short Rain I. Potatoes	Long Rain Onion	Short Rain Onion	Produce long Rain Maize/ Beans(1)	produce short rain maize/ Beans(1)	Produce Long Rain maize/ Beans(2)	Produce short Rain maize/ Bean(2)	Coffee Cherries	Produce Banana	Produce Banana/ maize	Produce Banana/ Beans1	Produce Banana/ Beans 2	local zebu cow	Cross bred Milk)	Grade cow (Milk)	Ox	sell short rain maize	sell short rain maize	sell long rain beans(1)	sell short rain beans(1)	sell long rain beans(2)	sell short rain beans(2)	sell long rain I.potatoes	sell short rain I.potatoes	sell bana-na	buy cre-dit	Hire long rain labour	Hire short rain labour	Maize Trans-sfer	Beans Trans-sfer	Irish potatoes Trans-sfer	Banana Trans-sfer	
Obj fn	-230	-170	-60	-52	-67	-49	-2200	-2200	4200	4200	-130	-110	-123	-100	12000	-102	-105	-106	-108	858	3200	3605	820	0.83	0.93	2.83	2.13	2.0	2.0	2.0	2.0	10.0	-8.0	-10.0	-10.0	0	0	0	0	
Long Rain Land	a	1			1		1		1		1		1		1	1	1	1	1	0.5	2.7	2.8	0.65																		3.75
Short Rain Land	a		1			1		1		1		1		1						0.5	2.7	2.8	0.65																		3.75
January Labour	a		20		11		11		48		32		22		22	42	20	32	31	31	1.0	2.0	3.4	2.41										-1						45.4
February Labour	a	22		22		23		33		32		22		22			20	32	31	31	1.0	2.0	3.4	2.41									-1							45.4
March Labour	a	18		26		21		44		53		25		25			20	29	34	34	1.0	2.0	3.4	2.41										-1						45.4
April Labour	a	18		26		26		39		50		24		24				27	28	28	1.0	2.0	3.4	2.41																54.0
May Labour	a															42	26	21	21	21	1.0	2.0	3.4	2.41																54.0
June Labour	a			12		12		48		50		12		13		40		9	9	21	21	1.0	2.0	3.4	2.41																54.0
July Labour	a											28		28		39						2.0	3.4	2.41																43.8
August Labour	a	22														39						2.0	3.4	2.41																43.8
September Labour	a			22		23		33		32		22		22		20		9	9	9	9	2.0	3.4	2.41																43.8
October Labour	a			26		21		44		53		25		25		20		29	34	34	34	2.0	3.4	2.41																45.4
November Labour	a			26		21		39		50		24		24		54	21	21				2.0	3.4	2.41																54.0
December Labour	a			26		26		39		50		24		24		54						2.0	3.4	2.41																54.0
working capital	a	230	170	60	52	67	49	2200	2200	710	710	-1900	110	-1900	100	2100	102	105	106	106	182	3200	3605	820																3400
Long Rain maize Yield	a	-2760											-810		-710			-520							1															0
Short Rain maize Yield	a		-889									-417		-420					-288							1														0
Long Rain Beans(1) Yield	a			-800									-360		-310												1													0
Short Rain Beans(1) Yield	a				-355															-290								1											0
Long Rain Beans(2) Yield	a					-547																							1										0
Short Rain Beans(2) Yield	a						-378																							1									0
Long Rain Irish Potatoes Yields	a							-50																							1								0
Short Rain Irish Potatoes Yield	a								-45																							1							0
Banana yield	a																-340	-430	-425														1						0
Maize subsistence	a																																	1					910
Beans subsistence	a																																		1				180
I. Potatoes subsistence	a																																			1			90
Banana subsistence	a																																				1		120.0
Hired labour long rain	a																																					1	10.0
Hired labour short rain	a																																						6000.0
Credit	a																																						

