THE UTILIZATION OF KENYA'S IRRIGATION POTENTIAL: A CASE STUDY OF KIBIRIGWI IRRIGATION SCHEME

BY

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This research paper is my original work and has not been presented for a degree in another University.

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This research paper has been submitted for examination with our approval as University Supervisors.

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I, however, remain responsible for any error in this work.

ABSTRACT

This study is mainly concerned with evaluating a Small Scale Irrigation Scheme, Kibirigwi, located in Kirinyaga district, one of Kenya's high agricultural potential areas. The main objective of the study is to add to the existing knowledge on Small Scale Irrigation Schemes with a more specific aim of identifying the factors that facilitate or inhibit the expansion of such schemes in Kenya. Small Scale Irrigation Schemes will continue to play an increasingly important role in Kenya's dominantly agricultural economy.

Kibirigwi Irrigation Scheme was selected for this Study mainly because it is a pioneer Small Scale Irrigation Scheme situated in an area generally considered to have adequate rainfall. And, unlike most other schemes where farmers are either settled or resettled on the Scheme, Kibirigwi Scheme was set within an existing land tenure system where farmers have Freehold Titles over their land. This poses interesting questions about the benefit, performance and progress within such a scheme.

In order to test some hypotheses about the farmers' performance, a sample of farmers randomly chosen were interviewed. On the basis of the interview and scheme records linear program models were ran to determine the

best patterns of production and binding constraints. In addition, cross-tabulations on age, sex and education were made to determine their significance on farmers performance.

Results indicate that subsistence production is a binding constraint to commercial agriculture, even though the impact varies from farmer to farmer. Labour in certain periods of the year, irrigated land, and credit to some farmers are other binding constraints.

Determination of planting period, allocation of credit and regulating the flow of inputs to and produce from the scheme were identified as other factors inhibiting expanded commercial production. There was a strong relationship between the farmers' sex and performance, where male farmers were found to perform better than female farmers. Generally those farmers between the age of 30 and 45 years of age and have attended school up to standard 4 performed best in terms of earnings.

On the basis of the results of this Study, it is concluded that the scheme is contributing positively towards improving the welfare of the people concerned even though it is still faced with managerial and technical problems. It is, therefore, recommended that the government through the Ministry of Agriculture and Livestock Development should continue to assist the scheme with finance and technical skills. Scientific Research om the Scheme should also be increased.

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CHAPTER ONE

INTRODUCTION

1.1 Statement of the Problem

This study is mainly concerned with evaluating a small scale irrigation scheme. It is based on a case study of Kibirigwi irrigation scheme, located in Kirinyaga District, one of Kenya's high agricultural potential areas. The study emphasises the identification of the problems, prospects and progress of the scheme as a basis for assessing future small scale irrigation schemes. More specifically, the study aims at identifying the major constraints that may limit the expansion of output on Kibirigwi irrigation scheme.

The Kenya government has stated that small scale irrigation schemes are going to play an increasingly important role in Kenya's agricultural development.[1] The statement emanates from the government's realization of certain salient features of the economy in general and the agricultural sector in particular. Agriculture has played and continues to play a leading role in Kenya in terms of employment and income generation, as well as the overall development of the economy.

Viewed over the last 20 years, Kenya's agricultural sector has undergone a number of structural changes in terms of productivity, factor proportions and product mix. The sector expanded rapidly during the first decade of independence because of improved infrastructure, monetized small-holder production, a dynamic commercial network and a well-staffed system of agricultural services. However, during the second decade the sector performed poorly due to increased cost of inputs, population pressure and droughts. For example it has been stated in the 1984-88 development Plan that

> "... the drought related reductions in the food production and the unprecedented large food imports of 1979-81 have caused policy makers to become accutely aware of the incipient imbalance between food supply and demand caused by the pressure of a rapidly increasing population on Kenya's limited area of high-potential arable land."[2]

The government aims at rectifying the situation by increasing agricultural production through expanded acreage particularly in the drier zones of the country and intensification of land use in the high potential areas. The two approaches are definately linked to the proper utilization of the national water resources. The need to identify water as one of the main resources of the economy is more succinctly expressed in the theme of the 1984-88 development plan: The mobilization of domestic resources for equitable development.

Identification and use of the national water resources is not a new phenomenon in Kenya. What is new is the strategy. Since independence the government has been emphasizing the promotion of large scale irrigation schemes. This was a euphoria generated and transmitted to the newly independent Less Developed Countries by the highly capitalized industrial economies in the early 1960's. The idea was that the less developed countries were deficient in capital which could be easily obtained from the developed countries. Irrigation projects in the less developed countries got a significant portion of this capital transfer.[3] Unfortunately a very small number of these projects succeeded. For instance in Kenya out of the six large scale irrigation projects initiated during the period only one, Mwea rice irrigation scheme, is self-supporting and generating revenue to the government. The rest are heavily subsidized by the government.

The government has decided to give more emphasis to small scale irrigation projects. It is therefore important to determine to what extent small scale irrigation schemes may be more successful than large scale schemes.

1.2 Objectives of the Study

The main objective of this study is to increase our understanding of small scale irrigation schemes with the aim of identifying the factors that may facilitate or inhibit the expansion of such schemes in Kenya. The specific objectives of the study are:

(1) To measure and compare the incomes of farmers on an irrigated small scale scheme and a non-irrigated area with similar ecological conditions with a view of ascertaining the impact of irrigation in a water constrained region.

(2) To investigate the institutional factors like water laws, land tenure, government regulations and farmers' characteristics to identify which among these may limit the expansion of small scale irrigation.

(3) To investigate the production problems facing small scale irrigation farmers with a view to identifying the main resource constraints that may limit the expansion of small scale irrigation, and finally

(4) To identify the policy implications arising from the above.

1.3 Importance of the Study

Government documents and pronouncements show that the planning and full utilization of the national water resources have been some of the priority areas. However, investigations carried out so far show that although Kenya's irrigation potential is high, it has been minimally developed. By rough estimates: Irrigation Potential is 230,000 hectares; Irrigated Land is 25,000 hectares; Per cent Irrigated is 9 per cent.[4] There are three probable explanations for these seemingly contradictory observations. First, irrigation may not be a major priority area in the current Kenyan situation and it is only being emphasized for some other extrenous motives. Secondly, irrigation may be a major priority area but its expansion is genuinely constrained by lack of finance and manpower. Finally, it may be due to application of inappropriate technological know-how. This study will attempt to investigate some of these factors.

A study like this, based on irrigation, seems to be quite relevant and important as far as Kenya's economic problems are concerned. First and foremost drought and famine have been recurrent features in Kenya over centuries. For instance at any time famine and death threaten 20 per cent of Kenya's entire population scattered in 14 districts covering the marginal lands. Substantial resources have been going to the maintainance of these people in terms of food relief and medical services. But despite this a substantial proportion of people in these areas suffer from malnutrition, deformation, susceptability to disease, mental retardation, desolation, etc.[5]

Secondly, as it has been stated in the National Food Policy Paper of 1981 and other government publications, the agricultural sector must continue to play a leading role in Kenya's development in terms of providing food, foreign exchange and employment. But the rapid expansion of population and a shortage of unexploited arable land in the main high potential areas are beginning to expose a potentially dangerous imbalance between the national supply of and demand for food and agricultural raw materials. One only viable solution in the long run seems to be a formal and well organized plan to increase productivity in the marginal areas by irrigation.

Thirdly, unemployment has reached alarming proportions in Kenya. Available data show that employment in the formal sector has been far below the estimated projections. Since 1980 a considerable number of redundancies and lay-offs have been recorded. This has been happening at a time when thousands of school leavers are flocking into the labour market annually. The dynamics of the employment problem are even more worrying than the current situation. At a growth rate of 3.9 per cent per annum, Kenya's population will be about 34 million by the turn of the century with a labour force of 12 million people. If the modern sector grows steadily at about 5 per cent per annum then it would absorb only 3 million of the labour force, implying that 9 million people have to be employed in agriculture and the rural informal sector. Improvement in the agricultural techniques of the high potential areas alone will not facilitate the absorption of the large labour force.[6] Hence the need to open up the marginal areas for the excess labour force.

Finally, the macro-economic links in the economy require that water be incorporated in the national planning process. For instance, the deteriorating ecology requires proper control and use of the water resource. Apart from irrigation, water is applied for domestic, industrial, transport, animal consumption and hydro-electricity production uses. There is need to co-ordinate all these uses so that water can yield the highest net return. On the other hand the link between the agricultural sector and the industrial and export sectors requires stability of the agricultural sector for the smooth running of the economy. Stability in agriculture is to a large extent determined by adequate availability and reliability of the water resource.

Reference to the agrarian economy, particularly in the Less Developed Countries, leads to the issue of inadequacy and unreliability of data. Generally there is lack of knowledge on the part of the policy makers about the details of what goes on in the agrarian sector. For example Georgseu-Rogen[7] has argued that the agrarian economy has to this day remained a reality without a theory. The farmers, on the other hand are quite conversant with their farming environment but they do not know the general framework under which they operate. The issue then, is how to get the information necessary for planning agrarian reforms such that the policy does not deviate much from the reality. As Schultz has observed

> "The level of agricultural production depends not so much on the technical considerations but in a large measure on what governments do to agriculture"[8]

What the government has to do to agriculture in terms of irrigation in Kenya is a crucial issue. The expansion of irrigation in Kenya is a fundamental agrarian reform because most farmers have not had a water management tradition. It is important for the government to know the conditions under which water management skills can be instilled among farmers, determining the resources and effort required to do so.

Planning for irrigation is quite difficult because irrigation projects require high initial physical capital investment which may not be converted to some other use if the intended projects fail. Furthermore the projects require inter-disciplinary action that is, working together of engineers, ecologists, agronomists, doctors, sociologists and economists. Plans of action can be made but if they are inappropriate then there will be a wide deviation between the desired goals and achievements. This makes research in irrigation practice a priority area.

1.4 Scope of Study:

This study is a case study based on Kibirigwi irrigation scheme of Kiine location, Ndia division, Kirinyaga district of Central province. The scheme is located on the Nairobi-Nyeri road, about 100 kilometres from Nairobi and 3 kilometres from the Nyeri-Kirinyaga boundary.(see Map 1). The characteristics of the area are described in detail in Chapter 2 of this study. The Study analyses organizational, production and distributional aspects of the Scheme in relation to the performance of the farmers.

The scheme was chosen for various reasons. It is one of the pioneer, though recent, small scale irrigation schemes to be initiated directly by the government through the Ministry of Agriculture and Livestock Development. Even though the government has shifted its emphasis from large to small scale schemes, future commitment towards small scale irrigation will depend on the success of these pioneer projects. There is need to closely monitor the progress, problems and prospects of such pioneer schemes.

1.4 Definitions

The following are definations of some of the major terms used in this study.

1. Irrigation: As applied in this study, irrigation means the artificial application of water to the soil for the purpose of supplying the moisture essential for plant growth. The three broad categories of irrigation are surface, sub-soil and overhead; defined in terms of the level at which water is applied. Surface irrigation involves the application of water on the soil surface. It includes Basin, Boarder, Furrow, Corrugation, Wild Flood, Space and Trickle Irrigation. Sub-soil irrigation involves applying water from underneath the soil and

root surface. This includes Water Table control, sub-soil pipes and potcher irrigation. The third category is overhead irrigation which involves applying water on top of the crops. This includes the watering can, hose pipe and sprinkler system irrigation. The area under study applies overhead irrigation of the sprinkler type.

2. Evapotranspiration Rate: The rate at which water is transfered from the soil back into the atmosphere through the plants for the purpose of normal plant metabolism. This rate depends on environmental conditions such as humidity and temperature, and the nature of the crop under consideration.

3. Gross Margin The difference between the value of an enterprise's gross output and the variable costs of that enterprise. The value of the enterprise is obtained by multiplying the output by the price. The variable costs include needs, fertilizer, sprays, livestock feeds, veterinary costs and casual labour.

4. Activity: This is an enterprise undertaken by a farmer on the farm for the purpose of earning an income (including subsistence). The activity can be a single crop, combination of crops or livestock.

5. Linear Program: A mathematical model that expresses the physical, behavioristic, or economic relationships between the various elements of a decision problem in a standardized mathematical form:[9] and linear programming is a standardized method of determining the optimal decision, action, or policy for the problem under investigation.[9] The linear programme basis is the pattern of activities undertaken in order to achieve the optimal solution. There is a range through which the activity prices and constraints can be altered without changing the pattern of activities undertaken. In such a case it is said the programme is within the basis.[10]

6. Lateral: As applied in this study a lateral is a piece of land equivalent to one quarter of an acre. Farms on Kibirigwi Irrigation Scheme are divided in small parcels (laterals) for the purpose of irrigation.

b. Institutions

NIB - National Irrigation Board

KIFCO- Kibirigwi Irrigation Farmers Co-operative Society.

F.A.O. - Food Agricultural Organization

N.O.R.D. - Norway Agency for International Development

M.O.A.& L.D. - Ministry of Agriculture and Livestock Development.

K.I.S. - Kibirigwi Irrigation Scheme.

1.6 Organization of the Study

Chapter 2 of this paper gives the background information on irrigation in Kenya and the environmental conditions of the area under study. Chapter 3 is a short survey of the literature on irrigation and the linear programming model which is applied in this study. Hypotheses, methodology and sources of the data are given in Chapter 4 while Chapter 5 gives data analysis and results. Finally, in Chapter 6 we give the summary, conclusions recommendations.

FOOTNOTES

1. Republic of Kenya: 1984-88 Development Plan. Government Printer, Nairobi, 1983.

2. Ibid: page 177.

3. For example see Home C.W., "The effect of water resourse development on economic growth", in Water in a Developing World. by Utton A.E. and Teclaff L. (Eds.), Westview Press inc. 1978.

4. For example see Republic of Kenya, National Master Water Plan Phase 1, Ministry of Agriculture and Livestock Development, Nairobi, 1975.

5. See Odingo R.S.: Drought and Man in Eastern Africa (Ethiopia, Kenya and Tanzania), A Contribution to the International Federation of Institute of Advanced Studies (IFIAS) 1972.

6. See Republic of Kenya, op cit, Page 82.
   In any case improvement in productivity may lead to a decline in employment if the labour output L/O ratio declines. Employment will be generated only if technological advancement is labour deepening, which can be achieved mainly by biological and chemical technological advancement. But these are in most cases achieved only when there is an adequate and reliable supply of water.

7. Georgescu - Roegen N. "Economic Theory and Agrarian Economics" in Eicher C and Witt L (Eds) Agriculture in Economic Development McGrill Hill Inc., N.Y. 1964.

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

9. See Daellenback H.G and Bell E.J., Users Guide to Linear Programming Prentice-Hall Inc. Englewood Cliffs, N.J. 1970, Page 2.

10. This defination is obtained from the LCSXDLA Marks 3 Computer Program Manual.

CHAPTER TWO

BACKGROUND INFORMATION

2.1: Agriculture and the Irrigation Potential

Kenya is basically an agricultural economy with over 85 per cent of her population deriving their income and employment from the agricultural sector. With an area of 583,000 square kilometres and a population of about 19 million, Kenya's population density of 30 persons per square kilometre is low compared to some parts of the world. However, only 9 per cent of the land is of high agricultural potential. The rest is either low potential, semi-arid or arid. The low potential of the land is aggravated by a rapid population growth rate of almost 4 per cent per annum, low productivity of the land and deteriorating ecological systems in both the high and low potential areas.[1]

The government has considered it prudent to have a well managed water resource programme as part and parcel of national development planning. Since independence the government has assigned a number of ministries and parastatal bodies the task of generating, co-ordinating and implementing water management programmes. These include the Ministries of Agriculture and Livestock Development and Water Development, the Mombasa Pipeline, the National Irrigation Board (NIB), the Tana and Arthi Rivers Development Authority (TARDA), the Lake Basic Development

Authority, and the Kerio Valley Development Authority. Among the parastatals the NIB is the one entrusted with irrigation programmes throughout the country, while others tend to be multi-objective and operate on a regional basis.

History and National Organization of Irrigation Schemes in Kenya.

Irrigation in certain parts of Kenya can be traced back to the colonial period. For example during the World War II irrigation schemes were started in Embu and Nyeri districts to provide fresh fruits and vegetables to the British soldiers fighting in the war in Eastern Kenya. After the war other schemes were started in Central and Eastern Provinces to occupy the Mau Mau detainees.[2] A number of these "spontaneous" schemes, like the Mwea Irrigation Scheme, survived into the post-independence era. Since independence the government has initiated its own water management and irrigation programmes.

Irrigation in Kenya is undertaken either on large scale organized,[3] small scale organized/or small scale unorganized. The NIB is concerned with large projects which are provided with sufficient infrastructure to accommodate settlers in the scheme. The major objectives of these projects is to raise agricultural production and to create employment for land-less people in the over-populated rain-fed areas. Cash crops like cotton, sugar cane and rice are grown. Currently the main projects run by the NIB include Mwea, Perkerra, Ahero, Kano, Bunyala, Yala, Hola and Bura.

The NIB was set up in 1966 to run an initial total area of 3,323 hectares with 2,163 plot holders. Since then its operations have expanded considerably such that by 1980 the cropped area and plot holders had increased to 9,538 hectares and 5,553 tenants respectively. Thus, over the period the cropped area and plot holders have been increasing at an average rate of 6.8 and 6.1 percent per annum respectively. Judged by the government subsidies that the parastatal receives annually the performance of these large scale irrigation projects seems to be poor.[4]

Small scale irrigation schemes are under the Small Scale Irrigation Unit, Land and Farm Management Division, Ministry of Agriculture. Their objective is to increase food production in the high potential areas. The projects are financed either by the government through the Ministry of Agriculture, foreign agencies or both. Suggestions for such projects generally come from the District Development Committees or the Provincial Director of Agriculture. Some of the more well known small scale irrigation schemes include the Pekerra Irrigation Scheme in Baringo district, Ishiara (Embu) Mitungu (Meru) and the scheme under study - Kibirigwi (Kirinyaga).

