OPTIMAL RESOURCE ALLOCATION IN FARM ENTERPRISES — A CASE STUDY OF EMBU DISTRICT, KENYA

LUKE OWINO OYUGI

DIVISION OF AGRICULTURAL ECONOMICS
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI-110012

1998

OPTIMAL RESOURCE ALLOCATION IN FARM ENTERPRISES — A CASE STUDY OF EMBU DISTRICT, KENYA

By

Luke Owino Oyugi

A Thesis
submitted to the Faculty of Post-Graduate School,
Indian Agricultural Research Institute, New Delhi,
in partial fulfilment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

IN

AGRICULTURAL ECONOMICS

1998

Approved by:

Chairman : (Dr R K Pandey)

Members: (Dr Parmatma Singh)

(Dr A K Srivastava)

(Dr B P Sinha)

Dr R K Pandey, PhD (Manitoba)
Head, Statistical Economics Division
Indian Agricultural Statistics Research Institute
New Delhi 110 012

CERTIFICATE

This is to certify that the thesis entitled " **Optimal Resource Allocation in Farm Enterprises: A Case Study of Embu District, Kenya**", submitted to the Faculty of Post-Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy** in Agricultural Economics by **Luke Owino Oyugi** embodies the results of the ***bona-fide*** research work carried out by him under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that such help or source of information during the course of investigation have been fully acknowledged.

(R K Pandey)
Chairman
Advisory Committee

New Delhi
Dated: July 1, 1998

DEDICATION

In Memory of my late father Oyugi Mak'Onyango Odhiro

ACKNOWLEDGEMENT

I wish to register my most sincere appreciation to the Government of India through Commonwealth Scholarship and Fellowship Scheme for funding the study. Shri D S Rawat of Indian Council for Cultural Relations (ICCR) was particularly helpful in providing enabling environment during my stay in India.

Most sincere gratitude to the Chairman of my Advisory Committee, Dr R K Pandey, Head, Statistical Economics Division, Indian Agricultural Statistics Research Institute. Other than academic affairs, I wish to acknowledge in a very special way Dr Pandey's recognition that the student's family play an important role in the success, particularly to a student who is spatially separated from the family. To that I say, "Ahsante" - thank you Sir for being sensitive. My thanks are also due to the Members of the Advisory Committee, Dr Parmatma Singh, Professor, Agricultural Economics Division, Indian Agricultural Research Institute; Dr A K Srivastava, Head, Division of Sampling Methodology, Indian Agricultural Statistics Research Institute; and Dr B P Sinha, Head, Agricultural Extension Division, Indian Agricultural Research Institute who rendered extremely valuable help through their scrutiny, suggestions and cooperation during the study period.

Special thanks to Dr B M Sharma, Ex-Senior Scientist, Agricultural Economics Division, Indian Agricultural Research Institute for sparing his valuable time to offer technical expertise in Linear Programming to me during the study. I am proud and deeply privileged to have been your student.

I am thankful to Dr Praduman Kumar, Head, Agricultural Economics Division, Indian Agricultural Research Institute who has not only rendered every possible help and computer facilities in the Division but also took active keen interest in the study. Dr R P Singh, the Principal Scientist, Agricultural Economics Division, has been of special inspiration to me when the going seemed to have reached a dead end. Please allow me to say it more bluntly - " when I felt it was the end of the road for me in Pusa"

The support staff have been helpful in getting things moving. I would not hesitate to mention Shri Vinod Kumar in particular, who was always with a workable solution whenever the "tunnel" was blocked. To all of them I am very thankful.

Special thanks to my colleagues, Paul T Lazarus, Mahendra Singh and Thimmappa K for all the support they provided to me during the study time. In deed they have been friends in need.

I wish to thank Jomo Kenyatta University of Agriculture and Technology, Kenya, for granting me the study leave and also demonstrating that it cared for my wellbeing during the study period.

My heartfelt thanks to Mr P M Amukoa, Deputy Director of Agriculture, Mr Charles Obado and Mr S Sikobe , Senior Agricultural Officers, all of Farm Management Division, Ministry of Agriculture, Kenya and Embu District Agricultural Extension staff, for all the assistance provided during data collection in Kenya.

I am indebted to Mrs L W Njeru and Mr Kimathi M'Nganatha, Senior Education Officers, Ministry of Education, Kenya for all the encouragement for me to pursue the study programme in India.

I am thankful to Mr J O Onduru, Second Secretary (ADM) and Dr K Cheluget, Counsellor, both of the Kenya High Commission, New Delhi for providing the necessary data link between Kenya and myself to enable continuous updating of data in India during the study period.

I would not forget to acknowledge the patience displayed by my wife Esther, my mother Pauline and the children on the tough conditions they have undergone during my long absence from them. I deeply appreciate the manner in which they faced the doldrums and helped me overcome the depressions and frustrations that naturally occur during the course of such work.

I sincerely acknowledge the dedication and the enginuity with which Shri P K Garg formated and processed the final form of this thesis.

It has not been possible to mention everybody who contributed to the success of the study in one way or another by name. To all of you I say thank you very much.

1st. **July, 1998** **Luke Owino Oyugi**

ABSTRACT

An extensive baseline survey conducted by the German Technical Co-operation (GTZ)/Farm Management Project in collaboration with Kenya's Ministry of Agriculture and Livestock Development in Embu District in 1991, revealed a number of issues among which are the diminishing farm sizes, large family sizes, and that crops and livestock enterprises are the main sources of livelihood and income for farm families. It also revealed that a large proportion of farm family members work outside the farms to supplement farm incomes. This indicated the poor remuneration capacity generated by the farm activities.

The overall objective of the study is to improve the income generating capacity of the farm enterprises in Embu District so as to stem the rural-urban migration through developing viable farm plans that on adoption would attract the young entrepreneurs to venture into farming business.

The specific objectives were (i) to study resource endowment and use in different farming situations (ii) to examine the existing cropping pattern, income and employment under different farming situations (iii) to study income and employment potential on the basis of existing and improved technology by developing optimal farm plans for different farm situations and (iv) to suggest policies for improvement of agricultural production.

The study was undertaken in Embu District of Kenya. All the identified zones of agricultural importance were included in the study area. In addition to secondary data, primary data were obtained from farmers selected by multistage stratified sampling technique through personal interviews . Three synthetic farm size groups viz., small, medium and large were developed for each agro-zones identified. Linear Programming was be used to determine optimum resource allocation for different combinations of farm enterprises under existing and improved technology situations. The input-output coefficients of farms were derived by averaging the information collected from the sampled farms. The existing technology was defined as a situation where capital was restricted and the improved technology with unrestricted capital. Capital borrowing and labour hiring activities facilities were incorporated under the improved technology situation in each farm category across all the identified agroecological zone.

The findings indicated that on optimisation of resources, incomes and labour employment increased considerably under both the existing and the improved technology situations. Adoption of recommended technology when combined with unlimited availability of capital yielded the highest returns and increased labour employment in the farming systems in all the eight agroecological zones considered in the study.

Conclusions and policy implications are made on the basis of the findings.

TABLE OF CONTENTS

		Page
CHAPTER I: INTRODUCTION		
1.1	Statement of the Problem	6
1.2	Objectives of the Study	8
1.3	Plan of Thesis	9
CHAPTER II: DESCRIPTION OF THE STUDY AREA		
2.1	Kenya	10
2.2	The Study Area	23
CHAPTER III: LITERATURE REVIEW		
3.1	Kenya	38
3.2	Use of Linear Programming Elsewhere in the World	45
CHAPTER IV: MATERIALS AND METHODS		
4.1	Analytical Tool	65
	4.1.1 Farm Enterprise Budgets	65
	4.1.2 Descriptive Statistics	66
	4.1.3 Linear Programming	66
4.2	Data Requirement and Sources	77
4.3	Sampling Plan	78
4.4	Database Management System	79
4.5	Questionnaire Administration	79
CHAPTER V: RESULTS AND DISCUSSION		
5.1	Social characteristics of The Farmers	81
5.2	Optimal Farm Plans	83
	5.2.1 Optimal Farm Plans for Agroecological Zone LH1	85
	5.2.2 Optimal Farm Plans for Agroecological Zone UM1	89
	5.2.3 Optimal Farm Plans for Agroecological Zone UM2	94
	5.2.4 Optimal Farm Plans for Agroecological Zone UM3	99
	5.2.5 Optimal Farm Plans for Agroecological Zone UM4	104

5.2.6 Optimal Farm Plans for Agroecological Zone LM3 109
5.2.7 Optimal Farm Plans for Agroecological Zone LM4 113
5.2.8 Optimal Farm Plans for Agroecological Zone LM5 116

CHAPTER VI: SUMMARY AND CONCLUSIONS

6.1 Summary 124
6.2 Conclusions and Policy Implication 132
6.3 Limitations of The Study 134
6.4 Suggestion for Future Studies 135

REFERENCES i-viii

APPENDIX

LIST OF TABLES

		Page
Table 1.1	Share Contributions of Various Sectors of GDP, 1964 - 1995 in Percentage	2
Table 1.2	Sources of Employment and Employment Growth, 1991 - 2001 in Million	3
Table 2.1	Kenya Population Census by Race in Census Years, 1948 - 1989	12
Table 2.2	Kenya's Population Growth in Million, 1990 - 1997	13
Table 2.3	Composition of Gross Domestic Product for Years 1994 and 1995 in US $ Million	18
Table 2.4	Annual Growth Rates of Real GDP, 1994-95 in Percentage	19
Table 2.5	Categories of Agricultural Land in Kenya in '000 Hectares	22
Table 2.6	Agroclimatic Zones	29
Table 2.7	Distribution of Holdings, Embu, 1991	31
Table 2.8	Distribution of Holdings, Embu, 1997	32
Table 2.9	Land Use Pattern, Embu District, 1991	33
Table 2.10	Average Yield of the Major Farm Enterprises, Embu, 1996	36
Table 4.1	Major Crop Enterprises in Embu District	70
Table 5.1	Age of Respondets in the Study Area	82
Table 5.2	Level of Education of Farmers in the Study Area	83
Table 5.3	Optimal Farm Plans, LH1, Embu District, 1996	86
Table 5.4	Resource Usage in Optimal Farm Plans, LH1, Embu District, 1996	88
Table 5.5	Optimal Farm Plans, UM1, Embu District, 1996	91
Table 5.6	Resource Usage in Optimal Farm Plans, UM1, Embu District, 1996	93
Table 5.7	Optimal Farm Plans, UM2, Embu District, 1996	96

Table 5.8	Resource Usage in Optimal Farm Plans, UM2, Embu District, 1996	98
Table 5.9	Optimal Farm Plans, UM3, Embu District, 1996	101
Table 5.10	Resource Usage in Optimal Farm Plans, UM3, Embu District, 1996	103
Table 5.11	Optimal Farm Plans, UM4, Embu District, 1996	105
Table 5.12	Resource Usage in Optimal Farm Plans, UM4, Embu District, 1996	107
Table 5.13	Optimal Farm Plans, LM3, Embu District, 1996	110
Table 5.14	Resource Usage in Optimal Farm Plans, LM3, Embu District, 1996	112
Table 5.15	Optimal Farm Plans, LM4, Embu District, 1996	115
Table 5.16	Resource Usage in Optimal Farm Plans, LM4, Embu District, 1996	117
Table 5.17	Optimal Farm Plans, LM5, Embu District, 1996	119
Table 5.18	Resource Usage in Optimal Farm Plans, LM5, Embu District, 1996	121

LIST OF FIGURES

		Page
Fig. 1.1	Map of Kenya Showing Embu District	11
Fig. 2.1	Map of Embu District Showing Agro-ecological Zones	27
Fig. 4.1	Linear Programming Model Matrix	72

ABBREVIATIONS

AEZ	Agro- Ecological Zone
ASAL	Arid and Semi-Arid Lands
CP	Compromise Planning
GDP	Gross Domestic Product
GTZ	Deutsche Gesselschaft fur Technische Zusammenarbeit
ha	Hectare, 1 ha = 2.47 acres
ICDP	Integrated Cattle Development Programme
kg	Kilogram
KTDA	Kenya Tea Development Authority
Kshs	Kenya Shillings, Kshs 58.36 = 1 US $, Kshs 1 = Rs 0.59, May 1998.
LH	Lower Highlands
LM	Lower Midlands
LP	Linear Programming
mm	Millimetre
MoA	Ministry of Agriculture
MOP	Multi-Objective Programming
MOTAD	Minimisation of Total Absolute Deviation
MVP	Marginal Value Product
PC	Personal Computer
POSA	Post-optimal Sensitivity Analysis
TA	Tropical Alpine
UH	Upper Highlands
UM	Upper Midlands
US $	United States Dollar

CHAPTER I

INTRODUCTION

Kenya has since independence in 1963 relied heavily on the agricultural sector as the base for economic growth, employment creation, and foreign exchange earnings. The sector is also a major source of food security and a stimulant to growth of off-farm employment apart from generating income to individual farmers. Approximately 80 per cent of the country's population live in the rural areas and depend on agriculture for their livelihood (Republic of Kenya, 1997). Of the total land surface in Kenya, about 80 per cent is classified as Arid and Semi-Arid Lands (ASAL). About 25 per cent of Kenya's population , and over 50 per cent of the total livestock in the country are found in the ASAL areas. Therefore it goes without saying that resource availability and utilization is of crucial importance. The multiple role of agriculture in economic growth , food production, employment creation, foreign exchange earning and provision of industrial raw materials cannot therefore be over emphasized.

The contribution of the agricultural sector to growth of real Gross Domestic Product (GDP) has been higher *vis-a-vis* other sectors of the economy. Table 1.1 illustrates share contributions of various sectors of GDP from 1964 to 1995.

During the period 1964-73, the sector contributed 36.6 per cent of GDP. This was 33.2 per cent in 1974-79, 29.8 per cent in 1980-89, and 26.2 per cent in 1990-95. Over the same periods, manufacturing

Table 1.1 Share Contributions of Various Sectors of GDP, 1964 - 1995 in Percentage

	1964-73	1974-79	1980-89	1990-95
Agriculture	36.6	33.2	29.8	26.2
Manufacturing	10.0	11.8	12.8	13.6
Services	53.4	55.0	57.4	60.2
Total	100.0	100.0	100.0	100.0

Source: Republic of Kenya, 1997a.

recorded 10 per cent, 11.8 percent, 12.8 per cent, and 13.6 per cent respectively signifying that the sector has a higher potential for further economic growth. The emerging trend is that agriculture has declined from an average of 36.6 per cent in 1964-73 to 26.2 per cent in 1990-95 periods. While manufacturing sector has had a steady increase from 10 per cent to 13.6 per cent over the same period. This trend conforms with empirical evidence that as a country industrialises, the contribution of manufacturing sector to GDP expands considerably and at some stage surpasses the agriculture and other primary industries. The potential for manufacturing, however, depends upon sustained growth of agricultural sector. The links between agriculture and industrial growth are very strong and will be specially important in Kenya's industrial development.

Although agriculture's contribution to GDP has been declining over the past few years, it remains one of the most important sectors driving economic growth and plays a central role in employment creation. Table 1.2 provides details of source of employment and employment targets from 1991 to 2001.

Table 1.2 Sources of Employment and Employment Growth, 1991-2001 in Millions.

Sector	1991	1994	2001	Increase(%)
Small Scale Agriculture	5.31	5.92	7.00	1.08
Large Scale Agriculture	0.42	0.47	0.55	0.08
Rural Informal	0.35	0.62	0.98	0.36
Rural Formal	0.23	0.41	0.55	0.13
Urban Formal	0.74	0.81	1.08	0.27
Urban Informal	0.70	1.16	1.83	0.66
Total Employed	7.77	9.40	12.00	2.61
Total Labour Force	10.10	11.50	13.70	2.23
Unemployed (%)	23.40	18.50	12.80	-

Source: Republic of Kenya, 1997b.

According to 1989 population census, out of the total labour force of 9.3 million people, 7.6 million or approximately 82 per cent were based in the rural areas whereas 1.7 million were in urban areas (Republic of Kenya, 1994). This indicates that the rural areas still command the largest share of the total labour force. Likewise the incidence of unemployment is likely to be more severe in the rural areas. Available data as presented in table 1.2 show that small scale agriculture, typical of Embu District, absorbs the largest share of the new addition to the labour force as well. Small scale agriculture is still projected to provide the largest share of jobs (1.1 million over 1994 - 2001 or 41.6 per cent of new jobs).

Since 1980, Kenya has not experienced stable growth in agriculture sector. Indeed the sector recorded negative growth rates for three consecutive years between 1991 and 1993. Some of the major constraints faced by the sector are summarized below:-

(i) high dependence on rain-fed agriculture.

(ii) inadequate and inefficient use of farm inputs and traditional techniques of farming.

(iii) inaccessibility to credit for smallholder farmers and women in particular.

(iv) inadequate rural infrastructure including poor roads and transport system.

(v) low budgetary allocation for agricultural sector.

In view of the difficulties faced in increasing land area under agriculture, Kenya's Eighth National Development Plan asserts that sustained agricultural output will come from more intensified production and rising productivity particularly to provide inputs for agro-based and food industries (Republic of Kenya, 1997a). This will enhance the realization of the projected GDP and employment growth rates enunciated in the current development plan. To achieve these targets, close examination of the existing cropping pattern, incomes and employment under different farming situations; otherwise the foretold expectations will remain elusive dreams.

This study has been undertaken in Embu District of Kenya. The district was chosen due to the following reasons. First, the district cuts across most of the major agroecological zones (AEZ) found in Kenya with exception of Coast and part of North Eastern Provinces. The agroecological zones in Embu District stretch from high altitude, snow capped Mt.Kenya, Tropical Alpine$_1$ (TA_1) to driest subzone of Low Midland$_5$ (LM_5) and Lowland$_5$ (Jaetzold and Schmidtz, 1983). However the major zones of agricultural importance are only eight. Details of these major agroecological zones are discussed in the next chapter. Therefore the findings of the study would be useful in other parts of Kenya with similar AEZ. Second, there is an acute shortage of farmland resulting from high population pressure necessitating the need to improve land productivity. Third, the land holdings are consolidated and are individually owned providing incentives for farmers to develop their farms even further. Fourth, that salaried employment in Embu district is not easy to come by, hence the young school leavers migrate to urban centres seeking for scarcely available employment opportunities (Oyugi, 1991). Fifth, that the smallholders have undertaken development of their farms for many years and yet the returns generated by the farm activities are inadequate in sustaining the livelihood of the farm families.

The present state of Kenya's agriculture is no longer "traditional" as defined by Schultz (1965), one may expect inefficiencies in agricultural resources. These inefficiencies have been pointed out more strongly in Kenya's current development plan. In the last three decades Kenya's agriculture has strived to keep up with the technological change in the agricultural production system. The change has been significant and as for now, continuing. This has provided a driving force for further changes in Kenya's export oriented industrial crops. The plan quotes - " This sub sectors will face formidable challenges during this Plan period, largely because of rapid advance of biotechnology and genetic engineering in other parts of the world" (Republic of Kenya, 1997a, p57). Adjustment in resource use in response to such changes in the technology is based largely on trial and error or guess work. This implies inefficiency in resource allocation, the magnitude of which may considerably effect the overall productivity of the area. Thus, a study on optimal resource allocation assumes a considerable importance.

1.1 Statement of the Problem

The German Technical Co-operation (GTZ)/Farm Management Project in the Ministry of Agriculture conducted an extensive baseline survey in Embu District, of Kenya in April 1991. The objective of the survey *inter alia* was to characterize the farming systems in all the Agro-ecological Zones (AEZ) in the district (Oyugi, 1991). The results of this survey revealed :-

(a) Diminutive farm sizes

(b) Large family sizes

(c) Main source of family livelihood being crop and livestock enterprises, and

(d) A Large proportion of family members working outside the farms to supplement their livelihood.

As population pressure increases, this trend is likely to perpetuate due to further land sub-divisions of the already small land parcels. The population in Embu is growing at an alarming rate of over 3 per cent (Republic of Kenya, 1989-93). The major source of income for the rural farm families in Embu still remains as crops and livestock enterprises. However these sources at the moment do not generate adequate income, hence there is a tendency for some members of the farm families to migrate to urban areas to seek for salaried employment to supplement farm incomes. Studies have been conducted in Kenya with the aim of increasing incomes and employment (International Labour Office, 1972). But upto date, the realisation of this objective is yet to be met adequately. Twenty five years after the study, the current national development plan still emphasises on the need to increase incomes and employment (Republic of Kenya, 1977). At the moment, 41 per cent of the members of the farm families in Embu migrate to urban centres looking for non-existent jobs (Oyugi, 1991). This migration to urban centres puts more pressure on the already over-stretched demand for resources such as shelter, transport, food, health care, water, schools etc. in towns. All these problems have been initiated by the low productivity of farming activities stemming from inadequate generating capacity of the farm enterprises. Sessional Paper No. 4 on National Food Policy (Republic of Kenya, 1981) stressed the need to be self sufficient in food production while on the other hand efforts have been made by Kenya Government and other non-governmental agencies in promoting family planning in general, and the benefits of having small families in particullar. The food policy placed more emphasis on increasing agricultural production by intensification of agriculture and increased productivity through improved technologies. Empirical evidences amply demonstrate that optimal allocation of resources played a greater role in stepping up productivity, increased farm incomes and employment opportunities. Highly variable farm incomes from farm enterprises put farmers entirely at the mercy of nature. Farmers have meagre resources at their disposal. It is difficult for farmers to achieve higher incomes and sustain a reasonable standard of living. It is therefore paramount that farmers allocate their limited resources optimally so as to yield assured and sustained flow of income from farm production activities. Hence higher production and greater earning from agricultural enterprises is the major need of Kenya to which this research project is addressing itself.

1.2 Objectives of the Study

The overall objective of the study is to increase the income generation from the farm enterprises in Embu District of Kenya so as to stem the urban migration of rural population through adoption of improved farm plans by the farmers and the young farm entrepreneurs in particular.

The specific objectives are :

(a) To study resource endowment and use in different farming situations.

(b) To examine the existing cropping pattern, income and employment under different farming situations.

(c) To study income and employment potential on the basis of existing and improved technology by developing optimal farm plans for different farm situations and

(d) To suggest policies for improvement of agricultural production and generation of higher income.

1.3 Plan of Thesis

The study is organized into six chapters. Chapter I is the introduction and describes the background leading to the study. Statement of the problem and objectives of the study are outlined in this chapter. Chapter II presents the description of the area of study, that is, the Republic of Kenya in general and Embu District in particular. Socio-economic characteristics of the area are highlighted here. Chapter III deals with review of the important related work done in the recent past by other researchers in Kenya and elsewhere in the world. Materials and methods used in achieving the objectives of the study are presented in Chapter IV. The main analytical tool used in this study, for optimal resource allocation in farm enterprises with the objective of maximizing net returns in different farming situations, linear programming, is presented in this chapter. Chapter V presents the results and discussions of the findings. Finally Chapter VI deals with the summary and conclusions drawn from the present study. Limitations and suggestions for further study are highlighted.

CHAPTER II

DESCRIPTION OF THE STUDY AREA

2.1 Kenya

The Republic of Kenya is located in East Africa. It falls between longitude 4° North and 4° South ; and latitudes 34° and 41° East. The Equator divides Kenya almost into two equal parts. To the West Kenya is bordered by Uganda, Tanzania on the southern border, Ethiopia and Sudan in the North and Somalia and Indian Ocean in the East. Figure 1.1 shows the map of Kenya in relation to other neighbouring countries. Total area is 582,642 km^2 of which 11,230 km^2 is water. The water area consists of 10,749 km^2 of lakes (Victoria, Turkana, Baringo, Magadi, Naivasha and Amboseli) and rivers (Tana, Athi, Mara, Nzoia, Turkwel and Ewaso Nyiro). Kenya is a unitary state divided into provinces. There are seven provinces including Nairobi which is the capital city. Provinces are further divided into districts.

The altitude spans from sea level to snow-capped mount Kenya on the Equator, elevating to a peak of 5,199 metres above the sea level.

Kenya is characterised by two distinct seasons based on rainfall pattern. The rainfall pattern is bimodal with long rains from mid-February to May and short rains from September to November. Hence the seasons are known as long rains and short rains seasons. Kenya experiences neither winters nor summers.