APPENDIX 8C

LP Matrix - Large Farm Model, Gaturi Location, Embu, 1979

Constraints	Produce long Rains Maize	Produce short Rains Maize	Produce long Rain Bean(1)	Produce short Rain Bean(1)	Produce long Rain Beans(2)	Produce short Rain Bean(2)	Produce Long Rain I. Potatoes	Produce Short Rain I. Potatoes	Long Rain Onion	Short Rain Onion	Produce long Rain Maize/ Beans(1)	Produce short rain maize/ Beans(1)	Produce Long Rain maize/ Beans(2)	Produce short Rain maize/ Bean(2)	Coffee Cherries	Produce Banana	Produce Banana/ maize	Produce Banana/ Beans1	Produce Banana/ Beans 2
															12000	-102	-105	-106	-106
Obj fn	-230	-192	-60	-52	-47	-49	-2200	-2200	4200	4200	-130	-110	-193	-169	1	1	1	1	1
Long Rain Land	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Short Rain Land		20		11		11		11		10		22		22	42				
January Labour	22		22		23		23		32		22		22		20		32	31	31
February Labour	18		18		24		24		53		23		25			26	24	24	24
March Labour	18		18		26		26		50		24		24		42		21	21	21
April Labour									50		12		13		40	9	9	21	21
May Labour				14		12		48			26		26		40		9	9	9
June Labour	22		22		23		23		32		50	22		22	40	21	23		
July Labour		22		22		23		45	50		25	25		25	40				
August Labour		22		22		23		79			24	24		24	40				
September Labour		22		22		26		79	710	710	130	110	123	100	2100	102	105	106	106
October Labour								2200			-1900		-1900				-520		
November Labour												-810		-710				-288	
December Labour	230	190	60	52	67	49	2200				-617		-620						
Working Capital	-2 700											-340		-310					-288
Long Rain Maize Yield	-285																		
Short Rain maize Yield			-200																
Long Rain Beans(1) Yield				-355															
Short Rain Beans(1) Yield					-549														
Long Rain Beans(2) Yield						-378													
Short Rain Beans(2) Yield							-59												
Long Rain Irish Potatoes Yields								-45											
Short Rain Irish Potatoes Yield																			
Banana yield																			
Maize Subsistence																			
Beans subsistence																			
Irish Potatoes subsistence																			
Banana subsistence																			
Hired labour long rain																			
Hired labour short rain																			
Credit																-340	-430	-425	

Constraints	local zebu cow	Cross bred Milk)	Grade cow (Milk)	Ox	sell short rain maize	sell short rain maize	sell long rain Beans(1)	sell short rain beans(1)	sell long rain beans(2)	sell short rain beans(2)	sell long rain I.potatoes	sell short rain I.potatoes	sell banana	Buy credit	Hire long rain labour	Hire short rain labour	Maize Transfer	Beans Transfer	Irish potatoes Transfer	Banana Transfer	RHS
Obj fn	558	1200	2028	6200	-0.83	-0.83	-2.23	-2.23	-2.8	-2.8	-135	-135	100.0	-0.1	-10.0	-10.0	0	0	0		
Long Rain Land	0.5	0.7	0.8	0.65																	2.97
Short Rain Land	0.5	0.7	0.8	0.65																	2.97
January Labour	1.0	2.4	3.4	1.4												-1					6.4
February Labour	1.0	3.1	5.0	1.4											-1						6.4
March Labour	1.0	3.1	5.0	1.4											-1						6.4
April Labour	1.0	3.0	3.6	1.4											-1						5.4
May Labour	1.0	3.0	3.6	1.4											-1						5.4
June Labour	1.3	3.5	4.0	1.4											-1						6.4
July Labour	1.4	3.0	4.0	1.4												-1					6.4
August Labour	1.5	3.0	4.0	1.4												-1					6.4
September Labour	1.2	3.0	4.0	1.4												-1					6.4
October Labour	1.0	3.0	3.6	1.4											-1						5.4
November Labour	0.5	1.2	1.8	0.7																	2.7
December Labour	0.5	0.7	0.8	0.65																	2.97
Working Capital																					0
Long Rain Maize Yield																					0
Short Rain maize Yield																					0
Long Rain Beans(1) Yield																					0
Short Rain Beans(1) Yield																					0
Long Rain Beans(2) Yield																					0
Short Rain Beans(2) Yield																					0
Long Rain Irish Potatoes Yields																					0
Short Rain Irish Potatoes Yield																					0
Banana yield																					0
Maize Subsistence																					0
Beans subsistence																					0
Irish Potatoes subsistence																					0
Banana subsistence																					0
Hired labour long rain																					0
Hired labour short rain																					0
Credit																					0

APPENDIX 8B

LP Matrix-Aggregate Farm Model, Gaturi Location, Embu, Kenya, 1979.