The third category of irrigation schemes is the Arid Area Projects. The aim of these schemes is to settle famine - prone normadic populations that live in the marginal areas of Kenya. The projects are mainly financed and run by F.A.O. , NORAD and other International and charitable organizations. Such schemes include Kakerongole. Katilu and Turkwel (Turkana), Kaj nuk (West Pokot), Merti, Meka Daka and Gar Zassa (Isiolo), Mbala-bala and Garissa (Garisa), and Mandera Scheme in Mandera district.

The fourth category are the privately owned and operated irrigation schemes mainly found in Central Province. According to Carruthers and Weir these schemes cover over 10,000 hectares and are almost exclusively on sugar and coffee estates, and on farms growing high value horticultural crops for export.[5]

Finally, of less importance and recognition are river valley irrigation practices which have not been fully assessed and recorded. The government does not seem to give emphasis to their development. River Valley irrigation is practised in many parts of Western province and some parts of Rift Valley, Nyanza and Eastern Provinces.

An issue that has been given less attention is the evaluation of the country's irrigation potential. Attempts have been made by both the ministries of agriculture and

and Water Development to identify the potential and systems of water utilization in Kenya. For example the Mission Report on the National Water Master Plan - Phase 1, indicated that the total area under river basins that could be economically developed was about 300,000 hectares.[6] The Irrigation and Drainage Research Projects of the Ministry of Agriculture, on the other hand, gave the potential as 600,000 hectares of poorly drained land.[7] However, it was noted that the economic scope for irrigation development appears to be contrained by lack of trained personnel and water management traditions. Finally, Carruthers and Weir, writing on rural Water supplies and irrigation development, have indicated that the potential is about 230,000 hectares.[8] It is evident that there is no consensus about Kenya's irrigation potential.

There is a divergence in the estimates because, firstly, they were made through guesswork. However, lately the country's water resources are being mapped and recorded systematically. Secondly, the estimates were made with different assumption on the level of technology to be applied. Since most of the large scale irrigation schemes in the less developed countries have failed, some people have been pessimistic about future programmes, yet others believe that with time and technological advancement large schemes may become viable.

3 The Legal Framework:

The legal framework under which irrigation operates constitutes the Land (Tenure) and Water Laws. The two define the rights and obligations of the individual or group of individuals in applying water for irrigation on a parcel of land. Land in Kenya is held under three types of tenure: customary, freehold and leasehold. Thus land tenure is subject to customary and modern laws. Communal land ownership has been understood to inhibit not only irrigation but other types of agricultural development. But as Okoth-Ogendo[9] argues, the individualization of land ownership has not improved agricultural productivity.

The water laws are also subject to customary and modern laws. The scarcity of water in most-African communities usually led to the "individualization" of water resources on community or family lines. For example, a community would identify its grazing territory on the basis of a river or pond. This type of individualization was reinforced by the colonial government by the creation of reserves which restricted Africans on ethnic lines in small and less productive areas.

After Independence the government drafted new water laws based on the British water laws. The new laws were contrary to the 'traditional laws' in the sense that now every body of water was vested in the government. The to use water would only be acquired through the water Act, be it for domestic, public, industrial or irrigation use. For instance the right to use water for irrigation requires a permit from the Water Appointment Board (WAB). The permit holder must provide for efficient drainage of the land which must return the used or unused water to a water course. There is also legislation on harmful effects of water; namely, flood control, overflow and bank control, soil erosion control and siltation and salination control.[10]

However, it should be noted that these laws are in most cases non-operational. As Carruthers and Weir[11] have pointed out, surface water in Kenya is faecally polluted due to inadequate sanitary arrangement in rural areas and poorly maintained urban facilities. Industrial pollution is also on the increase. For example in a recent study on the potential of the Kerio river it was recommended that it is unadvisable to use water from Kerio so long as this is polluted by effluent from the Kimwarer fluoride plant.[22]

2.4: Kibirigwi Irrigation Scheme

2.4.1: Environment:

The physical environment relevant to irrigation may generally be grouped under land, water and climate. These are, in turn affected by the location of the area and the altitude above sea-level. The Kibirigwi irrigation scheme is located in the upper Tana catchment zone which is dominated by volcanic uplands with Mount Kenya as the main physical feature of the region. Indeed, as Baker has noted:

> "The Mount Kenya land mass - comprising of volcanic materials covering some 2700 square miles in a circle approximating 65 miles in diameter - has been the determining factor underlying the present distribution of rainfall, topography and soil throughout the region".[13]

The region has been greatly dissected by swiftly moving rivers like Sagana, Thiba, Ragati, Ruguti, Mutonga and others: all being tributaries of the River Tana (See Map 2). The scheme, which runs along the Ragati river lies in an area described by Oswago[14] as gently undulating uplands with the slope lying between zero per cent and five per cent, at an attitude varying between 1430 metres and 1370 metres above sea level..

The soils of the area have been described in detail by Oswago[15] and later analysed by Njihia[16]. The scheme is located on the red soils of the upper Tana catchment which offers one of the largest single areas for small scale irrigation development in Kenya. For example according to Ilaco[17] a total area of nearly 271,000 hectares is suitable for irrigated agriculture in the upper Tana catchment of which 82 per cent (222,000 hectares) are red soils, the rest being black clay. The soils are deep, dark reddish-brown heavy clays with a clay content ranging between 50 and 70 per cent. Apart from being deep they have a large water storage capacity ranging between 10 and 14 milimeters per centimetre of soil. They are well drained and aerated, thus having high infiltration rate and rapid permeability.

These soil characteristics have certain advantages and disadvantages. The advantages are that the soils are well drained, minimising problems of water-logging and salinity. The disadvantages are susceptibility to land-sliding and erosion, making it difficult to apply surface irrigation (furrow method). However, with proper farming methods the soils can be protected against erosion and the high permeability reduced to acceptable levels to allow furrow irrigation.

In terms of water supply, the scheme gets water from the River Ragati, a tributary of the River Sagana also of the Tana River. Most of the Ragati water comes from rainfall in the upper altitudes of mount Kenya which receive more than 1700 milimetres of rainfall annually. Thus the river has abundant rainfall throughout the year. Secondly, the river water reaches Kibirigwi with less impurities, thus reducing the dangers of silting. Even though the river passes through the densely populated Mathira area of Nyeri district, the techniques and intensity of cultivation have not increased siltation of the river to alarming proportions. However, as Moris and Chambers[17] have observed, most of the rivers entering the upper Tana carry large quantities of silt, and are sometimes also polluted by acid residues from the coffee pulping factories. Thus the Ragati River may not be excluded from acid pollution particularly in future when agriculture and industrialization are intensified in the upper Tana catchment zone.

This area, just like most other parts of the upper Tana catchment zone, has a bimodal rainfall with most of the rain being aerographic. The months of March, April and May are usually a period of heavy rainfall (Long Rains) while October and November is a period of moderate rainfall (short rains). December, January, February June and July are generally dry months. The average rainfall figures are given in table 1 in the appendix.

Table 1 shows the monthly Kibirigwi rainfall from 1963 to 1982 and the monthly mean rainfall over the same period. Figure 1 graphically shows the average annual distribution of rainfall. The average annual rainfall for Kibirigwi is about 1280 milimetres which is significantly above the 1000 milimetre isoyet usually considered as the dividing line between adequate and inadequate rainfall for most agricultural crops.

Table 2 in the appendix shows the monthly rainfall as a percentage of the long term monthly average from 1963 to 1982. It is evident from the table that there is a significant monthly deviation from the mean rainfall year after year. The highest deviations are in January, February March and December. The deviations can be used as a measure of the level of risk to farmers.[18] The high variance shows that the farmers face high risk and uncertainty about the weather situation that would occur in a given month or year.

The tables and graph 1 present information on rainfall adequacy, incidence and reliability in Kibirigwi, which serves as a basis for the need of irrigation in the area. The general observation is that rainfall in Kibirigwi is adequate but its incidence does not permit continous agriculture and the yearly variance discourages farmers from making long term plans in advance. Therefore irrigation in this region is mainly to reduce risk and uncertainty, and thus increase productivity.

2.4.2: Socio-Political Environment and History

Historical and political environments are of some significance to irrigation because together with the physical environment they determine the level of effort required to secure the administrative, financial, legal and popular support necessary to embark upon changing the economic face of an area through irrigation.

Before the initiation of the scheme in 1976 Kibirigwi had been a settled area for quite a long period. According to Sorrenson,[19] early settlement in this area by the Kikuyu ethnic group may have started around the mid-sixteen century. However, the area was not fully occupied by the Kikuyu when the British arrived in the highlands towards the end of the nineteenth century. From the early European settlement to the present time many agrarian changes have taken place which could, to some extent, be regarded as an agrarian revolution.

Like other peoples of Kenya, the people of Kirinyaga have been greatly influenced by the colonial and post-colonial government policies. These policies have brought marked changes in their soio-political fabric. The nature, magnitude and direction of the changes have not been fully documented. At the time of establishing Kibirigwi irrigation scheme there was what could generally be described as peasantry agriculture. Land consolidation and registration had been completed in the early 1970's. Commercial agriculture in crops like coffee, tea and tomatoes, and subsistence agriculture in the form of maize, beans, Irish potatoes and cattle rearing has been going on over the last thirty years.

Three major observations can be made about the socio-political environment of Kibirigwi in relation to agriculture. First, any land conflict cases that may arise in Kirinyaga today will be among family members (touching on the inheritance) or between buyer and seller (touching on the transfer of rights from one agent to another). These conflicts are quite different from those experienced during land demarcation, consolidation and registration. For instance while the current land conflicts may tend to be on an individual basis, hence less political, those of consolidation involved large groups of people, leading to political agitation. Hence the land conflicts in relation to the operation of Kibirigwi irrigation scheme should be observed from a dynamic point of view, that is, more conflicts may arise in the long run because of population expansion, changes in technology and increased farmers' enlightenment.

Secondly, the people of Kirinyaga have wide experience in crop and animal husbandry. Some of them worked on European farms, others worked in forced irrigation programmes while others lived side by side with Europeans thus benefiting from the diffusion of technological know-how.

Finally, Kirinyaga district (hence Kibirigwi area) has been administratively linked to Embu district. Yet the Kikuyu ethnic group that occupy Kibirigwi area is economically associated with the Kikuyus of Nyeri and Muranga districts. Kerugoya as the district administrative centre of Kirinyaga is communicationally somehow detached from the main "Economic Vein" from Nairobi to Nyeri on which Kibirigwi lies (see map 2). The people of Kibirigwi interact more with Karatina as a major market centre in Nyeri district than Kerugoya, their district headquarters. This implies that Kibirigwi does not suffer from transport and market constraints like some other parts of Kirinyaga.

2.4.3 The Impact of the Environment on the Irrigation Scheme

The basic objective of setting up an irrigation scheme is to maximize social welfare. Since welfare can not be measured in real physical terms, proxies such as output, employment, equality and risk minimization are used in indicating welfare gain. The maximization of welfare is equivalent to the minimization of social costs. Some regions have characteristics which reduce the social, technical and economic costs that are to be minimized when setting up an irrigation scheme. Following are some of the characteristics of Kibirigwi that reduce the costs of setting up an irrigation scheme there:

- Kibirigwi lies in an area with adequate water supply, well drained terrain and fertile soils which reduce the costs of technical layout of the scheme.

- The area is in a region with suitable crop varieties with a financially attractive, efficient and reliable transport net work which reduces the costs of production and distribution, and finally

- Kibirigwi is in a region where people have undergone considerable agrarian reforms which have increased their skills, changed their attitudes towards commercial agriculture and expectations, which help to reduce the costs of management and administration.

2.4.4: History of the Scheme

Kibirigwi Irrigation Scheme was initiated in 1975 by the Tana River Development Authority (TRDA) and was implemented in 1977 by the Small Scale Irrigation Unit of the Ministry of Agriculture. The project is jointly financed by the Kenya and Netherlands governments.

The principal objective of setting up the scheme was to establish the methods by, and the extent to which the supply of irrigation water can increase representative farm income in high potential areas of the Tana Basin. An essential condition was that the methods and inputs used were to be within the farmer's means.

In order to achieve this principal objective, phase I of the project was aimed at

- Assessing the feasibility and profitability of applying irrigation in small holdings.
- Training farmers in growing vegetables commercially.
- Raising farmers' incomes through cultivation, and finally
- Analysing costs and benefits of the scheme whose total investment amounted to Ksh,6,000,000[20]

Phase I of the scheme was to run from 1977 to 1979 after which phase II was to be embarked upon. This was to include general expansion of the scheme, but more specifically:-

- Establishing a commercial vegetable production programme under irrigation, having an ultimate target of 600 acres cultivated yearly,
- Establishing a proper management of the co-operative society, organizing credit facilities, the supply of inputs and the marketing of produce,
- Training its staff, the farmers and (school children) in commercial vegetable production and irrigation technology,
- Establishing a system of water distribution control and methods for operation and maintainance of the irrigation system,
- Studying and improving the integration of rain-fed and irrigated crop production on the small holdings,
- Carrying out studies or tests for introduction of alternative uses of irrigation water for agricultural production (eg. fruit trees, flowers,

fodder crops for dairy production, etc).

- implementing soil concervation programmes.
- Establishing and analysing the costs and benefits of the project as a whole and its effect on the individual farm income.
- Developing a method for the cost-recovery in relation to the development of a reasonable farm income,
- Handing over the project to the management of the co-operative society by the end of Phase II, and finally,
- Assessing the project results in view of future small scale irrigation development in the upper Tana Catchment Area.[21]

Phase II of the Scheme was supposed to end in June 1983 by which time the Kibirigwi Irrigation Farmers Co-operative Society (KIFCO) would have improved to the extent of taking over the management of the scheme. The current estimated project value is given below:-

ITEM	KSH ('000)	OWNERS
a). Main Irrigation Scheme	5,500	MOA
b). Portable Field Equipment	1,100	Farmers
c). Buildings and Compound	2,400	MOA
d). Tractors, Trailors and Farm Equipment	700	KIFCO
e). Workshop Store Equipment	250	KIFCO
f). Knapsack Sprayers	150	Farmers
g). Office Equipment	100	KIFCO
h). TOTAL	10,200	

Source: Kibirigwi Irrigation Scheme: "Project Evaluation: Crucial Questions or Issues for Discussion" 1983.

2.4.5 Technical, Production and Management Aspects

The Irrigation Water Supply from the Ragati River is gravity fed to a pressure pipeline that runs for about 7 kilometers along the Nairobi-Nyeri road (see Map 3). Distributary channels stem from the main channel and they have outlets in each of the 256 farms and 4 schools. The design capacity of the intake is 150 litres per second of which 10 litres per second is meant for domestic use. Each farmer has been given two single-nozzle sprinklers. The sprinklers are of three categories of nozzle-sizes 9/64 inches 5/32 inches and 11/64 inches.

The farms are designed in small parcels called laterals. Farmers have two to twelve laterals. Each farmer is supposed to irrigate about half of the irrigable land during any planting period. Originally it was expected that farmers would have some extra land for rotation purpose but because of the shortage of land farmers are infact planting in the same parcel twice a year. This intensive farming with the application of irrigation water has alot of consequences on the future soil fertility, salinity, crop yield and the general performance of the scheme.

Each farmer can irrigate the farm for 24 hours a day, all year round, without causing any shortage of water to other users. Currently, farmers are not paying for the water but plans are under way to introduce water-use charges.[22]

Production in Kibirigwi is unique from most other irrigation schemes in Kenya because, unlike other schemes where farmers are tenants, farmers on Kibirigwi irrigation scheme own the land on which they farm. They have only signed an agreement with the government through Kibirigwi Irrigation Scheme (K.I.S.), as the Water-undertaker to perform certain duties. Among other things the farmer is supposed to:-

- become a member of KIFCO
- permit KIS or its employees to perform duties on his farm
- permit the passage of irrigation water through main and lateral pipes on his farm holding free of charge
- pay KIS, on a proportionate basis, the capital expenditure and interest of the irrigation network and scheme buildings at a rate to be mutually agreed
- instal and maintain an on-field sprinkler irrigation system to the satisfaction of the scheme management, and finally
- deliver all horticultural produce solely to the scheme management and to permit and authorize the scheme management to deduct from the monies accruing from the sales of horticultural produce such sums of money as are proper for the purposes of repaying all the costs involved.

The Water-Undertaker (KIS) agree, among other things, to :-

- instal the irrigation network to provide water for the agreed irrigation purposes

- undertake marketing and investigate market outlets to attain highest possible returns, and

- transfer all managerial responsibilities to the board of the co-operative society following an agreed schedule.[23]

Both the farmers and KIS were to mutually agree that the Scheme Management be established by the Ministry of Agriculture with the Scheme Management Committee as the consultative body on the general progress and welfare on the scheme. The agreement was to remain in force for five years. Now that the five years are over, plans are under way to sign a new agreement.[24]

The farmers on the scheme grow crops like coffee, maize, bananas and English potatoes on the non-irrigated part of the farm, and horticultural crops like tomatoes, onions, cauliflower, lettuce, cucumber, courgette, capscum and bobby beans on the irrigated plots, permitting rotation whenever possible.

The process of production starts with the scheme management making a detailed farm programme on what to produce, when and by whom. Farmers are then informed about which crops they can grow during a given period. Land preparation is done by the farmer either by hiring tractor services from the scheme, hiring ox-plough services from ox-plough owners or just digging with a hoe using family and hired labour.

Farmers are given farm inputs on credit basis Members apply freely for farm input such as vegetable seeds fertilizer and chemicals. A schedule is prepared on how many farmers are allowed to plant a given crop on a monthly basis in order to avoid over- and under_production. Farmers are usually put in five categories according to their previous performance and loan repayment for the purpose of current loan allocation. The credit ceiling is as follows:-

Table 2: CATEGORIES OF CREDIT ALLOCATION

Category	KSh. Per Period
1	3000
2	2000
3	1500
4	750
5	0

Souce: KIFCO records.

A farmer can apply for a new loan immediately he completes repaying the outstanding one; thus the ceiling is not rigid. Members in category 5 have to pay everything in cash.