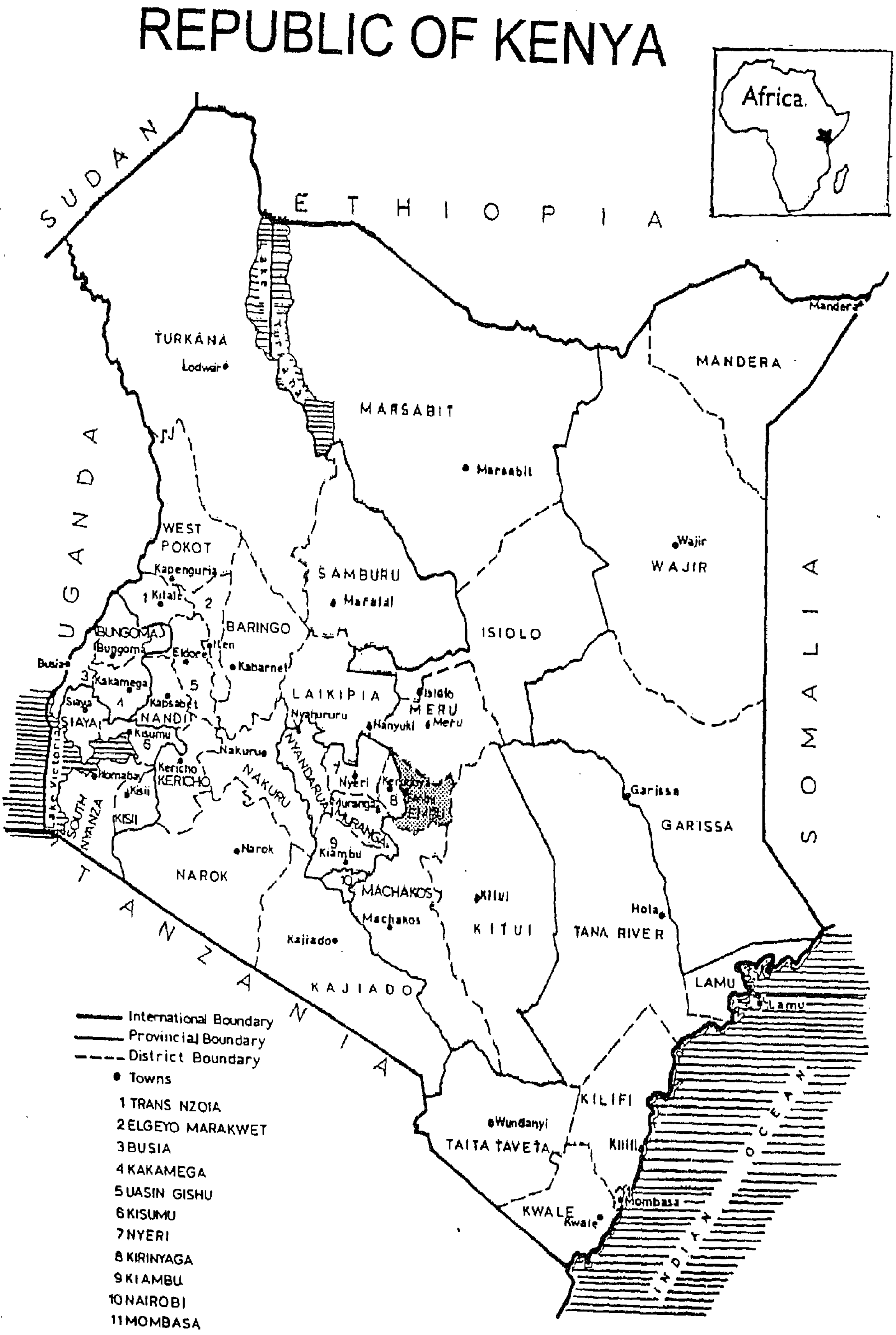

Figure 1.1 Map of Kenya Showing Embu District

The last population census in 1989 gave Kenya's population as 21 million compared to 15 million of the previous 1979 census. This is an incredible growth rate of 4 per cent per annum over the ten year period. Table 2.1 shows Kenya's population census from 1948 to 1989.

Table 2.1 Kenya Population Census by Race in Census Years, 1948-1989

	1948	1962	1969	1979*	1989**
African	5251120	8,365942	107333202	15101540	21252861
Non African					
Asian	97687	176613	139037	78600	89185
European	29660	55759	40593	39901	34560
Arab	24174	34048	27886	39146	41595
Other	3328	3901	1987	67874	25435
Total Non-A	154846	270321	209503	225521	190775
Total	5,405966	8,636263	10,942705	15,327061	21,443636

Source: Republic of Kenya, 1996b.

* For 1979 Other includes 57381 other Kenyans, 10213 others and 343 not stated.

** For 1989 Other includes 8719 others and 16716 not stated.

By 1995, Kenya's population is estimated at 27.519 million. Average population continued to increase over the years from 26 to 37 persons per square kilometres, in 1979 and 1989, respectively. Disparity in population density over the country , however, is significant as some districts such as Vihiga have as high as over 300 persons per square kilometres. The main factors accounting for high population density in these districts are fertile volcanic soils and high and reliable rainfall, suitable for agricultural activities. The very low population density areas such as Wajir, generally experience very high temperatures and very low and extremely erratic rainfall. Table 2.2 shows population growth, 1990 - 1997.

Table 2.2 Kenya's Population Growth in Million, 1990 - 1997

Year	No. (Million)	Growth Rate (%)
1990	23.715	3.16
1991	24.477	3.07
1992	25.240	2.97
1993	26.002	2.88
1994	26.762	2.79
1995	27.519	2.68
1996	28.267	2.59
1997	29.010	2.51

Source: Republic of Kenya, 1996a.

According to Economic Survey of 1996, (Republic of Kenya, 1996), the majority of Kenyans (60 per cent) are below 20 years old while only 4 per cent are at least 60 years old. In fact 48.9 per cent of the population is below 15 years. The elderly, aged 65 years and over, remain relatively fewer, being 3.6, 2.2, and 2.2 per cent according to 1969, 1979 and 1989 censuses, respectively. This clearly youthful population is typical of sub-saharan African countries where fertility has been relatively high. However, symptoms of fertility decline are apparently in decline proportions of under 10 years, which decreased from 35.8 per cent in 1969 to 34.6 per cent in 1989. Life expectancy stands at 59 years. This is higher than sub-Saharan countries but lower than both the low income countries (62 years) and the world average of 66 years.

The results of the analysis of 1989 population census showed literacy level standing at 69.4 per cent with males having an edge over females (75.7 per cent males and 63.3 per cent females). The literacy survey conducted in 1988 revealed that 54 per cent of Kenyans could read and write compared to 47 per cent in 1980. This was an upward trend from the previous years.

Rapid and sustained per capita income growth has remained an elusive target. During the first decade of independence, per capita incomes grew at the rate of 2.6 per cent per year. In the later years this has been disappointing. In the periods 1980-89, per capita income increased by 0.4 per cent and thereafter, 1990-95, declined to negative 0.3 per cent. Per capita income has dropped from US$ 327 in 1990 to US$ 294 in 1995 (Republic of Kenya, 1995). The estimated 1996 per capita income is given as K£ 773, equivalent to approximately US$ 265 (Republic of Kenya, 1997b).

The inflation rate declined sharply in 1995 from 45.6 per cent in 1993, 28.8 per cent in 1994 to 1.6 per cent in 1995. The current situation of inflation has painted an oblique picture. From the all time low in 1995, the overall inflation has climbed to 11.2 per cent in 1997/98 (Republic of Kenya, 1998). The overall 3-months annualized inflation in January 1998 rose to 19.9 per cent from 2.7 per cent in December 1997. The overall average annual inflation however stabilized at 11.2 per cent, the same level as in December 1997. This compared well with the real GDP growth rate of 4.9 per cent in 1995 from the lowest ever of 0.2 per cent in 1993. The increase in inflation stems from the emerging transport difficulties that continue to plague most parts of the country.

The problems are largely associated with the current *El-Niño*[1] rains that have made many parts of the country inaccessible. This inaccessibility created shortages in the supply of basic foods, causing the food sub-index for lower, middle and upper income groups to increase to 14.9 per cent, 15.1 per cent and 9.9 per cent respectively in January 1998 from 12.4 per cent, 8.6 per cent and 10.8 per cent in the same period in 1997 (Republic of Kenya, 1998).

The employment outside small scale agriculture and pastoral activities rose from 3.4 million persons in 1994 to 3.9 million 1995 (Republic of Kenya, 1996a). The noted expansion in employment was mainly in the private industries of modern sector and the informal sector of the economy. The expanding informal sector created 448,100 additional jobs in 1995. As a result the public sector reform programme, employment has been stagnating since 1991, and stood at 69000 persons in 1995, with annual growth of 0.2 per cent. The public sector share in total wage employment has declined from 49.6 per cent in 1994 to 44.3 per cent 1995. For over the last two decades, the economy has been unable to create jobs at the rate to match that of the nation's labour force. Since 1980, there has been virtually no change in the living standards of the Kenyans. If anything , the welfare of the majority of the people has declined as evidenced by the increase in the number of Kenyans living below the

---

1 A warm coastal current that flows south along the coasts of Ecuador and Peru in South America about Christmas time once observed by fishermen. The name is derived from the Spanish *el-niño Jesus* meaning "the Christ child". The *El-Niño* phenomenon is blamed for various catastrophes and is usually associated with flooding or any other violent disturbances in other parts of the world.

absolute poverty line.[2] In addition, the number of the unemployed and the underemployed has risen during the same period and has accumulated over the years. At present 11 million or 37.92 per cent Kenyans live below the poverty line (Republic of Kenya, 1997a).

The major imports continue to be crude petroleum, industrial machinery and industrial inputs such as iron and steel. In 1985, crude petroleum accounted for 37 per cent of the total value of imports; and 18.7 per cent and 7.5 per cent in 1993 and 1995 respectively. The second in importance among the imports is industrial machinery which accounted for 26.5 per cent of the total value of imports in 1975 and 12.9 per cent and 16.8 per cent in 1993 and 1995 respectively. Overall, in 1975 crude petroleum, industrial machinery, iron and steel accounted for 71 per cent of the value of imports. However the share of these three items in the total value of imports declined to 37.6 per cent in 1993 and 30.9 per cent in 1995. In 1993, other items such as motor vehicles and chassis, refined petroleum products and pharmaceuticals increased their shares in the total value of imports. This was mainly due to liberalisation of trade , through removal of import licensing, quantitative import restrictions and foreign exchange controls. However one effect of the aforementioned measures has been that the increase in value of imports has not been matched by corresponding increase in export earnings and the balance of trade has deteriorated. The balance of trade deficit increased

---

[2] Inability to acquire the minimum requirements in terms of food and non-food expenditure needed to satisfy the minimum basic needs. The FAO/ WHO minimum Recommended Daily energy Allowance (RDA) of 2250 calories per adult equivalent is used to derive the food poverty line. The food poverty line in Kenya of Kshs 702.99 is the minimum monthly consumption expenditure required to meet the recommended daily intake (of 2250 calories) from the chosen basket of food items.

from K£ 1378 million in 1993 to K£ 2892 million in 1995 (Republic of Kenya, 1997a). In relation to GDP at current prices, this works out to be 10.2 per cent and 14.9 per cent for 1993 and 1995 respectively. This shows that the balance of trade has continued to deteriorate since 1993 with trade liberalisation. It should however, be noted that even though liberalisation has increased the volume of imports, exports have also grown but at a lower rate than imports.

Kenya's exports are dominated by a few agricultural commodities namely tea, coffee and horticulture. In 1972, coffee accounted for 20.1 per cent, tea 13.4 per cent and horticulture 4.8 per cent of total export value. Other important items were petroleum products which accounted for 20.6 per cent. Thus, coffee, tea and horticulture accounted for 38.3 per cent of the value of exports. By 1990, tea had overtaken coffee as the main foreign exchange earner. Tea accounted for 25.5 per cent of total value of exports while coffee accounted for 17.9 per cent and horticulture 13.0 per cent. Manufactured goods accounted for 16.8 per cent. By 1995, coffee accounted for 15.5 per cent, tea 19.3 per cent and horticulture declined to 11.4 per cent. Manufactured goods performed well in 1994 accounting for 32.3 per cent of the value of exports. By 1997, Kenya emerged the world's number one exporter of tea, beating nearest rivals in tea production like China, India and Sri Lanka.

Agriculture is the mainstay of Kenya's economy. Maize is the staple food crop. Other food crops include beans, potatoes, rice and wheat. The main cash crops and foreign exchange earners are coffee, tea, pyrethrum sisal and horticultural crops such as vegetables, fruits and flowers. The livestock sector is mainly composed dairy and beef cattle, sheep and goats, poultry and pig enterprises. The development of other sectors of the economy depends upon agriculture. Agriculture provides food for both human and livestock population and raw materials for local and foreign industries. Agriculture is the largest sector of the economy. It accounts for 27.4 per cent and 27.9 per cent of the total GDP in 1995 and 1996 respectively. In 1995, sector shares recorded 10.1 per cent in manufacturing, 13.8 per cent in trade, restaurants and hotels, 7.0 per cent in transport storage and communication, 9.8 per cent in financial services, 5.6 per cent in building and construction and 14.4 per cent in government (Republic of Kenya, 1995). In 1996, the sector shares recorded 16.5 per cent in industry, 38.6 per cent in private services and 17.0 per cent in public services (Republic of Kenya, 1997a). The growth of GDP hence is a key indicator of the country's aggregate economic performance. Table 2.3 shows the composition of GDP for the years 1993 and 1994.

Table 2.3 Composition of Gross Domestic Product for the Years 1993 and 1994 in US $ Million.

Sector	1993		1994	
Agriculture	1869	(27.36)	1926	(27.36)
Manufacturing	699	(10.23)	713	(10.13)
Building and Construction	365	(5.34)	368	(5.23)
Utilities	841	(12.31)	863	(12.26)
Trade, Restaurants and Hotels	924	(13.53)	970	(13.78)
Transport, Storage and Communication	477	(6.98)	491	(6.98)
Financial Services	658	(9.63)	690	(9.80)
Government	998	(14.61)	1013	(14.39)
Total Real GDP	6831		7039	

Source: Republic of Kenya, 1995.

Figures in Parentheses are Percentages of the total GDP

The overall performance of the economy between 1964 and 1995 is presented in table 2.4. Between 1964 and 1973, GDP grew at an average rate of 6.6 per cent per annum because of mainly due to rural development policies that led to increased agricultural output, import substitution industrialisation strategy supported by access to East African Community markets and good macroeconomic management. Thereafter, this was subsequently followed by a period of continual declines. The two major sectors, agriculture and manufacturing have recorded declining performance over the last three decades, even though manufacturing appears more resilient.

Table 2.4 Annual Growth Rates of Real GDP, 1964-95 in Percentage.

Sector	1964-73	1974-79	1980-89	1990-95
Agriculture	4.60	3.90	3.30	0.40
Manufacturing	9.10	10.00	4.80	3.00
Private Household	3.50	14.00	10.00	10.50
Govt. Services	16.90	6.50	4.90	2.60
Finance, Real Est. etc.	9.80	12.40	6.70	6.60
Other Services	-	3.30	4.20	1.90
GDP	6.60	5.20	4.10	2.50

Source: Republic of Kenya, 1997a.

The decline in economic growth in the mid-1970s was first triggered by the first international oil crisis of 1973. The onset of the oil price crisis revealed serious structural constraints within the economy. Agricultural growth slowed down as the forces which boosted it's production during the 1960s weakened. The 2.5 per cent growth rate recorded in

1990-95 period actually masked the dismal performance in 1993. GDP grew by 4.3 per cent, 2.3 per cent, 0.5 per cent, 0.2 per cent, 3.0 per cent and 4.9 per cent in 1990, 1991, 1992, 1993, 1994, and 1995 respectively.

Current and Near Future Status of Kenya's Economy

By February 1998, the *El-Niño* rains which are being experienced in many parts of the world have had a devastating impact on the already fragile Kenyan economy. The full extent of the damage on various sectors of the economy is yet to be assessed, and may not be known soon since the rains are being predicted to continue upto June 1998 (Republic of Kenya, 1998). The damage has resulted in disruption of normal activities including supplies of food, transport, loss of human life and outbreak of water-borne diseases. *El-Niño* rains have already damaged large fields of food crops and farmers are not finding it easy to plant new crops as soil is waterlogged and in some cases the fields are flooded. The cash crops are not spared of the havoc *El-Niño* rains are inflicting on the economy. They too require sunshine after harvesting and transportation to the processing centres before final storage and transhipment to the international markets. Food shortages will be complicated by the already widely forecast *La-Niño* drought to follow the *El-Niño* rains, and are likely to translate into price increases which, if not pre-empted can undermine price stability in months ahead. The inevitable food deficit will have to be met by importing food which will require foreign exchange and budgetary allocations. Both monetary and fiscal policies to be pursued in the months ahead will have to take into account the *El-Niño* and *La-Niño* effects on economy.

Inflation picked up in the month of January 1998. The upturn in inflation was as a result of the rise in costs of inputs attributed to the rapidly deteriorating infrastructure and the inadequate supply of basic foods in many parts of the country. Details have been discussed elsewhere in this chapter.

Information available for the year (1997) to November 1997 indicates that GDP expanded by 3.2 per cent in real terms. The estimated growth is expected to decline further to 2.9 per cent, as more complete information on agriculture, manufacturing, tourism and trade becomes available (Republic of Kenya, 1998). Agricultural production is forecast to decline. Food crops, Coffee, tea, sisal production are destined for a decline. The decline is attributed to the drought that devastated production in the first quarter of 1997 and the adverse effects of the *El-Niño* rains. The decline in agricultural output is forecast to have adversely affected the overall GDP in 1997 and early 1998, since the sector contributes approximately a quarter of the total GDP and has strong linkages to other sectors of the economy.

Kenya's Agricultural Sector

Kenya's Agricultural sector is divided into small scale, large scale arable and pastoral sub sectors. The agricultural land can be further classified into high, medium and low potential depending on rainfall. High potential annual rainfall is 857.5 mm or more. Medium potential annual rainfall is between 753 mm and 857.5 mm while low potential annual rainfall is 612.5 mm or less (Republic of Kenya, 1996b). Arable farming is mainly concentrated in high and medium potential areas whereas the low potential areas are predominantly pastoral. Generally small and large farms in both high and medium pastoral areas are the main source of crop and livestock production. Small farms are between 0.2 and 12 ha. though there are some outside this range (Republic of Kenya, 1996b). In large scale farming districts namely, Nakuru, Uasin Gishu, Kericho, Nandi and Laikipia, the average farm size is around 700 ha. On overall 25 per cent of the farms range between 20 and 50 ha. On the whole, 11.92 per cent of land is high potential 5.55 per cent medium and 73.98 per cent low potential. Table 2.5 shows categories of Kenya's agricultural land by province.

Table 2.5 Categories of Agricultural Land in Kenya ('000 ha.)

Province	High Potential	Medium Potential	Low Potential	Total	Other	Total Land Area
Central	909	15	41	965	353	1318
Coast	373	796	6563	6832	1472	8304
Eastern	503	2185	11453	14145	1431	15576
Nairobi	16	-	38	54	14	68
North Eastern	-	-	12690	12690	-	12690
Nyanza	1218	34	1252	1252	-	1252
Rift Valley	3025	123	1220	15368	1515	16883
Western	741	-	-	741	82	823
Total	6785	3157	42105	52047	4867	56914

Source: Compiled from Republic of Kenya, 1996b, Table 129

Low potential areas account for 42,105,000 ha. out of total land area of 56,914,000 ha. These figures highlight the fact that more than 74 per cent of Kenya's land is less suitable for rainfed agricultural production. Hence there is need to intensify production in the remaining smaller portion so as to sustain the population in terms of food production and foreign exchange earning capacity. Kenya's agriculture is predominantly rainfed. By 1992-93, 8,637 ha. land was under irrigation declining from 11,132 ha in 1986-87. This is a decrease if 22.41 per cent over a period of 6 years. The irrigation schemes are public institutions. The infrastructure and canal maintenance are paid for by public funds. the crop grown under irrigation is mainly paddy rice. The other crops such as onions, chillies, cotton and sugarcane are not cultivated widely under irrigation.

The overall goal of this study of improving the income generating capacity of farm enterprises so as to stem rural urban migration through developing viable farm plans that can be adopted by farmers and attract the young entrepreneurs to venture into farming business cannot therefore be overemphasized. Farming as a business is still a virgin entrepreneurial venture which is yet to be exploited. Once put into full operation, business farming will stem rural urban migration currently threatening to explode the already overstretched urban resources.

2.2 The Study Area

The research was undertaken in Embu District of Kenya. The map in Chapter II (Figure 1.1) shows the district in relation to other districts. Embu District is predominantly small scale farming district. the farms are individually owned. Each farm family lives within the family land giving rise to a myriad of individual homesteads scattered haphazardly throughout the district. This kind of set-up is typical of Kenyan rural small scale farms and is commonly found all over Eastern Africa. Farm families do not live in communal villages from where they move out in the morning to operate their farms and come back in the evenings. In one homestead there may be two or more households, but the members of the households are close family members of the land owner, the farmer and for all practical purposes, they are regarded as one family. In actual sense they are usually the farmer's sons who are already married and therefore would be leaving the homestead at a later date to put up their own homesteads in the inherited potions of the land once land subdivision is accomplished. In some cases, a son may leave the locality altogether for a purchased piece of land elsewhere.

Embu District cuts across most of the major agroecological zones (AEZ) found in Kenya with exception of Coast and part of North Eastern Provinces. The agroecological zones of Embu District (Fig. 2.1) stretch from high altitude, snow capped Mt.Kenya, Tropical Alpine I (TAI) to driest subzone of Low Midland$_5$ (LM$_5$) and Lowland$_5$ (Jaetzold and Schmidtz, 1983). The map showing the details of agroecological zones of Embu District is provided in figure 2. However the major zones of agricultural importance are only eight. Details of these major agroecological zones are discussed later in the next section.

The last population census of 1989 revealed that there were 370,138 people in Embu living on 2,805 sq km of land area (Republic of Kenya, 1994) compared to 1979 population census which gave a figure of 263,173 (Republic of Kenya, 1981). This is astronomical population growth of 4.06 per cent per annum, living on the same piece of land. The 1993 population is projected at 472,059 (Republic of Kenya, 1989 - 1993). High and medium potential agricultural lands are 66,000 ha and 186,000 ha. respectively, giving a total of 252,000 ha. of agricultural land. Hence by working out the ratios, the land/man ratio has receded from 0.96 ha. in 1979 to 0.68 ha in 1989 in spell of about 10 years.

This is a serious trend that calls for heavy demand on the meagre resources and as food requirements to sustain the ever swelling population. One way of alleviating the problems is to improve land productivity and enhancing the entrepreneurial vision of the population towards farming. Improving the productivity of farm enterprises would go along way in ensuring self sufficiency in food production (Republic of Kenya, 1981). Embu district is one of the six districts of Eastern Province. The district occupies an area of 2,174 sq km out of the province's total area 154,540 sq km. It is the smallest of all the districts in the province. It is bordered to the north by Meru District, to the east by Kitui, to the south by Machakos, and to the West by Kirinyaga District. The district is primarily engaged in agricultural production. The majority of labour force is engaged in agricultural production particularly in small holdings. However the number of people in the agricultural labour force has dropped from 74.43 per cent in 1987 to 71.73 per cent in 1993 (Republic of Kenya, 1991). This is an indication of potential labour force seeking employment in non agricultural sector. The major implication is that the farming has become less attractive due to low productivity and low income generating capacity.

Similar to other districts in Kenya, Embu District is divided into divisions administratively which are further divided into locations and finally into sublocations. Sublocations are the smallest administrative units in a given area. Details of administrative structure of Embu District is given in the appendix.

Salient Features of the Agroecological Zones of Embu District:[3]

The distribution of rainfall in Embu is typically bimodal with two distinct rainy seasons, the first rains with their peak in April and the second with their peak in November; the intervening dry season is distinct, except in the misty and cloudy altitudes above 1500 metres.

The pattern of the agroecological zones is typical, starting on Mt.Kenya with the Tropical Alpine (TA) Zones, TA I and II. They are National Park now but some parts of TA I could possibly be opened up for seasonal grazing of stock from the over-populated zones below the forest. The forest reserves are mainly situated in steep wet areas unsuitable for agricultural use, the Upper Highland 0 (UH 0) and the Lower Highland 0 (LH 0). The agroecological zones Lower Highland 1 (LH 1), Upper Midland 1-4 (UM 1-4), Lower Midland 3-5 (LM 3-5) and Lowland 5 (L 5) occur at descending altitudes, which is not such a high potential area as is often thought. It consists mainly of the zones L 4 and L 5. The details of agroecological zones summarised below are shown in fig. 2.1.

The land use potentials are climatically based. Good husbandry, crop protection and rotation are also essential, especially for combating diseases (for instance fungus in the wet climates)1 and insect pests. The yield expectations given in the AEZ are only valid if these farm management standards are optimal and the soils are suitable and well manured.

---

[3] The material presented in this section has been adopted from Jaetzold and Schmidt, 1983.