Constraints	Produce long Rains Maize	Produce short Rains Maize	Produce long Rain Bean(1)	Produce short Rain Bean(1)	Produce Long Rain Beans(2)	Produce short Rain Bean(2)	Produce Long Rain I. Potatoes	Produce Short Rain I. Potatoes	Long Rain Onion	Short Rain Onion	Produce long Rain Maize/ Beans(1)	Produce short rain Maize/ Beans(1)	Produce Long Rain maize/ beans(2)	Produce short Rain maize/ Bean(2)	Coffee Cherries	Produce Banana	Produce Banana/ maize	Produce Banana/ Beans1	Produce Banana/ Beans 2
															12000	-102	-105	-106	-106
Obj fn	-230	-192	-60	-52	-47	-49	-2200	-2200	4200	4200	-130	-110	-193	-169	1	1	1	1	1
Long Rain Land	1		1		1		1		1		1		1		1				
Short Rain Land		20		11		11		11		10		22		22	42				
January Labour	22		22		23		23		32		22		22		20		32	31	31
February Labour	18		18		24		24		53		23		25			26	24	24	24
March Labour	18		18		26		26		50		24		24		42		21	21	21
April Labour									50		12		13		40	9	9	21	21
May Labour				14		12		48			26		26		40		9	9	9
June Labour	22		22		23		23		32		50	22		22	40	21	23		
July Labour		22		22		23		45	50		25	25		25	40				
August Labour		22		22		23		79			24	24		24	40				
September Labour		22		22		26		79	710	710	130	110	123	100	2100	102	105	106	106
October Labour								2200			-1900		-1900				-520		
November Labour												-810		-710				-288	
December Labour	230	190	60	52	67	49	2200				-617		-620						
Working Capital	-2 700											-340		-310					-288
Long Rain Maize Yield		-285																	
Short Rain maize Yield			-200																
Long Rain Beans(1) Yield				-355															
Short Rain Beans(1) Yield					-549														
Long Rain Beans(2) Yield						-378													
Short Rain Beans(2) Yield							-59												
Long Rain Irish Potatoes Yields								-45											
Short Rain Irish Potatoes Yield																			
Banana yield																			
Maize Subsistence																			
Beans subsistence																			
Irish Potatoes subsistence																			
Banana subsistence																			
Hired labour long rain																			
Hired labour short rain																			
Credit																-340	-430	-425	

Constraints	local zebu cow	Cross bred Milk)	Grade cow (Milk)	Ox	sell short rain maize	sell short rain maize	sell long rain beans(1)	sell short rain beans(1)	sell long rain beans(2)	sell short rain beans(2)	sell long rain I.potatoes	sell short rain I.potatoes	sell banana	Buy credit	Hire long rain labour	Hire short rain labour	Maize Transfer	Beans Transfer	Irish potatoes Transfer	Banana Transfer	RHS
Obj fn	558	1200	2028	6200	-0.83	-0.83	-2.23	-2.23	-2.8	-2.8	-135	-135	100.0	-0.1	-10.0	-10.0	0	0	0		
Long Rain Land	0.5	0.7	0.8	0.65																	2.97
Short Rain Land	0.5	0.7	0.8	0.65																	2.97
January Labour	1.0	2.4	3.4	1.4												-1					6.4
February Labour	1.0	3.1	5.0	1.4											-1						6.4
March Labour	1.0	3.1	5.0	1.4											-1						6.4
April Labour	1.0	3.0	3.6	1.4											-1						5.4
May Labour	1.0	3.0	3.6	1.4											-1						5.4
June Labour	1.3	3.5	4.0	1.4											-1						6.4
July Labour	1.4	3.0	4.0	1.4												-1					6.4
August Labour	1.5	3.0	4.0	1.4												-1					6.4
September Labour	1.2	3.0	4.0	1.4												-1					6.4
October Labour	1.0	3.0	3.6	1.4											-1						5.4
November Labour	0.5	1.2	1.8	0.7																	2.7
December Labour	0.5	0.7	0.8	0.65																	2.97
Working Capital																					0
Long Rain Maize Yield																					0
Short Rain maize Yield																					0
Long Rain Beans(1) Yield																					0
Short Rain Beans(1) Yield																					0
Long Rain Beans(2) Yield																					0
Short Rain Beans(2) Yield																					0
Long Rain Irish Potatoes Yields																					0
Short Rain Irish Potatoes Yield																					0
Banana yield																					0
Maize Subsistence																					0
Beans subsistence																					0
Irish Potatoes subsistence																					0
Banana subsistence																					0
Hired labour long rain																					0
Hired labour short rain																					0
Credit																					0