An interview with farmers in 1983 showed that, on average, category 5 of the farmers had pending loans averaging KSh.2,000 which they got around 1980. They have failed to repay the loans and therefore they can not get new ones. These farmers are in a kind of vicious cycle: They can not farm effectively without loans for farm inputs, and they can not get new loans before clearing the pending ones. Categories 4, 3 and 2 have loans averaging KSh.1000 which they got in 1982 and 1983. Category 1 had no loans outstanding in KIFCO at the time of the interview.

Throughout planting, cultivation and harvest, farmers are visited by four extension officers and the Scheme Management to guide them in farming practices. Harvest of scheme crops i.e. tomatoes, onions etc) is done twice a week and all the scheme crops are transported by trailors to the scheme warehouse. The crops are sorted, graded and packed, ready for export or delivery to Nairobi's wholesale market. Records are kept for every farmer's output and the farmers are paid for their produce on a monthly basis. From the Gross Revenue of each farmer a 7 per cent commission is deducted. What remains is called the Gross Pay-out, from which loan-repayment is deducted. The percentage of loan-repayment deductions depend on the total credit outstanding. The rates of deduction are shown in table 3 below. The farmers have savings accounts in Kirinyaga District Co-operative Union Bank through which they are paid for their crop deliveries.

Table 3: Credit Deductions

Outstanding Amount (KSh)	Deductions (Percent of Gross Pay-out)
Up to 500	20
" 1000	30
" 1500	40
" 2000	50
" 2500	70
" 3000	90
Above3000	100

NB: The Gross Payout less loan deduction is called net payout.

Source: Kibirigwi Irrigation Scheme records (1983).

The management of Kibirigwi irrigation scheme is still in its initial stages and is bound to undergo considerable changes in future. The three agents that inter-link to run the scheme are the government (through the Ministry of Agriculture and Livestock Development and KIS), the co-operative and the farmers. Figures 2 and 3 show the national organization and Kibirigwi management structures respectively.

2.4.5 General Life on the Scheme

Arao and Houtman[25] carried out a Baseline Agro-Economic Survey on the Scheme in 1980 which showed that there was no radical difference between the farmers on the scheme and those in other areas of the province. The majority of the farmers lived in grass-thatched mud-walled unit Only 7 per cent of the farmers had piped water up to their homesteads. The main dish, Irio, was a good source of protein, starch and the essential fats. The farmers appeared generally healthy, even though scattered cases of Kwasiokor were observed among some children. The annual agricultural income from coffee comprised 40 percent of the total agricultural income. There was a high fluctuation of income between 1971 and 1980 because of weather changes.

In their survey, Arao and Houtman had 50 per cent of the informants as male and 50 per cent as female. The average age of the informants was 47 years and 47 per cent of the sample were older than average. The average level of education was standard Three but only 33 per cent of the farmers had formal education up to Standard Seven.

In our survey about 30 per cent of the respondents were female and 70 per cent male. This indicates that 30 per-cent of the sampled farms are wholly organized by females. The average age of the informants was 45 years, which is not significantly different from Arao and Houtman estimates. About 18 percent of the respondents had no education at all, 44 per cent had education up to Standard eight and less than 10 per cent went beyond Standard eight.

Most of the farmers lived in mud-walled and corrugated-iron-sheet roofed houses. A few farmers had wooden (timber) and stone-walled houses. In the adjacent Kiangwachi area most of the houses had mud walls and grass-thatched or roofed with corrugated iron sheets. In addition to <u>Irio,</u> the farmers have plenty of vegetables and fruits as part of their dish.

The aim in this Study is to analyse the changes that have taken place since Arao and Houtmans baseline Studies.

FOOTNOTES

1. Kenya Government: Sessional Paper No.4 of 1981 on National Food Policy. Government Printer, Nairobi, 1981.

2. See Sorrenson, M.P.K., Land Reform in the Kikuyu Country. Oxford University Press, Ely House, London, 1967.

3. The terms "large scale" and Organized" here are not used in the sense commonly applied. They are just operational terms applied by the Ministry of Agriculture to identify certain types of irrigation activities related in operation or management.

4. See National Irrigation Board, Annual reports.

5. Carruthers and Weir "Rural Water Suppliers and Irrigation Development" in Heyer J. et el (eds), Agricultural Development in Kenya: An Economic Assessment. Oxford University Press, London, 1976.

6. Kenya Government, Ministry of Agriculture Mission Report on the National Water Master Plan, Phase I 1979.

7. Kenya Government, Ministry of Agriculture Irrigation and Drainage Research Project Report, 1978.

8. Carruthers and Weir, "Rural Water Supplies and Irrigation Development" in Heyer J., et el (Eds) op cit.

9. Okoth-Ogendo, "African Land Tenure Reform" in Heyer J., et el (Eds) Op cit pp 152-186.

10. Kenya Government, The Water Act. cap 371 and 372 of the Laws of Kenya, Government Printer, Nairobi, 1975.

11. Carruthers and Weir, "Rural Water Supplies and Irrigation Development" in Heyer J., et el (Eds) Op cit p.292.

12. Kenya Government, Kerio Valley Development Authority General Development Plan for Kerio Valley Basin, Water resource study, Feb. 1982.

13. Baker B.H., Geology of the Mount Kenya Area, Report No. 2[illegible] Geological Survey of Kenya. Nairobi, Kenya, 1969.

14. Oswago O.O., Detailed Soil Survey of Kibirigwi Irrigation Scheme, Kirinyaga District. Detailed soil survey report No. D 10. Kenya Soil Survey, NAL, NAIRQBI, Kenya, 1979.

15. Oswago O.O. Op.cit.

16. Njihia E.M. Soils, Irrigation and Water Use in a Small Scale Sprinkler Irrigation Scheme, Kibirigwi, in Kirinyaga District, of Central Province, Kenya. IDRP Report, No. 39, Nairobi. 1979.

17. Moris and Chambers (Eds). Mwea: An Irrigated Rice Settlement in Kenya. Welt forum - verlage GmbH, Munchem, 1973.

18. For Works on Risk Minimization and Irrigation See Selby, H.E.: "The Importance of Irrigation in the Economy" Journal of Farm Economics. Vol. 31, 1948.

19. Sorrenson M.P.K: Land Reform in the Kikuyu Country Oxford University Press, Ely House London, 1967.

20. Kenya Government: Ministry of Agriculture, Small Scale Irrigation Unit (SSIU) The Kibirigwi Irrigation Scheme, 1980.

21. Kibirigwi Irrigation Scheme Records.

22. It has been suggested by the Management that the farmer should pay Sh. 300 per year.

23. Kibirigwi Irrigation Scheme records.

24. The Chairman of Kibirigwi Irrigation Co-operative Society (KIFCO) said during an interview with him that they were in the process of drafting a new agreement.

25. Arao L.A. and Houtman C.B., Baseline Agro-Economic Survey of Kibirigwi Irrigation Scheme, IDRP Report No. 26, NAL. June, 1980.

CHAPTER THREE

LITERATURE REVIEW

The aim in this chapter is to review the literature on the economics of irrigation. The review includes theory, empirical research and findings, the methodology applied in such research and the problems encountered. Essentially, the economics of irrigation is the Standard Economic theory and practice modified to suit the complexity of irrigation as an Economic Activity. It gained prominence only two decades ago when large scale irrigation development projects in the Less Developed Countries failed to perform as had earlier been anticipated. Consequently the scope and analytical framework of the subject have not been well developed.

For analytical convenience the economics of irrigation can generally be divided into three major sub-sections:

- The importance of irrigation in agricultural and national development.

- Methods of evaluating the economic viability of the various irrigation techniques and crop combinations, and finally

- the evaluation of irrigation side-effects, that is, the environmental, cultural and political impacts of irrigation.

At the Macro-economic level the subject deals with the link between irrigation and macro-economic variables like employment, output and agricultural stability either regionally or nationally. A number of researches have been done in various parts of the world on the importance of irrigation in agricultural and national development. For example, Cochrane[1] has specified the methodology of research in policy and used it to identify the physical, economic and social factors in the formulation of land use policies in the river basins of the United States of America. He concludes that socio-economic factors are crucial in determining the desireable policies in these basins.

Using input-output analysis, Crosson[2] showed that irrigation can help to improve industrial capacity utilization by ensuring a steady supply of inputs. He concludes that irrigation can expand and support urbanization and employment. Writers on the Chinese economy also seem to agree over the important role played by irrigation projects in boosting Chinese agriculture, national output and employment in the period that China recorded rapid economic growth.[3]

Here in Kenya, Moris and Chambers[4] researched on Mwea Rice Irrigation Scheme and came up with interesting conclusions as to why the scheme has been a major success contrary to the failure of various large scale schemes, particularly in less developed countries. They identified historical and ecological factors as key to the scheme's success.

In addition, Micro-economic studies have been done on the importance of irrigation to agricultural development. The aim has been to identify the relationship between irrigation and the level of agricultural output, changes in technology and farmers'adaptability to that technology at farm level. For example, using production function analysis researchers in Pakistan concluded that there was a positive and linear relationship between wheat yield per hectare and water input[5]. In another study on India's High Yelding Varities Programme in wheat, Vyas[6] showed that farmers with an access to water supply were more adoptive to new technology than those without. He noted that where irrigation had been successful the farmers' agricultural behaviour and the actual capacity to adopt new technology improved considerably.

Palmer-Jones[7] used the method of estimating irrigation response from data on unirrigated crops to get the impact of irrigation on a tea farm in Malawi. He says that provided certainconditions are met, the response of a crop to irrigation can be approximated from historical data on the unirrigated crop. The three conditions required are:, that ideal weather occur once during the data series; that irrigation has the same effect on yield as ideal weather; and finally that no interaction exists between technological advance and response to weather and/or irrigation. This is done by assuming that irrigation will lead to an increase in yield equal to the difference between actual yield and the yield if ideal weather occured.

Risk and uncertainty have been cited as major problems affecting farmers' decision variables[8]. This has prompted irrigation researchers to identify the impact of irrigation on farmers' risk reduction and decision taking. For example Carruthers and Donaldson[9] used a simulation model to estimate the effective risk reduction through irrigation of a perenial crop in three areas of East Pakistan. Their results showed that reduction of risk increases the value of the output by about 20 per cent. However, they conclude that the method used is effective for specific rather than generalized situations. Ho[10] extended the analysis of risk and investigated how different tenure systems alter the risk to landowners and tenants. He concluded that tenure arrangements determine whether it is the tenant, landlord or government who bears the risk.

Studies done here in Kenya include those of Carruthers[11] and Jacobson.[12] In a pilot survey at a water scheme in Kabare and Inoi (control area), in Kirinyaga district, Carruthers showed that there was no relationship between water supply and the level of farm income. Yet in another study at the Zaina Scheme, Nyeri District, Jacobson found that graded cattle increased by 66 per cent while those in the control area increased by only 36 per cent over the period 1961-1965. But in a 1970 survey there was no difference in the herd size or proportion of farmers owning grade cattle between Zaina and the control area. However, Zaina produced three times as much milk as the control area.

In an M.A. Thesis, Kangangi[13] studied Kibirigwi irrigation scheme to assess its impact on rural development. Analysing variables like yield, employment and land-use, he concluded that the scheme has contributed significantly to rural development.

These studies reveal a number of facts about the impact of irrigation to rural development. First, the impact is region and time specific. The results obtained from one scheme can not be generalized for the rest of the schemes nor in the same scheme in another period. Secondly, the researchers were using different approaches and definations to evaluate the impact of the various projects they were undertaking. Consequently, comparison of any two studies is not usually possible.

The second sub-section of the economics of irrigation, that is, the methods of evaluating the economic viability of various irrigation techniques and crop combination has had a wide coverage all around the world. Many books have been written on the principles of irrigation, giving various methods of irrigation and the cost implications. Economists have often given these costs and benefits a 'social feel' by adopting social cost-benefit analysis. In actual fact, cost-benefit analysis as a technique was considerably advanced by the need for proper planning for large scale River Basins in the United States of America[14]. A number of manuals have been published on the costing of irrigation schemes. For example, in a policy paper of the World Bank on the framework for irrigation water charges, Duane[15] says that cost recovery is an important and controversial step in the appraisal of irrigation projects since the recovery policies affect the distribution of project benefits, both in the intertemporal and intratemporal sense. He says that the World Bank policy has been to require a recovery of at least the public sector operation and Maintenance (O&M) costs, and up to 100 per cent of all direct public cost of the project.

Water engineering and costing has been done for specific projects in Kenya, most of which have been large-scale projects undertaken by the National Irrigation Board. These have often been followed by cost-benefit evaluation.

The third and final area of the economics of irrigation is the measurement and evaluation of the impact of irrigation on the environment. This falls under the disciplines of ecology and pathology. However, in economics it falls under the theory of externalities. Studies which have been done in various parts of the world show the impact of irrigation on precipitation, aquatic ecosystem, soil and biological balance, human pathology and culture.[16] A study done in Kenya's Kano plains, Nyanza Province, on a comparison of mosquito populations between irrigated and non-irrigated areas showed a significant increase in the case of the former[17]. Generally, the impact of irrigation on the environment here in Kenya has not been fully documented.

One of the most challenging question in the study of irrigation is the kind of analytical tools appropriate for use. One can adopt the production function analysis in which water is considered as a variable input in the multivariable production function of a given crop. By use of marginal analysis one can get the optimal water use and revenue acrued. Alternatively one can adopt cost-benefit analysis to evaluate the visibility of a given irrigation project where the objective is to get a positive net benefit from the project. Finally, one can apply a Linear programming model. The farmer (or government) as an economic unit operating in a given situation is assumed to be making decisions and implementing them in an endeavour to optimize certain objectives subject to a set of constraints.

Whatever method used should have a bearing on the basic theory of the firm particularly if the study is based on small scale agriculture. A small farm is a multi-product firm which can be analysed by use of the neoclassical theory of a multi-product firm. The theory is based on "optimality", "marginality and scarcity". Optimality in the sense that the firm has alternatives from which to choose and there is only one alternatives from which to choose which yields the optimum value. The objective of the decision maker is to attain this optimal value. Marginality in the sense that the optimal alternative is judged from its additional benefit. Finally, scarcity in the sense that the firm is constrained by certain variable and fixed inputs which have to be combined in given proportions.

The following conditions should hold for optimization to take place:

- perfect competition in the factor and product markets.
- No technological linkages or jointness
- The goal of the firm is to optimize some value (for example maximize profit).
- Each seperate function is neoclassical.[18]
- Production processes do not change over time.
- perfect knowledge of technical production relationship and finally,

- The firm is constrained by certain variable and fixed inputs.[19]

Then, for a multi-product enterprise whose output levels are $Y_1, Y_2 .....Y_n$ and uses quantities $R_1, R_2 ....$ R_m of m different inputs, the generalized production function may be written as

$$f(Y_1, Y_2 ... Y_n, R_1, R_2 .... R_m) \leq 0$$ [20]

Applying a lagrangian function with the variables Y and R (as defined above) and parameter t, where t is the lagrangean multiplier, the 1st and 2nd order conditions of neo-classical maximization criteria will give the following outcomes of the optimal solution:

1). That the marginal value product is equal to the marginal factor cost.

2). That the marginal rate of technical substitution between a pair of variable inputs, holding the level of all output and all other inputs constant, should be equal to their incremental input price ratio: which is a corollary to the dictum that the ratios of the marginal products and prices should be equal, and finally

3). That the value of the lagrangian multiplier at a solution point measures the sensitivity of the optimal value of the objective function ($\pi^* = \pi^* (Y^*, R^*)$) to arbitrary small changes in the constraint level.[24]

The above three outcomes answer all questions pertaining to decision variables of a neoclassical firm. But there have been a lot of critisisms about the realism or usefulness of the marginal analysis of neo-classical economics. Apart from the lack of knowledge about the functional firms of production, the assumptions under which the firm is assumed to operate (for instance complete certainty) are unrealistic. Further more recent expositions consider the firm as a utility maximizer and not profit maximizer as assumed in the neo-classical analysis. To seal the flaws left by neo-classical theory, linear programming, Game theory and organization theory have been developed. The remaining section in this chapter is a review of the literature on linear programming, the analytical tool choosen for this study.

Linear programming is a special case of mathematical programming in which functions are linear[22]. It is also a special case of an input-output model in which there is choice.[28] Linear programming is a linear production function formed from a collectiom of linear production activities. It is homogenous of degree one and thus yields constant returns to scale. It is assumed that the Production Activities are linear, the variables are divisible, additive and finite, there exists perfect knowledge about the functional forms and variables, and finally the existence of the optimization objective. These assumptions are modifications of the neo-classical assumptions stated above.[24]

Although the use of linear programming to farming activities in Developing Countries is still limited, the model has been applied successfully in Developed Countries. Miller and Nautheim[25] used the model to illustrate the use of cost minimization strategy with reference to a wheat farm in the Great Plains of the United States of America. They compared the optimum organization of the enterprises developed by minimum cost and profit maximization strategies of management on the same farm and discussed the interrelationship between results of the two models. They concluded that a cost-minization strategy is superior to a profit maximization one since the former can be used to determine the resources required for a targeted income. Secondly, the cost minimizing strategy can be used to derive cost curves for a researcher interested in the size of the firm.

Kottike[26] used farm record data to show that budgeting and linear programming can yield the same results. He concludes that the two methods are complementary and one way of applying them is to use Linear Programming in research for solving complex farm adjustment problems and to convert the results into the farm budgeting form in reporting the results to the farmer.

One of the major criticisms of early linear programmes was the assumption of single values for the technical and price coefficients used in the model. Techniques have since been developed that allow the coefficients to be random variables with specified probabilities. The new developments include parametric, dynamic, recursive, and stochstic models.[27]

In the field of irrigation, Rogers and Smith[28] used mathematical programming to determine the integrated use of ground and surface water for irrigation project planning in Egypt. The authors conclude that the model could be used in determining the pulse-well, canal and surface drainage capacities, the project size and the cropping pattern.