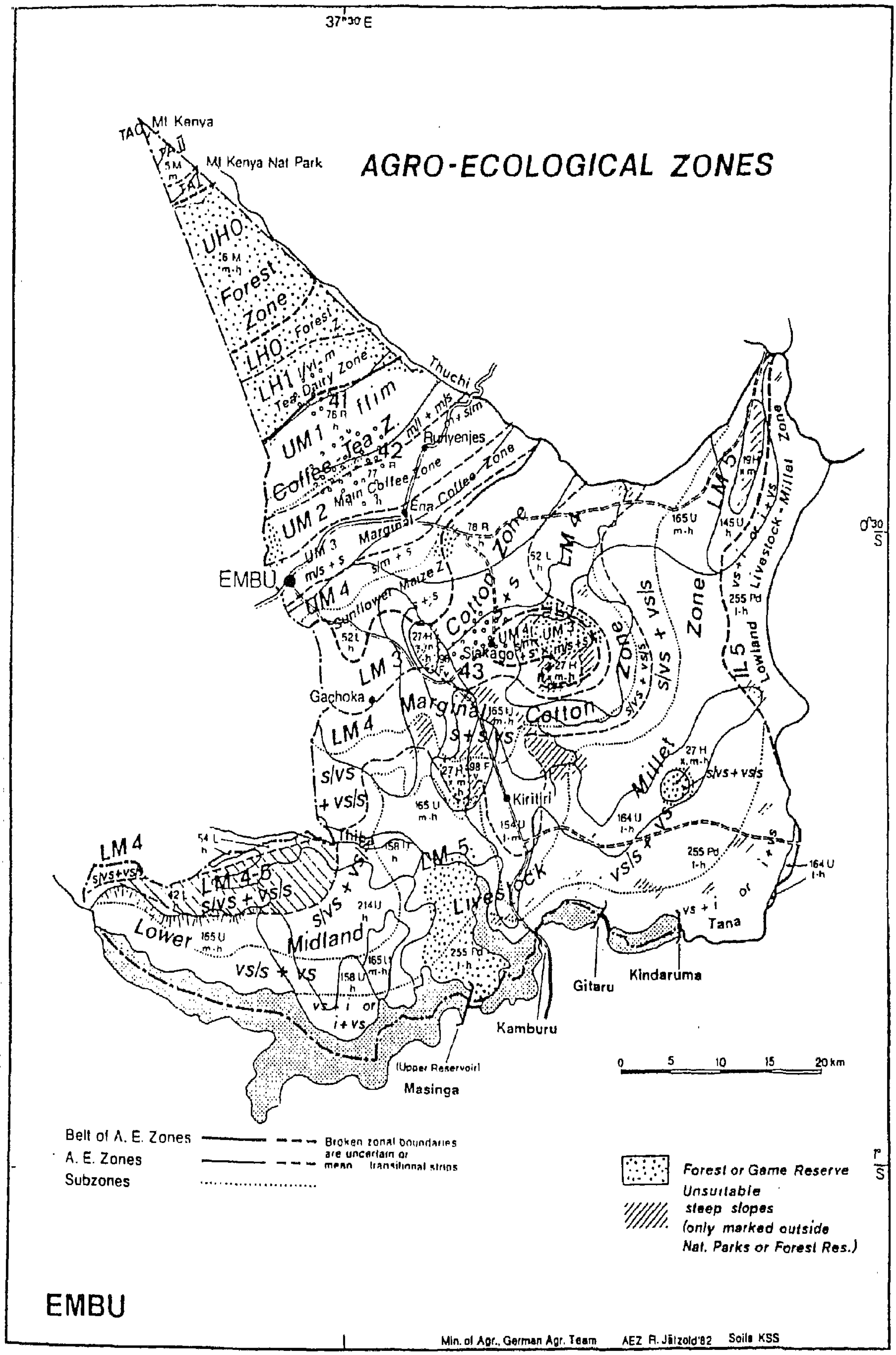

Figure 2.1 Agroecological Zones of Embu District

Code	Agroecological Zone	Description	Land Use
TA 0	Tropical Alpine 0	Rocks and Glaciers	National Park
TA I+II	Tropical Alpine I&II	Moore and Heathland	National Park
UH 0	Upper Midland 0	Forest Zone	Forest Reserve
LH 0	Lower Highland 0	Forest Zone	Forest Reserve
LH 1	Lower Midland 1	Tea-Dairy Zone	
UM 1	Upper Midland 1	Coffee-Tea Zone	
UM 2	Upper Midland 2	Main Coffee Zone	
UM 3	Upper Midland 3	Marginal Coffee Zone	
UM 4	Upper Midland 4	Marginal cotton zone	
LM 3	Lower Midland 3	Cotton Zone	
LM 4	Lower Midland 4	Marginal Cotton Zone	
LM 5	Lower Midland 5	Livestock-Millet Zone	
L 5	Lowland 5	Livestock-Millet Zone	

Embu District shows the typical agro-ecological profile of the windward side of Mt.Kenya, from the cold and wet upper zones to the hot and dry lower zones in the Tana River Basin. The average annual rainfall reflects this contrast: more than 2200 mm at 2500 m to less than 650 mm near the Tana River at 700 metres. The variation is mainly due to the mountain but also to the "water recycling" effect of the forest. Above 2500 metres, rainfall decreases due to the lower moisture content of the colder air and the stronger influence of the trade wind system, but nevertheless the area is still very wet. Some herbaceous parts of the Tropical Alpine Zone (TA 1) may be opened for seasonal grazing of livestock for the farmers living below the forest, due to the demands of increasing land pressure.

The Upper Highlands are so wet and steep that forest is the best land use (UH 0). The same is true for the upper and north-eastern parts of the Lower Highland Zones (LH 0). Even in the Tea-Dairy Zone LH 1 precipitation is still 1800 mm per year on average. Compared to the Livestock-Millet Zones LM 5 and L 5, with 650-800 mm, it would seem that the potential there is about a half or a third that of the Tea-Dairy Zone LH 1 or the Coffee-Tea Zone UM 1, but in fact, the climatic potential is already less than a tenth, and if the poor soils are considered, then the potential is even less. Table 2.6 provides agroclimatic details of zones of agricultural importance.

Table 2.6 Agroclimatic Zones

AEZ	Altitude (m) (metres)	Annual Temp (°C)	Annual Rainfall (mm)
LH1	1770 - 2070	15.8 - 17.7	1750 - 2000
UM1	1590 - 1830	17.5 - 18.9	1400 - 1800
UM2	1400 - 1590	18.9 - 20.1	1200 - 1500
UM3	1280 - 1460	19.6 - 20.7	1000 - 1250
UM4	1280 - 1400	20.0 - 20.7	960 - 1100
LM3	1070 - 1280	20.7 - 22.0	900 - 1100
LM4	980 - 1220	21.0 - 22.5	780 - 900
LM5	830 - 1130	21.7 - 23.5	700 - 900

Source: Jaetzold, R. and H.Schmidt (1983).

The reason for this low potential is the rapidly decreasing rainfall expectation during the agro-humic periods (i.e. the growing periods of annual crops) which also decreases very quickly in length from permanent cropping possibilities at LH 1 and UM 1 to less than 40 days in the 1st rains and about 50 days in the 2nd rains at the driest sub-zone of LM 5 and L 5. Rainfall expectation of the first rains in 6 years out of 10 exceeds 900 mm in LH 1 but drops to only 150 mm in zones LM 5 and L 5.

A transitional belt exists between zones LM 4 and LM 5 where, on the good black soils found there, the maize of zone 4 can still be successfully cultivated; on the red soils of the soil catena there, less demanding crops like millet or sorghum are preferred.

Although Embu is endowed with varied agroecological zones, the major zones of agricultural importance are only eight as listed below:

LH 1	Lower Midland 1	Tea-Dairy Zone
UM 1	Upper Midland 1	Coffee-Tea Zone
UM 2	Upper Midland 2	Main Coffee Zone
UM 3	Upper Midland 3	Marginal Coffee Zone
UM 4	Upper Midland 4	Marginal cotton zone
LM 3	Lower Midland 3	Cotton Zone
LM 4	Lower Midland 4	Marginal Cotton Zone
LM 5	Lower Midland 5	Livestock-Millet Zone

Agricultural Background of Embu District

Embu District is generally classified as a high potential district in terms of agricultural production. It is predominantly small scale farming area. The farming is described as small scale since the size of holdings fall below 12-hectare limit category defined by Central Bureau of Statistics as Small Farm (Republic of Kenya, 1995). A baseline survey conducted earlier on 312 sampled farms in the district revealed that the mean farm size in Embu was 2.31 hectares with 52.2 per cent of the farms below 1.62 hectares (Oyugi, 1993). Table 2.7 presents the distribution of holdings in Embu in 1991.

Table 2.7 Distribution of Holdings, Embu, 1991

Farm Category	Range (ha.)*	Mean (ha.)	Proportion (%)
Small	Upto 0.40	0.36	8.0
Medium	0.40 - 0.81	0.73	14.7
Large	0.81 - 1.62	1.32	29.5
Extra Large	Above 1.62	3.77	47.8
Total			100.0

Source: Oyugi, 1993.

*Original data quoted in acres. (1 acre = 0.40 ha.)

The current study finding revealed that the mean farm size declined from 2.31 hectares in 1991 to 2.00 hectares in 1997. The decline of farm size represents 13.42 per cent in time space of seven years. This is as result of progressive subdivision of land to smaller land parcels, confirming the response of 54 per cent of the farmers in 1991 study indicating that they would subdivide their land in future. Continuous subdivision of land in Embu occurs because the traditional land inheritance practices is characterised by land fragmentation so that the each of the farmer's sons gets his own portion. Table 2.8 presents the current land distribution in Embu.

Table 2.8 Distribution of Holdings, Embu, 1997

Farm Category	Range (ha.)*	Mean (ha.)	Proportion (%)
Small Farm	Upto 0.40	0.30	6.4
Medium Farm	0.40 - 0.81	0.67	23.1
Large Farm	0.81 - 1.62	1.28	28.2
Extra Large Farm	Above 1.62	3.34	42.3
Total			100.0

*Categorisation kept the same as table 2.7 to enable comparison.

The current study reveals that as for now, subdivision is continuous process as and the number of the previous large farms are diminishing. Note that the proportion of the Extra Large Farm diminished from 47 per cent in 1991 to 42.3 per cent in 1997, Similarly the Large Farm declined from 29.5 per cent to 28.2 per cent over the same period. The proportion of the Medium Farm increased from 14.7 per cent in 1991 to 23.1 per cent in 1997. However, the proportion of the Small Farm decreased from 8.0 per cent to 6.4 per cent over the same period. This is an indication of farmers sons' migrating to acquire land in other parts of the country as the land becomes too small for further economically viable subdivision.

Irrigation

Kenya's agricultural sector is characterised by over-dependence on rain-fed agriculture. Irrigation accounts for less than 1 per cent of cropped land in Kenya. The bulk of irrigation in the country is undertaken by smallholder farmers who irrigate 16700 hectares compared to 9023 hectares by the large-scale, centrally managed developments under the National Irrigation Board (NIB). However Embu is endowed with a large scale irrigation scheme at Mwea-Tabere where paddy rice is cultivated. This is gravity fed irrigation scheme, centrally managed under the National Irrigation Board. In 1992/93 there were 3240 plot holders and the cropped area was 5846 hectares yielding 23448 tones. The value of the rice output was K£ 7388.024 (Republic of Kenya, 1997a).

Land Use Pattern

In Embu a substantial part of the cropped area is allocated to cultivation of food crops as summarised in Table 2.9.

Table 2.9 Land Use Pattern, Embu District, 1991

Land Use	Percentage
Maize	16.58
Wheat	0.04
Sorghum	0.26
Millet	0.23
Bulrush Millet	0.05
Rice	0.23
Beans	8.90
Peas	0.06
Grams	0.26
Black Beans/*Njahi*	0.01
Pigeon Peas	0.51
Cowpeas	3.04
Irish Potatoes	0.99
Sweet Potatoes	0.27
Cassava	0.46
Cocoyams/Arrow Root	0.14
Yams	0.22
Maize and Beans	1.98
Maize and Pigeon Peas	0.19
Irish Potatoes and Beans	0.01

Table 2.9 contd.

Mixed Crops (Unspecified)	0.04
Cotton	4.46
Sunflower	0.06
Sugarcane	0.25
Pineapples	0.03
Coffee and Maize*	0.03
Coffee and Beans**	1.88
Coffee and Irish Potatoes*	0.27
Coffee, Maize and Beans*	0.01
Coffee	4.29
Tea	3.37
Citrus	0.07
Mangoes	0.10
Passion Fruit	0.17
Avocadoes	0.25
Bananas	2.07
Papaw	0.19
Macadamia	0.09
Tree Tomatoes	0.01
Woodlot	1.80
Napier/Bana/Rhodes Grasses	0.77
Improved Pasture/*Kihuga* Grass	0.09
Natural Pasture	1.82
Onions	0.09
Tomatoes	0.15
Melons	0.02
Cabbage	0.05
Sukuma Wiki(Kales)	0.07
Fallow (Short-term)	8.41
Bush Fallow (Long-term)	15.85
Total	100.00

Source: GTZ/Farm Management Project, Embu Survey, 1991.

* Practice not recommended but emerges whenever producer price of coffee falls. Cutting down coffee trees is unlawful. So farmers instead undersow coffee plantations to increase land productivity.

** Practice not recommended but tolerated.

With exception cash crops viz., tea (3.37 per cent), coffee (4.29 per cent), Cotton (4.46 per cent), Sunflower (0.06 per cent), Tobacco (0.16 per cent) and Macadamia (0.09 per cent), all other crops are cultivated for food. Maize, beans and Irish Potatoes are the main food crops. Bananas are widely used for subsistence requirements but most of the produce is sold for cash in urban centers where the prices are more attractive and the demand is high. Tobacco cultivation is undertaken in scheduled area (Ena) and the crop is promoted by two private companies, the British American Tobacco (BAT) Company and the Mastermind Company. Farmers cultivate tobacco on contract basis. The buying company specifies conditions under which a farmer is accepted and registered as a tobacco farmer. Similarly, paddy rice is grown under irrigation in a scheduled area (Mwea Rice Irrigation Scheme) managed by the National Irrigation Board which is a public institution. The farmers are allocated land under tenancy law and they grow rice only. They have no mandate to grow any other crop apart from rice. Decision making on these farms rests with the National Irrigation Board.

Productivity Performance of Major Crop and Livestock Enterprises

The yields of the principal crops and livestock enterprises are presented in Table 2.10.

Table 2.10 Average Yield of the Major Farm Enterprises, Embu, 1996

Enterprise	Yield (kg/ha.)
Maize	2880
Beans	720
Irish Potatoes	12000
Bananas (Bunches)	170
Tea	3500
Coffee	2500
Cotton	540
Pigeon Peas	500
Green Gram	360
Cowpeas (Leaves)	2500
Sorghum	720
Eggs (Trays)	820
Milk (Pure Breed)	3200
Milk (Cross Breed)	2500

Source: District Agricultural office, Embu, 1997.

Infrastructural Facilities

There is a good network of roads in Embu. Most parts of the district are easily accessible by roads except during the rainy seasons where some difficulties may be experienced. The roads in the tea growing areas are maintained by the Kenya Tea Development Authority (KTDA).

All the major market centres have electricity and telephone facilities are available in even very small market centres.

Commercial banking facilities are available from the branches of the four leading commercial banks viz., Kenya Commercial Bank, Barclays

Bank, Standard Chartered Bank and National Bank of Kenya. The Kenya Commercial Bank which is the largest indigenous owned bank provides mobile bank facilities that penetrate deep into the small rural villages. Non-banking financial institutions are also available in the urban areas. The commercial banks are supplemented by coffee co-operative Societies and co-operative unions which operate banking facilities alongside the co-operative functions. Credit facilities are available from Agricultural Finance Corporation, commercial banks and coffee co-operative societies and co-operative unions.

CHAPTER III

LITERATURE REVIEW

The review of the important studies which are directly or indirectly related to the objectives of the present study are given in this chapter. The chapter discusses in brief some of the studies conducted in Kenya and elsewhere in the world in the field of resource allocation or optimisation of farm resources by the use of linear programming. The chapter has been organised into two sections (1) the work conducted in Kenya and (2) the work done elsewhere in the world. The review of the literature under each section has been discussed in the subsequent paragraphs.

3.1 Kenya

The current and the previous Kenya's national development plan emphasizes the importance of agricultural extension system in creating awareness and in dissemination of relevant upto date technologies which will enable farmers to achieve greater yields (Republic of Kenya, 1994 and 1997). In fact a previous development plan states that productivity in agriculture depends on the application of scientific knowledge in generating improved technologies and applying them to production system (Republic of Kenya, 1989). It further states that the objectives for agricultural research during the plan period will include *inter alia* helping in production of food and other farm products at costs the farmers can afford. Therefore the general conclusion arising from the two documents is that the government has made it a priority to improve the productivity of farm enterprises through research leading to adoption of appropriate technologies. One of the technologies that can be applied to improve the productivities of farm enterprises by applying appropriate farm plans such as the ones this investigation proposes to undertake in Embu district.

Several other scholars have used linear programming to analyze resource use on Kenya's small holder agriculture. Clayton (1963) conducted a pioneer study on improvement of farm productivity by efficient resource utilization and allocation on small scale farms. However Clayton did the research only on selected farms in Nyeri district. His work therefore does not benefit either the whole Nyeri district or any other part of Kenya.

Odero-Ogwel and Clayton (1973) in their study investigated a regional aggregative model which took into account the total factor endowment of individual holdings within a regional agricultural economy. The study showed opportunities of increasing farm incomes by expanding tea production and improving dairy production which would give thrust to both domestic and external commodity markets. The selection of a representative sample on the basis of total farm factor endowment was an important means of reducing bias in the aggregation process. The model itself was explored under the different assumptions of perfect and imperfect knowledge. The model was applied to Nyeri District, Kenya, which was an example of a developing, diversified peasant economy which faces conditions and problems commonly encountered in Africa. An attempt had been made to modify the model, initially as a purely output-maximizing one, to take account of the stochastic elements of risk and uncertainty which loom so large in producers' production choices to attain desirable welfare and security. The results of the aggregative model, as applied to

Nyeri District, showed that there were distinct possibilities for increasing productivity. An important finding was the relatively unprofitable nature of arable crop production. There was great potential for saving in Nyeri agriculture, though the level of net saving depended, in the long run, upon the levels of consumption in the farming area. There were possibilities for increasing employment of rural labour. However, problems still existed in regard to the empirical construction and operation of the model. Likewise the study was confined only to Nyeri. No attempt was made to expound the study such that the results would be beneficial to other parts of Kenya with similar agricultural zones.

The only elaborate work done in Embu in the field of farm planning was done by Asamenew (1980) and Asamenew and Mwangi (1985). They used linear programming approach to look into factors which constrain agricultural production in small scale farms in the star grass zone of Embu district, and in particular Gaturi location. A survey was conducted involving 40 farmers in Gaturi location, using linear programming as the principal tool of analysis. Different enterprise combinations were evaluated to show how farmers' income can be increased after satisfying their household food requirements by reallocation of resources. Several conclusions were made from the study. Results showed that farmers' income could be substantially increased by reorganization of resources. The most limiting factors to agricultural production were land, working capital and labour. The levels of the limitations were identified for each farm model, small, medium and large farm groups. Milk production was the most profitable enterprise in the study area. Policy implications of the study were considered. The introduction of ox traction was recommended to ease acute labour shortage in the area and milk production coupled with the formation of a dairy cooperative was suggested. It was also found that in Gaturi location, the best plan emerges when family labour is supported by hired casual labour and the borrowed capital used. At the time of the study, the gross margin obtained by the farmers was lower than that obtained in the optimal plans of the four model farms developed by linear programming technique. One shortcoming with the two studies is that the work was purely confined to star grass zone of Embu district and in particular Gaturi location which is a very small area. Gaturi location does not cut across all the agroecological zones in Embu District and the study was undertaken in only one agroecological zone in Gaturi, the star grass zone. No attempt was made to look at the situations in other small scale farming areas outside this area. Embu is endowed with diverse agro-ecological zones which need similar attention. If this were done then there would be a possibility of applying the results obtained in Embu to all other areas in Kenya with similar agroecological zones.

Few agricultural economists have focused their work in the area of farm planning particularly in Kenya. Most of the work done are based on subjects related to either agricultural marketing or policy. However Mukhebi (1981) directed his investigation on the feasibility of generating higher income and employment in Kenyan small scale agriculture to alleviate rural poverty. The study was located in Mbiuni location of Machakos district. Linear programming models were used in each of the three representative farm size groups developed, evaluating profit maximizing objectives. The overall conclusion of the study indicated that the population becomes poorer as the land base per worker declines. A variety of farm policies were recommended in order to increase income and employment to alleviate poverty. The recommendations included, among others, emphasis on food production , labour-using and land-saving technologies. However Mukhebi's work did not address itself on how to go about achieving those objectives. Another shortcoming with the study is the generalization of the findings to cover the whole of Kenyan small scale agriculture. Nonetheless Mukhebi suggested further work to be undertaken to provide more definitive answers for each agricultural zone in which small scale agriculture is practised. Therefore this study in Embu District, in a way is a follow-up of Mukhebi's suggestion.

Oyugi (1984) examined the economic influence of tobacco growing on food production in Migori division, South Nyanza district of Kenya. He used gross margin analysis in measuring relative profitability of tobacco *vis-a-vis* alternative farm enterprises. Linear programming model was used in determining optimal combination of tobacco enterprise and other farm enterprises for various farm size models in tobacco growing areas of Migori. Oyugi came out with two important conclusions in his study. First, that tobacco growing has no significant negative effect on the production of food crops and in particular maize. Second, that tobacco is the most profitable enterprise per unit of land and has complementary relationship with food crops in utilization of land resources. However Oyugi's study did not address itself to the varied agro-ecological zones in Migori or other parts of the country, possibly where tobacco is also grown. The study was confined only to tobacco growing area in Migori.

Abdullahi *et al* (1986) in their study in Kyeni South Location, Embu District, aimed at describing and analysing the farming system, to identify constraints and to make proposals for research and development. The area was medium potential and comprised of the main and the marginal coffee zone. The principal constraints identified were the low proportion of cash income which was invested in farming, labour constraints at particular times of the year, and the inadequacy of conservation measures. Since it is not considered possible to greatly increase the quantity of resources employed, the interventions proposed were mainly directed at improved management practices and environmental protection. A more integrated approach to research was recommended, particularly one which considered coffee in its place in the farming system. This study however solely focused on coffee enterprise in two agroecological zones. Other farming enterprises in the same zones were ignored.

Nyoro and Roe (1986) conducted a study on the economic characteristics of farming systems in Kenya's main coffee producing districts, viz. Kiambu, Murang'a, Nyeri, Kirinyaga, Embu, Machakos, Kisii and Meru districts, based on information from two farm surveys in 1983/84 and 1984/85. They developed a series of farm models to represent different agroecological zones and smallholder farm sizes. Comparisons were presented on the cost and income structures. Marked differences in the level of net revenues and disposable cash income were found between agroecological zones and farm sizes. Agrochemicals generally represented the single most important cost items for the 1.5 ha small-holdings, while on the larger farms hired labour accounted for approximately half of total costs. Generally the overall output and cash income decreased with altitude. A farm size of at least 1 ha could sustain a smallholder the family in subsistence consumption. The minimum farm size increased to 1.3 ha when school fees were included.

Barasa *et al.* (1992) used gross margin analysis and linear programming techniques to identify the main factors causing the declining output of cotton in Funyula Division of Busia District, Western Kenya. Both primary and secondary data were collected. Primary data were collected through personal interviews from a sample of 60 farmers. Secondary data were obtained from various reports published by the Ministry of Agriculture. Results indicated that cotton performed poorly when compared to other crops such as maize and beans. The combination of yield, increasing technology and higher cotton prices would lead to increased production.

Kidane (1993) examined the major economic problems related to milk production in Kenya. A linear programming model was employed to investigate how resources could be reallocated among competing enterprises in order to maximize farm income. Three farm models were developed, defining small, medium and large farms, with sizes 2.04 ha, 3.9 ha, and 7.98 ha respectively, to identify the economic constraints related to each farm size. The data for the study came from a field survey carried out in Embu District. The district produces cash and subsistence crops such as milk, coffee, maize, beans, potato, and banana. The results suggest that land and operating capital were the major limiting factors of production. Sensitivity analysis was used to determine the stability of the optimal solution by varying the values of the limiting resources. Accordingly, changes in the land area and value of working capital had significant effects on milk production. Kidane concluded that dairy industry development was feasible in the study area, but that farmers should be given incentives such as credit facilities to enable them to purchase additional farm inputs. Thus, milk production would be intensified by keeping grade cows and improving the methods of feeding. With intensification, labour and capital would be effectively utilised.