APPENDIX 9

THE QUESTIONNAIRE

Farmer's number_____

District_____

Location_____

Sub-location_____

Date of Interview_____

Enumerator_____

1. General Household Demographic Information:

1) Household Head _____ _____
(age) (sex)

2) Level of Education:

a) Read and write_____

b) Attended Farmer's Training Centre_____

c) Primary School_____

d) Secondary School_____

e) Others (specify)_____

_____

_____

3) Are you_____

A) single b) married c) divorced d) widowed

4) How many children do you have?_____

5) Household Structure Format

House member	age	sex	level of education	living on the farm or not
Husband				
Wife (wives)				
a)				
b)				
c)				
d)				

6) What is your main occupation?

a) Farmer_____

b) Small trader in_____

c) Business - shop operator_____

d) Others (specify)_____

_____

7) Do you have any subsidiary occupation or sources of income besides farming?

a) Yes _____ b) No_____

If yes, state the occupation_____

_____

8) Does any member of the household work for someone else away from the farm, for a wage or salary?

a) Yes_____ b) No_____

If yes, how much did he earn to the household during last year?

_____

II Farm Structure

1) Do you own this farm?

a) Yes_____ b) No_____

If no why _____

_____

2) What is the total size of this farm?

Acres_____ Hectares_____

3) Area of land by major uses:

Uses of land	Owned		Rented	
	Acres	hect.	Acres	hect.
i) Annual crops				
ii) Pasture				
iii) Tree Crops[1]				
iv) Homestead (houses, barn yard, etc)				
v) Other land (land in roads, paths, ditches, wells, etc)				
Total land				

4) What area is used for cultivation at present?

Acres_____ or Hectares_____

[1] In the case of trees crops give the number of trees and age.

III Livestock Enterprise

a) Dairy Herd

Class	Grade Cattle		Local Cattle		Total kg or litre
	Number	Total milk prod. kg/lt.	Number	Total milk prod. kg/lt.	
Cows (total)					
Cows in milk					
Heifers over 2 yrs					
Heifers 1-2 yrs					
Female calves					
Less than 1 yr					
Young bulls over 1 yr					
Mature bulls					
Oxen					
Total					

b) What other livestock do you own?

Livestock	Number
i) Goats	_____
ii) Sheep	_____
iii) Donkeys	_____
iv) Poultry	_____
(a) Layers	_____
(b) Broilers	_____
(c)	_____
(e)	_____

2) How large is your grazing land?

3) What feeds do you feed your livestock?

i_____ iii)_____

ii) _____ iv)_____

4a) Do you give the following feeds to your dairy course?

Type	Home Grown	Purchased	Value
i) Feed grains (type)	_____	_____	_____
(a)	_____	_____	_____
(b)	_____	_____	_____
(c)	_____	_____	_____
ii) Hay	_____	_____	_____
iii) Silage	_____	_____	_____
iv) Others (specify)	_____	_____	_____
_____	_____	_____	_____

b) How much did you spend on veterinary service last year?