Inspite of its limitations, linear programming has been applied severally (at least at research level) here in Kenya. With the objective of identifying the constraints that faced farmers in Central Province, Clayton[29] used the model to establish that farmers were not growing pyrethrum in Nyeri because of the land constraint. In her Ph.D. thesis, Heyer[30] established that risk and uncertainty of food supply was the major reason why farmers in Machakos District, Eastern Province, were not paying adequate attention to cotton growing.

Using the same technique Ateng[31] established that farmers in Makueni location of Machakos district were right in applying low level technology in maize production, given the economic conditions in which they operated. And in an effort to expand the compatability of the model, Mukhebi[32] used sample data from Mbiuni location, Machakos district, to show that there was an income-employment trade-off in agricultural production. He used a multi-objective linear programming model instead of a single

There are a number of problems associated with the use of linear programming particularly in Less Development Countries. Data requirement constitutes one of the serious problems. One is required to know the input - output coefficients of each activity, the activity prices and the resource constraints. Usually the costs of data collection outweigh the benefits obtained by a single farmer by using the model. It has been observed that if farmers keep proper records of their farming activities then the cost of data collection would be drastically reduced.

The second problem associated with the model is that it is quite complex, requiring a wide knowledge of mathematics before one can apply it. At the extreme end, the models need sophisticated computor hardware. Ordinary farmers do not have all these. One of the areas where linear programming can viably applied is in research. The third problem associated with the model is that it can only be useful solving problems on a specific farm. It is difficult to get a representative farm in a situation of diverse ecological, economic and social conditions. The best solution is to get data on specific farms and use optimality analysis with the hope of capturing the conditions of other farmers in the 'neighbourhood.

From the literature survey it is clear that there have been many seperate studies in irrigation and the use of linear programming in farming situations, but very few studies have been done, on irrigation using linear programming technique. At this stage one may ask whether linear programmimg is a useful tool in analysing irrigation projects in Kenya.

Irrigation in Kenya is undertaken under diverse and complex situations of the environment and socio-economic conditions of the people. Proper planning and co-ordination of decisions would require a model that is comprehensive and flexible enough to accomodate most of these diverse situations. As explained in the chapter four of this study the linear program model is flexible enough to accomodate these situations. Secondly, most of the irrigation schemes are required to keep records of the activities that go on in the scheme which reduce the cost of data collection over time. Furthermore, the computer services in the country have advanced to a stage of solving complex programming models at manageable costs, particularly if the programmes are undertaken by the government. Given the important role the government has accorded to the national water resources in general and small scale irrigation in particular, the results of linear programming can be used in planning for the water resource in a better way than if each factor or project was analysed in isolation.

The dismal performance of the existing large scale schemes negate the methods used initially to appraise the projects. The National Irrigation Board was observing in its annual reports that experience on the the irrigation schemes had shown that farmers must get tangible results if they have to co-operate fully with the stringent demands made by reasonably sophisticated modern agricultural techniques, and thatgood results could be obtained only when the farmers' objectives are well syncronized with the market and natural conditions. Such a syncronization requires a flexible but systematic model and linear programming possesses both of these characteristics. It is thus strongly felt that linear programming can be applied to irrigation situations in Kenya.

FOOTNOTES

1. See Cochrane, W.W., "Research in Public Policy" Journal of Farm Economics Vol. 32, 1949.

2. See Crosson, "The Impact of Irrigation Investment on Regional and Urban Development," in Inter-Basin Transfer of Water: American Case Study, by Cummings R. (Ed) 1975.

3. For example See Nawask G.T., Economic Growth and Employment in China. World Bank Publication. 1979.

4. See Chambers R. and Moris (Eds)., Mwea: An Irrigated Rice Settlement in Kenya. Weltforum - verlage GmbH, Munchem, 1973.

5. The researches have been cited in Clark C., The Economics of Irrigation, New York Pergawn Paess, Oxrod , 1967.

6. Vyas, V.S., "India's High Yielding Variaties Programme in Wheat, 1966-67 to 1972", International de Majoramiento de Maiz Y Trigo (CIMMYT) Mexico City, 1975.

7. Palmer Jones R.W., "Estimating Irrigation Response from Data on Unirrigated Crops" American Journal of Agricultural Economics Vol. 57, 1976, pp. 85-87.

8. For example see Crosson op cit.

9. Carruthers I.D. and Donaldson G.F. "Estimation of Effective Risk Reduction Through Irrigation of a Perennial Crop" Journal of Agricultural Economics, Vol. 22, 1979.

10. HO, S.P.S., "Uncertainty and the Choice of Tenure Arrangements' Some Hypotheses" American Journal of Agricultural Economics, Vol.57 1976, pp. 89-192.

11. Carruthers, I.D. Impact and Economics of Community Water Supply. Wye College, University of London, 1973.

12. Jacobson B. et el: "The Case of Rural Water in Kenya in Strategies for Improving Rural Welfare" IDS University of Nairobi, Occassional Paper No. 4, 1974.

13. Kangangi, G.M.: The Role of Small Scale Irrigation Schemes in Rural Development: A Case Study of Kibirigwi Irrigation Scheme. M.A. Thesis, University of Nairobi. 1982.

14. See Irvin G., Modern Cost-Benefit Methods, The MacMillan Press Ltd., London, 1978.

15. Duane, P.,, A Policy Framework for Irrigation Water Charges, World Bank Staff Working Paper No.218, July 1975.

16. Worthington E.B. et el, Arid Land Irrigation in Developing Countries: Environmental Problems and Effects. International Council of Scientic Union, Oxford, 1977.

17. See Worthington, E.B. Et al, Op cit.

18. A neo-classical function means it is twice differential, the first partial differentials being positive while the second partial differentials being negative.

19. See Bauomol W.J., Economic Theory and Operations Analysis Pretince Hall inc., Englewood Cliffs N.J. 1977.

20. We fomulate it in the for $f(Y_1 \ldots Y_n : R_1 --- R_m) \leq D$, to allow for waste or inefficiency in the production process. This necessities the existence of an equilibrium. For a further analysis of the existence of an equilibrium See Linear Programming and Economic Analysis The RAND Corporation, McGraw-Hill Book Company, London, 1958.

21. See Chiang A.C., Fundamental Methods of Mathematical Economics, 2nd Edition, MacGraw Hill inc. 1967.

22. See Heyer, J., Agricultural Development and Peasant Farming in Kenya. Ph.D. Thesis, University of London, 1966.

23. Boulding, K.E., Linear Programming and the Theory of the Firm, The MacMillan Company, New York, 1960.

24. Ibid,.

25. Miller T.A., and Nautheim C.W., "Linear Programming Applied to Cost Minimizing Farm Management Strategies". Journal of Farm Economics, Vol. 46 1964.

26. Kottike M.W., "Budgeting and Linear Programming can give Identical Solution", Journal of Farm Economics, Vol, 43, 1961.

27. For example See., Hutton R.F., "Survey of Operations Research Techniques", Journal of Farm Economics. Vol. 47, Pt Z, 1965.

28. Smith and Rogers, "New approaches in organizing for Land and Water Use", Journal of Farm Economics, Vol. 44, 1962.

29. Clayton E.S. "Economic and Technical Optima in Peasant Agriculture". Journal of Agricultural Economics, Vol. 12, 1961.

30. Heyer J. Op.cit.

31. Ateng, B.A., Linear Programming: An Application to the Identification of the Best Existing Farming Strategy for Peasant Farmers in Kenya. M.A. Thesis, 1977.

32. Mukhebi, A.W., "Income and Employment Generation in Kenya Small Scale Agriculture". A Ph.D. dissertation, Washington State University, 1981.

REFERENCE

1. Baumol W.J., Economic Theory and Operations Analysis. Prentice Hall, inc Englewood Cliffs, N.J., 1977.

2. Boulding, K.E., Linear Programming and the Theory of the Firm. The MacMillan Company, New York, 1960.

3. Carruthers I.D. Impact and Economics of Community Water Supply, Wye College University of London, 1973.

4. __________ and Donald G.F. "Estimation of Effective Risk Reduction Through Irrigation of a Perenial Crop". Journal of Agricultural Economics, Vol. 22,1971.

5. Chambers, R. Et el., Mwea: An Irrigated Vice-Settlement in Kenya. Weltforum-Verlag GmbH, Munchen, 1973.

6. Chiang, A.C.,: Fundamental Methods of Mathematical Economics. 2nd Edition, McGrill-Hill inc, 1967.

7. Clark C: Economics of Irrigation, New York Pergamn Press, 1967.

8. Dorfman R., et. el., Linear Programming and Economic Analysis. The RAND Corporation/McGraw-Hill Book Company. London, 1958.

9. Heyer J.: Agricultural Development and Peasant Farming in Kenya, Ph.D., Thesis, University of London, 1966.

10. Hutton R.F.: "Survey of Operation Research Techniques" Journal of Farm Economics.

11. Jacobson B, et al,: "The Case for Rural Water in Kenya in Strategies for Improving Rural Welfare" IDS University of Nairobi, Occasional Paper No. 4, 1974.

12. Mukhebi, A.W., Income and Employment in Kenya's Small Scale Agriculture. Ph.D, Thesis Washington State University, 1981.

13. National Irrigation Board: Annual Reports.

14. Vyas V.S.: India's High Yielding Varieties Programme in Wheat 1966-1967 to 1972. International de Majoramiento de Maiz Y Trigo (CIMMYT) Mexico City, 1975.

15. Worthington E.B. et el,: Arid Land Irrigater in Developing Countries: Environmental Problems and Effects. International Council of Scientific Union, Oxford, 1967.

CHAPTER FOUR

HYPOTHESES, METHODOLOGY AND DATA SOURCES

4.1 The Hypotheses

This Chapter presents the hypotheses, methods applied in testing the hypotheses and the data sources. The three hypotheses to be tested in this study are as follows:

HYPOTHESIS 1: The agricultural income of farmers on an irrigation scheme is not significantly higher than that of farmers in an un-irrigated area.

HYPOTHESIS 2: Some government regulations are an obstacle to raising output on small scale irrigation schemes.

HYPOTHESIS 3: The expansion of irrigation is to some extent limited by institutional and social factors.

4.2 Methodology

Hypothesis 1 and 2 are tested by running Linear Programming models of the form

$$\text{Max } Z = \sum_{j=1}^{n} C_j X_j \qquad j = 1, 2 \_\_\_\_\_ n \qquad (1)$$

Subject to

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad i = 1, 2 \text{------} m$$

$$X_j \geq R_j \qquad (j = 1, 2 \text{------} k : K \geq n)$$

$$\text{and} \quad X_1, X_2 \text{----} X_n \geq 0$$

where the variables and parameters are defined as follows

Z: Objective function (Gross Margin) to be maximized.

X_j: Agricultural activity undertaken by the farmer.

C_j: Gross Margin of activity X_j.

a_{ij}: Unit of resource i required to produce one unit of output X_j.

n: Alternative activities that the farmer can undertake.

b_i: Resource constraints that the farmer faces.

m: Number of resource constraints.

R: Other social and institutional constraints facing the farmer.

K: Number of other constraints.

The Linear Programe models were ran for the three specific farmers from the scheme whose details are given in Chapter 5. The farmers were randomly chosen from the first, third and fifth categories of farmers as explained in Section 4.3 below. It was not possible to run programs. for a large number of farmers because of data limitations. Even though the Scheme management keeps records of the activities going on in the scheme, there were no detailed records of the farmers' characteristics and conditions. There was therefore need for a more detailed analysis of the farmers' conditions in order to formulate representative technological parameters and resource levels. Programs for a large number of farmers would have been done at the expense of less detailed analysis of a few specific farmers, which was deemed important in this study.

However sampling was done in such a way that the three farmers represented as much as possible the three categories of farmers, namely, progressives, moderates and laggards (see Section 4.3 in this Chapter). Secondly, in order to increase our knowledge of the possible performance of other farmers, sensitivity analyses were done on the basic results of the three farmers. Resource limits were varied and their impact on the net return analysed. This was done on the assumption that farmers' performance on the Scheme could to a large extent be determined by the availability of resources like land, labour, credit and market outlets. Therefore by varying the resources of the three farmers it was possible to have a proxy of the resources levels other farmers. In any case most agricultural researchers who use Linear programming are of the opinion that in a situation of a large number of farmers and limited information, it is better to analyse specific farmers and apply sensitivity analysis rather than analyse an average farm by aggregating the data.[1]

The models were ran on the ICS computor using the XDLA Marks 3 Package. The package gives the maximum value of the attainable output within the given resource constraint and the farming pattern required to give the optimal solution. The package also gives the resources which are effective limits to production in their order of importance. By use of sensitivity analysis and parametric programming the package gives the impact of changes in the resource constraints and activity prices on the optimal solution. Additional information is obtained by adding the subsistence constraint to the basic model to determine its impact on the farmers decision variables

Each farmer's results are analysed to identify the level of income obtained from the irrigation activities, the resource constraints and the impact of changes of these resources to each farmer. By comparing the results of the farmers it is possible to identify the diversity of the farming conditions under which the farmers operate on the same scheme. The specific results are then combined to give the overall performance of the scheme. On the basis of the overall performance, the average income (Y_1) of the farmers is calculated. This average income is the 'ideal income' since it is attainable only if the farming pattern under consideration is applied. This ideal income is compared with the actual income (Y_A) as estimated from the sample of 27 farmers responses to the interviews (see Questionaire and table of calculated income in the appendix). A third income (Y_E) is calculated on the assumption that the agricultural income of the farmers in this scheme would have grown at the same rate as that of other farmers within the district had the scheme not been provided with irrigation water. The income is estimated by exterpolating the average income of the farmers on the scheme as obtained by Arao and Houtman in the Agro-Economic Baseline Study of 1980.[1] This exterpolated income (Y_E) is compared with the Actual Income (Y_A) to determine the significance of irrigation water on farmers' agricultural income. If the two incomes are substantially different then the difference is to a large extent caused by the availability of irrigation water.[2]

The ideal income is compared with the actual income (Y_A) to determine if they are substantially different. If so, then the difference may/brought about by government /be regulations which will be identified and analysed in detail.

Tables 4a, 4b and 4c in the appendix give the technical coefficients and resource availability for farmers 1, 2 and 3 respectively. Except for the credit coefficients and resource limitations the other parameters are the same for the three farmers.

Hypothesis 3 is tested by use of statistical methods of cross-tabulations of means and calculation of correlation coefficients. This method of data analysis allows us to determine the extent to which the performance of the farmer is explained by his background, characteristics and the resources at his disposal. The farmers characteristics include education, age, sex and experience with the local environment. The resources at the farmer's disposal include land, labour and credit. In addition, the farmer operates within a social and institutional framework which affects both his ability to make decisions and the optimal resources at his disposal. These include market forces as reflected in the factor and product prices; government regulations as reflected in the scheme management's objectives and policies; and the legal framework reflected in the Water and Tenure laws. Thus, after identifying the factors which affect the farmers performance it will be ascertained as to what extent the social and institutional factors limit or enhance the performance.

4.2.1: Specification of Model Variables:

X_{js}: These are the farm activities which are either single crops or a mixture of crops.

Six activities are analysed and are identified in terms of the type of crop or the period of the year in which they are grown. The six activities are:

- Early Maize and Beans (MIB1)
- Late Maize and Beans (M1B2)
- Early Onions (ONS1)
- Late Onions (ONS2)
- Early Tomatoes (TOM1)
- Late Tomatoes (TOM2).

The calender for the activities is given in Chart 1 of the appendix.. The Chart for instance shows that first season maize and beans (M1B1) extend from January to October. Second season activity (M1B2) extends from August to April. The farming pattern for the two activities was obtained from the study by Schmidt. and Swoboda.[3] The patterns for onions and tomatoes on the other hand were obtained by analysing their Nairobi wholesale prices. The analysis was to determine the period of the year when prices are highest so that production could be adjusted accordingly. As shown in graph 3 in the appendix the highest prices for the two crops are between April and June, and October to November. During the two periods the rain-fed crops would still be growing. In order for first season onions to mature in April, land preparation should start in October. The patterns of the other activities are analysed likewise.

The unit of measurement for each activity is the area under which the crop or crop mixtures are put. Since laterals are used as a measure of the land under horticultural crops on the scheme, all the other activities will be defined likewise.

A number of farm and non-farm activities that enter into the farmer's decision choice have been left out of the analysis either because they are not important in the analysis or by their nature they could not be combined with those already specified due to some basic assumptions of the Linear Program. The farm activities that are significant but have been left out of the model are coffee growing and cattle rearing. They have been left out because they are perenial activities which can not be combined with the seasonal activities under consideration. For instance in our model if a given activity assumes a zero value in the optimal solution then it implies it does not exist during that particular period. Coffee and cattle rearing can not cease to exist in a given short period and be revived in the following period. The activities could have been incorporated if dynamic programming or simulation models were applied, but this would require long term data collection and analysis[4]. Instead these activities are considered separately to determine their economic impact on the farmer.

The non-farm activities which have been put under consideration but not included in the model are wood-work, house building, marketing activities, petty trading, casual jobs, labour employment, ox-plough hiring, household chores and leisure. Since these activities are important in so far as the allocation of labour is concerned, the labour requirement for the necessary activities like house building household chores, attendence to sickness and leisure is subtracted from the total labour available to a given farmer at a given period. The other activities are left out of the analysis with the assumption that they could be done during the slack-labour period.[4]

C_{js}: These are the respective net revenues per lateral of each activity and are obtained by subtracting the total variable costs from the total revenue of each activity. Hence,

$$C_j = Q_j P_j - \left(\sum_{j=1}^{T} F_{ij} \ P_{ij} \right) \qquad (2)$$

Where:

Q_j = The average output (in Kilograms) of activity j per lateral

P_j = The average price per kilogram of activity j

F_{ij} = The variable inputs of activity j

P_{ij} = The respective average prices of the variable inputs. Their values are shown in table 1 of the Appendix.

a_{ijs}: These are the coefficients in the technological matrix. The five types of coefficients considered in this analysis are labour, water, irrigated land, un-irrigated land and credit coefficients.