Abate (1995) investigated the level of farm efficiency and production constraints of small farmers in coffee growing areas in the districts of Dale, Aleta Wondo and Dila Wonago in Sidamo, Ethiopia and in the district of Murang'a, Kenya. In particular the study (1) identified and described farm specific technical efficiency levels for traditional farms in the coffee sector of the two countries; (2) analysed and specified farm level technical efficiency differentials between the individual farmers and various agroecological zones taking into account the different socioeconomic environments of the two countries; (3) identified constraints associated with the farm production decisions and used linear programming to indicate the short-term optimum allocation of farm resources; (4) identified the long run optimal production and investment decisions; and (5) evaluated the effects of improvements in production techniques on the efficiency and resource utilization patterns of the farms. It is concluded that there were observable efficiency differentials in the smallholder coffee sector of Ethiopia and Kenya which imply the potential for relatively inexpensive immediate and intermediate gains in output that did not depend on major new investments or research programmes. However, continued sustainable agricultural development required major structural adjustments and policy measures.

3.2 Use of Linear Programming Elsewhere in The World

A large number of studies have been undertaken in the field of resource allocation or optimisation of resources using linear programming elsewhere in the world in the recent past.

Gangwar (1966) carried out a study of optimal allocation of resources on cultivators holdings in Kanjhawala Block in the Union Territory Delhi using linear programming technique. The main objectives were to (i) to explore possibilities of increasing net returns to fixed resources by reallocation of resources (ii) to determine the increase in net returns under improved technology scenario (iii) to estimate the effect of capital availability on farm income generation under the existing technology situation and (iv) to determine the impact of improved technology on employment creation. The results of the study revealed one important fact among others, that optimisation of resources substantially increased net returns.

Sinha (1967) conducted a study on resource allocation among competitive crop enterprises on cultivators' holdings in Bihar. The thrust of his study was to probe into potentialities of enhancing net returns to the existing fixed resources through reallocation of the resources and to explore the possibilities of attaining higher net returns in the event of increased capital and labour availability. Linear programming technique was used to optimise resource allocation. Seventy eight farmers were sampled and interviewed to obtain primary data. The findings of the study revealed that optimisation with both limited capital and unlimited capital availability had marginal impact on net returns compared to the existing situation. The net returns increased by mere 7.46 per cent and 3.88 per cent respectively. The former situation meant that farmers were operating at a level very close to the optimum point. Therefore the optimisation procedure resulted in a very small increase in total returns compared to the existing situation. In the latter case, the marginal increase in the net returns indicated that the level of capital availability was almost adequate and a further increase in the capital availability would not enhance net returns. Similarly labour employment opportunities did not increase significantly because the optimal plans did not differ substantially from the farmers' existing practice as no more expansion of the enterprises were recorded.

Das (1971) conducted a study on resource allocation and optimum cropping pattern in Burdwan District of West Bengal. The objectives of the study were (i) to derive optimal farm plans for representative farms under existing technology with the view of examining the extent the existing production plans could be improved through reallocation of the existing resources. (ii) to derive optimal farm plans for farms under multiple cropping on adoption of recommended multiple cropping programme (iii) to examine the impact of credit on farm incomes under existing technology as well as recommended multiple cropping technology and (iv) to examine the impact of recommended multiple cropping programme on employment opportunities. A total 72 farms were sampled for the study. Both primary and secondary data were used. Linear programming technique was used to derive optimal plans. The results indicated that when improved technology was combined with credit availability, incomes and employment opportunities increased significantly.

Bibangambah (1975) in his study on farm business planning in developing countries made it clear that the opinion that individual farm planning was not applicable to peasant agriculture was not acceptable. Various forms of farm planning were discussed. Farm planning methods were divided into the old ones including comparison and budgeting and the newer methods of linear programming, particularly mathematical. His conclusion was that in East Africa, a farm business advisory service capable of helping farmers both in diagnosing farm business and in formulating plans was needed.

Bhowmick (1982) analyzed risk in farm production in Kamrup district of Assam. The objectives of the study was to study the variability of yield and price of various crop and livestock enterprises, to work out the optimal plans under different farm situations and to develop the optimal farm plans under risk and uncertainty. In addition to secondary data, primary data were obtained from farmers selected by multistage stratified sampling technique through personal interviews . Three synthetic farm size groups viz., small, medium and large were developed for each agro-zones identified. Both the deterministic linear programming and parametric programming (similar to MOTAD) techniques were used in the study. The input-output coefficients of farms were derived by averaging the information collected from the sampled farms. Three resource situations with two combinations of crop and livestock enterprises mix under restricted (existing) and unrestricted capital borrowing and labour hiring facilities were tried for each size group of farms in each zone.

The findings of the study revealed instability in the rainfed agriculture of Kamrup district. In every agricultural case examined, the coefficient of variation was high. Small farms generally showed a steady increase in cropped area under mixed farming on optimisation. The area under potato increased on all sizes under mixed farming. On the whole, farm returns increased under mixed farming. Farm returns substantially increased due to liberalised supply of capital. However in chronically flood affected zone, the largest percentage increase in net returns due to resource optimisation was on medium farms. Labour employment increased in all farm sizes.

Debertin and Pagoulatos (1985) examined the impacts of alternative management strategies for the production of alfalfa within the context of a total farm plan. A linear programming model was used to represent a 600-acre farm which can grow either grain crops or alfalfa. Alfalfa production competes with the grain crops for available land, labour, machinery, and field time over a calendar of tillage, planting, cutting, spraying, and harvesting activities. The profitability of an acre of alfalfa and the contribution of alfalfa to net returns for the farm varied quite widely depending on the particular alfalfa management strategy selected.

Farhat (1987) used linear programming in his study to develop gross margin maximising farm plans for an exemplary state farm in Iraq. The activities of the farm included a variety of cash crops, fodder crops, poultry and livestock activities. Sensitivity analyses were also used to serve as a guide to the stability of the various plans. The effects of crop rotations, buying in concentrate feeding stuffs, government constraints on outputs, and alternative price systems were examined. The data used were from a 1979-1983 survey of resource inventories, and represented conditions at average performance. Under the prevailing Iraqi Agricultural policy, the results of the study indicated the importance of using crop rotation systems and of bought-in concentrate feeding stuffs. They also indicated that among all the alternatives considered, the dairy activity combined with certain fodder crops, poultry and malting barley as a cash crop was the most profitable combination. In a fully relaxed model, within Iraqi prices, poultry would dominate all the farm activities, while in a fully relaxed model with world prices, the solution is consistent with the existing farm plan. The study indicated the effectiveness of the linear programming technique in addressing the problem of farm planning. It also showed how influential the system of relative prices was upon the optimal solution. It is suggested that the Iraqi authorities should establish an effective set of agricultural prices which stimulated agricultural production and satisfied a competitive equilibrium in the agricultural sector.

Deoghare (1987) investigated the possibilities of increasing income and employment under different farm situations of different farming systems in Karnal District of Haryana in India for the agricultural year 1985/86. One hundred and sixteen farmers were randomly selected for the study from different categories viz., marginal, small, medium and large to have representative sample to develop synthetic farm situations. The farmers were further classified on the basis of motive power viz., bullock operated, tractor operated and bullock plus tractor operated. A synthetic farm situation was developed under each situation. Four farming systems namely crop farming system, crop and dairy farming system , crop and poultry farming system and crop, dairy and poultry farming system were identified. using linear programming technique, optimal plans were worked out under each of the four farming systems identified at two levels of technology, existing and recommended, with and without capital borrowing.

The results of the study indicated that the poverty existing with the farmers on tractor operated small farms was not merely because of poor endowments they have but also due to irrational allocation of available resources. By optimal allocation of farm resources under existing technology, it was possible to increase income above the poverty line.

With provisions made for borrowed capital , both farm incomes and employment were substantially increased in each farming system under the existing technology. The same were further increased by adopting recommended technology. The results further revealed that without the availability of adequate credit facilities, recommended technology cannot improve the conditions of the farmers on bullock operated and bullock operated plus tractor operated farms above poverty line. unrestricted capital availability and recommended technology also accelerated the entire gamut of income and employment potential under crop dairy and poultry farming systems.

Sankhyan, Prihar and Cheema (1988) conducted a study to demonstrate the use of multiple objective programming (MOP) by using compromise planning (CP) in the context of farm planning under Indian conditions. Compromise programming was used to select a sub-set of optimum farm plans from a set of efficient ones and the model farm used was from Punjab. In terms of amount of gross margins generated, one of the compromise plans was found to be very close to the existing farm plan being currently followed by the farmers, a solution which may appear to be irrational within the traditional linear programming framework.

Agbor and Enabor (1989) used linear programming technique to identify optimum and economically viable crop combinations for different sites, spacings and species in Cross River State, Nigeria. The objectives of the study were to organize intercropping of forest trees and food crops in the tropical moist forest zone and to maximize the farmers' annual net profit from the use of available resources. The tree species were intercropped with various food crops. Data were collected from a sample of 185 farmers by use of a 2-stage multiple stratification sampling design, subdividing the study area into 5 zones based on the local government areas, and then selecting 5 villages within each zone. The villages corresponded to the areas with ongoing afforestation projects. Results showed that on bush fallow sites, intercropping certain species of trees and some identified food crops was the most profitable cropping option. This was due to the long rotation of the forest tree species and the accumulated annual maintenance cost of the plantations. Also, total tree crop yield per hectare depended on spacing. A narrower spacing showed higher total tree crop yield per hectare than a wider spacing.

Bhogal, Sharma and Singh (1989) in their study used a profit-maximizing linear programming model to formulate optimum crop and milk production plans for small and marginal farmers in Meerut district, an Integrated Cattle Development Programme (ICDP) district of Uttar Pradesh. Data used in the model were collected for 1979/80 and 1980/81. The income and employment implications of operating under the optimal plan were also investigated. Four optimum plans were formulated incorporating combinations of improved and existing technologies. The optimum plans developed suggested that buffaloes, particularly Murrah buffaloes, are the most suitable milch animals and that their number could profitably be raised to three per farm. The considerable potential for increasing family income and employment through optimum integration of crop and milk production activities was also established.

Salokhe and Pariyar (1990) carried out analysis using linear programming techniques for two different sizes of farm: one with 5 ha land area and the second with 1.5 ha land area to increase the profit per unit farm area for the Tarai belt of Nepal. A standard LP format was adopted, identifying an objective function and land, labour, capital, personnel, institutional and husbandry as constraints. Adoption of the suggested cropping pattern on the 1.5 ha farm lead to about 3.5 times more profit and the cropping intensity increased from its present level of 135 to 280 per cent. Similarly, farmers with 5 ha of farmland generated 2.7 times more profit by optimum cropping. In this case cropping intensity increased from its present level of 135 to 214 per cent.

Gajanana (1990) conducted a study in Tumkur, a drought prone district of Karnataka to determine the extent of instability in farming and the adjustment mechanisms devised by the farmers against the risk. Primary data was obtained from sampled farmers in the district. Linear programming was used for optimisation of resources , parametric programming (MOTAD) was used to determine efficient plans and coefficient of variation around the trend was used as an index of stability, particularly arising from yield and price variability.

The findings indicated that on optimisation, returns and labour employment increased considerably. Adoption of recommended technology when associated with unlimited availability of capital yielded the highest returns and increased labour employment especially in crop, sericulture and dairy farming systems.

Chandra (1991) carried out economic analysis of different irrigation system in Ghaziabad District of Uttar Pradesh with the objectives (i) to study the income, employment and cropping pattern under different existing irrigation system situations and (ii) to optimise farm resources of selected farms under different irrigation systems. Linear programming technique was used to maximise net returns. Primary data were collected from sampled farmers through personal interviews using a questionnaire. These data were mainly physical input-output coefficients of crops grown on each plot. The results of the study revealed that on optimisation, employment opportunities, cropped area and net returns increased substantially.

Manos (1991) conducted a study on farm planning with multiple objectives in Greece. The aim of the study was to show how multiple objectives can be manipulated in farm planning. A common objective in farm planning is the maximization of the producer's gross margin. This can be achieved by using a linear programming model which optimizes the allocation of available resources to farm enterprises and thus maximizes the total gross margin of a farm. However, farms and especially those which include livestock enterprises are often faced with multiple objectives, such as the maximization of their gross margin, the minimization of total costs, the minimization of feed costs, etc. Such problems can be solved by developing a multiobjective programming model which can incorporate more than one goal. A brief presentation was made of multiobjective programming and especially of compromise programming. This was followed by an application of compromise programming to the production planning of a Greek farm which included both crop and livestock enterprises. Finally, the results were compared with the corresponding ones of the already existing plan and those achieved by linear programming.

Sankhayan and Cheema (1991) conducted an analysis of the variations in linear programming models used for farm planning and their consequences in terms of the results of optimum farm places. An effort was also made to suggest logically accurate and operationally simple formulations of linear programming models for preparing optimum farm places consistent with present day realities on the farm. A typical Indian Punjab farm was used as the basis of experimentation with model building for preparing an optimum farm plan. Three correct and relatively simple alternative formulations of the linear programming model were undertaken for this farm. It is concluded that: (1) it was essential in all models not to include the cost of those inputs in the working capital coefficients for which separate buying activities were provided in the model: and (2) it was optional to use interest as a component of individual working capital coefficients provided the form of the model used was consistent with such a situation.

Goswami and Meenakshisundaram (1992) attempted to develop suitable farm plans for hill areas of India where shifting cultivation is practised, in order to augment incomes in a situation where the loss of top soil due to shifting cultivation had brought about a drastic decline in productivity per unit area. The study developed optimum plans for Rongram block in West Garo Hills district, Meghalaya, at existing and improved levels of resource use, with capital borrowing and simultaneous hiring of capital and human labour. Cross-section data for 100 farmers practising shifting cultivation in 5 selected villages were collected by interview method for the year 1987/88. The study indicated that systematic farm planning is a paying proposition under the existing technology and with the existing resource base of the traditional hill farms. Credit, human labour and improved technology were the major operative bottlenecks on the hill farms.

Viljoen *et al* (1992) used integrated farm planning approach in the Kroonstad area of South Africa during the early 1980s to promote farming efficiency. Using linear programming, 29 farm plans were developed. Two years after completion of the last plan, a research project was conducted to determine the extent of plan implementation; reasons for deviations from planning proposals; and guidelines for future planning endeavours. The work reported the findings of the research in the light of using linear programming.

Cetin (1992) in his study in Turkey determined optimal production patterns for different farm situations. Inspite of the considerable development of Turkish agriculture, the sector still faced important problems. The situations examined were (i) before-land consolidation situation (optimal plan 1) and (ii) the after-land consolidation situation (optimal plan 2) on farms in Karacabey district, Bursa province, in order to show the effect of land consolidation on farm income. Linear programming was used to determine the optimum farm production pattern under current technology for the sample farms. According to the results, gross margin could be increased by 5.5 per cent under optimal plan 1 and by 22.7 per cent under optimal plan 2. Underemployment would also decrease from 52 per cent to 32 per cent under optimum plan 1 and decrease to 19 per cent under optimum plan 2.

Gupta and Verma (1993) conducted a study in Naga-Ki-Dhani village in Jaipur district, Rajasthan, India. Four optimum crop plans to stabilize farm income and employment during drought years were developed using linear programming techniques. The results of the optimum plans showed that use of improved varieties of crops developed specifically for water scarcity conditions, would increase farm income. The employment opportunities under the optimum plans developed with cash borrowing did not increase significantly over those of the plans developed with the existing level of resources. However, available working capital during drought years would not enable full use of whatever little irrigation water was available in the open wells, and hence credit should be made available to farmers in drought years.

Goswami (1993) developed a set of risk efficient plans for hill farms in the West Garo Hills district of Meghalaya, India. Shifting cultivation in combination with settled agriculture and livestock is the predominant form of agriculture. However, the practice of shifting cultivation leads to soil erosion, denudation of forests and reduction in income, resulting in great risk and uncertainty in tribal farms. Five villages with both shifting and settled cultivation were selected at random, from which 100 small farms were selected by following the probability proportional random sampling technique. Data required for the study were collected by the use of questionnaire and interview. A parametric linear programming model was used to develop a risk efficient set of plans. The results indicated the involvement of a high degree of risk in the existing plans. The alternative plans developed in this study were found to be efficient from both the income and risk point of view.

Panin (1993) in his study used a representative farm linear programming model based on farm management data of small-holders from Botswana to determine the effect of efficient allocation of farm resources on crop production. Efficient resource allocation is not only endemic to large scale farmers surrounded by a multitude of resources, but also to subsistence farmers. Most subsistence farmers face the problem of efficient resource allocation due to lack of proper record keeping and quantitative management techniques. The results showed that the optimal allocation of existing farm resources in the study area increases crop production income by 46 per cent compared to traditional allocation patterns. Cultivable land and harvest labour were the limiting resources on the farm. Productivity needed to be increased, which would put farmers in a position to be able to hire additional harvest labour.

Singh (1993) studied technological change and its implications for crop production and resource use in Eastern Uttar Pradesh. One of the objectives of the study was to examine the effect of improved technologies on resource use and crop production. Linear programming technique was used to make maximising production plans for the study area under different optimal situation so as to examine the effects of improved technologies on crop production and resource use in the region as a whole. The findings of the study indicated a substantial increase in production of paddy, wheat, rapeseed and mustard with introduction of improved level of technology. In fact the optimal plans where restriction on fertilisers was removed, and under improved/recommended scenario, the production of paddy and wheat nearly doubled. The introduction of crop activities at the improved level of technology increased the net returns from selected crops by about 70 per cent over the existing level.

Can (1993) conducted a study on a sample of 88 farms in Erbaa district, Tokat province, Turkey, to determine the minimum farm size that would provide sufficient income and achieve optimal farm organization in 1991. The linear programming results indicated that profit increases of 71, 79 and 148 per cent respectively were possible through optimal organization for the three groups studied. The farm size which would provide sufficient income for the farm family was calculated as 24.6 da[4], of which 13.53 da was irrigated land and 11.07 da dry land.

Krisna and Pathak (1993) examined economic models and their requirements in farm planning. Farm planners have a vital role in helping the farmer in the use of new farm inputs and practices and in reorganizing farm business to attain increased production and income. Although the work was confined to India, the results are applicable elsewhere in the world. The results indicated that there are various economic models which the farm planners can use. Economic models for farm planning have been grouped into two categories: (1) models based on perfect knowledge and certainty, i.e., production function, conventional budgeting and linear programming models, and (2) models of risk and uncertainty, diversification models, probabilistic and game theoretic models. Data requirements for different economic models will vary for different farm planning situations. In general, information is needed on: (1) resource quantities available (also additional resources that can be acquired); (2) outputs; (3) technical input-output coefficients; (4) expected prices; and (5) social, institutional and personal restraints. Additional information on yield and price variability is needed for models of uncertainty. The usefulness of the production function model as a direct aid in farm planning is very limited. But production functions can be a potential aid in estimating response functions for different farm inputs. Several research applications of linear programming and whole farm budgeting have been reported. The use of these models in farm management extension work at the farm level is very limited. Partial budgeting models offer greater promise in extension farm

---

[4] A unit of measurement for land commonly used in Turkey.

management work. A step in this direction has already been taken in the 'package programme' in which the role of farm planning in agricultural extension work is being demonstrated with considerable success.

Uddin, Talukder and Alam (1994) conducted a study to determine the optimum cropping plan for a group of farms in a farming systems research area of Mymensingh district, Bangladesh. Data were obtained from 40 farms in the district during 1993/94, and suggested that there was a considerable divergence between the existing and optimal crop plans when considered under both restricted and unrestricted levels of capital. Linear programming was applied to a farm plan producing crops, cattle, poultry and fish. Twenty crops were listed, and land allocated to them under the existing conditions are compared with optimum land allocation levels for restricted capital and unrestricted capital. With a restricted level of capital, the optimum plan could still increase farm incomes through rearranging land resources to more profitable enterprises. The optimum plan was capital intensive, but highly profitable, suggesting that the provision of credit might help expand the area under more profitable crops.

Sher and Amir (1994) used linear programming to create several plans for different expert assumptions of the unpredictable factors dominating production, to evaluate the expected value of each plan and to select the largest one. Agricultural production systems are operated under severe uncertainty. One possibility in coping with the uncertainty in the decision-making process, is to use a planning technique that would take care of the uncertainties. Linear programming was used as the first stage of the decision-making process. However, the method followed in his study used the LP's post-optimal sensitivity analysis (POSA). POSA's insensitivity limits of the decision variables of the various solutions were used to create a set of two-sided non-equivalent inequalities. On the basis of this set and a fuzzy solution of a system of inequalities, fuzzy constraints were formulated. An algorithm to optimize a linear objective function with varied coefficients subjected to fuzzy constraints was developed and presented. The approach and the method were introduced and demonstrated using an unirrigated farm whose production was dominated by unpredictable rainfall. To evaluate the method, its production and the regular LP production plans were compared, with a significant advantage to the suggested method.

Jolayemi and Olaomi (1995) attempted to develop a new procedure for linear programming model that could be used to obtain an optimum crop combination for a mixed cropping scheme. Unlike two earlier solution procedures for this model, the new procedure did not involve the enumeration of all possible crop combinations or crop sub-groups obtainable from any set of crops under consideration for mixed cropping. This made it far more efficient. Instead of formulating and solving all linear programming problems associated with all possible crop sub-groups the new procedure formulated and solved a few linear programming problems with respect to a few crop sub-groups selected systematically. Many hypothetical crop selection problems are simulated and solved to demonstrate the superiority of the procedure over the existing ones.

Goswami (1995) conducted a study during 1986/87 to develop suitable optimum farm plans for 100 farms practising shifting cultivation in Rangram block in the West Garo hills district of Meghalaya in India, with the objective of increasing income and employment and reducing the use of shifting cultivation. Optimum farm plans were developed using linear programming techniques for three situations: (1) existing resource level; (2) existing resource level but with relaxation of working capital; and (3) existing resource level but with simultaneous relaxation of working capital and human labour. The optimum plans developed for these situations included high-yielding varieties of autumn and winter rice (*Oryza sativa* L.), arecanut (*Areca catechu* L.) and cattle (*Bos indicus* L.) with increase in area and number. The increase in income was 139, 287 and 303 per cent in optimum plan I, II and III respectively compared with the existing plan. Human labour employment increased by 30 per cent in optimum plan III, whereas bullock labour employment decreased in all the optimum plans.

Manos and Gavezos (1995) used a multiobjective programming model used for production planning of a farm region in northern Greece. The model included three objectives, namely the maximization of the total gross margin of the region, the minimization of its variation over a span of 12 years and the minimization of the total variable capital needed. The three objectives were compromised to a single standardized objective function and the model was solved by compromise programming. As a measure of the variation of the total gross margin, the sum of the mean absolute deviations of the gross margins of farm enterprises over the 12 year period was used, which was minimized by use of MOTAD (Minimization of Total Absolute Deviations) model. The final model included a compromise objective function of the three objectives and 92 constraints referring to the available resources viz. land, labour, machinery and variable capital as well as the constraints produced by the MOTAD model. The results were compared both with those of the existing production plan of the region and those achieved by the linear programming technique.

Studies reviewed have proved that linear programming is a powerful tool in the field farm management for maximisation incomes in the farm business. It is also evident from the literature that most of the studies had been confined to the use of linear programming as a profit maximising tool at micro-level through resource allocation. Very few studies have dealt with resource allocation exclusively zone-wise, where each zone in a given area is individual treatment. It is fairly obvious that there is always differences in agroclimate from one region to another. Therefore, drawing blanket inferences is unrealistic if the results are to used for generalisation of a wider area. Studies that have incorporated different levels of technology in alternative normative plans to examine the impact of optimal resource allocation on employment creation and income generation according to agroecological zones are scanty. Most of the studies conducted are more or less of academic interest.

This study attempts to be more practical in the use of linear programming by developing viable farm plans for each agroecological zone in a given area, under different technology situations across different farm size categories. The impact of optimal resource allocation on incomes and employment are examined.

In reference to Kenya in general and Embu in particular, this study attempts to bridge the existing gap between past studies which have been concentrating in small areas, covering only one agroecological zone, by broadening the studies to cover larger areas with different agroecological zones. The results of the study would be applicable to all other major agroecological zones in high potential areas in Kenya.

The methods by which the aforementioned objectives would be achieved are discussed in the next chapter. The chapter draws heavily on the lessons learned and experiences gained by the previous investigators, whose work have been reviewed here. The techniques they had used in the studies, have been considered in the developing the methods used in the current study.

CHAPTER IV

MATERIALS AND METHODS

This chapter discusses briefly data collection methods and analytical tool used in the study.