) What are you livestock products?

	Production		s o l d			household use	
	Unit	Quantity	Qt	Price	Value	Qt	Value
Milk							
Butter							
Eggs							

5) What crop mixtures did you grow during last season (short and long rains)

Crop or crop mixture	No of plots		Area Acres		Yield harvested (bag/kg)				sold or to be sold (bag/kg)	Quantity retained as seeds (bag/kg)
	LR	SR	LR	SR	QUAN. LR	QUAN. SR	PRICE	TOTAL Value		

Note: LR = Long rains

SR = Short rains

6. What inputs did you use during the last cropping season?

Crop or crop mixture	Seed			Fertilizer			Dust & Spray			Herbicide		
	Type	Qt	Vol.	Type	Qt	Value	Type	Qt	Value	Type	Qt	Value

b) What is the calving interval of your dairy cow(s)?_____

_____

LAND and Related Investment

(1) Give the estimated value of each type of investment you own

Kind of Investment	Value
i) Land	
ii) Buildings	
iii) Drainage works	
iv) Irrigation works	
v) Fences, hedges, etc.	
vi) Tree crops	
vii) Crops in fields	
viii) Others	
TOTAL	

2) Give value of all implements, tools, machinery etc. having useful life longer than a year.

Kind	Number	Date of purchase	Purchase price	present value
i) Tractors				
ii) Vehicles				
iii) Tools and				
Implements				
a)				
b)				
c)				

IV) Labour Input

1) How many family members are available for farm work?

Family members	Number	Number of hours worked/day	Period available for farm work month/day	kind of farm work performed
Husband				
Wife (wives)				
Boys over 15 yrs				
Girls over 15 yrs				
Relatives over 15 years and below 60 yrs				

2) Do you have any permanent labourer?

(a) Yes_____ (b) _____

If yes how many?

3) Are they assigned any specific tasks?

e.g. Weeding _____

Household work _____

_____ _____

_____ _____

_____ _____

_____ _____

4) How much do you pay him/her per month_____

5) Do you employ casual labourers?

(a) Yes_____ (b) No_____

Month	No. of employee	Rate of payment per day	Total amount paid/ day	Total amount paid/ month	Type of work employed for	Remarks
JAN						
FEB						
MAR						
APR						
MAY						
JUNE						
JULY						
AUG						
SEPT						

Month	No. of Employees	Rate of payment per day	Total amount paid/ month	Type of work employed for	Remarks
OCT					
NOV					
DEC					

V) Farming Operation

Crop or crop mix & activity	Month	Family labour man/days	Employed labour only (hands) man/days	Ox-team (owned) days	Ox-team (hired) days
Dairy					
a) Herding					
b) Feeding					
c) Milking					
d)					
e)					
f)					
a) Land prep					
b) Planting					
c) Weeding					
d) Harvesting					
e) Transport					
f)					
a) Land prep					
b) Planting					
c) Weeding $\frac{1}{2}$ Weeding					
d) Spraying Dusting					
e) Harvesting					
f) Transport					
g)					

VI) CREDIT

1) Did you borrow anything for your farm needs last season?

(a) Yes_____ (b) No_____

If yes, from where:

a) Friends_____

b) Relatives_____

c) Farmers cooperation_____

d) Local money lender_____

f) Others (specify)_____

_____

2) When and how much did you borrow?

a) Kind_____ (b) Cash_____

_____ _____

3) When and how much are you going to pay back?

_____ _____

_____

4) For what purpose did you borrow?

_____

_____

_____

5) Are you satisfied with the present arrangement of credit supply?

(a) Yes_____ (b) No_____

If no, why not?

a) Approval takes to long_____

b) It requires too much security_____

c) Delays in payments_____

d) Couldn't get the loan wanted_____

e) Others (specify) _____

6) Do you plan to get more loans in the future?

(a) Yes_____ (b) No_____

If yes, state purpose and amount

purpose_____amount_____

If no, why not?

a) has enough cash_____

b) present debts too high_____

c) it is too risky_____

d) others (specify)_____