The labour coefficients are obtained from the study done by Heyer[6] and more recently by Schmidt and Swoboda[7]. The coefficients are adjusted in accordance with the special conditions identified in the scheme during the fieldwork of this study. For example. Schmidt did their study in Kisii but concluded that the coefficients could be lowered by 10 per cent to be applicable to areas with similar ecology on the East of the Rift Valley.

The land coefficients are equal to 1 in the model since, by defination, activities are identified in terms of the land under which they are put. The assumption here is that land productivity is uniform throughout the scheme for a given activity. This assumption was verified by identifying the geographical distribution of progressive farmers on the scheme and they were found to be uniformly distributed over the area, indicating that the location of the farmer did not influence his performance.

The irrigation water coefficients could not be obtained anywhere because no detailed studies have been done about crop responses to irrigation in the environment under study. Efforts to get the information from farmers and the scheme management proved fruitless. This necessitated reliance on the study by Njihia[8] in calculating the coefficients, which requires further elaboration.

4.2.2: Calculation of the Irrigation Technical Coefficients

The amount of irrigation required by a particular crop at a given time depends on the interaction of a number of environmental and biological factors. The environmental factors include rainfall, rate of percollation, humidity and the rate of run-off while the biological factors include root depth, evapotranspiration rate and the growth pattern of the crop. The factors determine not only the moisture requirement by each crop but also the amount of moisture balance around the root. Estimates of these factors are obtained from separate studies by Njihia[9] and Schmidt.[10]

The moisture in the soil depends on the balance between water input and output. The simplified form of the water budget is

$$I : R_E + L_i = E + L_o + D \qquad (3)$$

where: I = The amount of irrigation water in millimetres

R_E = Expected Rainfall in millimetres

L_i = Expected subsurface inflow

E = Expected evapotranspiration

L_o = Subsurface outflow

D = Deep percolation.

Under relatively flat ground surface conditions like those of Kibirigwi, the rate of surface inflow (L_i) and outflow (L_o) can be assumed to be zero. The irrigation requirement equation can then be written as

$$I_E = R_E - E - D \qquad (4)$$

The values of the variables in equation (4) above are estimated on a monthly basis for each of the six activities. The expected Irrigation (I_E) is the amount of irrigation required to fill any deficit between the expected rainfall (R_E) and the sum of evapotranspiration and Deep percolation. The expected irrigation is measured in terms of "Irrigation Days" where one irrigation day is equivalent to 12 hours of continuous sprinkling. The schemes sprinkler nozzles are made in such a way that twelve hours of continuous sprinkling are equivalent to 50 millimetres of rainfall.

The expected rainfall (R_E) is obtained from the long terms monthly rainfall probabilities in the scheme. Crude rainfall probabilities are calculated by ranking the monthly rainfall figures for the period 1962 to 1982 in an ascending order and summing the years in which the monthly rainfall is equal to or less than average. The sum is then divided by the total number of observations to get the probability that the rainfall will be equal to or less than the mean monthly rainfall. The following equation is used.

$$R_E = \bar{M}\ (1-(P-0.5)) \qquad (5)$$

where: R_E = Expected monthly rainfall

$\bar{M}$ = Mean monthly rainfall

P = The probability that the monthly rainfall will be equal to or less than the mean.

The calculated figures are given in table 1 below. The column of mean rainfall is derived directly from table 1 of the appendix.

Table (1) below shows that except for the months of March and October, most of the monthly rainfall is below the mean, and therefore the expected rainfall is less than the mean.

The evapotranspiration characteristics of tomatoes and onions were estimated from Njihia's[11] report about an experiment he conducted on the scheme in 1982. Njihia states that the tomato is a deep-rooted crop which can withdraw water from large depths, particularly under soil conditions prevailing in Kibirigwi. Secondly, the tomato

Table 1: Expected Rainfall

Month	Mean rainfall (mm)	Probability (P)	Expected Rainfall (mm)
JAN	28	0.60	25
FEB	40	0.65	34
MAR	96	0.45	100
APR	321	0.55	305
MAY	285	0.50	285
JUNE	47	0.60	42
JUL	39	0.55	37
AUG	40	0.60	36
SEP	35	0.60	32
OCT	119	0.46	125
NOV	174	0.60	156
DEC	46	0.70	38

Source: Calculated from table 1 of the appendix plant is most responsive to soil moisture conditions from the start of fruit set onwards, and the differential response is related to the pattern of root growth. Excessive amount of water in the root zone is harmful to the crop though the extent of the harm can not be easily ascertained. The onion, on the other hand, is a shallow rooted crop which requires watering throughout the growing season.

The evapotranspiration characteristics of maize and beans are obtained from the study by Schmidt and Swoboda[12] and they are summarized in graph 2 in the appendix. The graph shows quarterly average rainfall, evapotranspiration and the expected water deficit. The deficit occurs between June and August, and November and February. It is important to note that even though the month of June has very low rainfall there is no evapotranspiration deficit because of the stored surplus.

The deep percolation figures are obtained from Njihia's study. The percolation depends on the soil characteristics, as such the figures do not vary over time or with different crops.

Tables 5, 6 and 7 in the appendix show the annual water budget for maize and beans, onions and tomatoes respectively. The last two columns of each table show the expected irrigation for each activity in terms of irrigation days.

4.2.3: Calculation of the Credit Coefficient.

Credit here refers to the money (or farm inputs of an equivalent amount) given to the farmer at the beginning of the planting season by the scheme management which has to be repaid after the crops have been harvested and delivered. It is the rate of interest on the credit which is most important since it indicates the opportunity cost of tying finance to a given agricultural activity., For example if a certain activity requires KSh.3000 per hectare and the rate of interestr is 10 per cent, then the opportunity cost is the interest foregone by tying KSh.3000 to the activity which will be KSh.300. In this study it is assumed that the credit from the scheme never goes to the production of maize and beans since the credit is usually given in kind and is specifically for horticultural activities. The cost of producing onions and tomatoes is estimated from the estimates given by the Ministry of Agriculture and Livestock development in 1976[13] as shown in table 2 below.

Table 2: Estimated Production Costs (in Ksh) of Tomatoes and Onions.

Activity	1976	1982	1982	1982
	Cost/Acre	Cost/Acre	Cost/Lateral	Cost/Las
Onions	910	1640	410	25
Tomatoes	1093	1968	492	30

Source: Ministry of Agriculture: Economic Evaluation of Kibirigwi Irrigation Scheme 1975.

The Kibirigwi Irrigation Farmers co-operative society offers credit at 1.2 per cent per month in the outstanding amount[14] Since most of the horticultural crops mature within four months, the interest charge for five months, including one month of preparation and delivery will be approximately 6.1 per cent. The interest charged on credit to each farmer will depend on the outstanding amount and the repayment period. Since progressive farmers tend to repay their loans earlier than the less progressive ones, the later are bound to pay higher interest for every activity than the former. Therefore a progressive farmer is bound to have smaller credit coefficients for the linear programme than the non-progressive ones. In order to include these differences the average repayment period for each category of farmers was used such that the longer the repayment period each category had, the higher the credit coefficient. The calculations give the coefficient as KSh.25 and KSh.30 for onions and tomatoes respectively.

The following section explains how the Right - Hand Hand - Side (RHS) constraints of the Linear Programming Matrix are obtained.

b_{is}: These are the respective total resources at the disposal of the farmer at a given time. The resources are monthly labour, monthly irrigation water, irrigated land, un-irrigated land and seasonal credit.

The monthly availability of labour was obtained from the farmers' responses to Questions 7, 8, 9, 10, 11 and 12 of the Questionnaire (See Questionnaire in the Appendix). The following are the basic assumptions made about the characteristics of labour.[15]

(1). A full-time adult works for 8 hours a day.

(2). Children between 10 and 15 years are given a weight of 0.25 that is, they work for an equivalent of 2 adult-hours a day.

(3). Children below 10 years are not included in the farm labour force.

(4). The children who go to school work on the farm during school holidays only: These holidays are normally during the months of April, August and December.

(5). A man works 6 days a week, that is, 25 days a month. Combining assumption 1 above, a man provides 200 man days a month. Removing public holidays, unexpected absence from the farm and man hours engaged in other activities like household chores, coffee growing and leisure, a man provides 160 man hours per month for the activities under study.

(6). Labour employed on permanent basis is assumed to work for 8 hours a day, and finally

(7). Casual labour is assumed to be available mainly in the months of March, April and May.

The monthly availability of water for irrigation is determined by the capacity of the sprinklers which, according to Njihia[16] supply water equivalent to 50 millimetres of rainfall in 12 hours. In the initial model it is assumed that currently water is a free resource such that the farmer can irrigate all day long and throughout the year without incurring any costs. Thus the constraint is the number of days available to irrigate. Since 12 hours are considered as "1 irrigation day" a farmer has about 60 irrigation days in a month. The assumption of water being a free resource is dropped in the sensitivity analysis in order to assess the impact of imposing a water fee to the farmer.

The credit available to the farmer is obtained from the scheme record as explained in chapter 2 of this Study. The land available to the farmer is obtained from responses to questions 13 and 15 of the Questionnaire.

Finally, the subsistence constraint is measured by the minimum requirement of maize and beans production. However, these two crops are also grown for rotation purpose on the scheme. Since it is not possible to separate the two purposes for each farmer it is difficult to assign minimum requirement for each farmer because while subsistence depends on the size of the family and level of income, rotation depends on the decisions made by the scheme management. As such an average of 3 laterals per year was adopted in the model to represent both the subsistence and rotation purposes.[17]

4.3 Data Sources

Both Primary and Secondary data are used in testing the above stated hypotheses. Primary data was obtained by interviewing a sample of farmers from the study area, that is, Kibirigwi Irrigation Scheme. The interviews took place between May and August 1983. Sampling of the farmers was done by first stratifying the whole population of 256 farmers on the scheme into five categories. The criterion of stratification was the level of each farmer's farm output deliveries to the scheme co-operative society between June 1982 and July 1983. The scheme management used the same criterion to stratify the farmers in the scheme for the purpose of credit allocation. The assumption here is that the deliveries are used as a proxy of the farmer's performance. Random samples of 10 per cent of the farmers in each category were chosen and interviewed using a structured Questionnaire. Farmers' characteristics, resource availability, irrigation practice and performance were obtained from the interviews. In addition, general information about the performance of the scheme was obtained from the informal discussions with the scheme Manager, Assistant Manager, Chairman of Kibirigwi Irrigation Farmers Co-operative Society and one member of the co-operative's Committee.

Secondary data was obtained from government publications through the Ministry of Agriculture, the Central Bureau of Statistics and the Kibirigwi Irrigation Scheme records.

FOOTNOTES

1. For example see Judith Heyer in Agricultural Development and Peasant Farming in Kenya, Ph.D. Thesis, University of London, 1966.

2. See Arao L.A. and Houtman C.B. Baseline Agro-Economic Survey of Kibirigwi Irrigation Scheme. IDRP Report No. 26, NAL, June 1980.

   According to Arao and Houtman the average income of the farmers during the year 1977/78 was approximately KShs. 9,000, 40 per cent of which was generated by coffee. Agricultural income was defined as the sum of all Gross margin figures generated by each enterprise during the two seasons in a particular year, less permanent labour costs. The average milk production, the average annual income for 1977/78 would then be approximately KShs. 9,500 per year.

3. This is based on the fact that prior to the setting up of the scheme, irrigation practice was non-existent in the scheme. See Arao L.A. and Houtman C.B. op.cit.

4. Schmidt and Swoboda, Farm Management Hand-book for Kenya Vol.2, Natural Conditions and Farm Management Information. Ministry of Agriculture and Livestock Development, 1983.

5. See Dorfman R. Samuelson P. and Solow R. Linear Programming and Economic Analysis The RAND, Corporation, Tokyo 1958, page 165.

6. The same approach is applied by B.A. Ateng' and Judith Heyer when studying Kenya's Small Scale Farming Situation, see Ateng' B.A. Linear Programming: An Application to the Identification of the Best Existing Farming Strategy for Peasant Farmers in Kenya. M.A. Thesis, University of Nairobi, 1977.

7. Heyer, J., "A Linear Programming Model for Peasant Agriculture in Kenya", IDS, University of Nairobi.

8. Schmidt and Swoboda op.cit.

9. Njihia E.M., op.cit.

10. Njihia E.M., op.cit.

11. Schmidt and Swoboda op.cit.

12. Njihia E.M. op.cit, page 24.

11. Schdmidt and Swoboda op.cit, page 693.

12. See Ministry of Agriculture and Livestock Development, Economic Evaluation of the Kibirigwi Irrigation Scheme, 1975.

13. This information was obtained from the Kibirigwi Scheme Management Records.

14. The assumptions are based on the observations made on the scheme. These observations tend to confirm the assumptions adopted by Schmidt and Swoboda, Judith Heyer and B.A. Ateng on the characteristics of labour employment in small scale farms in Kenya.

15. Njihia, E.M. op.cit., page 15.

16. Because of the assumption of homogenous linear production activities of degree 1 it is possible to set any constant for the Right-Hand-Side constraints and use sensitivity analysis to determine whether the constraint is limiting or not, and if it is, the lower and upper limit from which it will leave the basis. Secondly doubling of the Left-Hand-Side technical coefficients is equivalent to halfing the Right-Hand-Side constraints. This makes it possible to use any unit of measurement for both the technical coefficients and the Right-Hand Side coefficients. For instance we can convert the Irrigation Days" into shillings so long as the conversion parameter reflects the existing economic conditions and it is applied to all elements in a given row of the technological matrix.

CHAPTER FIVE

DATA ANALYSIS AND RESULTS

This chapter presents the data analysis and results of the Study. The first Section gives the background information of each of the three farmers considered in the Linear programming models followed by the empirical results obtained from the computor package. The farmers were randomly selected from categories One, Two and Three of the farmers categories in the scheme records as explained in Chapter Two. The second section gives the overall results which look at the differences and similarities of the results obtained for specific farmers. Hypotheses 1 and 2 are tested on the basis of these comparisons. The third section looks at such attributes like age, sex and education in relation to the farmers performances. Cross-tabulations are used for comparison purposes to determine their impact on the farmers' performance.

5.1 FARM 1

Farmer's Background

The owner of the farm is an unmarried lady aged 33 years She has 4 children, one over 15 years old and 3 under 10 years of age. She stays with her 4 children in a temporary two-roomed grass-thatched house. She attended school up to standard 8.

The farmer has 3.9 acres of land which she bought in 1974. She is therefore, a relatively new person in Kiine location. She organizes the farm herself. The farmer has 4 laterals of irrigated land on which she grows horticultural crops. In addition she grows maize, beans and English potatoes and has 100 coffee trees.

Apart from farming, the farmer used to operate a health clinic at Kibirigwi market from which she used to earn about Ksh.1500 per month. She closed the clinic in 1979 when thiefs broke in at night and stole all the drugs and equipment. Prior to the closure, the farmer had obtained a loan of KSh.2,000 in cash from KIFCO which she invested in the clinic. Since the clinic business collapsed the farmer has failed to repay the loan and is not entitled to any loan from KIFCO.

Production on the farm is quite low as compared with other farms. For example between June 1981 and June 1982 she managed to deliver only 238 Kilograms of tomatoes to KIFCO. The farmer has a total of 2925 man hours of labour in a year, which include her own labour, casual labour during the peak period and that of her son during school vacations.

The farmer was not pleased with the way the scheme was being operated. She said there was over-grading of the tomatoes in the scheme, observing that while in Karatina there were only two grades, there were three grades in the scheme. The farmer also observed, that the credit offered by KIFCO was inadequate and unreliable. For example, she said sometimes KIFCO gives credit in-terms of farm inputs which were not useful to the farmer.

Table 4a in the appendix gives a summary of the technological matrix and resource constraints of this particular farmer as explained in Chapter 4. The following are the results obtained from the Linear program for this particular farmer.

Results without the subsistence constraint.

Net Return: KSh. 23,062 per year

Optimal Solution:

Activity	Quantity (Laterals)
MIB1	0
MIB2	0
ONS1	1.879
ONS2	0
TOM1	1.604
TOM2	1.010

The optimal solution shows that the farmer should grow 1,879 laterals of first season onions, and 1,604 laterals and 1,010 laterals of first and second season tomatoes respectively. The critical constraints on production are the June, October and November labour whose shadow prices are KSh.4.95 KSh.27.00 and Ksh.112.00 per man hour respectively. Thus the most scarce resource to this particular farmer is the November labour whose additional unit increases the net return by KSh.112.00. The rest of the resources in the program are slack.

Sensitivity Analysis

The optimal solution shows that first season onions, first season tomatoes and second season tomatoes are the activities to be undertaken. Varying the prices of these activities would alter the net return. For example if the price of first season onions is lowered from KSh.6,800 to Ksh.448 per lateral the activity is dropped to give way to second season onions. If the price of second season tomatoes is lowered from Ksh.2,400 to KSh.1816 per lateral then the activity will be dropped to give way to second season onions. Thus the analysis shows that second season onions is the next most competing activity.

Varying the Left-Hand-Side resources constraints would give the following results: If the June labour is reduced from 160 man-hours to 10 man-hours per month then the production of first season tomatoes ceases; If the October labour is reduced from 160 man-hours to 65 man-hours per month then the production of second season tomatoes ceases. On the other hand if the June labour is expanded to 204 man-hours per month, it ceases to be a constraint, giving way to first season credit as the binding constraint. Expanding the October labour to 244 man-hours per month would make the September labour the limiting constraint. This analysis implies that next to the June, October and November labour constraints are the September labour and first season credit.