4.1 Analytical Tool

The overall objective of the study was to improve the income generating capacity of the farm enterprises in Embu District so as to arrest the rural-urban migration through developing viable farm plans that can be adopted by farmers and attract the young entrepreneurs to venture into farming business. In a bid to achieve the objective, several analytical tools were used such as computations of means, ranges, percentages etc. Farm enterprise budgets were prepared to determine net enterprise returns for the major farm enterprises in the study area. These provided the building blocks for linear programming matrices. Linear programming was the principal tool used to study the maximization of returns to the farms under different farming situations through optimal allocation of resources subject to the specified constraints.

4.1.1 Farm Enterprise Budgets

The net enterprise was calculated by subtracting all the occurring of Cost A_1[5] from the gross returns. Sixteen cost items are listed by Kahlon and Karam Singh (1992) as Cost A_1. However in the context of the study

---

5 Variable costs, imputed costs of family labour and depreciation of fixed capital

area, items such as irrigation charges and canal water charges listed by Kahlon and Karam Singh are omitted since they do not occur in the study area. Returns to fixed resources and particularly returns per ha. of land were then calculated. The budgets also covered labour requirements, month by month for every enterprise under study. Hence the budgets provided the necessary technical coefficients vital for the study.

(i) **Physical input-output data:** Yield levels and quantities of different inputs used for each crop/livestock enterprise. The input coefficients, that is the quantities of different inputs required for one hectare of land to produce crop activity or livestock unit were derived from these data.

(ii) **Prices:** The prices of various inputs used such as seed, fertilizers, pesticides, feeds, etc and the prices of various outputs received by the farmers at harvesting time, were also provided. *Lotus 1-2-3*[6], a spreadsheet software package was used in preparing farm enterprise budgets.

4.1.2 Descriptive Statistics

Simple descriptive statistics and tabular analysis were used to compute resource availability and other farming constraints. Land available, size and type; enterprises , labour and capital available with the farmers were also determined.

4.1.3 Linear Programming

Linear Programming (**LP**) is a mathematical procedure used by decision makers to find the best possible way of utilizing the scarce resources so as to achieve maximum returns from a large number of

---

[6] A product of Lotus Development Corp., USA.

alternatives given a set of conditions. LP can also be used to solve cost minimization problem. The method demands rigorous definitions of conditions. Young *et al.*(1978) categorizes the components of LP problems into the following three items :

(a) A goal or objective

(b) A set of alternative activities

(c) A set of restraints (constraints)

The **goal or the objective** is the decision maker's desire and in a farming situation varies depending on the farm being considered. Linear programming requires that a single quantifiable objective be specified. This is known as **Objective Function** .

It is suggested that a workable objective function for most small scale farmers is to maximize cash incomes from the farm and at the same time provide food and other subsistence items required by the farm family, while keeping labour within the desired limits (Young *et al.* 1978).

The set of **alternative activities** - are all the different types of production or any other related activities which are or could be carried out in the farm.

The set of **restraints** or constraints specify the available resources such as land, labour, capital etc which limit the extent to which any activity or combination of activities can be included in the farm plan (Beneke *et al.* 1973).

Linear programming procedure selects the combination and the level of each activities which best achieves the objective subject to resource use being within limits of defined restraints. To use this method as detailed in Upton (1973 and 1983) the condition must be presented in the following form:

(a) A limited choice of several activities

(b) A certain fixed constraints affecting the choice

(c) Straight line or linear relationships

Using net returns already calculated and other coefficients derived from the secondary data, linear programming matrices were prepared for every category of a representative farm across agroecological zones and in every farm situation. Similar categorization of farms had been used elsewhere by Oyugi *et al.* (1987). The matrices were entered into a Personal Computer (**PC**) using *LP88*[7] Linear Programming package to generate the model farm plans. Sensitivity analyses were examined to reveal the stability of the farm plans in the event of input/output price changes. Subsistence requirement constraints of the farm family were also incorporated into the linear programming models.

Selection of Activities

A thorough knowledge of processes or activities practised by the farmers is of paramount importance in computing the solutions for profit maximizing problem through linear programming technique.

Real activities were crops grown and livestock kept in different categories of farms. The pattern of activities undertaken by farmers was uniform however there were some differences in the crops grown in different agroecological zones. The details of the major crop enterprises

---

[7] A Linear Programming Package developed by ESP Inco., USA

in different agroecological zones are given in table 4.1 There were two livestock activities, dairy and egg production which were common in all the agroecological zones. Crop processes are ways and means of growing crops on farms. Thus if a crop was grown in various seasons, each season was considered as an activity. Similarly livestock processes are ways and means of rearing livestock on the farm. Thus if a livestock product is produced by different methods, each method of production is considered as an activity.

Hiring and borrowing activities were incorporated into the linear programming model for improved technology farm. These activities are referred to as labour hiring and capital borrowing activities.

Specification of the Model

There are three quantitative components of linear programming model:

(i) An objective function

(ii) Resource requirements or process of obtaining objectives and

(iii) Resource restrictions or resource availability.

Algebraically, this is stated in compact form as:

$$\text{Maximize } Z = C'X$$

$$\text{Subject to :}$$

$$AX \leftrightharpoons B$$

$$X \geq 0$$

where

A is an m x n matrix of technical coefficients

C is an n x 1 vector of prices or other weights

Table 4.1 Major Crop Enterprises in Embu District

Agroecological Zone	Crop
LH1/UM1	Tea Coffee Maize Beans Irish potatoes
UM2/UM3	Coffee Maize Beans Irish potatoes Bananas
UM4	Cotton Maize Beans Irish potatoes Bananas
LM3	Cotton Maize Beans Irish potatoes Bananas Pigeon peas
LM4	Cotton Maize Beans Sorghum Bananas Pigeon peas
LM5	Cotton Maize Beans Sorghum Bananas Pigeon peas Cow peas Gram

X is an n x 1 vector of activities

B is an m x 1 vector of resources or other constraints

C'X = Z the objective function

The above expression in an expanded form is written as:

$$\text{Maximize } Z = C_1X_1 + C_2X_2 + \ldots\ldots. C_nX_n$$

Subject to:

$$a_{11}X_1 + a_{12}X_2 + \ldots\ldots. + a_{1n}X_n \leq b_1$$
$$a_{21}X_2 + a_{22}X_2 + \ldots\ldots. + a_{2n}X_n \leq b_2$$
$$\vdots$$
$$a_{m1}X_1 + a_{m2}X_2 + \ldots\ldots\ldots + a_{mn}X_n \leq b_m$$

and X_j (columns 1 to n) all should specified in positive values starting from zero or any other positive value ($X_j = 0$). a_{ij} = i[th] resource required to produce one unit of [j]th crop or livestock activity. In a condensed form, this can be written as:

$$\text{Maximize } Z = \sum_{j=1}^{n} C_jX_j$$

Subject to :

$$\sum_{i=1}^{m} a_{ij}X_i \leq b_i$$

$$X_j \geq 0$$

b_i = [i]th resource available with the farmer for use in the production of crops and livestock.

i **ranging from 1 to m denoting the number of rows (constraints) in the problem.**

j **ranging from 1 to n indicating the number of columns (crop, livestock and other activities) in the problem.**

A model of linear programming matrix structure is presented in figure 4.1.

Activities	X_1	X_2	X_n	Sign	B-Column
Net Returns Row	C_1	C_2	C_n		
Constraint$_1$	a_1X_1	a_1X_2	a_1X_n	s_1	b_1
Constraint$_2$	a_2X_1	a_2X_2	a_2X_n	s_2	b_2
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Constraint$_m$	a_mX_1	a_mX_2	a_mX_m	s_m	b_m

Fig. 4.1 Structure of Linear Programming Matrix

Notes:

The **Sign Column** (s_1, s_2,.....s_m) shows whether each of the constraints is maximum, minimum or equality constraint.

The **B (Basis) Column** (b_1, b_2,.....b_m) shows the level at which each of the constraints operate.

The **Activity (X) Columns (numbered 1 to n)** list each of the activities to be included in the LP model.

The **Net Returns (or Net Revenue) row (C_1, C_2,.....C_n)** lists the per unit net returns for each of the activities.

The **Constraint rows (numbered 1 to m)** list all of the constraints to be included in the linear programming matrix.

The **Matrix Coefficients** are represented by a_1X_1,.....a_mX_n. These are positive or negative numbers which indicate how each of the activities use or generate units of the resources. A positive coefficient indicates that the activity uses the resource, and negative coefficient indicates resource generation.

Constraints Used in the Model:

There are two types of constraints used in the model, resource constraints and non-resource constraints.

(a) Resource Constraints

The most limiting resources in farm production are land and capital. At certain periods of the year, labour also becomes restrictive. The resource constraints which were included in the model are given below:

(i) Land

Different authors classified land in different ways based on various factors such as soil type, irrigation, suitability of land to grow particular crop(s) and even on the basis of seasons. Malya and Radhakrishnan (1962) in their studies classified land into two categories, dry and wet while Jaikrishna (1961) classified land on the basis of irrigable and soil types. Desai (1962) and Devadoss (1980) classified land into irrigated and unirrigated categories. Oyugi (1984) and Oyugi *et al.*(1987) classified land according to crop seasons, long-rains land and short-rains land. Deoghare (1987) classified land into five groups, *Kharif* irrigated, *rabi* irrigated, summer irrigated, *kharif* unirrigated and *rabi* unirrigated. Chandra (1991) classified land into six types based on structure and effective use of land viz., early *kharif*, normal *kharif*, early *rabi*, normal *rabi*, late *rabi* and *zaid*.

In this study land has been classified into two categories, long-rains land and short-rains land.

(ii) Labour

Twelve labour constraints were incorporated into the model. Labour availability was constrained according to months, from January to December. The constraint period should be sufficiently short within which only substitution of resource may take place. All the twelve periods are critical periods during which labour available with the farmers fall short of requirement and become constraints. The data regarding the available farm family labour including permanent labour was ascertained from the sampled farmers. All labour was standardized adult equivalent. This type of standardization has been used by Mukhebi (1981) and Oyugi (1984) in their studies in Kenya. The adult equivalent conversions based on age group were defined as follows:

$7 \leq 15$ years = 0.5 adult equivalent

$>15 \leq 70$ years = 1.0 adult equivalent

Children under the age of 7 years and adults over 70 years were ignored. No distinction was made between labour provided by adult male or female as in other studies such as Deoghare (1987), Chandra (1991), Sinha (1967), Das (1971) and Gajanana (1990) on the basis of wage rate differential. One adult equivalent providing eight hours labour was taken as one manday. The actual labour available for farm operations was determined by deducting a period of non-work days owing to religious holidays, school days (for school going children), imputed sick leave, *barazas*[8], market days and group meeting (for women) days.

(ii) Capital

Working capital available with the farmers in some cases may not be adequate to meet different requirements of different farm activities. The deficiency may also limit the adoption of improved technological practices. the term **operating capital** herein used synonymously with **working capital** in the study was defined as expenses incurred to meet day to day expenses for crop production and livestock rearing expenses in cash and in kind. That is to say that working capital included cash, value of items given out in kind and also depreciation charges on machinery and other farm implements. Working capital for crops and livestock included the following items.

(1) Cost of seed.

(2) Cost of fertilizers, pesticides, herbicides, manures and other agrochemicals.

(3) Cost of hired machinery and/or running costs of owned machinery.

(4) Labour hiring charges.

(5) Cost of feeds viz., forage and concentrates.

---

8 Regular meetings organized by local administrative officials where matters of topical issues, arbitrations and development issues are discussed.

(6) Depreciation of capital items and livestock.

(7) Veterinary care expenses.

(8) Replacement costs of heifers and chicks.

(9) Cost of hired transport.

(10) Insurance charges.

(b) Non-Resource Constraints

Non-resource constraints are those constraints which hinder the production of certain activities beyond some point not because of lack of production resources but due to some set norms or psychological reasons affecting the decision of the farmers. The non-resources incorporated in the model are discussed below:

(i) Minimum Subsistence Crop Requirement

The farmer is not only a producer but he is also a major consumer of the farm product. The farmer ensures that the production of food crops for the farm family consumption is taken into account irrespective of profitability considerations. In Kenya, even if it is possible to purchase subsistence requirements from the market more cheaply than producing them on the farm, the farmer will still go out of his way to produce at least some of the food requirements. This provides the necessary food security in case of shortages or rise in the market prices.

Several researchers have incorporated the constraint in the model. Desai (1961) and Banerjee (1974) estimated the requirement on the basis of Balanced Diet Schedule suggested by Nutrition Committee appointed by the government of India. Similar technique was used by Oyugi (1984) basing his estimation on nutritional survey and campaign against malnutrition in Kenya conducted by Bohdal *et al* (1968). Gangwar (1966) plus Sirohi and Gangwar (1968) derived total food requirements on the basis of 20 ounces of grain per adult per day. Sinha (1967) and Sharma (1975) calculated the minimum requirements for food grain on the basis of factual information obtained from individual farm families. This latter method was adopted for the current study.

(ii) Minimum Subsistence Milk Requirement

It is a common practice in Embu District of Kenya for farmers in high and middle altitude agroecological zones where the agroclimate is conducive to rearing of dairy animals to at least keep one dairy cow. The cows are kept to provide milk requirements for subsistence needs and sell extra for cash. The rearing of these dairy animals is done irrespective of profit implications. Therefore this constraint was included in the models for relevant agroecological zones.

4.2 Data Requirement and Sources

Both primary and secondary data were used in the study. Primary data were collected from a sample of farmers by use of structured questionnaire through personal interview. Secondary data were obtained from publications of the Ministry of Agriculture, Kenya. The libraries at the Ministry's headquarters in Nairobi and the District headquarters in Embu, were the main sources of the secondary data. Additional secondary data were also collected from the libraries of Jomo Kenyatta University of Agriculture and Technology and University of Nairobi.

The primary data collected included farm sizes, major farm enterprises and their sizes, yields, input usage and price of inputs and outputs. Informal interviews were conducted on local input and output outlets to obtain input and output price levels respectively. Similar method was used to obtain additional information on farming systems of the study area from the local district agricultural extension staff.

4.3 Sampling Plan

A multistage stratified random sampling was used to select the respondent farmers. The first stage of sampling involved listing of all the major agroecological zones in Embu District from which the sampling units would be drawn. Eight major agroecological zones were identified.

The second stage involved listing of all the sublocations[9] in every agroecological zone. This exercise enabled sublocations to be grouped according to agroecological zones. The sublocations in the agroecological zones formed the sampling frame from which the samples of respondent farmers were drawn. Seventy sublocations were listed and grouped according to the major agroecological zones identified. Detailed list of the sublocations in each of the agroecological zones are given in the Appendix.

In the third sampling stage, a random sample of a sublocation was drawn from each agroecological zone. A list of farmers was prepared for each of the sublocations drawn. The farmers were then categorised into two groups, the "adopters" and the "non-adopters". In each category

---

[9] The smallest administrative unit of an area whose administrator is known as an Assistant Chief.

five farmers were randomly selected. A farmer was classified as an adopter if he had satisfied the following conditions:-

(i) Used high yielding varieties.

(ii) Applied the recommended improved husbandry practices.

4.4 Database Management System.

dBase[10] was used as database management system for data entry, storage and retrieval. A database structure was created in line with the structure of the questionnaire. **dBase** was selected because of its powerful features and flexibility in data handling. Data from **dBase** can be exported to other software programmes like spreadsheet, graphics, statistical and wordprocessing packages for further processing and analyses. Also, **dBase** on its own can carry out some limited analytical work such as computing range, mean and standard deviation. In addition, **dBase** features enormous capacity for cross tabulation which is of vital importance to the nature of data collected. Its user-friendly feature is a distinct advantage and the investigator was well versed with the software.

4.5 Questionnaire Administration

The appropriateness of the questionnaire was tested by pretesting it on ten farmers in the study area. The data collected from pretested questionnaires were then entered into the computer so as to verify the efficiency of the created database in managing data. In both cases, any anomalies observed in the questionnaire and the database structure were corrected accordingly. Final versions of the questionnaire and the database structure were then prepared.

---

[10] A Database Management Software Package developed by Ashton Tate Inc., USA.

Before the interviews were conducted, the respondent farmers were notified in advance on the fixed date and time of the intended interview by the field extension staff of the area. The interviews were conducted personally by the investigator in all the cases. It took two to three hours to complete one questionnaire. A maximum of three questionnaires were completed per day.

CHAPTER V

RESULTS AND DISCUSSION

In this chapter the results of the study on optimal allocation of resources in farming enterprises in Embu District are presented and discussed. The chapter is organized into two main sections. The first section discusses the socio-characteristics of the farmers in the study area. The second section deals with the optimal plans developed, the cropping pattern, farm income and labour employment across different agroecological zones in each of the three farm size categories viz., small, medium and large, under the existing and the improved technology scenarios.

A total of seventy eight farmers were interviewed. Eight major agroecological zones were identified. The zones were LH1, UM1, UM2, UM3, UM4, LM3, LM4 and LM5. Details of the characteristics of the agroecological zones have been discussed in the previous chapters. Ten farmers were interviewed in each of the agroeclogical zones except one agroecological zone where only eight farmers were interviewed. The personal interviews with the farmers formed the main source of primary data for the study. Technical coefficients for linear programming problems were obtained from this source.

5.1 Social characteristics of the Farmers

Among the seventy eight respondents interviewed, thirty were females. The female respondents, therefore, accounted for 38.46 per cent of the farmers interviewed. This compares favourably that heads of households who are females constitute 30 per cent of Kenya's household heads (Republic of Kenya, 1997a). This is a clear indication of the increasing role played by women as farm managers in rural small scale farming situations.

The age of the respondents varied from 27 to 67 years with mean age of 44 years. Table 5.1 shows the age dynamics of the respondents.

Table 5.1 Age of Respondents in the Study Area

Range (Yrs)	Number	Percentage
Upto 30	9	11.54
31 - 40	23	29.49
41 - 50	25	32.05
51 - 60	14	17.95
Above 60	7	8.97
Total	78	100.00

The majority (61.54 per cent) of the respondents were between 31 and 50 years old. Only 11.54 per cent of the respondents were 30 years or younger. Youth from farming families are getting allienated from the farming profession and moving to urban based employment. This is an indication that farming is yet to attract the younger generation. Farmers above 60 years old accounted for 8.97 per cent of the respondents.

In all the farms sampled, land was fully (100 per cent) owned by the farmers, indicating long term leasehold is not a common practice in the area. Some farmers rented pieces of land from neighbours to cultivate additional crops on short time basis. This accounted for 23.08 per cent. This demonstrates that land is a limiting resource in production. The rents for the rented land were paid for only in cash.

Literacy level of the farmers varied considerably from farmers with no formal education to farmers with post-secondary school education. The majority (92.31 per cent had at least primary school[11] level of education. Table 5.2 indicates the details of the level of education of the sampled farmers.

Table 5.2 Level of Education of Farmers

Level of Education	Number	Percentage
Uneducated	6	7.69
Primary	40	51.28
Secondary	26	33.33
Post-Secondary	6	7.69
Total	78	100.00

Although the majority of the farmers are literate, only 25.64 per cent are full time farmers. The rest are engaged in other income generating businesses in addition to farming. This demonstrates that farming does not occupy a high priority in income generating activities. That is to say that presently farming alone is inadequate as a source of income for the farm families in Embu whose average size stands at 6.78 persons per household.

5.2 Optimal Farm Plans

This section deals with the optimal farm plans for different agroecological zones. Optimal farm plans were developed for small, medium and large farm categories. under the existing and improved technology situations. Comparisons are made between the optimal farm plans under

[11] Upto eight years of formal education. A person who has attained at least eight years of formal education is considered as literate.

existing technology and the farms under improved technology. Useful conclusions are made in the light of results obtained.

The optimal farm plans were developed using linear programming technique. The plans generated covered all the eight major agroecological zones in Embu District. In each of the linear programming models prepared, a minimum subsistence constraint was incorporated to ensure a flow of food requirement from farm activities to farm family. It is a common practice that farmers in Embu draw some of the subsistence needs from the farm produce. In some of the agroecological zones, it is also common for farmers to include some production activities in their farming system even if these activities do not generate profits. These activities were also incorporated in the models accordingly. Many of these activities are in the form of non-resource constraints. Three synthetic farm categories were developed viz., small, medium and large. Similar technique had been used elsewhere by Das (1971), Mukhebi (1981), Oyugi (1984) and Deoghare (1987). The plans were developed separately for each farm category. In each farm category, an optimal farm plan was developed under the existing technology and the improved technology. That is to say, six optimal farm plans were developed for the three farm categories - small, medium and large across the eight agroecological zones. In total therefore, forty eight optimal farm plans were generated., The results of the study under the existing and the improved technology scenarios are presented and discussed according to the eight agroecological zones. Unlike the existing technology, the improved technology scenario had provisions for labour hiring and capital borrowing activities.

5.2.1 Optimal Farm Plans for Agroecological Zone LH1

The agroecological zone LH1 is also known as Tea-Dairy Zone, an indication of it's suitability for tea and dairy production. The main cash enterprises in this zone are tea and dairy. Coffee is also widely grown here but the performance of this crop is not as good, particularly at higher altitudes where there is frequent occurrences of frostbite. Maize, beans and Irish potatoes are cultivated mainly for subsistence requirements.

Maize-beans intercrop and Irish potatoes were incorporated in the model for subsistence requirements. The minimum requirements for each of the activities were specified at some level. Since it is a common practice for farmers in this zone to keep at least one dairy cow under zero-grazing[12] unit, dairy production was also constrained to at least one dairy unit[13] to cater for consumption needs. Therefore the linear programming model included maize, beans, Irish potatoes, coffee, tea, dairy and egg production. Egg production was included in the model for commercial purposes. Maize, beans and Irish potatoes are grown in two seasons viz., long-rains and short-rains seasons. Therefore each crop grown in a separate season was treated as unique activity.

The mean farm sizes for the three categories of farms, small, medium and large were 0.61, 1.26 and 2.66 hectares respectively. The optimal farm plans are presented in Table 5.3.

---

[12] Livestock production system in which the dairy cattle is kept in a stall and all the necessary feeding is provided in the stall. The livestock is confined to the structure throughout, day and night. This system is more popular in the areas where land is a constraint.

[13] One cow plus one calf.

Table 5.3 Optimal Farm Plans, LH1, Embu District, 1996

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	*Unit*						
Maize-Beans LR	ha.	0.10	-	-	0.22	-	-
Maize-Beans SR	ha.	-	0.10	0.10	0.08	0.10	0.10
Irish potatoes LR	ha.	0.04	-	-	0.04	-	-
Irish potatoes SR	ha.	-	0.11	0.11	-	0.04	0.04
Coffee	ha.	-	0.15	0.18	-	-	-
Tea	ha.	0.04	0.15	0.16	0.43	0.47	0.47
Dairy	du.	1.00	1.00	1.00	1.00	1.00	1.00
Total Net Returns	Kshs.	18492	24907	26073	28713	29988	38257
B: Resource Usage							
Land LR	ha.	0.28	0.41	0.55	0.59	0.57	0.85
Land SR	ha.	0.14	0.62	0.76	0.61	0.71	0.99
Labour	md.	386	470	497	735	768	915
Capital	Kshs	53000	80300	93300	117000	148000	183000
C: Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					55.27	20.40	46.73
Increase in Employment (%)					90.41	63.40	84.10

Notes:

1 du. (dairy unit)	=	1 cow + 1 calf
LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)

The results revealed that optimal farm plans under the improved technology are far much superior to the optimal plans under the existing technology, in terms of employment creation and income generation in all the three farm categories. Net farm incomes increased from Kshs 18492, 24907, 26073 to Kshs 28713, 29988 and 38257 for small, medium and large farm categories respectively. This is an increase of 55.27, 20.40 and 46.73 per cent for small, medium and large farm categories respectively over the existing technology. Employment opportunities increased by 90.41, 63.40 and 84.10 per cent for small, medium and large farm categories respectively.

The usage of production resources also increased under the improved technology situation. More land, labour and capital were put into production process across all the farm categories. Table 5.4 provides the details of resource usage under both the existing and improved technology situations. The utilization of the land in the long-rains increased from 0.28, 0.41 and 0.55 hectares to 0.59, 0.57 and 0.85 hectares for small, medium and large farm categories respectively. This accounted for a proportional increase from 49.90, 32.54 and 20.68 per cent to 96.72, 45.24 and 31.95 per cent for small, medium and large farm categories respectively. Similarly the utilization of land in short-rains season increased from 0.14, 0.62 and 0.76 hectares to 0.61, 0.71 and 0.99 hectares for small, medium and large farm categories respectively. This accounted for proportional increase from 22.95, 49.21 and 28.57 per cent to 100, 56.35 and 37.22 per cent for small, medium and large farm category respectively.