Results with Subsistence

Net Return: Ksh.254.45 per year

Optimal Solution:	Activity	Quantity (laterals)
	MIB1	1.106
	MIB2	1.549
	ONS1	0
	ONS2	0
	TOM1	0
	TOM2	0

Abbreviations used in the Linear Program

a. Activities:

MIB 1 - First season maize and beans

MIB 2 - Second season maize and beans

ONS 1 - First season onions

ONS 2 - Second season onions

TOM 1 - First season tomatoes

TOM 2 - Second season tomatoes.

b. Resources:

LABA - January Labour	WATA - January Irrig. water
LABB - February Labour	WATB - February Irrig. water
LABC - March Labour	WATC - March Irrig. water
LABD - April Labour	WATD - April Irrig. water
LADE - May Labour	WATE - May Irrig. water
LADF - June Labour	WATF - June Irrig. water
LABG - July Labour	WATG - July Irrig. water
LABH - August Labour	WATH - August Irrig. water
LABI - September Labour	WATI - September Irrig. water
LABJ - October Labour	WATJ - October Irrig. water
LABK - November Labour	WABK - November Irrig. water
LABL - December Labour	WATL - December Irrig. water

UNRA - First season un-irrigated land

UNRB - Second season un-irrigated land

IRRA - First season irrigated land

IRRB - Second season irrigated land

CREA - First season credit

CREB - Second season credit

The optimal solution indicates that the farmer can grow only first and second season maize and beans. The critical constraints to the farmer are now the February and October labour whose shadow prices are KSh. 0.80 and KSh. 0.75 per man-hour respectively. These are the highest respective man-hour wages that the farmer should pay for additional February and October labour. It can be observed that the impact of introducing subsistence consideration is to reduce the Net Return to the farmer, the shadow prices of the factors of production and change the pattern of resource constraints.

The actual situation shows that the farmer earned a Gross Return of KSh. 6,700 from farm products during the period 1981/82 of which KSh.3,087 was from coffee deliveries, KSh. 578 from horticultural crops and the remaining from maize, beans and other farm produce. This implies that horticultural crops accounted for only 8.6 per cent of the total Gross Return. The actual income is higher than the one computed from the linear program because the actual income includes coffee and other activities which are left out of the linear program. Secondly, in the linear program analysis, we assumed initially that the maximum amount of labour available to this particular farmer in February and October is 160 man-hours per month. However, it is possible that the farmer diverted labour from such activities like coffee weeding and household work to grow more maize, beans and horticultural crops.

5.2 FARM 2

Farmers Background

The farmer is a man aged 70 years. He is married with 5 children, 4 of whom are above 15 years of age. All the children live on the farm and only the one under 15 years goes to a near-by secondary school. The farmer stays with three other relatives on the farm all of whom are above 15 years of age. He stays in a three-roomed semi-permanent house.

The farmer has a total of 4 acres of land which he got during land consolidation about 40 years ago. Currently he has 6 laterals of irrigated land. The farmer grows maize, beans and English potatoes in addition to scheme crops. He also has two heads of graded cattle.

In June 1983 the farmer had an outstanding loan of Kshs.1280 from KIFCO which he intended to repay within four months by delivering farm produce to the scheme co-operative. According to the scheme regulations the farmer was allowed a total credit of Ksh.1500 so long as he did not have any outstanding amount.

Production of horticultural crops on this particular farm is neither high nor low. For instance between June 1981 and June 1982 the farmer managed to deliver horticultural crops worth Ksh.5119 which was not significantly different from the scheme average of Ksh.6,560. Compared with the first farmer, this farmer is considerably better.

This farmer was also not pleased with the way the scheme was being operated. He complained of low prices for tomatoes on the scheme as compared to those of Karatina open market. The survey showed that the monthly average prices of Karatina open market were about 25 per cent higher than those of the scheme. However, the farmer did not consider the daily tomato price fluctuation and the transport and marketing costs if he were to market his produce in Karatina. About credit, the farmer said it was far much less than he needed. He also complained that sometimes the scheme management supplied herbicides and fertilizers that were not effective. This view was confirmed from the scheme technical officers who agreed that they sometimes order herbicides from individual manafacturers just on the manufacturer's advise. Sometimes the salesmen either give misleading information to promote sales or the technical officers may not understand the instructions fully. There was a case when an agent of a herbicide manufacturing firm instructed the technical officers to mix the herbicide with water in the ratio of

1 to 8 and the technical officers instructed farmers to mix the herbicide in the ratio of 1 to 4, thus doubling the concentration and the costs to the farmer.

Table 4b in the appendix shows the matrix of the linear program applied to this particular farm and the results are given below.

Results without the Subsistence Constraint

Net Return: KShs. 29203

Optimal Solution	Activity	Quantity(laterals)
	MIB1	2.756
	MIB2	2.756
	ONS1	3.243
	ONS2	3.243
	TOM1	0
	TOM2	0

The optimal solution shows that the farmer can grow 2.756 laterals of first and second season maize and beans and 3.243 laterals of first and second season onions. The critical constraints are first and second season irrigated land and first and second season credit. The shadow prices for first and second season irrigated land are Ksh.90 and

Ksh. 100 respectively, and those for first and second season credit are Kshs. 181.35 and Ksh.52.50 respectively. These indicate by how much the net return would When each of the limiting resources is increased by 1 unit respectively. Labour and irrigation water are not limiting constraints, as such their shadow prices are zero.

Sensitivity Analysis

The lower limit of the production of maize and beans activities for both season is zero. This means that, being subsistence crops, their value and production are not determined by the market price. If the price of first season onions is lowered to KSh.4134 75 per lateral, then its production ceases, giving way to first season tomatoes. On the other hand if the price of second season onions is lowered to Ksh.2,034 per lateral then it will be dropped to give way to second season tomatoes.

The limiting resources are first and second season irrigated land and first and second season credit. If the irrigated land is reduced from 4 laterals to 3.24 laterals then the production of first and second season maize and beans ceases. This indicates that if the farmer has a free choice of producing maize and beans and enough of the resources to do so, then as the irrigated land becomes scarce farmers will shift away from the production of maize and beans. In other words the scarcity of land raises the oppotunity cost of the high value horticultural crops. Secondly, if the first and second season credit are reduced to zero then the production of first and second season onions cease. The upper limits of first and second season irrigated land are 8.09 and 8.5 laterals respectively. When these two resources cease to be limiting constraints they give way to April and October labour.

Results with Subsistence Constraint

Net Return: KSh. 29203 per anuum

Optimal Solutin:	Activity	Quantity (laterals)
	M1B1	2.756
	M1B2	2.756
	ONS1	3.243
	ONS2	3.243
	TOM1	0
	TOM2	0

The optimal solution shows that the farmer grows the same crops both with and without the subsistence constraint. This is so because his most limiting constraints, first and second season credit does not affect subsistence production. For this particular farmer labour is abundant to the extent that it can be utilized in the production of such low yielding activities like maize and beans without constraining any other production.

5.3 FARM 3

Background Information

The owner of the farm is a married man aged 31 years. He has 6 children, 3 of whom are under 10 years of age, 2 between 10 and 15 years and 1 above 15 years old. Four of the children attend school full-time. The farmer has never had any formal education.

He has a total of 4 acres of land which he inherited from his father 8 years ago. In addition to scheme crops the farmer grows maize and beans. He has also 400 coffee trees, 1 grade cow and an ox-team. Apart from engaging in activities on his own farm the farmer is sometimes hired by other farmers to plough for them using his ox-team. He does the ploughing mainly during the months of December, January and February, charging Ksh.120 per acre ploughed.

The farmer has a total of 6,279 man-hours of labour per annum which is provided by one permanent employee, his wife, his children during school vacations and himself. In June 1983 the farmer had no outstanding loan with KIFCO and he was allowed to borrow a maximum of KSh.3,000 at a time. This farmer is one of the five best farmers on the scheme in terms of horticultural crop deliveries. Production on his farm is quite high. For example between June 1981 and June 1982 he managed to deliver over 22,530 kilograms of tomatoes to the scheme.

Table 4c in the appendix shows the matrices of the technical coefficients and resource limits that were used in running the program for this particular farmer. The results are given below.

Results without the Subsistence Constraint.

Net Return: Ksh.47,657

Optimal Solution:

Activity	Quantity(laterals)
M1B1	0
M1B2	0
ONS1	6
ONS2	0
TOM1	0
TOM2	2.857

According to the optimal solution the farmer can grow 6 laterals of first season onions and 2.857 laterals of the second season tomatoes. The critical constraints on production are the October labour and first seasnn irrigated land. The shadow price for the October labour is approximately

KSh.28, implying that if the labour of this month is increased by 1 man-hour then net return will be increased by Ksh.28. The shadow price for the first season irrigated land is approximately Ksh.5657. Apart from these two all the other resources are slack.

Sensitivity Analysis

As shown in the optimal solution above the activities undertaken are first season onions and second season tomatoes. If the price of the first season onions is lowered to Ksh. 6,042 per lateral then this activity will be dropped to give way to first season tomatoes. The lower limit of the second season tomatoes is Ksh.1806 per lateral beyond which the activity gives way to second season onions.

In terms of the resource limits, if the October labour is lowered from 480 man-hours to 240 man-hours per month the production of second season tomatoes will cease. On the other hand expanding the October labour to 650 man-hours makes it a slack variable, being replaced by the February labour as the constraint. The first season irrigated land can be lowered to zero before it ceases to be a costraint, in which case the production of first season onions ceases giving way to second season maize and beans with first season unirrigated land as the constraint.

Results with Subsistence Contraint.

Net Return: KSh 38,193

Optimal Solution:

Activity	Quantity (laterals)
M1B1	0.577
M1B2	2.423
ONS1	5.422
ONS2	0
TOM1	0
TOM2	0.428

The optimal solution shows that the farmer has now to plant 0.577 and 2.423 laterals of first and second season maize and beans respectively, 5.422 laterals of first season onions and 0.428 laterals of second season tomatoes.

The critical constraints on production are the October and November Labour, first season irrigated land and subsistence. The shadow prices of October and November labour are Ksh.28 and KSh.27 respectively. The shadow price of the first season irrigated land is Ksh.4260 while that of subsistence is Ksh.4,742 per lateral This implies that if subsistence is reduced by 1 lateral net revenue will be increased by Ksh.4742. In other words the oppotunity cost of subsistence production is Ksh.4742 per lateral per annum.

The rest of the resources in the program are slack.

The actual situation shows that the farmer earned KSh.75,743 from farm produce in the period 1981/82; out of which Ksh.54850 (72 percent) was from horticultural crops, KSh.9000 (11.8 percent) from coffee, Ksh.11040 (14.5 percent) from milk sales and only about 2 percent from maize, beans and other farm produce.

5.4 Overall Results

Table 1 below shows a summary of the major results obtained from the analyses of the three farms. The first column shows the combination of crops produced by each farmer to maximize Net Returns without the subsistence constraint. The figures in brackets are levels of production in laterals. It is evident from the table that there is no uniformity in the pattern of production for the three farms. For instance while farmer 1 can grow both onions and tomatoes farmer 2 can not grow any tomatoes in the given conditions. Farmer 3 grows a large amount of first season onions and a considerable amount of second season tomatoes but none of the other activities. Since production patterns are a reflection of resource endowments, it implies farmers have different relative levels of resource endowments.

Table I: Overall results

FARM	1 ACTIVITIES A in (LATERALS)	2 ACTIVITIES B in (LATERALS)	3 RESOURCE CONSTRAINTS A (SHADOW PRICE) (Shs)	4 RESOURCE CONSTRAINT B (SHADOW PRICE) (Shs)	5 NET RETURN A (Ksh/Year)	6 NET RETURN B (Ksh/Year)
I	ONS I (I,88) TOM I (I,60) TOM 2 (I,0I)	MIB I (I,II) MIB 2 (I,55)	LAB I (4.95) LABJ (27,00) LABK(II2,00	LABE (0,80) LABJ (0,75)	23,062	254
2	MIB I (2,75) MIR 2 (2,75) ONS I (3,24) ONS 2 (3,24)	MIB I (2,75) MIB 2 (2,75) ONS I (3,24) ONS 2 (3,24)	CREA (I8I,35) CREB (52,50) IRRA ([illegible]0,00) IRRB (I00,00)	CREA (I8I,35) CREB (52,50) IRRA (90,00) IRRB (I00,00)	29,203	29,203
3	ONS I (6,00) TOM 2 (2,85)	MIB I (0,577) MIB 2 (2,422) ONS I (5,422)	LABJ (28,50) IRRA (5657,I5)	LABJ (28,50) LABK (28,25) IRRA (42,60) SUBT (47,42)	47,657	38,I93
MEAN	-	-	-	-	33,307	22,550

Column 2 shows the crop combination for each farmer with the subsistence constraint compared, the first and second columns show that the introduction of subsistence in the model changes the pattern of production depending on the level of the farmers initial resource endowment. For example while farmers 1 and 3 are affected by subsistence farmer 2 is not.

Columns 3 and 4 of table 1 show the limiting resources for each farmer with and without the subsistence constraint respectively. Again, there are marked differences of resource constraints among the three farmers. For instance while farmer 1 is limited by the September, October and November labour, farmer 2 is limited by irrigated land and credit while farmer 3 is limited by the October labour and irrigated land. This is because of the different seasonal labour requirement for each activity and the differences in labour availability for each of the three farmers. Generally the October labour and first season irrigated land are the most limiting resources for the scheme as a whole. The main explanation is that according to this production patterns, based on market price patterns, most of the land preparation and planting of horticultural crops is done in October and these require alot of labour. First season irrigated land is constraining because net return per lateral during this season is high than that of the second season, the difference being caused by seasonal fluctuations.

The fifth column shows the net return for each farmer without the subsistence constraint. It shows that farmer 1 can get a new return of Ksh.23,062 if she utilized all her resources while farmer 2 and 3 would get Ksh.29,203 and Ksh.47,657 respectively. This implies the average net revenue for the three farmers is Ksh.33,307, that is, without the subsistence constraint. However, if the subsistence constraint is included, as indicated in column 6 of table 1 the net returns for the three farmers will be Ksh.254, Ksh.29,203 and Ksh.38,193 respectively. The average net return for the three farmers is Ksh.22,550. Therefore, on average, subsistence reduces net revenue for the three farmers by 47 per cent. Subsistence is then a significant constraint to production for these three farmers.

The reduction in the net revenue when we introduce subsistence in the model is explained by the replacement of more valuable activities by less valuable ones. The lowering of the shadow prices of factors of production is explained by the fact that demand for a factor of production is a derived demand which depends on the marginal physical product of the factor and the price of the product. The introduction of subsistence activities is like lowering the price of a product, hence the marginal value product of the factor of production.

The Price of Irrigation Water

We started with the assumption that water was a free resource and from the analyses turned out to be a slack resource throughout. We then conclude that in terms of technical feasibility irrigation water is not a limiting resource to any farmer on the scheme nor to any production patterns of the crops under consideration. The issue, then, is to determine its economic feasibility.

Table 2 below shows the monthly water utilization level for each of the three farmers, assuming the production patterns obtained in the optimal solutions of the linear program. The figures are obtained by dividing the lower limits of the monthly water resources by the respective total resources available. The lower limit constraints figures were obtained from the sensitivity analysis of the linear program. The table shows that on average farmer 1 uses only 14 percent of the water resource while farmers 2 and 3 use 30 and 32 percent respectively. The average water utilization level on the scheme for the three farmers is then 25 percent.

Table 2: Percentage Water Utilization Level

Month	FARM I	FARM 2	FARM 3	Average
January	29	50	50	43
February	34	60	60	52
March	22	57	44	38
April	0	0	0	0
May	0	0	0	0
June	7	20	I9	I6
July	7	35	I9	2I
August	5	I5	I4	I2
Sept.	0	0	0	0
Oct.	27	42	70	47
Dec.	32	45	50	25
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Average	I4	30	32	25

Source; Calculated from the Liner Program results

In addition to the 10 per cent of the water used for domestic purposes, only 35 per cent of the capacity available to the three farmers is utilized. Since the farmers were randomly selected we can conclude that their average situation represents the actual scheme situation, implying that only 35 per cent of the scheme capacity is utilized if technical efficiency is to be attained.

The rule-of-thumb for determining economic efficiency is by equating marginal cost to marginal revenue. A water charge affects the marginal cost only if it is levied per unit of output or water used. A fixed water use charge does not lead to economic efficiency since it is not reflected in the marginal cost. In any case, it is like a regressive tax since those with smaller farms will pay relatively more per acre than those with large ones, hence, for equity considerations it is inappropriate. The best rate is to be calculated as per unit cost or per unit revenue accrued to the farmer. If it is calculated as per unit cost then the aim is to recover the fixed and variable costs of supplying the irrgation water. Calculated as per unit of revenue accrued implies equity considerations both at the scheme and national level where the water charge is made according to the payers ability and willingness to pay.

The fundamental point in both cases is for the farmers to pay for the full benefits they receive from the scheme. However, since there are quite a number of benefits that accrue to other people not within the scheme (for example distribution and retail trade and constant availability of fresh vegetables for urban dwellers) it is not fair for the farmers on the scheme to pay for all the benefits accrued. Therefore the rule is normally for the farmers to pay for the maintainance and capital costs of the scheme and assume that the external benefits and costs would balance. This rule can be applied at the scheme level. At the farm level, ability to pay could be the most appropriate for equity considerations.

The value of the scheme project in 1983 was estimated at Kshs.10,200,00. The scheme management proposed that the cost of equipment should be repaid within 15 years. If it is repaid at a constant rate then annual repayment would be KSh.680,000. The management also estimated the annual maintainance costs to be KSh.81,000. The total cost per year would then be Ksh.761,000. If this money was to be recouped from the 256 farmers on an average basis, then each farmer would be required to pay Ksh.2972.65 per year for 15 years. This amount is quite high for most of the farmers on the scheme. From the scheme records the average payout to the farmers for the period 1981/82 was KSh.5094. Recovering the costs in the manner suggested above would mean deducting over 50 percent of the payout. In any case the repayment figure is very low since we have assumed the maintainance costs to remain constaint over time. Therefore, a number of other alternatives should be considered.

First, from the linear program analysis only 35 per cent of the capacity is utilized when Net Returns are optimized. Ways have to be sought to increase water utilization in order to reduce the average overhead costs. This can include expansion of the irrigated land on the scheme and around the scheme, and the intensification of the cropping pattern to three crops a year.

Secondly, productivity on the scheme should be increased by identifying, high value crops such as flowers, mushrooms and other horticultural crops which are not grown elsewhere in Kenya because of lack of adequate water supply and looking for ways and means of improving the productivity of the less progressive farmers.

Finally after achieving the optimal level of producdtivity and the best paying crops a method of metering and selling the water to the farmers on a willing-buyer-willing-seller basis could be introduced. The rate could be determined by the government depending on how it ranks the value of various water uses. Definately the rates will be lower than those applied for domestic water consumption since the government considers irrigation water use as a residual function. Farmers should then be permitted to let their parcels to whoever wishes to utilize the irrigation water if they themselves are unable to farm. The cost of metering and supervision may be quite high but this should be weighed against the cost of idle machinery. During our survey the scheme management observed that 27 farmers (10 percent) were not producing any scheme crops and yet they could not be permitted to let their equipment and land to other people for legal reasons we shall analyse later.

In general, there is no rigid way by which the scheme management can introduce water charges. It depends on the set objectives and the probable responses from farmers. Most of the farmers who were doing well and were interviewed said they were not willing to let their parcels to outsiders. The less productive farmers on the other hand said they were willing to let their parcels but were denied by the scheme management. Therefore, if economic efficiency was the criterion for setting the water charge then the method of willing-buyer-willing-seller would be the most appropriate.

General Scheme Performance

Table 3 shows the average annual farm income of the five categories of farmers in the scheme as calculated from the sample survey.

Table 3: Estimated Farm Income 1981/82

Category	Per cent of Farms	Income (KSh/Year)
1	18.5	6,800
2	11.1	9,700
3	29.6	8,239
4	18.5	17,246
5	22.2	47,711
mean	-	17,900

The table shows that the average income for the period 1981/82, was Ksh.17,900 even though more than 75 per cent of the farmers had income below the mean. Therefore, according to this survey the actual farm income (Y_A) was Ksh.17,900; out of which 50 per cent was from irrigation products, 29 per cent from coffee, 9 per cent from maize and beans, 11 per cent from milk sales and 2 per cent from other products.

Secondly we have observed from the linear program analyses that if the resources were utilized to the optimal level then the average annual income for the activities under consideration would be Ksh.33,307 without subsistence and Ksh.22,500 with subsistence. Since from the survey horticultural crops plus maize and beans contributed about 59 per cent of the farm income, the total farm income for the linear program, or ideal income (Y_I) would be Ksh.56,452 per annum without subsistence and Ksh.38,135 per annum with subsistence.

Finally, as stated in chapter four the baseline agro-economic survey by Arao and Houtman[1] showed that the average farm income of farmers on the scheme was Ksh.7,750 per annum. We make the assumption that if there was no irrigation the farm income of farmers on the scheme would have grown at the rate of other areas within the district. Since this long term growth rate is not known we use the agricultural output growth rate in the district as a proxy. From the Annual Reports[2] of Kirinyaga district agricultural department, agricultural output in the district grew at an average rate of 4 per cent per annum even though the annual growth rates were erratic because of weather conditions. Therefore if the scheme was not introduced in the region, the farmers income would have been Ksh.9,066 in the period 1981/82.

Our aim is to try, and compare these incomes with a view of testing hypotheses 1 and 2. The three incomes are summarized in table 4 below.

Table 4: Estimated Farm Incomes for 1981/82

Income Type		Ksh.
Exterpolated	(Y_E)	9,066
Actual	(Y_A)	17,900
Ideal	(Y_I)	45,000

The results indicate that the actual income (Y_A) is higher than the exterpolated income by about 97 per cent. The difference must have been brought about by the introduction of the scheme. To get a clear picture of the contribution of the scheme to farmers we analyse the changes in the composition of income, employment generation and the use of other farm inputs.

Table 5 below shows the changes in the composition of income between the periods 1978/79 and 1981/82.

Table 5: Income Composition, 1978/79 and 1981/82

Source of Income	Per cent of Total	
	1978/79	1981/82
Coffee	40	29
Horticultural crops	10	50
Milk Sales	5	11
Other	45	10
Total	100	100

Source: The 1978/79 column data are obtained from Arao and Houtman, op.cit.

From the table it is evident that there have been marked changes in the composition of income. The contribution of coffee has declined from 40 per cent to 29 per cent. Milk sales have risen from 5 per cent to 11 per cent and horticultural crops, which were initially grown in river valleys and during the rain season, have risen from 10 per cent to 50 per cent. The changes have been brought about by the availability of irrigation water.

Employment generation is measured in terms of permanent and casual labour. In Arao and Houtman's baseline survey only 3 per cent of the farmers had permanent employees whom they were paying Ksh.100 to Ksh.150 per month. In the survey 18 per cent of the farmers had permanent employees paying them between Ksh.200 and Ksh. 300 per month. In terms of casual labour Arao and Houtman observed that 76 per cent of the farmers hired casual labour, paying them Ksh.10 to Ksh.15 per day. In the survey approximately 70 per cent of the farmers interviewed said they hired casual labour during certain periods of the year, paying them Ksh.15 per day. It is evident that in general, employment generation has increased with more farmers going for permanent labour. The move to permanent employees is a reflection of increased farm activities throughout the year due to irrigation and farmers ability to pay the wages.

Finally, Arao and Houtman noted that the use of improved seeds fertilizer and herbicides was quite low. For example farmer applied fertilizer only up to half the required level. It is not possible to evaluate to what extent the use of farm inputs has increased because since the start of the scheme new products requiring relatively more inputs have been introduced. However, the October 1982 and January 1983 progress reports from the scheme management indicated that most farmers were not following the advice of the management with regards to the application of fertilizer and chemicals. The farmers tended to over-use certain types of fertilizer and herbicides.

We can conclude that the scheme has not only increased the farm income of farmers on the scheme but has also changed its composition, raised employment and wages on the scheme and increased the use of farm inputs. Thus we reject the null hypothesis that the farm income of farmers on an irrigated areas is not significantly higher than that of those ion un-irrigated area. We accept the alternative hypothesis that the farm income of farmers on an irrigation scheme is significantly higher than that of these on an un-irrigated area.

The results in table 4 show that the ideal income (Y_I) is twice as much as the actual income, income (Y_A) obtained by the farmers on the scheme. This significant difference is brought about by certain factors which we wish to analyse in detail. Most important will be the government regulations which were identified during the survey as key factors hindering the farmers from achieving the ideal income as calculated from the linear program.

The first regulation concerns the setting of the farming calender. The scheme management has set its financial year to coincide with the government financial year which starts in July. Therefore farmers have to prepare their farms in July and August and do the planting such that crops are ready in November, December and January. According to the market price analysis (See graph 3 in the appendix) prices are usually low during this time of the year because of over-supply from rainfed areas. Therefore farmers get half of the value of the price they would got if they delivered their produce in April and May.

The linear program analyses did not include this regulation with a view of trying to identify the best crop schedule on the scheme. The most important impact of including this regulation in the model would have been to reduce the returns of each activity (C_{is} in the model) since the crops would then be sold at a lower price than otherwise. Since the "off-peak" prices are half the peak prices the optimal solutions would have been reduced by half. Therefore the cropping pattern is an important regulation that should be seriously analysed before being imposed.

Secondly, as explained in chapter 2 of this paper, the scheme management allocates production (through the provision of inputs) to the farmers not according to the resource constraints of the farmer but according to the farmers own choice. Farmers decisions are mainly guided by the prevailing market prices and they hardly assess the level of resource scarcities and costs. This has two effects to their performance. First, the farmer may pick activities in which they don't have enough resources, making then to lose all the crop or get far much less than they would have actually got. This was evidenced in the survey and analysis. All the farmers sampled said they prefer growing tomatoes to any other activity because of its high return, and, indeed, every farmer who grew any horticultural crops grew tomatoes. But the linear program analyses showed that owing to different resource endowments farmers are more advantaged in growing certain than others. Secondly, since farmers base their decisions on current prices, and horticultural prices fluctuate from time to time the "cobweb problem' of excess supply at low prices and under-supply at high prices is likely to occur.

The issue of over - and under-production has been voiced by the scheme management in its progress reports. For example in the progress report number 17 of January

1983 the management noted that between October and December 1982 production reached a total of 492,676 kilograms which was 286 per cent of the estimated level based on seeds issued to the farmers. The management observed that additional seeds, especially tomatoes, must have been purchased locally since tomato production was 427 per cent of the expected quantity. The management also added that there were low prices, particularly in Nairobi, due to over-supply from Perkerra Bungoma and Loitokitok.

The third government regulation concerns the cost of credit to the farmers. As explained in chapter 2 of this study, farmers are allocated credit according to how well they performed in the previous season and an interest rate of 1.2 per cent per month is charged on the outstanding amount of the loan. These have two implications on the farmers. First, the less progressive farmers will never move out of low productivity since they do not readly get credit facilities. Secondly, if by sheer bad lucj some progressive farmer performs pooly, then he may continuously climb down the credit ladder until he reaches the bottom. The net impact will be increasing inequality in the scheme. Already there is considerable inequality since, according to the 1981/82 production records about 77 per cent of the farmers produced less than 30 per cent produced 60 per cent of the total output. If the productivity of the 77 per cent were raised to the scheme average level then the total output on the scheme would be increased by about 30 per cent.

On the basis of these results we accept the null hypothesis that some government regulations limit output on the irrigation scheme.

5.3 SOCIAL AND INSTITUTIONAL FACTORS

This section gives some of the possible social and institutional factors that may affect farmers' performance as derived from the sample data. Performance here is measured by the level of the farmers farm incomes as calculated from the sample survey. The factors are cross-tabulated with the level of farmer's income to determine their relationship.

Sex and the level of farm income.

First we wish to establish whether female farmers farm income is significantly different from that of male farmers. It has often been observed that female farmers are usually discriminated upon by both the rural society and even the government development agents. The arguement has been that extension services are provided by male officers who may not know the problems facing female farmers nor have the social skills to obtain them. Secondly, female farmers do not spend time at market centres where most farming information is disseminated. Thirdly, female farmers may not have the labour organizational skills. Finally, female farmers may be less favoured in the provision of credit since land, the best security for a farmer, is usually registered under males.

The general result would then be poor performance by female farmers. In order to establish this fact the farmers sex is cross-tabulated with the farmer's income. The results are given in table 6 below.

Table 6: Percentage of Farmers Within each Sex Category in each Income Group.

Income Group	Male	Female	Total
0-5,000	10.5	37.5	24
5001-10,000	31.6	37.5	34.5
10001-15,000	10.5	0	5.3
15001-20,000	10.5	0	5.3
20001-30,000	15.8	.12.5	14.2
30001-45,000	0	12.5	6.2
Above 45,000	21.0	0	10.5
Total	100	100	100

The results confirm the fact that female farmers' performance is lower than that of males. For instance while over 75 per cent of the female farmers have annual income less than or equal to Ksh.10,000, only 42 per cent of the males are within this income category, and none of the female farmers had farm income above the Ksh.45,000 level.

It was not possible to identify which of the above possible reasons were responsible for this particular difference, however, the survey sample indicated that most of the female farmers fall within the categories of farmers who get within the categories of farmers who get no credit or very limited credit from the scheme. Secondly the four technical assistants on the scheme were males and a discussion with them indicated that they did not think that female farmers on the scheme had any female farmers on the scheme had any special problems to be considered.

Age and the level of income

There is a general belief that tradition is a major hindreance to technical progress and general performance in small scale farming. Aging farmers are also said to be more resistent to change than young farmers. If so, then the level of the farmers' farm income should vary with the farmers age. In order to ascertain this fact the farmers' ages are cross-tabulated

Table 7 : Percentage of Farmers Within each Category of age in each Income group

Income Group Ksh	Age Category <25	26-35	36-45	46-55	56-65	Above 65
0- 5000	0	0	12.5	25	25	50
5001-10,000	0	50	37.5	25	25	25
10,001-15,000	0	16.6	0	0	25	0
15,001-20,000	100	0	0	0	0	25
20,001-30,000	0	0	0	25	0	0
30,001-45,000	0	0	0	25	0	0
Above 45,000	0	16.8	37.5	0	0	0
Total	100	100	100	100	100	100

with their levels of farm income and results given in table 7.

The table indicates that most progressive farmers are between the age of 25 and 45 years. For example about 32 per cent of the farmers between the age of 25 years and 35 years have farm incomes above Ksh.20,000 while none of the farmers above 65 years of age is within this income category. The solution to this problem may not be found in encouraging the old farmers to produce more but to encourage more young people to become farmers. Thus, the solution lies in the land tenure conditions as reflected in inheritance and the system which should impart the right skills and altitudes to the youths.

Education and Farm Income

Education has often been considered as one of the Key variables determining performance. The arguement has been that in uncertain and risky farming environments education helps to improve the farmer's ability to acquire and process information efficiently. Secondly, the farmer himself as a Unit of labour acquires skills in form of human capital through education. Therefore the farmers farm income is expected to increase with his or her education. Another held view is that formal education tends to reduce the farmer's participation in small scale agriculture as it increases his or her propensity to migrate to urban areas to look for modern employment.

Table 8 below is intended to show which of the above held views is applicable to Kibirigwi Irrigation scheme. The results tend to support the latter view that education tends to reduce the farmers performance. For example all those who went to school beyond standard 5 had farm income above the scheme mean of Ksh.20,000. The probable explanation of this is that more educated farmers tend to diversity their activities and put more emphasis to off-farm activities; for instance the case of the female farmer used in the linear program analysis, who went to school up to Standard 8, starting a health clinic in the near-by-market and later abandoning it.

On the basis of these three observations we conclude that sex, age and education are some of the factors that affect the farmers' performance on Kibirigwi Irrigation Scheme.

Table 8 : Farmers' Education and the Level of Farm Income

Income Group	Education Catgory		
Ksh	NONE	STD I TO 4	STD 5 AND ABOVE
0-5,000	33.3	I6.6	II.I
5001-I0,000	I6.7	I6.6	55.6
I0,00I-I5,000	0	8.3	II.I
I5,00I-20,000	0	8.3	II.I
20,00I-30,000	I6.6	I6.6	II.I
30,00I-45,000	0	I6.6	0
ABOVE 45000	33.4	I6.6	0
TOTAL	I00.0	I00.0	I00.0

The Water Laws

Water laws are of great significance to farmers n Kibirigwi Irrigation Scheme because together with other laws they determine the rights and obligations of the farmer to use and benefit from irrigation water. The Water Act is covered in cap 372 of the laws of Kenya. The most important part of the Act is Section 3 which states that

> ".... the ownership of everybody of water under or upon any land is vested in the government, subject to any rights of user in respect thereof which, by or under this Act or any other written law, have been or are granted or are recognized as being vested in any other person."

The control of water is exercised by the Minister for Water Development in accordance with the Act. The Ministers main duties are to promote the investigation, conservation and proper use throughout Kenya of the water resources. The Minister has the powers to construct and maintain works upon any land and impose rates to whoever benefits from such works. The Act also permits the formation of the Water Resource Authority the Water Appointment Board and the Water Appeal Board as bodies assisting the Minister in exercising the rights of the control of the water resources.

Subsection 1 of section 124 of the Water Act defines the terms under which a Water Undertaker can be formed. Under Section 143 Subsection 1, a Water Undertaker who is not a Local Authority can, with the approval of the Minister make regulations providing for tariffs and the management of his supply. Sections 35 to 49 specify how and who should apply for a water permit to utilize any water resource.

In accordance with the Water ACt, Kibirigwi Irrigation Scheme was formed as a water undertaker to supply irrigation water to Kibirigwi farmers as the Water users. They also signed an agreement which was to define their terms of operation. It is this Agreement in relation to the Water Act which pose a number of issues that may act as a hindrance to increased production on the scheme.

First, the farmers as an important party to the Agreement are not conversant with the Water Laws. They do not know their rights and obligations with regard to the use and disposal of water on the scheme. The majority of the farmers interviewed said they had never heard of the Water Act except for the Agreement they signed with the scheme management. Less than 10 per cent of the farmer knew that the water rates they were to pay was to be a mutual agreement between them and the scheme management. None of the farmers interviewed knew that if he or she was aggrieved by the management he had the right to sue the management either for a withdrawal or compensation. The situation of making the farmers uncertain about their legal rights in a scheme where decisions are supposed to emanate from the farmer reduces their ability to choose the best decisions.

Another weakness of the Agreement is its rigidity in relation to the prevailing Economic conditions. For example one of the regulations included in the Agreement was that farmers were to take all their horticultural produce to the scheme co-operative society. But farmers have been comparing the prices offered at the scheme to those offered at Karatina and those announced over the radio every evening and in most cases scheme prices are always lowest. This has encouraged farmers to sell thr their produce at night to some agents at a better price than the scheme one. The selling of crops at night has been going on inspite of the managements' warnings. Infact three farmers were accused in Kerugoya courtr for selling their produce outside the scheme and their water was disconnected afterwards.

The Agreement has a number of flaws that inhibit the farmers decision choice. For instance it does not specify the penaultíes that should be imposed to the farmer as a water user if he defies the regulations.

Secondly, the Agreement does not give a provision for the farmer to let or lease his or her farm. This has seriously disadvantaged the farmers in optimizing the value of their land in a region where land leasing and letting is a common practice.

What is puzzling is that the scheme management has prohibited scheme farmers from selling their produce outside the scheme, it has made provisions for outside famers to bring their produce to the scheme. The arguement of the management is that this provision helps to fully utilize the scheme Godown (warehouse) and transport capacity which are in excess of scheme production. While that may be true it also has the negative effect of depressing the scheme prices since the management sells the produce to established markets (agents) in Nairobi at a higher price and sells the excess on the open market at a lower price and averages the prices when paying the farmers. More so, the outside produce may give the impression that the scheme productivity is high while in actual sense it may be declining.

On the basis of these considerations, we conclude that the legal framework is a hindrance to increased production on the scheme. Overall we conclude that-some social and institutional factors affect the expansion of expansion of production on the scheme, and that they may continue to do so in future if they are not rectified. Therefore we accept the null hypothesis that some social and institutional factors inhibit the expansion of irrigation.