Table 5.4 Resource Usage in Optimal Farm Plans, LH1, Embu District, 1996

Technology Level		Existing Technology			Improved Technology		
Farm Category		Small	Medium	Large	Small	Medium	Large
Size	ha.	0.61	1.26	2.66	0.61	1.26	2.66
Land LR	ha.	0.28 (45.90)	0.41 (32.54)	0.55 (20.68)	0.59 (96.72)	0.57 (45.24)	0.85 (31.95)
Land SR	ha.	0.14 (22.95)	0.62 (49.21)	0.76 (28.57)	0.61 (100.00)	0.71 (56.35)	0.99 (37.22)
Labour (F)	md.	386 (67.36)	470 (82.02)	497 (86.74)	560 (97.73)	563 (98.25)	571 (99.65)
Labour (H)	md.	-	-	-	175	205	344
Capital (A)	Kshs	53000 (100.00)	80300 (99.14)	93300 (73.67)	117000 (100.00)	148000 (100.00)	183000 (100.00)
Capital (B)	Kshs	-	-	-	23294	-	-

Figures in parentheses are percentages.

Notes :

LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F) = Family Labour
Labour (H) = Hired Labour
Capital (A) = Capital Available
Capital (B) = Borrowed Capital

The usage of family labour also followed the same pattern by increasing from 386, 470 and 497 mandays to 560, 563 and 571 mandays for small, medium and large farm categories respectively. This accounted for an increase in family labour usage from 67.36, 82.02 and 86.74 per cent to 97.73, 98.25 and 99.65 per cent for small, medium and large farm categories respectively.

Under the improved technology situation, the demand for labour in some critical months exceeded family labour supply. This resulted in hiring of labour to the tune of 175, 205 and 344 mandays for small, medium and large farm categories respectively. Capital available with farmer varied according to size of the farm. Generally the larger the farm the higher the amount of capital available with the farmer. Across the farm categories and under both the existing and improved technology situations, all the capital available with the farmer was fully (100 per cent) utilized except for medium and large farm category under existing technology where the use of capital stood at 99.14 and 73.67 per cent respectively. In the small farm category under improved technology, additional capital of Kshs 23294 was borrowed to bridge the gap.

Further perusal of the results revealed that land is binding during the short-rains season in small farm category. The shadow price or MVP (Marginal Value Product) of land was recorded as Kshs 578.20. This indicated that it pays to rent land during this season provided the rent paid is less than the MVP.

5.2.2 Optimal Farm Plans for Agroecological Zone UM1

The agroecological zone UM1 is also known as Tea - Coffee zone indicating the transitional nature of the zone from being predominantly tea to coffee as one moves from higher altitude to lower altitude zones. This zone is neither a prime tea zone nor predominantly coffee zone since it is a little bit too low for optimal performance of tea but also a little bit too high for the optimal performance of coffee. However both crops are still grown profitably. Going through the zone, one notices that the upper parts of the zone is predominantly covered by tea and the lower parts by coffee. Tea and coffee are the main cash crops in this zone. Maize, beans and Irish potatoes are grown for mainly subsistence requirements.

Maize-beans intercrop and Irish potatoes were included in the model for subsistence requirements. The minimum requirement for each of the activities was specified rigorously. Pure-stand maize was included into the model because some farmers with larger pieces of land do cultivate pure-stand maize. It is a common practice for farmers in this zone to keep at least one dairy cow under zero-grazing unit for farm family milk needs. Therefore dairy production constraint was included in the model. The minimum level was kept for at least one dairy unit. Chicken are commonly reared for commercial egg production. Therefore, this activity was included in the model. The linear programming matrix was composed of the following activities, maize-beans intercrop, pure-stand maize, Irish potatoes, coffee, tea, dairy and egg production. Maize-beans intercrop, pure-stand maize and Irish potatoes are grown in two seasons, the long-rains and the short-rains seasons. Therefore every activity undertaken in a separate season was treated as a separate activity.

The three farm size categories , small, medium and large were 0.40, 1.52 and 2.09 hectares respectively. The optimal farm plans developed are presented in table 5.5.

The results indicated that the optimal farm plans under the improved technology are economically more viable than the optimal farm plans under the existing technology in terms of employment creation and income generation across the farm categories. Net farm income increased from Kshs 15867, 24626 and 24882 to Kshs 20270, 31671 and 29234 for small, medium and large farm categories respectively. This represented a proportional increase of 27.75, 28.61 and 17.49 per cent for small, medium and large farm category respectively over the existing technology.

Table 5.5 Optimal Farm Plans, UM1, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	**Unit**						
Maize-Beans LR	ha.	0.10	0.02	-	-	0.70	0.70
Maize-Beans SR	ha.	-	0.08	0.10	0.18	0.03	0.03
Irish potatoes LR	ha.	0.04	0.04	-	-	-	-
Irish potatoes SR	ha.	0.04	-	0.04	0.06	0.04	0.04
Coffee	ha.	0.03	0.26	0.26	-	1.30	1.89
Dairy	du.	1.00	1.00	1.00	1.60	1.48	1.25
Total Net Returns	Kshs.	15867	24626	24882	20270	31671	29234
B: Resource Usage							
Land LR	ha.	0.27	1.52	1.60	0.40	1.52	2.09
Land SR	ha.	0.13	0.54	0.59	0.40	1.52	2.09
Labour	md.	376	421	470	451	981	1111
Capital	Kshs	51000	88000	90000	97000	154000	171000
C: Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					27.75	28.61	17.49
Increase in Employment (%)					43.88	133.02	136.38

Notes :

1 du. (dairy unit) = 1 cow + 1 calf
LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)

Land usage under the existing and improved technologies in both the long-rains and short-rains seasons, across the farm categories was 100 per cent except for the small and large farm categories in the long-rains season and in all farm categories in the short-rains season under the existing technology. In the latter case the utilization was 67.50 and 76.56 per cent for small and large farm categories respectively and 32.62, 35.53 and 28.23 per cent in the short-rains for small, medium and large farm respectively. Table 5.6 gives details of the resource usage under the existing and the improved technologies. The results demonstrate that land is a major production constraint under the improved technology situation. Increasing amounts of labour were used in production under the improved technology compared to the existing technology.

Family labour utilization increased from 376, 421 and 470 mandays to 480, 566 and 566 mandays for small, medium and large farm categories respectively. This was an increase from 65.62, 73.47 and 82.02 per cent to 83.77, 98.78 and 98.78 per cent for small, medium and large farm categories respectively. Under the improved technology, labour demand was in excess of family labour supply and therefore additional labour was hired to fill the gap. The labour hired was 61, 415 and 545 mandays for small medium and large farms respectively.

The amount of capital available with the farmer varied considerably with farm size irrespective of the prevailing technology level. The larger the farm the higher the amount of capital available with the farmer. In all the three farm categories and under both the existing and the improved technology situations, capital available with the farmer was utilized fully (100 per cent).

Table 5.6 Resource Usage in Optimal Farm Plans, UM1, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category Size	ha.	Small 0.40	Medium 1.52	Large 2.09	Small 0.40	Medium 1.52	Large 2.09
Land LR	ha.	0.27 (67.50)	1.52 (100)	1.60 (76.56)	0.40 (100)	1.52 (100)	2.09 (100)
Land SR	ha.	0.13 (32.50)	0.54 (35.53)	0.59 (28.23)	0.40 (100)	1.52 (100)	2.09 (100)
Labour (F)	md.	376 (65.62)	421 (73.47)	470 (82.02)	480 (83.77)	566 (98.78)	566 (98.78)
Labour (H)	md.	-	-	-	61	415	545
Capital (A)	Kshs	51000 (100)	88000 (100)	90000 (100)	97000 (100)	154000 (100)	171000 (100)
Capital (B)	Kshs	-	-	-	-	-	-

Figures in parentheses are percentages

Notes :

LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F)	=	Family Labour
Labour (H)	=	Hired Labour
Capital (A)	=	Capital Available
Capital (B)	=	Borrowed Capital

Under the improved technology the results further showed that land in both long-rains and short-rains seasons are binding. The shadow price or MVP for the lands were far in excess of Kshs 5000 per unit land. The lowest MVP recorded was Kshs 5230 per hectare in the short-rains season occurring in the small farm category. The highest MVP was Kshs 17915 per hectare recorded in the long-rains season occurring in the small farm category. These results demonstrate that renting additional land during the seasons when land is binding is economically beneficial. However it is important to note that the high MVP recorded is due to high returns from tea and coffee enterprises. These are perennial crops and neighbouring farmers are likely to be unwilling to rent out their land for such long periods which may run into several decades.

5.2.3 Optimal Farm Plans for Agroecological Zone UM2

The agroecological zone UM2 is the main coffee zone. In fact it is more widely known as coffee zone than by other name. Apart from Coffee, the zone is also suitable for many other crops such as maize, beans, Irish potatoes and bananas. However farmers in this zone seem to allocate more resources for production of coffee not only because of expected high returns from coffee but also because the crop acts as loan guarantee. Coffee prices depend on the world market prices. The prices fluctuate violently from year to year. Despite the risks and uncertainties associated with coffee enterprise, it remains the doyen of the farmers in this zone.

In the problem formulation minimum subsistence requirements for the farm family were taken into account. Maize-beans intercrop and Irish potatoes were incorporated into the model for subsistence requirements.

The minimum level for each of the activities was specified rigorously as averaged from the farmers responses. Other activities which were included in the model were pure-stand maize, bananas and egg production. Since it is a common practice for the farmers to keep at least one dairy cow for subsistence milk requirement, milk production constraint was incorporated into the model with a minimum level of one dairy unit under zero-grazing unit. Crops that are cultivated in two seasons such as maize and Irish potatoes were treated as separate activities in the long-rains and the short-rains seasons.

The three farm categories, small medium and large were 0.59, 1.08 and 3.00 hectares respectively. The results of the optimisation problem are presented in table 5.7.

The results indicate that optimal farm plans under the improved technology are economically more viable than the optimal farm plans under the existing technology in terms of employment creation and income generation across the farm categories. Net farm incomes increased from Kshs 49086, 66741 and 77415 to Kshs 70300, 121822 and 143914 for small, medium and large farm categories respectively. This accounted for a proportional increase from 43.22, 82.53 and 85.90 per cent for small, medium and large farm categories respectively over the existing technology situation. Employment generation under the improved technology increased by 34.36, 56.61 and 80.29 per cent for small, medium and large farm categories respectively over the existing technology.

Land usage under the existing and improved technology levels in both the long-rains and the short-rains seasons across the farm categories was 100 per cent with exception of large farm category in the existing

Table 5.7 Optimal Farm Plans, UM2, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	**Unit**						
Maize-Beans LR	ha.	0.47	0.10	0.10	0.10	0.10	0.10
Maize LR	ha.	-	0.56	1.11	-	-	2.10
Maize SR	ha.	-	0.45	0.97	-	-	-
Irish potatoes LR	ha.	-	0.29	-	-	-	-
Irish potatoes SR	ha.	0.47	0.50	0.31	0.10	0.10	2.20
Coffee	ha.	0.22	0.03	0.16	0.39	0.88	0.70
Dairy	du.	1.00	1.00	1.00	1.00	1.00	1.00
Total Net Returns	Kshs.	49086	66741	77415	70300	121822	143914
B: Resource Usage							
Land LR	ha.	0.59	1.08	1.48	0.59	1.08	3.00
Land SR	ha.	0.59	1.08	1.54	0.59	1.08	3.00
Labour	md.	422	454	487	567	711	878
Capital	Kshs	63000	97437	99451	137000	205000	404124
C: Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					43.22	82.53	85.90
Increase in Employment (%)					34.36	56.61	80.29

Notes :

1 du. (dairy unit) = 1 cow + 1 calf
LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)

technology level. In this latter case , land usage in the long-rains and the short-rains seasons was 49.33 and 51.33 per cent respectively. This result demonstrates that land is a major constraint to production in this agroecological zone. Increasing amounts of labour was used in the production process under the improved technology compared to the existing technology situation. Table 5.8 provides the details of resource usage under the existing and improved technologies. Family labour utilization increased from 422, 454 and 487 mandays to 512, 534 and 560 mandays for small, medium and large farm categories respectively. This represented a proportional increase from 73.65, 79.23 and 84.99 per cent to 89.35, 93.19 and 97.73 per cent for small, medium and large farm category respectively over the existing technology. Under the improved technology level, labour demand was more critical and family labour fell short of supplying adequate labour.

This resulted in hiring of additional labour of 55, 177 and 318 mandays for small, medium and large farm categories respectively. Capital available with the farmer varied according to the farm size. Larger farms had more capital available with the farmer irrespective of the technology level. Across the farm categories and under both the existing and improved technology levels, the available capital with the farmer was fully (100 per cent) utilized with the exception of medium and large farm categories under the existing technology. In this case the capital utilized represented 73.26 and 51.80 per cent respectively. Additional Kshs capital of 5124 was borrowed for large farm under the improved technology to alleviate the shortage.

Table 5.8 Resource Usage in Optimal Farm Plans, UM2, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category Size	ha.	Small 0.59	Medium 1.08	Large 3.00	Small 0.59	Medium 1.08	Large 3.00
Land LR	ha.	0.59 (100)	1.08 (100)	1.48 (49.33)	0.59 (100)	1.08 (100)	3.00 (100)
Land SR	ha.	0.59 (100)	1.08 (100)	1.54 (51.33)	0.59 (100)	1.08 (100)	3.00 (100)
Labour (F)	md.	422 (73.65)	454 (79.23)	487 (84.99)	512 (89.35)	534 (93.19)	560 (97.73)
Labour (H)	md.	-	-	-	55	177	318
Capital (A)	Kshs	63000 (100)	97437 (73.26)	99451 (51.80)	137000 (100)	205000 (100)	399000 (100)
Capital (B)	Kshs	-	-	-	-	-	5124

Figures in parentheses are percentages

Notes :

LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F)	=	Family Labour
Labour (H)	=	Hired Labour
Capital (A)	=	Capital Available
Capital (B)	=	Borrowed Capital

The results further revealed that land is a major constraint to production in the zone. Land resource was binding across all the farm categories under the existing and the improved level of technologies in both the long-rains and short-rains seasons except for large farms under existing technology. The shadow price or MVP of land in both seasons was considerably high, Kshs 80177 per unit, occurring in the small farm category during the short-rains season. However the possibilities of a farmer renting land to grow coffee are slim. The high MVP recorded is due to high returns from coffee, a perennial crop with a lifespan of over forty years.

5.2.4. Optimal Farm Plans for Agroecological Zone UM3

The agroecological zone UM3 is also known as marginal coffee zone. Tea and coffee being the most prominent cash crops in Embu District, the agroclimatic zones are sometimes referred to in relation to the two major crops, hence the naming - marginal coffee zone. As the name suggests, coffee is grown in this area but the performance of the crop is dismal. Faced with low yields, coffee farmers here are prone to making losses in coffee production from time to time depending on price levels. The other major production activities are maize-beans intercrop, pure-stand maize, bananas, Irish potatoes, dairy and egg production. Bananas are grown for both subsistence and cash. Part of the farm produce is sold for cash irrespective of whether the produce was initially intended for subsistence.

Maize beams intercrop and Irish potatoes were incorporated into the linear programming model to satisfy subsistence requirements of the farmer. The minimum for each of the activities was specified. Livestock enterprises viz dairy and egg production, were included in the model mainly for commercial purposes. Maize-beams intercrop, pure-stand maize and Irish potatoes are grown in the two seasons the long-rains and short rains seasons. Hence each of the activities undertaken in a separate season was treated as separate activity.

The synthetic farm sizes were 0.70, 1.06 and 2.21 ha. for small, medium and large farm categories respectively. The results of the linear programming are presented in table 5.9.

The results indicated that the optimal farm plans under the improved technology are economically superior to the optimal farm plans under the existing technology in terms of employment creation and income generation in all the farm size categories. Farm incomes increased from Kshs 13880, 22518 and 43311 to Kshs 18734, 31100 and 58500 for small, medium and large farm categories respectively. This accounted for a proportional the increase of 34.97, 38.11 and 35.07 per cent for small medium and large farm classes respectively over the existing technology. Employment creation under improved technology increased by 8.92, 28.24 and 60.63 per cent for small, medium and large farm size classes respectively over the existing technology.

Land usage under the existing and improved technologies in both the long-rains and short-rains seasons, and in every farm size class was 100 per cent. This demonstrated the fact that land is a major constraint in production in this agroecological zone. Although increasing amounts of labour were employed in production under the improved technology compared to the existing technology, the numbers as well as in terms of percentage, the figures were marginal. Family labour utilization increased from 84, 131 and 174 man days to 91, 168 and 280 mandays for small,

Table 5.9 Optimal Farm Plans, UM3, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	**Unit**						
Maize-Beans LR	ha.	0.07	0.07	0.07	0.10	0.10	0.10
Maize-Beans SR	ha.	0.03	0.03	0.03	-	-	-
Maize LR	ha.	-	-	-	0.60	0.96	2.11
Irish potatoes SR	ha.	0.04	0.04	0.04	-	1.06	2.21
Banana	ha.	0.63	0.99	2.14	-	-	-
Egg	pu.	0.09	0.25	0.07	-	-	-
Total Net Returns	Kshs.	13880	22518	43311	18734	31100	58500
B. Resource Usage							
Land LR	ha.	0.70	1.06	2.21	0.70	1.06	2.21
Land SR	ha.	0.70	1.06	2.21	0.70	1.06	2.21
Labour	md.	84	131	174	91	168	280
Capital	Kshs	34000	58000	82000	76953	115769	241415
C. Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					34.97	38.11	35.07
Increase in Employment (%)					8.92	28.24	60.63

Notes :

1 pu. (poultry unit)	=	100 layers
LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)

medium and large farm size classes respectively. This accounted for a proportional increase from 14.58, 22.86 and 30.42 per cent to 15.88, 28.45 and 38.22 per cent. Although the available family labour was not completely exhausted in general, there were particular months, August and November, under improved technology situation in which additional labour was hired to the tune of 5 and 61 mandays for medium and large farm classes respectively. This increased labour employment by 8.92, 28.24 and 60.63 per cent for small, medium and large farm categories respectively over existing technology situation. Capital available with the farmer was fully (100 per cent) exhausted. Table 5.10 provides the details of resource usage under the existing and improved technology situations. Capital available with the farmer as in the previous cases increased with the size of farms in both technology situations.

The larger the farm the higher the capital available with the farmer. Capital was found to be more limiting under improved technology situation where additional capital of Kshs 4953, 19769 and 116415 for small, medium and large farm respectively was borrowed.

Under the improved technology, the results revealed that land in both long-rains and short-rains seasons are binding in all the three farm size categories. The shadow price or MVP for land in the cases was in excess of Kshs 1000 per unit of land. The lowest MVP was Kshs 1220 per ha. occurring in the long-rains season in the large farm category. The highest MVP was Kshs 66304 per hectare occurring in the short-rains season in the small farm category. Again, renting land in such cases would pay wherever land for renting is available.

Table 5.10 Resource Usage in Optimal Farm Plans, UM3, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category		Small	Medium	Large	Small	Medium	Large
Size	ha.	0.70	1.08	2.21	0.70	1.08	2.21
Land LR	ha.	0.70 (100)	1.06 (100)	2.21 (100)	0.70 (100)	1.06 (100)	2.21 (100)
Land SR	ha.	0.70 (100)	1.06 (100)	2.21 (100)	0.70 (100)	1.06 (100)	2.21 (100)
Labour (F)	md.	84 (14.58)	131 (22.86)	174 (30.42)	91 (15.88)	168 (28.45)	280 (38.22)
Labour (H)	md.	-	-	-	-	5	61
Capital (A)	Kshs	34000 (100)	58000 (100)	82000 (100)	72000 (100)	96000 (100)	125000 (100)
Capital (B)	Kshs	-	-	-	49534	19769	116415

Figures in parentheses are percentages

Notes :

LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F)	=	Family Labour
Labour (H)	=	Hired Labour
Capital (A)	=	Capital Available
Capital (B)	=	Borrowed Capital

5.2.5 Optimal Farm Plans for Agroecological Zone UM4

The agroecological Zone UM4 does not support the traditional cash-crops of Embu District, tea and coffee. The zone occurs in drier, lower attitudes, where the two cash-crops are not successfully cultivated. Cotton performs reasonably well but the crop is almost abandoned due to low producer prices. Maize, beans and Irish potatoes are grown mainly for subsistence requirements, however farmers sell part of these produce for cash.

Maize-beans intercrop and Irish potatoes were included in the model for subsistence requirements. The minimum requirements for each of the activities were specified rigorously. Pure-stand maize was included in the model to cater for farmers with large pieces of land who may cultivate maize in pure stand. Banana and cotton production was incorporated into the model. Egg and dairy production were the livestock activities considered in the model. Maize-beams intercrop, pure-stand maize and Irish potatoes are grown in both long-rains and short-rains seasons, hence each activity undertaken in a separate season was treated as a separate activity.

Synthetic farm size categories, small, medium and large were 0.53, 1.17 and 3.19 ha. respectively. The optimal farm plans developed are presented in table 5.11.

The results revealed that the optimal farm plans under the improved technology are economically more viable than the optimal plans under the existing technology in terms of employment creation and income generation across the three farm size categories. In real terms the increases are

Table 5.11 Optimal Farm Plans, UM4, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	**Unit**						
Maize-Beans LR	ha.	0.10	0.10	0.10	0.49	1.13	2.33
Maize-Beans SR	ha.	-	-	-	0.53	1.17	2.19
Irish potatoes LR	ha.	0.04	0.04	0.04	0.04	0.04	-
Irish potatoes SR	ha.	-	-	-	-	-	0.04
Egg	pu.	0.26	0.41	0.53	0.20	-	-
Total Net Returns	Kshs.	2735	4284	5446	3789	5489	7767
B. Resource Usage							
Land LR	ha.	0.14	0.14	0.14	0.53	1.17	2.33
Land SR	ha.	-	-	-	0.53	1.17	2.33
Labour	md.	103	158	199	157	183	356
Capital	Kshs	26000	38000	47000	50000	62740	121487
C. Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					38.54	28.12	42.62
Increase in Employment (%)					52.02	16.01	78.80

Notes :

1 pu. (poultry unit) = 100 layers
LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)

comparatively lower than those of the higher altitudes where tea and coffee are grown. None of the net returns rise above, Kshs 7800 across all the three farms categories under either existing or improved technology situations. Net returns increased from Kshs 2735, 4282 and 5446 to Kshs 3789, 5489 and 7767 for small, medium and large far categories respectively. This accounted for an increase of 38.54, 28.12 and 42.62 per cent for small, medium and large farm categories respectively over the existing technology. Employment creation increased by 52.02, 16.01 and 78.80 per cent for small, medium and large farm classes respectively over the existing technology.

Land usage under the existing technology was low both in the long rains season and the short-rains seasons. However, there was a progressive increase in usage under the improved technology. Land usage in the long rains increased from 26.42, 11.97 and 4.39 per cent under the existing technology to 100 per cent for both small and medium, and 73.04 per cent for large farm size class under the improved technology. Short-rains land under the existing technology remained fallow in all the three farms categories. However under the improved technology situation, the land was utilized fully (100 per cent) in the small and medium farms, and 69.91 per cent in the large farm category. Table 5.12 shows the details of resource usage under the existing and the improved technology situations. Family labour utilization increased from 103, 158 and 199 mandays under the existing technology to 157, 183 and 320 mandays for small, medium and large farm classes respectively under the improved technology. This represented an increase from 17.99, 27.57 and 34.75 per cent to 27.35, 31.98 and 55.85 per cent for small, medium and

Table 5.12 Resource Usage in Optimal Farm Plans, UM4, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category Size	ha.	Small 0.53	Medium 1.17	Large 3.19	Small 0.53	Medium 1.17	Large 3.19
Land LR	ha.	0.14 (26.42)	0.14 (11.97)	0.14 (4.39)	0.53 (100)	1.17 (100)	2.33 (73.04)
Land SR	ha.	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.53 (100)	1.17 (100)	2.23 (69.91)
Labour (F)	md.	103 (17.99)	158 (27.57)	199 (34.75)	157 (27.35)	183 (31.98)	320 (55.85)
Labour (H)	md.	-	-	-	-	-	36
Capital (A)	Kshs	53000 (100)	80300 (100)	80300 (100)	117000 (100)	148000 (100)	183000 (100)
Capital (B)	Kshs	-	-	-	-	12740	71487

Figures in parentheses are percentages

Notes :

LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F)	=	Family Labour
Labour (H)	=	Hired Labour
Capital (A)	=	Capital Available
Capital (B)	=	Borrowed Capital

large farm classes respectively. Additional 36 mandays of labour was hired to meet the labour shortage in the large farm category under the improved technology. Capital available with the farmer was fully (100 per cent) utilized across the farm size categories and under both the existing and improved technology situations.

Under the improved technology and in medium and large farm size categories, additional Kshs 12740 and 71487 respectively was borrowed to bridge the gap of capital shortage.

The results indicated that capital is a constraining factor to production in this zone. Under the improved technology situation where capital was unrestricted, land usage increased dramatically, particularly in the short-rains season where land usage increased from fallow to 100 per cent in small and medium farm category and 69.91 per cent in large farm category. Similar trend was observed with the long-rains land as previously discussed.

Under the improved technology, the results indicated that both the long-rains land and the short-rains land are binding in small and medium farm categories. The shadow price of Kshs 4344 and Kshs 18585 per ha for small and medium farm categories respectively were recorded. However for large farm category, land resource was not binding. Close observation revealed that as one moves from the wet high attitudes to drier lower attitude zones, farm sizes increased. Land becomes less and less binding. This trend was observed also by Hirose (1985). Instead capital is becoming progressively binding as one moves towards the lower attitudes.

5.2.6. Optimal Farm Plans for Agroecological Zone LM3

The agroecological Zone LM3 is christened as cotton zone. This is because the traditional cash-crop of this zone has been always cotton. However cotton crop has been progressively abandoned over the years by farmers due to poor returns. More the less some farmers still grow the crop for cash of better alternatives. As a result the emerging cropping pattern tends to incline towards growing crops which can be used for subsistence as well. Maize, beans, Irish potatoes, bananas and pigeon peas are grown for subsistence as well as cash.

The linear programming model incorporated Maize-beans, intercrop, Pure-stand maize, and Irish potatoes grown in both long-rains and short-rains seasons. The long-rains and the short-rains crops were treated as separate activities. Since bananas and pigeon peas cropping periods cover both seasons and hence were treated as single activities. Egg and dairy production were considered as commercial ventures. Minimum subsistence requirements for maize-beans intercrop and Irish potatoes were included in the model to cater for the farm family food needs. Cotton production activity occupied prominent position as cash crop in the model.

The three farm size classes, small medium and large were 0.61, 1.05 and 3.03 hectares respectively . The optimal farm plans generated are presented in table 5.13.

The results revealed that the optimal farm plans under the improved technology are economically superior to the optimal farm plans under the existing technology in terms of employment creation as well as income generation in all the three farm size categories. Net farm incomes increased

Table 5.13 Optimal Farm Plans, LM3, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	**Unit**						
Maize-Beans LR	ha.	0.03	0.03	0.03	0.61	1.05	2.30
Maize-Beans SR	ha.	0.07	0.07	0.07	0.57	1.01	2.05
Irish potatoes LR	ha.	0.04	0.04	0.04	0.04	0.04	-
Irish potatoes SR	ha.	-	-	-	-	-	0.04
Banana	ha.	0.26	0.59	0.49	-	-	-
Pigeon peas	ha.	0.28	0.39	2.47	-	-	0.73
Total Net Returns	Kshs.	2795	6035	11473	4323	7788	16326
B. Resource Usage							
Land LR	ha.	0.61	1.05	3.03	0.61	1.05	3.03
Land SR	ha.	0.61	1.05	3.03	0.61	1.05	2.82
Labour	md.	77	158	306	114	232	400
Capital	Kshs	16000	28000	41000	40000	77000	131000
C. Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					54.67	29.05	42.30
Increase in Employment (%)					48.05	46.84	30.72

Notes :

LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)

from Kshs 2795, 6035 and 11473 to Kshs 4323, 7788 and 16326 for small, medium and large farms respectively. This accounted for a proportional increase of 54.67, 29.05 and 42.30 per cent for small, medium and large farm categories respectively. Employment increased by 48.05, 46.84 and 30.72 per cent for small, medium and large farm respectively.

Land usage under the existing and the improved technology scenarios and in both the long-rains and short-rains was 100 per cent except for short-rains land, under the improved technology in the large farm category which was 93.07 per cent Table 5.14 provides details of usage of production resources under the existing and the improved technologies. Family labour utilization was however low. The family labour utilization increased from 77, 158 and 306 mandays under the existing technology to 114, 232 and 400 mandays under the improved technology for small, medium and large farm category respectively. This indicated surplus family labour occurring under the existing and the improved technology scenarios. Nonetheless under the improved technology, in large farm category, additional 36 mandays were hired to meet labour shortfall in some critical months. Capital available with the farmer varied according to farm size. The larger the farm the higher the capital available with the farmer . All the capital available with the farmer was fully (100 per cent) utilized in every farm category under the existing and the improved technology scenarios. The results demonstrate that land and capital pose major constraints to crop production in the area.

Under the existing technology and the improved technology, the results indicated that land is binding for both long-rains and short-rains

Table 5.14 Resource Usage in Optimal Farm Plans, LM3, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category		Small	Medium	Large	Small	Medium	Large
Size	ha.	0.61	1.05	3.03	0.61	1.05	3.03
Land LR	ha.	0.61 (100)	1.05 (100)	3.03 (100)	0.61 (100)	1.05 (100)	3.03 (100)
Land SR	ha.	0.61 (100)	1.05 (100)	3.03 (100)	0.61 (100)	1.05 (100)	2.82 (93.07)
Labour (F)	md.	77 (13.44)	158 (27.54)	306 (53.40)	114 (19.94)	232 (40.53)	400 (69.81)
Labour (H)	md.	-	-	-	-	-	36
Capital (A)	Kshs	16000 (100)	28300 (100)	41300 (100)	40000 (100)	77000 (100)	131000 (100)
Capital (B)	Kshs	-	-	-	-	-	-

Figures in parentheses are percentages

Notes :

LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F)	=	Family Labour
Labour (H)	=	Hired Labour
Capital (A)	=	Capital Available
Capital (B)	=	Borrowed Capital

seasons across all farm categories except for the short-rains land under the improved technology in the large farm class. The shadow price of land varied from the lowest figure of Kshs 641 per hectare recorded under the existing technology to the highest figure of Kshs 3471 per hectare under improved technology. Similarly shadow price of capital varied from Kshs 223.06 under the improved technology to Kshs 1153.59 under the existing technology.

5.2.7 Optimal Farm Plans for Agroecological Zone LM4.

The agroecological zone LM4 is a low, dry zone best described as marginal for agricultural purposes. The cropping pattern is predominantly subsistence. Cotton cultivation is undertaken by some farmers hence it is named as marginal cotton zone. Draught tolerant crop varieties are popularly grown in this zone. Therefore, in the model construction all possible activities of the main crops were considered.

The linear programming model included maize-beans intercrop, pure-stand maize, cotton pigeon peas, banana, and egg production. Commercial activities that yielded negative set returns were omitted from the model. Cotton was therefore omitted from the model under the existing technology because it gives negative net returns. Subsistence enterprises were included in the model, whether or not they yielded positive net returns. Therefore, the minimum requirements for each of these activities were specified at the same levels. Maize and beans are grown in two seasons, long-rains and short-rains seasons. Each crop activity undertaken in a separate season therefore was treated as a separate activity.

Three farm size classes, small, medium and large were 0.65, 1.22 and 3.45 hectares respectively. The optimal farm plans were worked out and the results are presented in Table 5.15.

The results indicated that the optimal farm plans under the improved technology are economically superior to the optimal farm plans under the existing technology in terms of employment creation and income generation in all the three farms size categories.

Net farm incomes increased from Kshs 938, 1951 and 4120 to Kshs 1710, 3385 and 5621 for small, medium and large farm categories respectively. This accounted for a proportional increase of 82.27, 73.51 and 36.43 per cent for small, medium and large farm categories respectively over the existing technology. Employment creation under the improved technology increased by 72.51, 67.48 and 88.42 per cent for small, medium and large farm categories respectively over the existing technology. Land usage under improved technology, in both long-rains and short-rains seasons and across the farm categories increased substantially over the existing technology.

Land utilization during the long-rains season increased from 0.36, 0.55 and 0.98 hectares to 0.65, 1.22 and 2.21 hectares for small, medium and large farm categories respectively. This resulted in 100 per cent usage for every farm category except large farm where the increase accounted for 64.06 per cent over the existing technology. Similar trend was observed with usage of land in the short-rains season. Land usage in this case increased from 0.25, 0.45 and 0.88 hectares to 0.65, likewise, this accounted for 100 per cent increase across all the farm categories except for large farm where the increase accounted for 39.13 per cent

Table 5.15 Optimal Farm Plans, LM4, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	**Unit**						
Maize-Beans LR	ha.	0.10	0.10	0.10	0.47	1.01	2.21
Maize-Beans SR	ha.	-	-	-	0.47	1.01	1.35
Banana	ha.	0.26	0.45	0.88	0.18	0.21	-
Total Net Returns	Kshs.	938	1951	4120	1710	3385	5621
B. Resource Usage							
Land LR	ha.	0.36	0.55	0.98	0.65	1.22	2.21
Land SR	ha.	0.26	0.45	0.88	0.65	1.22	1.35
Labour	md.	46	79	147	79	132	277
Capital	Kshs	7000	11800	18300	12100	17800	25500
C. Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					82.27	73.51	36.43
Increase in Employment (%)					72.51	67.48	88.42

Notes :

LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)

over the existing technology. Table 5.16 provides details of resource usage under the existing and improved technology scenarios. Family labour utilization increased from 46, 79 and 147 mandays to 105, 206 and 271 mandays for small, medium and large farm categories respectively. This represented an increase from 8.11, 13.72 and 25.73 per cent to 18.39, 36.03 and 47.34 per cent respectively over the existing technology. No additional labour was hired. Capital available with the farmer varied according to the farm size classes, under the existing and the improved technology scenarios. The larger the farm and higher the capital available with the farmer. Across all the farm size classes and under both the existing and improved technology situations. The available capital was fully (100 per cent) utilized. This an indication of capital being a major constraint in production.

Under the existing technology where capital is restricted, in other words, there is no provision for borrowing capital was binding across the three farm categories. Neither land nor labour was binding in this case. However, under the improved technology scenario, results revealed that land is binding in both the long-rains and short-rain seasons, across all the farm categories except for large farm. The shadow price or MVP recorded was Kshs 1582 per hectare for land in both seasons. Renting additional land in such case would pay so long as the rent paid is below the MVP of land.

4.2.8 Optimal Farm Plans for Agroecological Zone LM5

The agroecological zone LM5 is located in a low attitude zone with not very high potential for agriculture. In fact it is known as millet zone implying that millets are the only crops likely to perform well given their

Table 5.16 Resource Usage in Optimal Farm Plans, LM4, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category Size	ha.	Small 0.65	Medium 1.22	Large 3.45	Small 0.65	Medium 1.22	Large 3.45
Land LR	ha.	0.36 (53.85)	0.55 (45.08)	0.98 (28.41)	0.65 (100)	1.22 (100)	2.21 (64.06)
Land SR	ha.	0.26 (38.46)	0.45 (36.89)	0.88 (25.51)	0.65 (100)	1.22 (100)	1.35 (39.13)
Labour (F)	md.	46 (8.11)	79 (13.72)	147 (25.73)	105 (18.39)	206 (36.03)	271 (47.34)
Labour (H)	md.	-	-	-	-	-	-
Capital (A)	Kshs	7000 (100)	11800 (100)	18300 (100)	12100 (100)	17800 (100)	2550 (100)
Capital (B)	Kshs	-	-	-	-	-	-

Figures in parentheses are percentages

Notes :

LR	=	Long Rains
SR	=	Short Rains
Kshs.	=	Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F)	=	Family Labour
Labour (H)	=	Hired Labour
Capital (A)	=	Capital Available
Capital (B)	=	Borrowed Capital

drought tolerance ability. The cropping pattern of this zone is predominantly subsistence although the recent times have seen early maturing, draught escaping crop varieties with high returns gaining popularity in the zone.

All the major crops which are grown in this zone were included in the model, maize-beans intercrop, pure stand maize, cotton, pigeon peas, bananas cowpeas and sorghum were crop activities while egg production represented livestock activity. Cotton and sorghum give negative returns and therefore omitted from the model under improved technology since the returns are positive in this situation. Maize-beans intercrop activity is undertaken primarily for subsistence requirements. Therefore the minimum requirement constraint for this activity was incorporated into the model. All the crops with exception of banana and pigeon peas are grown in two seasons. Hence each crop grown in a separate season was treated as a separate activity.

The farm sizes for the three categories of farms, small, medium and large were 0.58, 1.36, 4.32 hectares respectively. The optimal farm plans developed are presented in table 5.17.

The results revealed that optimal farm plans under the improved technology are economically more viable than optimal farm plans under the existing technology in terms of employment creation and income generation across the three farm categories. Net farm incomes increased from Kshs 8588, 11108 and 13705 to Kshs 13901, 16579 and 20984 for small, medium and large farm category respectively. This accounts for proportional increase of 61.86, 80.05 and 53.11 per cent for small, medium and large farm categories respectively over the existing technology.

Table 5.17 Optimal Farm Plans, LM5, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Size Category		Small	Medium	Large	Small	Medium	Large
A. Enterprise	Unit						
Maize-Beans LR	ha.	0.10	-	-	-	-	-
Maize-Beans SR	ha.	-	0.10	0.02	0.58	1.36	4.32
Cowpeas LR	ha.	0.49	0.60	1.31	-	-	-
Gram LR	ha.	-	1.02	0.11	0.58	1.36	4.32
Egg	pu.	0.37	0.45	-	0.65	1.35	1.35
Total Net Returns	Kshs.	8588	11108	13705	13901	16579	20984
B. Resource Usage							
Land LR	ha.	0.58	1.36	0.14	0.58	1.36	4.32
Land SR	ha.	0.58	0.70	0.12	0.58	1.36	4.32
Labour	md.	274	357	563	345	747	1169
Capital	Kshs	12500	21800	36500	36000	70500	95000
C. Incomes and Employment Potential over the Existing Technology							
Increase in Total Net Returns (%)					61.86	80.05	53.11
Increase in Employment (%)					26.06	109.25	107.64

Notes :

1 pu. (poultry unit) = 100 layers
LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)

Employment creation under the improved technology increased by 26.06, 109.25 and 107.64 per cent for small, medium and large farm categories respectively over the existing technology.

Land usage under the existing and improved technologies across the farm categories was 100 per cent except in three cases. Land utilization on medium farms, under the existing technology during the short-rains season was 51.47 per cent. Under the existing technology, during both the long-rains and short-rains seasons, land utilization was 3.24 and 2.78 per cent respectively on large farms.

However family labour utilization displayed increasing trend under the improved technology compared to the existing technology. Table 5.18 gives details of utilization of resources under the existing and the improved technology situations.

Family labour usage increased from 274, 357 and 490 mandays to 345, 555 and 569 mandays for small, medium and large farm categories respectively. This represented a proportional increase from 47.80, 62.28 and 85.49 per cent to 60.25, 96.82 and 99.25 per cent for small, medium and large farm respectively over the existing technology. Additional labour of 192 and 600 mandays was hired under the improved technology for medium and large farm categories respectively to bridge the gap of labour shortage. Capital available with the farmer on the other hand varied according to the farm size in both the existing and the improved technology scenarios. Larger holdings had more capital available with the farmer than smaller ones. In all the farm situations however, the available capital was 100 per cent utilized.

Table 5.18 Resource Usage in Optimal Farm Plans, LM5, Embu District, 1996.

Technology Level		Existing Technology			Improved Technology		
Farm Category Size	 ha.	Small 0.58	Medium 1.36	Large 4.32	Small 0.58	Medium 1.36	Large 4.32
Land LR	ha.	0.58 (100)	1.36 (100)	0.14 (3.24)	0.58 (100)	1.36 (100)	4.32 (100)
Land SR	ha.	0.58 (100)	0.70 (51.47)	0.12 (2.78)	0.58 (100)	1.36 (100)	4.32 (100)
Labour (F)	md.	274 (47.80)	357 (62.28)	490 (85.49)	345 (60.25)	555 (96.82)	569 (99.25)
Labour (H)	md.	-	-	-	-	192	600
Capital (A)	Kshs	12500 (100)	21800 (100)	36500 (100)	36000 (100)	70500 (100)	95000 (100)
Capital (B)	Kshs	-	-	-	-	-	-

Figures in parentheses are percentages

Notes :

LR = Long Rains
SR = Short Rains
Kshs. = Kenya Shilling (1 Kshs = US $ 0.01669)
Labour (F) = Family Labour
Labour (H) = Hired Labour
Capital (A) = Capital Available
Capital (B) = Borrowed Capital

Conclusions

Close observation of the linear programming results revealed that under the existing technology and also the improved technology in both long-rains and short-rains seasons across the farm size categories land resource was binding. The only exceptions were medium farm category under the existing technology during the short-rains season and in large farm category during both seasons. The shadows prices varied from lowest figure of Kshs 747 to the highest, Kshs 10390. Leasing additional land whenever possible makes economic sense in such cases.

By perusing through the optimal farm plans across the eight agroecological zones, it is amply evident that adoption of improved technology combined with unrestricted capital availability, increases both incomes and employment opportunities irrespective of farm size.

Across the agroecological zones considered, land holdings increased in size as one moves from high altitude to low altitude zones. At the same time agricultural potential decreases likewise. The higher altitude zones are better endowed agriculturally than the lower altitude zones. This tendency has been confirmed by the current study which has recorded progressively less amount of capital available with a farmer as one moves from higher altitude to lower altitude zones. Labour resource is more limiting in the high altitude than low altitude zones. These findings can be summarised in a as below:

Altitude	Agricultural potential	Land	Labour	Capital
High	High	Limiting	Limiting	More
Low	Low	Nonlimiting	Nonlimiting	Less

The reasons why not all farmers are using improved technology is a subject for further investigations. However there are possible explanations: (i) Inadequate extension services regarding the advantages of using improved technology. (ii) Inability to understand the imparted improved technical know-how on the side of farmers. (iii) Farmers are averse to risks associated with implementation of the improved technology. (iv) Availability of affordable credit facilities.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Summary

Embu District is well endowed agriculturally. The diversified agroecological zones support the growing of various crops and rearing of different livestock species. Achieving self sufficiency in food production is a major goal in post-independent economic development planning of Kenya. A food policy in addition to population policy has to be put in place keeping in view the dire necessity of feeding the growing population. The food policy has placed more emphasis on increasing agricultural production by intensification of agriculture and increased productivity through improved technologies. Empirical evidences amply demonstrate that optimal allocation of resources played a greater role in stepping up productivity, increased farm incomes and employment opportunities. Profit in farming depends more on rational decisions rather than merely hard physical work. Highly variable farm incomes from farm enterprises put farmers entirely at the mercy of nature. Farmers have meagre resources at their disposal. It is difficult for farmers to achieve higher incomes and sustain a reasonable standard of living. It is therefore paramount that farmers allocate their limited resources optimally so as to yield assured and sustained flow of income from farm production activities. Hence proper combination of enterprises coupled with improved technology are crucial to placing farm business in a sound footing.

The influx of the job seekers into urban centres in Kenya is a national problem. Many young able bodied individuals from rural areas stream into the country's major cities with a hope of securing the ever elusive salaried employments. Embu District like any other district in Kenya has not been spared of this plague of rural-urban migration. The increasing population growth accompanied by large family sizes, diminishing farm holdings, falling standard of living and declining or stagnating farm incomes have exacerbated the situation.

Keeping the aforesaid facts in view, the present study is an attempt to investigate and explore the possibilities of increasing farm incomes and labour employment on different farm categories under different technology situations so as to stem the malady of migration from rural to urban agglomerations and also to attract the young entrepreneurs to venture into farming business. The specific objectives of the study were:

(i) To study resource endowment and use in different farming situations.

(ii) To examine the existing cropping pattern, income and employment under different farming situations.

(iii) To study income and employment potential on the basis of existing and improved technology by developing optimal farm plans for different farm situations, and

(iv) To suggest policies for improvement of agricultural production.

Embu District was purposively selected for the present study. Eight major agroecological zones were identified and included in the study. Both primary and secondary data were used. Primary data were obtained from randomly selected farmers through multistage stratified sampling technique.

Data from sampled farmers were collected by use of structured questionnaire through personal interview. Three synthetic farm size categories viz., small, medium and large, were developed for each agroecological zone considered. Linear programming technique was used to determine optimum resource allocation for different combination of enterprises under the existing and improved technology scenarios. The technical coefficients of farm enterprises were derived from the data collected from the sampled farms. In the existing technology situation, capital input was restricted and no provision was made for hiring of labour. However in the improved technology scenario, capital input and labour employment were unrestricted. The impact of resource optimisation on incomes and employment opportunities were thereafter examined. Minimum subsistence requirement constraints were incorporated into linear programming model to cater for farm family food needs. Appropriate computer software packages were used for database management and processing. The results of the study are summarised as follows:

Out of seventy eight respondents interviewed, 38.46 per cent were women, highlighting the increasing role played by women as farm managers. The majority (58.97 per cent) were above 40 years old. In fact 61.54 per cent of the respondents were between 31 and 50 years old. Only 11.54 per cent of the respondents were upto 30 years old. This was a strong indication that farming is yet to attract the younger generation.

The findings also revealed that farming was not yet a full time occupation as only 25.64 per cent were full time farmers. The rest were *telephone/briefcase farmers*[14] who were either full time employees of other establishments and/or are engaged in other income generating businesses in addition to farming. This was a clear indication that farming is not a priority income generating activity.

The optimal farm plans developed for all the agroecological zones considered generally displayed more or less similar pattern under the improved technology situation. Farm incomes and employment opportunities increased substantially over and above the existing technology scenario. Generally speaking, capital available with a farmer increased with the increase of altitude. The higher the altitude the higher the capital available with the farmer. Altitude *per se* had nothing to do with capital availability but throws light on the tendency for agricultural potential to increase progressively with the increase in altitude. The high potential agroecological zones where high income generating crops such as tea and coffee are grown, are found in relatively high altitudes. The converse was true for land resource. The higher the altitude the smaller the land holdings. In view of the stated facts , it can be inferred that land is a more limiting resource than capital in the higher altitude zones, whereas capital is more limiting in the lower altitudes than land resource. By the same token labour resource is more limiting in the higher altitude zones with higher agricultural potential than the lower less potential zones. The rest of this section discusses the results of specific agroecological zones.

In the agroecological zone LH1, better known as Tea Zone, the optimal farm plans developed under improved technology situation indicated

---

14 Farmers who are in touch with their farming activities from their urban bases through telephone or by occasional brief visits to the farms.

increase in net incomes of 55.27 per cent, 20.40 per cent and 46.73 per cent for small, medium and large farm categories respectively over the existing technology. Similarly employment opportunities increased by 90.41 per cent, 63.40 per cent and 84.10 per cent respectively. Additional labour of 175 mandays, 205 mandays and 344 mandays for small, medium and large farm categories respectively was hired to supplement family labour.

The results in the agroecological zone UM1 which is a transitional Tea/Coffee Zone followed similar pattern as that one of LH1 in terms of net returns and employment generation. The optimal farm plans developed under the improved technology situation indicated the increase in net incomes of 27.75 per cent, 28.61 per cent and 17.49 per cent for the small, medium and large farm categories respectively over the existing technology. Employment creation increased by 43.88 per cent, 133.02 per cent and 136.38 per cent for small, medium and large farm size classes respectively. Additional labour of 61 mandays, 451 mandays and 545 mandays respectively was hired to supplement family labour.

The results in the agroecological zone UM2 or Coffee Zone displayed similar trend as LH1 and UM2. In fact the three agroecological zones occupy the top three positions in terms of endowments. The increase in incomes and employment opportunities achieved by the optimisation in this zone was slightly lower than the ones realised in the first two zones discussed. The optimal farm plans developed under the improved technology situation indicated increase in net returns of 43.22 per cent, 82.53 per cent and 85.90 per cent for the small, medium and large farm categories respectively over the existing technology. Employment opportunities increased by 34.36 per cent, 56.61 per cent and 80.29 per cent respectively. Additional labour of 55 mandays, 177 mandays and 318 mandays for the small, medium and large category respectively was hired to supplement family labour. Land usage across small and medium farm categories, under both the existing and improved technology situations was 100 per cent except for large farm category. In the latter case, there was an increase in the land usage from 49.33 per cent and 51.33 per cent for long-rains land and short-rains land under the existing technology to 100 per cent for both lands under improved technology situation.

The results of resource optimisation in agroecological zone UM3 yielded interesting observations compared to the other agroecological zones so far discussed, LH1, UM1,and UM2. Under the improved technology scenario, a big jump was recorded in the increase of net returns while the increase in employment creation was just moderate. The difference in the rates of increase between net returns and employment creation in the previously discussed agroecological zones were not as marked as in this case. The optimal farm plans developed under improved technology recorded increase in net returns of 34.97 per cent, 38.11 per cent and 35.07 per cent for small, medium and large farm categories respectively over the existing technology situation, while employment opportunities increased by 8.92 per cent, 28.24 per cent and 60.63 per cent respectively. Land utilisation across the farm categories under both the existing and improved technology scenarios was 100 per cent. Additional labour hired was minimal, 5 mandays and 61 mandays for medium and large farm categories respectively. However large capital requirements of Kshs 49534, Kshs 19769 and Kshs 116415 were borrowed for small, medium and large farm categories respectively.

On optimisation of resources, the results in the agroecological zone UM4 exhibited pattern similar to UM3 in terms of increase in net incomes and employment creation. The difference in rates of increase between net returns and employment creation was extremely wide. Optimal farm plans developed under improved technology situation recorded increase in net returns of 38.53 per cent, 28.12 per cent and 42.62 per cent for small, medium and large farm categories respectively, while employment opportunities increased by 52.02 per cent, 16.01 per cent and 78.80 per cent respectively. Additional capital of Kshs 12740 and Kshs 71477 for medium and large farm categories was borrowed to augment the capital available with the farmer.

The agroecological zone LM3 is also known as Cotton Zone. The optimal farm plans developed under both the existing and improved technology situations failed to embrace cotton in the basis. This is a clear indication of low net returns generated by cotton crop. Resources are generally allocated to enterprises with high MVP. Nonetheless the optimal farm plans developed recorded increase in net ret returns of 54.67 per cent, 29.05 per cent and 42.30 per cent for the small, medium and large farm categories respectively. Similarly employment creation increased by 48.05 per cent, 46.84 per cent and 30.72 per cent respectively. Additional labour hired was marginal, 36 mandays for large farm category only. Land utilization was 100 per cent under both the existing and improved technology situations except for short-rains land under improved technology. In this case land usage was marginally lower than 100 per cent use. Although the percentage increase in the net returns were impressive, the actual figures in real terms were rather disappointing.

The results of optimisation of resources in the agroecological zone LM4 were similar to the ones in LM3 in terms of increased net returns and employment creation. The impressive percentage increases translated poorly in terms of actual figures. The optimal farm plans developed under the improved technology situation recorded increase in net returns of 82.27 per cent, 73.51 per cent and 36.43 per cent for the small, medium and large farm categories respectively over the existing technology. In the absolute figures an increase of 82.27 per cent represented a difference of Kshs 772 (from Kshs 938 to Kshs 1710) which cannot sustain even one adult equivalent in the Kenyan rural area. This elucidates the fact that impressive percentages are not necessarily supported by the realistic high returns from the enterprises. Similarly, employment opportunities increased by 72.51 per cent, 67.48 per cent and 88.42 per cent for small, medium and large farm categories respectively.

The agroecological zone LM5 is marginal in terms of agricultural endowments. It's semi-arid climatic conditions make it the least endowed zone of the eight agroecological zones considered in the study. It is apparent from the casual examination that no significant production can be achieved in this zone without provision for irrigation facilities. Despite the adverse climatic conditions, the optimisation of resources under the improved technology situation, yielded favourable results. The optimal farm plans developed recorded increase in net returns of 61.86 per cent, 80.05 per cent and 53.11 per cent for the small, medium and large farm category respectively over the existing technology. Similarly employment creation increased by 26.06 per cent, 109.25 per cent and 107.64 per cent respectively. Land usage under the improved technology situation was

100 per cent. There was no additional capital borrowed though 192 mandays and 600 mandays for medium and large farm categories respectively was hired to supplement family labour.

6.2 Conclusions and Policy Implications

On the basis of the results presented, the following conclusions can be drawn which would result in increased net returns and employment creation in Embu District.

1. The results of the study clearly demonstrated that there is an enormous scope for increasing net farm incomes and employment opportunities in farming by just reallocation of resources. Extension services should step up the use of resource allocation optimisation techniques. With the current liberalisation of microcomputers at district level, there is no limitation in using computer aided optimisation programmes. The district extension staff should prepare models of farm plans covering various farming situations for all the agroecological zones represented in the district. This will enable the optimal farm plans for individual farms to be generated quickly with minor adjustments whenever a farmer makes a request. Machinery for collecting data on input-output coefficients of the farms should be strengthened.

2. The study indicated that capital availability was a constraint generally on all the farms in the study area but it was more severe on the farms outside Tea and Coffee Zones. The government should make arrangements to fulfill the credit needs of farmers for productive purposes to enable them to introduce changes in cropping pattern.

The credit facilities should be readily available at affordable terms. This would accelerate the entire gamut of income and employment potential and offer one way to solve the problem of low incomes in different farming situations.

3. Land is a more constraining resource in high potential agroecological zones. It is not possible to increase land size. Therefore, farmers should be encouraged to rent land whenever possible on short term basis to expand production. Renting of land would be profitable so long as the rates are below MVP for land. This suggestion would benefit individual farmers. However by increasing land productivity, the community in particular and the nation at large will gain.

4. Labour input is a more severe constraint in Tea and Coffee Zones. Provision of affordable credit facilities would increase wage paying capacity and attract more labour from labour surplus areas.

5. The exclusion of cotton crop from the basis of optimal plans in the Cotton Zone sends ominous signals on the future of cotton industry. There is immediate need to re-examine the price policy regarding to the industry with the view of making it attractive to farmers.

6. Optimisation of resources recorded higher responses in terms of increased incomes in the zones outside Tea and Coffee Zones. This peculiar low response in Tea and Coffee Zones is explained by the fact that farmers in these zones operate closer to optimum point than the farmers elsewhere. In Kenya, Tea and Coffee Zones have

an increased number of extension agents. Ministry of Agriculture general extension staff, Tea Extension Officers from Kenya Tea Development Authority, Coffee Officers from Ministry of Agriculture and Coffee Extension Officers from Co-operative Societies/Unions are all posted to the two zones with a common objective of enhancing production. Other zones have much less extension staff posting. It follows naturally that higher responses would be recorded in the Tea and Coffee Zones. Therefore there is need to increase extension services in the other agroecological zones outside Tea and Coffee Zones as well.

6.3 Limitations of the Study

1. Due to budgetary constraints, manpower and logistical support were limited. As a result collection of data from a large sample of farmers could not be possible. A larger sample, perhaps would have yielded better results and greater reliability.

2. The interviews for collection of primary data were conducted at the end of the second cropping season. Very few farmers kept farm records. The quality of the data collected depended on the farmers memory capacity. Hence substantial errors were bound to occur in the derived technical coefficients.

3. The optimal farm plans developed were based on static programming conditions. Incorporating risk factor the programming situations would have added a more realistic picture to the results.

6.4 Suggestion for Future Studies

It is an established fact that since the liberalisation of Kenya's economy in 1992, prices of farm inputs and products have been erratic and fluctuating violently. Since then, farmers have been producing under increased risk. There is need to conduct a production study under risk so that the resultant plans incorporate risk element.

REFERENCES

Abate, G. (1995). Production Efficiency Analysis: The Case of Smallholder Farming in The Coffee Sector of Ethiopia and Kenya. *Farming Systems and Resource Economics in the Tropics.* **23**: xi + 316pp

Abdullahi Y. A., P. Hekstra, M.A. Ibrahim, S. Pleumpanya, M.R. Wickstead (1986). The Farming System in the Coffee Area, Kyeni South Location, Embu District, Kenya. ICRA Bulletin International Course for Development Oriented Research in Agriculture, Netherlands. **22**: 46pp.

Agbor, L.N.O. and E.E. Enabor (1989). Intercropping of Forest Trees and Food Crops Under Agroforestry in The Tropical Moist Forest Zone of Nigeria: A Linear programming Analysis. Trees for Development in Sub-Saharan Africa. Proceedings of a Regional Seminar Held by The International Foundation for Science (IFS), ICRAF House, Nairobi, Kenya, February 20-25 :103-117.

Asamenew, G. (1980). Resource Allocation for Small Scale Farmers of Star Grass Zone in Embu District, Kenya. A Linear Programming Approach. M Sc thesis, University of Nairobi.

Asamenew, G. and W.M. Mwangi (1985). Resource Allocation for Small Scale Farmers of the Star Grass Zone in Embu District, Kenya: A Linear Programming Approach. Discussion Papers, Institute for Development Studies, University of Nairobi. **277**: 15pp.

Banerjee, B.N. (1974). Economic Analysis of Farm Business of Small Farmers in Chandauli Tehsil District, Varnasi, Uttar Pradesh. PhD Thesis, Indian Agricultural Research Institute. New Delhi.

Barasa, T.N., M.O. Odhiambo and O.L.E. Mbatia (1992). Economic Analysis of Smallholder Cotton Production in Kenya: A Linear Programming Case Study of Funyula Division, Busia District. *Eastern Africa Economic Review.* 8(2):142-158

Beneke R.R. and R. Winterboer, (1973). Linear Programming Applications to Agriculture. The Iowa State University Press. Ames.

Bhogal, T.S., J.S. Sharma and L.R. Singh. (1989). Optimum Crop and Milk Production Plans For Small and Marginal Farmers in An I.C.D.P. District of Uttar Pradesh. *Agricultural Situation in India.* **44**(4): 259-264.

Bibangambah, J.R. (1975). Farm Business Planning in Developing Countries: The Need, The Problems and Prospects. *Eastern Africa Journal of Rural Development.* **8**(1-2): 129-141.

Bhowmick, B.C. (1982). Analysis of Risk in Farm Production in Kamrup District, Assam - A Parametric Risk Programming Approach. PhD. Thesis Indian Agricultural Research Institute. New Delhi.

Bohdal, M., N.E. Gibbs and W.K. Simmons, (1968). Nutritional Survey and Campaign Against Malnutrition in Kenya, 1964 - 1968. Report to the Ministry of Health, Kenya on WHO/FAO/ UNICEF Assisted Project.

Can, N. (1993). Optimal Operational Organization and Farm Income Level in Erbaa District of Tokat province. Koy Hizmetleri Tokat Arastirma Enstitusu Mudurlugu Yayinlari. **125**: 74pp.

Cetin, B. (1992). Determination of Optimal Production Patterns on Farms Where Land Consolidation Was Applied in The Karacabey District of Bursa Province. International Congress on Agrarian Reform and Rural Development. 22-27 September, Ankara, Turkey, Union of Chambers of Commerce, Ahi Evran Hall. 581-592.

Chandra, D. (1991). Economic Analysis of Different Irrigation Systems in Ghaziabad District of Uttar Pradesh. PhD Thesis, Division of Agricultural Economics, Indian Agricultural Research Institute. New Delhi.

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

Das, D.K. (1971). A Study of Resource Allocation and Optimum Cropping Pattern With Special Reference to Multiple Cropping Programme in Burdwan (IADP) District, West Bengal. PhD Thesis, Division of Agricultural Economics, Indian Agricultural Research Institute. New Delhi.

Debertin, D.L.; Pagoulatos, A. (1985). Optimal Management Strategies For Alfalfa Production Within a Total Farm Plan. *Southern Journal of Agricultural Economics*, Southern Agricultural Economics Association, USA. **17**(2): 127-137.

Deoghare, P.R. (1987). Impact of Mixed Farming on Income and Employment on Farms in Karnal District of Haryana. PhD Thesis, Division of Agricultural Economics, Indian Agricultural Research Institute. New Delhi.

Desai, D.K. (1961). Increasing Income and Production on Indian Farms. Possibilities With Existing Resource Supplies on Individual Farms. *Indian Journal of Agricultural Economics*, **XVI**(3): 1-15.

Desai, D.K. (1962). Budgeting and Programming in Farm Management. *Indian Journal of Agricultural Economics*, **XVII**(1): 196-205.

Farhat, M.Y. (1987). A Linear/Parametric Programming Analysis of An Iraqi State Farm. Lebanese Association for The Advancement of Science, Beirut, Lebanon. 10th. Science Meeting June 4-6, 34.

Devadoss, S. (1980). A Study of Maximisation of Income and Employment on Small Farms of Theni Block, District of Madurai, Tamil Nadu. Unpublished. Indian Agricultural Research Institute. New Delhi.

Gajanana, T.M. (1990). Farm Planning in Dry Zone - A Study in Tumkur District of Karnataka. PhD Thesis, Indian Agricultural Research Institute. New Delhi.

Gangwar, A.C. (1966). A Study of Optimal Allocation of the Resources on Cultivator's Holding in Kanjhawala Block. An Application of Linear Programming. PhD Thesis, Indian Agricultural Research Institute. New Delhi.

Goswami, S.N. (1993). Farm Planning in Hills Under Risk and Uncertainty: A Parametric Linear Programming Approach. *Indian Journal of Economics*. **74**(292): 51-60.

Goswami, S.N. (1995). Appraisal of Hill Farms in West Garo Hills of Meghalaya Practising Shifting Cultivation, for Developing Optimum Alternative Farming System. *Indian Journal of Agricultural Sciences.* **65**(1): 58-65.

Goswami S.N. and V. Meenakshisundaram (1992). Prospects of Increasing Farm Income in Traditional Hill Areas of West Garo Hills District (Meghalaya). *Indian Journal of Agricultural Economics.* **47**(2): 247-254.

Gupta, S.S. and R.C. Verma. (1993). Stabilization of Farm Income and Employment Under Water Scarcity Conditions. *Annals of Arid Zone.* **32**(3): 183-186.

Hirose, S. (1988). Food Production and Traditional Farming Technology in the Embu District, Kenya. 1. Land Use and Cropping System. *Japanese Journal of Tropical Agriculture.* **32**(4): 228-241.

International Labour Office. (1972). Employment, Incomes and Equality. Strategy for Increasing Productive Employment in Kenya. Report of An Inter-Agency Team Financed By the United Nations Development Programme and Organised By the International Labour Office. Geneva.

Jaetzold, R. and H. Schmidt (1983). Farm Management HandBook of Kenya, Vol IIC, East Kenya, Ministry of Agriculture, Nairobi.

Jaikrishna (1961). A Linear Programming Model for Selection of Crop Enterprises on an Average Farm in the Western Uttar Pradesh. *Indian Journal of Agricultural Economics*, **XVI**(4): 13-21.

Jolayemi, J.K. and J.O. Olaomi. (1995). A Mathematical Programming Procedure for Selecting Crops for Mixed Cropping Schemes. *Ecological Modelling.* 79(1-3): 1-9.

Kidane, H. (1993). Economic Constraints of Smallholder Milk Production in Kenya: A Linear Programming Approach. *Borneo Review.* **4**(2): 161-173.

Krisna, J. and S.M. Pathak. (1993). Economic Models and Their Data Requirements in Farm Planning. *Economic Planning in Free Societies.* **29**(3-4): 9-16.

Malya, M. (1962). Linear Programming and Farm Planning. *Indian Journal of Agricultural Economics*, **XVII**(1): 206-211.

Manos, B. and E. Gavezos E. (1995). A Multiobjective Programming Model for Farm Regional Planning in Northern Greece. *Quarterly Journal of International Agriculture.* **34**(1): 32-52.

Manos, B.D. (1991). Farm Planning With Multiple Objectives. An Application of Compromise Programming in Greece. *Agricoltura Mediterranea.* **121**(3): 224-238.

Mukhebi, A.W. (1977). Optimization Techniques in Farm Planning. The Linear Programming Case. Agricultural Economics Studies No. 4. Department of Agricultural Economics. University of Nairobi.

Mukhebi, A.W. (1981). Income and Employment Generation. Kenya Small Scale Agriculture. PhD Dissertation. Department of Agricultural Economics. Washington State University.

Nyoro, J.K. and J.D.M. Roe. (1986). Economics of Agricultural Production on Smallholder Coffee Farms in Kenya. *Kenya Coffee.* **51**(596): 137-153.

Odero-Ogwel, L. and E. Clayton (1973). Regional Programming Approach to Agricultural Sector Analysis: An Application to Kenya Agriculture. Agrarian Development Studies Report, School of Rural Economics and Related Studies, Wye College. Ashford. 5: viii+88pp.

Oyugi L.O. (1984). The Economic Influence of Tobacco Growing on Food Production in Migori, South Nyanza District of Kenya. M Sc Thesis, Department of Agricultural Economics, University of Nairobi.

Oyugi, L.A., A.W. Mukhebi and W.M. Mwangi (1987). The Impact of Cash Cropping on Food Production: A Case Study of Tobacco and Maize in Migori, South Nyanza District of Kenya. *Eastern Africa Economic Review*, 3(1). Nairobi.

Oyugi, L. A. (1992). Farm Management Extension Guidelines, Nakuru District, 1991. Ministry of Agriculture, Deutsche Gesellschaft fur Technische (GTZ) Farm Management Project.

Oyugi, L.A. (1993). Agricultural Statistics. Embu District 1991. Ministry of Agriculture, Deutsche Gesellschaft fur Technitche Zusammernarbeit (GTZ), Farm Management Project, Nairobi.

Panin, A. (1993). Resource Allocative Efficiency of Smallholder Farmers in Botswana. *Agricultural Economics Analysis and Rural Development.* **3**(3): 7-13.

Radhakrishnan, D. (1962). An Application of Linear Programming for Farm Planning - A case Study in West Godavari District of Andhra Pradesh. *Indian Journal of Agricultural Economics*, **XVII**(2): 73-82.

Republic of Kenya (1981). Kenya Population Census 1979, Vol 1, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi

Republic of Kenya (1981). National Food Policy, Sessional Paper No. 4 of 1981, Nairobi.

Republic of Kenya (1989). Embu District Development Plan, 1989-1993, Ministry of Planning and National Development, Nairobi.

Republic of Kenya (1989). The National Development Plan for the Period 1989 to 1993. The Government Printer, Nairobi.

Republic of Kenya (1994a). The National Development Plan for the Period 1994 to 1996. The Government Printer, Nairobi.

Republic of Kenya (1994b). Kenya Population Census 1989, Vol 1, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi

Republic of Kenya (1995). Statistical Abstract, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi

Republic of Kenya (1996a). Economic Survey, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi

Republic of Kenya (1996b). Statistical Abstract, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi.

Republic of Kenya (1997a). The Eighth Development Plan for the Period 1997 to 2001. The Government Printer, Nairobi.

Republic of Kenya (1997b). Economic Survey, Central Bureau of Statistics, Ministry of Planning and National Development, Nairobi

Republic of Kenya (1998). "El-Niño's Impact on Kenya's Economy". Monthly Economic Review, February. Central Bank of Kenya, Nairobi :7-9.

Sankhayan, P.L. and H.S. Cheema (1991). Using Linear Programming Models for Generating Optimum Farm Places - An Expository Analysis. *Indian Journal of Agricultural Economics.* **46**(4): 601-612.

Salokhe, V.M. and M.P. Pariyar. (1990). Optimum Farm Planning By Linear Programming for Tarai Belt of Nepal. AMA, *Agricultural Mechanization in Asia, Africa and Latin America.* **21**(4): 76-80.

Sankhyan, P.L., R.S. Prihar and H.S. Cheema (1988). Developing Optimum Cropping Plans for A Typical Punjab Farm With Multiple Objectives By Using Compromise Programming. *Indian Journal of Agricultural Economics.* **43**(2): 163-174.

Schultz, T.W. (1965). Transforming Traditional Agriculture. Yale University Press, New York.

Sharma, B.M. (1975). Farm Labour Employment and Income Implication of Cropping, Fertilizer, Credit Use and Farm Mechanization - a Normative Analysis of Farms in Alipur Block, Delhi. PhD Thesis, Indian Agricultural Research Institute. New Delhi.

Sher, A. and I. Amir (1994). Optimization With Fuzzy Constraints in Agricultural Production Planning. *Agricultural Systems.* **45**(4): 421-441.

Singh, S.K. (1993). Study of Technological Change and Its Implications for Crop Production and Resource Use in Eastern Uttar Pradesh. PhD Thesis. Indian Agricultural Research Institute. New Delhi.

Sinha, R.P. (1967). Optimal Resource Allocation Among Competitive Crop Enterprises on Cultivator's Holding. PhD Thesis. Indian Agricultural Research Institute. New Delhi.

Sirohi, A.S. and A.C. Gangwar (1968). Economic Optima in Resource Allocation for the Cultivators of Kanjhawalah Block. *Indian Journal of Agricultural Economics.* **XXIII**(3): 1-14.

Upton, M. (1987). African Farm Management. Cambridge University Press, Cambridge.

Upton, M. (1973). Farm Management in Africa, Principles of Production and Planning. Oxford University Press, London.

Uddin, T., R.K. Talukder and M.S. Alam (1994). Optimum Cropping Plan for A Sample of Farms in A Farming System Research Area of Bangladesh. *Bangladesh Journal of Agricultural Economics.* **17**(1-2): 85-96.

Viljoen, M.F. and C. van der Westhuizen (1992). The Implementation of Optimal Farm Plans Obtained from The Application of An Integrated Farm Planning Approach. *Agrekon.* **31**(2): 90-93.

Young D.F. and P.A. Rickards (1978). Agriplan, User's Manual For Small Farm Analysis, Farm Management Unit, Agricultural Services Division, Food and Agriculture Organization (FAO) of United Nations, Via delle Terme Di Caracalla, 00100, Rome.

APPENDIX

DIVISIONS, LOCATIONS, SUB-LOCATIONS AND AGRO-ECOLOGICAL ZONES, EMBU DISTRICT, 1996.

DIVISION	LOCATION	SUB-LOCATION	AEZ
Manyatta	Nginda	Kiriari	LH1/UM1
Manyatta	Nginda	Mbuburi	LH1/UM1
Manyatta	Nginda	Ngovio	LH1/UM1
Manyatta	Nginda	Kibugu	UM1
Manyatta	Gaturi	Kaumtiri	UM1
Manyatta	Gaturi	Kanjuki	UM1
Manyatta	Ngandori	Manyatta	UM1
Manyatta	Ngandori	Kairuri	UM1
Manyatta	Ngandori	Kamwenja	UM1
Manyatta	Ngandori	Mukangu	UM1
Manyatta	Ngandori	Kirigi	UM1/UM2
Runyenjes	Kagaari North	Kanja	UM1
Runyenjes	Kagaari North	Mukuuri	UM1/UM2
Runyenjes	Kagaari North	Kianjokoma	UM1
Runyenjes	Kagaari South	Gitari	UM1
Runyenjes	Kagaari South	Gikuri	UM1/UM2
Runyenjes	Kyeni North	Rukuriri	UM1
Runyenjes	Kyeni North	Mufu	UM1
Runyenjes	Kyeni North	Kiangugi	UM1
Runyenjes	Kyeni North	Kathari	UM1/UM2
Manyatta	Gaturi	Makengi	UM2
Manyatta	Gaturi	Kevote	UM2
Manyatta	Nginda	Kathangari	UM2
Manyatta	Ngaturi	Nembure	UM2
Gachoka	Mbeti North	Nthambo	UM2
Gachoka	Mbeti North	Njukiri	UM2
Runyenjes	Kagaari North	Mbuinjara	UM2/UM3
Runyenjes	Kagaari South	Gichiche	UM2
Runyenjes	Kagaari South	Kigari	UM2
Runyenjes	Kyeni South	Kathangari	UM2
Runyenjes	Kyeni South	Kathanjuri	UM2/UM3
Runyenjes	Kyeni South	Kigumo	UM2/UM3
Manyatta	Ngaturi	Gathunduri	UM3
Manyatta	Ngaturi	Ena	UM3
Manyatta	Ngaturi	Kithimu	UM3
Runyenjes	Kagaari South	Kawanjara	UM3
Runyenjes	Kyeni South	Karurumo	UM3/UM4

Gachoka	Mbeti North	Kangaru	UM3
Gachoka	Mbeti North	Kamiu	UM3
Manyatta	Ngaturi	Kithegi	UM4
Runyenjes	Nthaura	Siakago	UM4/LM3
Runyenjes	Kagaari South	Nthagaiya	UM4
Gachoka	Mbeti North	Itabua	UM4
Gachoka	Mbeti South	Kiamuringa	UM4
Siakago	Nthaura	Rianda	UM4/LM3
Runyenjes	Kyeni South	Kasafiri	LM3
Runyenjes	Kagaari South	Gichera	LM3/UM4
Siakago	Evurori	Nguthi	LM3/LM4
Siakago	Nthaura	Gitiboru	LM3
Gachoka	Mavuria	Mavuria	LM4
Gachoka	Mavuria	Mbita	LM4
Gachoka	Mavuria	Kithunthire	LM4
Gachoka	Mavuria	Kirima	LM4
Gachoka	Mbeti South	Gachuriri	LM4
Gachoka	Mbeti South	Gachoka	LM4
Gachoka	Makima	Makima	LM5
Gachoka	Makima	Mbondoni	LM5
Gachoka	Karaba	Karaba	LM5
Gachoka	Karaba	Wachiro	LM5
Gachoka	Karaba	Gatengi	LM5
Gachoka	Karaba	Riakanau	LM5
Gachoka	Kiambere	Gichiche	LM5
Gachoka	Kiambere	Riacina	LM5
Siakago	Evurori	Evurori	LM5
Siakago	Evurori	Thambu	LM5
Siakago	Mominji	Gangara	LM5
Siakago	Kiangombe	Iria Itune	LM5
Siakago	Kiangombe	Kamarandi	LM5