FOOTNOTES

1. See Arao L.A. and Houtman C.P. Baseline Agro-Economic Survey of Kibirigwi Irrigation Scheme. IDRP Report No. 26, NAL. June 1980.

2. See Kenya Government, Ministry of Agriculture Annual Agricultural Reports, Kirinya District, 1978-1982.

3. This information was obtained from Kibirigwi Irrigation Scheme records for the period under consideration.

4. For instance See Hatch J.K. etel Strategies for Small farmer Development: An Empirical Study of Rural Development Projects. Volume 1. Development Alternatives Inc. 1923 Jefferson Place, N.W. Washington, D.C. 20036, May 1975.

CHAPTER SIX

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1: Summary and Conclusions

This study covers a small scale irrigation scheme at Kibirigwi in Kirinyaga district. The main objective of the study was to evaluate the scheme with a view of assessing the importance of and constraints to, small scale irrigation in Kenya's high potential areas. One of the objectives was to investigate whether there was significant difference between the agricultural income of farmers on an irrigated area and those in an un-irrigated area. Results showed that farm income on an irrigated scheme is significantly higher than that on an unirrigated area. Secondly, the contribution of horticultural crops to farmers' income has surpassed that of coffee on the irrigation scheme. Other aspects like employment generation and the use of other farm inputs were also considered. Results showed that irrigation increased permanent farm employment, use of fertilizer and herbicides.

The overall conclusion is that the scheme is contributing positively towards the development in terms of income and employment generation of the area under study. However, it is not possible to ascertain whether the scheme is viable or not since capital repayment has not been started. Given the heavy capital investment, the capital repayment deductions can be expected to reduce the farmers' net income.

Another objective of the Study was to identify some of the government regulations that may affect production on the scheme. Setting the farming calender, allocating farm inputs (seeds) to farmers and the rationing of credit to farmers by the scheme management were identified as some of the government regulations that may reduce production on the scheme. It was observed that the scheme management set the farming calender in relation to the government financial year which does not with the market conditions. It was also noted that management allocates seeds to farmers after their own requests. Their requests are based on current prices. Given the seasonal fluctuation of horticultural produce prices, the cyclical problem of high supply at low prices and vice versa is bound to occur.

Finally, it was observed that the scheme management allocates credit to farmers according to the farmer's previous crop deliveries. This has the effect of making the poor farmers to continue performing poorly, leading to inequality and apathy among the less progressive farmers. We therefore conclude that some government regulations are an obstacle to increased crop production on the scheme.

The third objective was to identify some social (demographic) and institutional factors that may affect the expansion of irrigation. Sex, age, education and the legal framework were identified as key factors affecting performance. It was observed that generally female farmers perform rather poorly compared with their male counterparts. In terms of age, it was observed that the most progressive farmers are those between 25 and 45 years of age, probably because at this stage the farmers have enough experience and they still have the engergy and initiative to work. Formal education on the other hand did not show any positive impact on the farm income. Finally, it was observed that the Agreement signed by the farmers and the scheme management in particular, and the Water Laws in general are a hindrance to the expansion of irrigation and crop production because of their rigidity in relation to the changing economic circumstances. The overall conclusion is that these social (demographic) and institutional factors are a bottleneck to expanded small scale irrigation production.

During the study a number of other issues came up. First, the results indicate that it is possible to apply the Linear Program models in research and planning small scale irrigation schemes. Secondly, the models also showed that farmers subsistence requirements are a significant constraint to increased horticultural production for commercial purposes. The inclusion of subsistence in the models on average reduced the optimal net returns by 47 per cent. The sensitivity analyses showed that it is not possible to generalize that it is only one or the other resource that is the limiting constraint to all farmers on the scheme. Different farmers have different resource constraints in the various phases of the farming process. However, for the farming pattern adopted in the program the constraining resources that appeared severally were the October labour and the first season irrigated land.

On technical considerations irrigation water was found to be a slack resource through-out the year: less than 40 per cent of the water is applied. The issue then was to identify the best method of setting a water charge that could achieve economic efficiency. It was

Observed that a method of willing-buyer willing-seller would be the most appropriate for the economic conditions prevailing in Kibirigwi. It was also observed that if the criteria of capital recovery were applied under the current circumstances it would be a very heavy burden on the farmers unless gradual recovery is adopted.

6.2: Recommendations

On the basis of this summary of findings and conclusions the following recommendations are made, particularly for Kibirigwi Irrigation Stheme.

Water Use: Farmers are not familiar with the crop water use requirement particularly for the specific horticultural crops, leading to over- and under-utilization of the water resource. There is an urgent need on the side of the government to research into this aspect and determine the appropriate irrigation pattern for the specific crops on the scheme. The information obtained should then be carefully disseminated to the farmers.

Secondly, flat rate charges are repressive to farmers and it is not in line with the optimization and efficiency criteria of decision making. If a water charge is to be set, then it should be on a willing-buyer willing-settler basis and charged per amount of water used.

Thirdly, the Water Agreement between the scheme management and farmers is rigid and inappropriate to the changing social-cultural and economic circumstances on the scheme. Since; the original Agreement was meant to run for five years, the new Agreement to be signed should be more flexible and enforceable. Specifically, provisions should be made for farmers to let their irrigated land if they themselves are unable to utilize the land because of unavoidable circumstances.

Labour Use: Labour is one of the most limiting constraints on the scheme. Most farmers can not have extra casual labour because of the lack of working or liquid cash. The problem can be resolved by the scheme management. First, the scheme management should assess each farmer's labour availability before allocating him/her seeds for planting. Some crops utilize more labour in certain periods than others. Farmers who are seriously constrained by labour should be allocated less labour intensive crops. Secondly, the scheme management could supply casual labour to farmers on a credit basis. Farmers who are constrained by labour could be reporting every morning to the scheme management and as the basis of these reports the scheme management could hire casual workers on behalf of the farmers. The casual workers could be told to be reporting at the scheme management offices every morning to assess the possibility of being employed. Those who can not be employed may look for employment elsewhere. The scheme management could then send the casual workers to work on specific farms for a given piece-rate and the total costs deducted from the farmer's returns after crop delivery.

Credit Allocation: The allocation of credit according to the farmer's previous performance has the impact of disillusioning the less progressive farmers. Other methods of credit rationing should be adopted. For example the scheme management could mutually agree with the less progressive farmers so that the farmers can be given the required credit provided that the management supervises the farm operation to make sure that production is efficient in order to recover the loan and earn some income for the farmer. The farmers can then be gradually left alone in the subsequent years.

Secondly, the interest of 1.2 per cent per month on the outstanding loan is quite high since cumulatively it would be about 15.4 per cent per annum. Given that the management deducts a commission of 7 per cent of the Gross Payout, the interest on credit should be reduced accordingly. At least it should be in line with the co-operative societies' lending rates which are normally below 12 per cent per annum.

Thirdly, there seems to be some confusion on the type and source of the farm inputs that should be supplied to the farmers. This confusion has led to the misuse of farm inputs, particularly the herbicides and fungicides. The scheme's technical officers should rely on recommendations from the National Agricultural Laboratories, the Horticultural Research Station in Thika or any other government sanctioned, bodies than from the 'salesman' of private companies. This should also be accompanied with regular visits by the technical officers to the Research Stations to familiarize themselves with new findings.

of integrating the project in the general frame-work of Rural Development.

Suggested Research Area: This study left out a number of issues related to Small Scale Irrigation in Kenya in general. There is need to apply the linear programming models to other small scale irrigation schemes in order to generalize the conclusions drawn for general national Small Scale Irrigation Schemes. Secondly, there is need to investigate into the dynamics of Small Scale Irrigation by applying dynamic programming, simulations and Input-Output Models. This would help to incorporate prerenial crops, risk and uncertainty and the allocation of the production of certain horticultural crops in certain regions.

Limitations

However, the study suffers from two major weaknesses. First, given that it is a case study of a relatively small area, it is not possible to generalize the conclusions for the rest of the country. To do so would require a survey of most of the small scale irrigation schemes in Kenya. (Such a survey would on the other hand over-shadow the detailed and intrinsic factors affecting farmers in small irrigation schemes). The second limiation is that data, especially on technical aspects of the scheme, has not been fully documented. Therefore in most cases crude estimates are applied. This necessitated the application of analytical tools that give a range of possibilities rather than a single solution.

REFERENCES

1. Ateng' B.A. Linear Programming: An Application to Identification of the Best Existing Farming Strategy for Peasant Farmers in Kenya. M.A. Thesis, University of Nairobi, 1977.

2. Baumol W.J. Economic Theory and Operations Analysis: Prentice Hall Inc. Englewood Cliffs, N.J. 1977.

3. Carruthers I.D. Impact and Economics of Community Water Supply . Wye College, University of London, 1973.

4. ________ and Donald G.F.: "Estimation of Effective Risk Reduction Through Irrigation of a Perenial Crop." Journal of Agricultural Economics Vol. 22, 1971.

5. Chambers R. et el, Mwea: An Irrigated Rice Settlement in Kenya. Welt forum Verlag GmbH, Munchen, 1973.

6. Clark C., Economics of Irrigation New York Pergawn Press, New York. 1967.

7. Cochrane, W.W.: "Research in Public Policy". Journal of Farm Economics Vol. 32, 1949.

8. Crosson P.R. "The Impact of Irrigation Investment on Regional and Urban Development" in Cummings, R (Ed) Inter-Basin Transfer of Water: American Case Study. The Iowa State University Press, 1975.

9. Dorfman R. et el Linear Programming and Economic Analysis. The RAND Corporation. McGraw-Hill Book Company, London, 1958.

10. Georgescu-Roegen N. "Economic Theory and Agrarian Economics" in Eicher, C. and Wilt, L. (Ed.) Agriculture in Economic Development McGrill Hill Inc., 1964.

11. Heyer, J. Agricultural Development and Peasant Farming in Kenya, Ph.D. Thesis, University of London, 1966.

12. Hutton R.F. "Survey of Operation Research Techniques" Journal of Farm Economics Vol. 47, PT2, 1965.

13. Kibirigwi Irrigation Scheme, Scheme Records 1975-1983.

14. Mukhebi A.W. Income and Employment in Kenya's Small Scale Agriculture Ph.D. Thesis, Washington State University. 1981.

15. National Irrigation Board, Annual Reports 1966-1982.

16. Republic of Kenya, Sessional Paper No. 4 of 1981 on National Food Policy, Government Printer, Nairobi, 1981

17. ________ Ministry of Agriculture, Irrigation and Drainage Research Project Report, Nairobi, 1978.

18. ________ The Water Act, Cap 371 and 372 of the Laws of Kenya, Government Printer, Nairobi, 1975.

19. ________ Kerio Valley Development Authority: General Development Plan for Kerio Valley Basic, Water Resource Study, Nairobi, 1982.

20. ________ "Soils Irrigation and Water Use in a Small Scale Sprinker Irrigation Scheme, Kibirigwi, in Kirinyaga District of Central Province, Kenya" IDRP Report No. 39, Nairobi, 1979.

21. ________ "The Kibirigwi Irrigation Scheme". Ministry of Agriculture, Small Scale Irrigation Unit. Nairobi, 1980.

22. ________ Economic Evaluation of Kibirigwi Irrigation Scheme. Ministry of Agriculture and Livestock Development, Nairobi, 1975.

23. ________ Farm Management Hand-book for Kenya Vol 2. Natural conditions and Farm Management Information, Ministry of Agriculture and Livestock Development. Nairobi, 1983.

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

25. Sorrenson, M.P.K. Land Reform in the Kikuyu Country. Oxford University Press, Ely House, London, 1967.

26. Worthington E.B. et. el; Arid Land Irrigation in Developing Countries, International Council of Scientific Unions, Oxford, 1977.

27. Vyas V.S. "Indias High Yielding Variaties Programme in Wheat 1966-7 to 1972". International de Mahoramiento de Maiz Y Trigo (CIMMYT). Mexico City, 1975.

A P P E N D I C E S

QUESTIONNAIRE

DISTRICT ______________________ INTERVIEWER ______________________

LOCATION ______________________ DATE ______________________

SUB-LOCATION ______________________ SERIAL NUMBER ______________________

SECTION A: FAMILY BACKGROUND AND LABOUR SUPPLY

I. Name of farmer ______________________

2. How old are you? ______________________ Years

3. How long have you stayed in this location? _____ Years

4. How did you get this farm?

   a. Inherited ____________

   b. Bought ____________

   c. Given by Government ____________

   d. Others (specify ____________

5. For how long have you been operating on this farm?

6. What highest level of formal Education did you reach?

   a. None ____________

   b. Std 1-4 ____________

   c. Std. 5-8 ____________

   d. Form 1-6 ____________

   e. above (specify)______) ____________

7. (i) Are you married?

   Yes ____________

   No ____________

   (ii) If Yes in 7(i), how many wives do you have?

   One ____________

   Two ____________

   Three ____________

   Four ____________

   (iii) How many your wives work on the farm full time and Part time

	Full Time	Part time
None	________	________
One	________	________
Two	________	________
Three	________	________
Four	________	________

(iv) For those who work Part time in (7iii) state when they work on the farm

____

8. (i) How many of your children are

Between	1-10 Years	________
"	11-15 Years	________
Above	15 Years	________

(ii) How many of each category go to school

Between	1-10 years	________
"	11-15 years	________
Above	15 years	________

(iii) How many of each category work on the farm full time?

Between	1-10 years	________
Between	11-15 years	________
Above	15 years	________

9. (i) How many relatives live with you on this farm? State their ages in years

	AGE
None	A ________
One	B ________
Two	C ________
Three	D ________
Four	E ________
Other (Specify)	________

(ii) How many of the relatives work full time and Part time on this farm?

	Full Time) AGE	Part time) AGE
None	A ________	A ________
One	B ________	B ________
Two	C ________	C ________
Three	D ________	D ________
Four	E ________	E ________
Other (specify)	________	________

(iii) For those who work part in (9ii) state when they work on the farm

____

IO. (i) How many hours of farm-work are done per day during peak period by each family member of relative living on this farm.

Adults ______________________ hrs

Children ______________________ hhrs

(ii) Did you receive help in the form of working parties?

Yes/No

(iii) Was the working party communal or paid?

Communal/paid

(iv) Which the following farm operations did they perform on your plot:

- land clearing ....no. of people ....no. of days performed ......days.
- planting ....no. of people......no of days performed .... days
- Weeding .....no of people......no of days performed .... days
- harvesting ...... no. of people ...... no of days performed .... days.
- other........ no. of people ....no. of days performed .... days

(v) If the working party was paid, what was the basis for payment?

- on the basis of area completed
- per day's work.

(vi) If payment was made on the basis of area completed, was the size of one area? .... meters.

(vii) If payment was made on day's work basis, how much was paid for a day's work Kshs .... per day

SECTION B. HIRED LABOUR

11 (i) How many Permanent do you have

None ____________

One ____________

Two ____________

Three ____________

Four ____________

Other (specify________) ____________

(ii) What is the monthly Payment to the employees in terms of

Wage ____________

Food ____________

Housing ____________

Other (specify ________) ____________

(iii) Do you think think the current permanant employees are enough?

(iv) If No in II (iii), what prevents you from hiring moreppermanent employees

cash constraint ____________

Non-availability of labour ____________

Poor returns from crops ____________

Other (specify ________) ____________

(v) How many hours does permanent labour work per day?

________________ hrs.

12 (i) How many casual labourers did you engage during the last peak season?

none ____________

one ____________

two ____________

three ____________

four ____________

other (specify_______) ____________

(ii) what was their total wage Kshs ____________

(iii) For how long did you engage them? ____________ months

SECTION C: THE FARM AND FARM OPERATION

13 (i) How big is this farm?________________ acres

(ii) Give the acreage of other pieces of land elsewhere th...

belongs to you

a ______________________ acres
b. ______________________ acres
c. ______________________ acres
d. ______________________ -acres

(iii) Do you organize farming on these other farms

Yes ______________________
No ______________________

(iv) Have you ever rented land from others?.................Yes/No

(v) If yes, when did you last rent this land ______________________

(vi) How many acres did you rent? ______________________ acres

(vi How much did you pay for this? ______________ Kshs. per ______

(vii) For how many years did you rent this piece of land?

______________________ years.

(viii) Have you ever let any land you own to others? ______________ Yes/No

(ix) If yes, did you let any in

- L.R. season 1979 ______________________ acres.
- S.R. season 1979 ______________________ acres.

(x) For how much did you let this piece of land?

______________________ Kshs. per ______________________

14 (i) Which crops would you like to grow on the Irrigation on Plot this year. Rank them in terms of importants starting with the most important.

1. ______________________
2. ______________________
3. ______________________
4. ______________________

(ii) Why would you like to grow the first crop in question 14 (i) above?

a) Because it is more profitable than others ______________
b) It Requires less attention ______________________
c) It is less labour demanding ______________________
d) Its Price does not fluctuate much ______________________
e) Other (Specify) ______________________

14 (iii) What is the Price of each of the above crops at Karatina, Kibigoti or any other market.

Crop	Price Karatina	Kibigoti	Others (excluding KIFCO)
I. ______	______	______	______
2. ______	______	______	______
3. ______	______	______	______
4. ______	______	______	______

(v How much could it cost you to transport a sack of onions or box of tomatoes from your farm to Karatina Market?

Sack of onions Ksh. ______

Box of tomatoes Ksh. ______

(v) If KIFCO delays in Paying you for the output you have delivered to them what do you do to get cash to perchase houschold items?

(a) From other source of income (name it) ______

(b) Borrow from neighbour or relative ______

(c) Sell crops on the Open Market ______

(d) Other (Specify______) ______

(vi) Do you think the way KIFCO Pays you for your output is proper?

Yes ______

No ______

(vii) If NO in 14(vi), why do you think it is not proper?

a) They delay in payment ______

b) The Prices are low ______

C. The Prices fluctuate alot ______

d) The Records are not proper ______

e) Other (Specify______) ______

(viii) What do you think could be done to solve the problem in 14 (vii)

______

______

IRRIGATION PRACTICE

15 i) How much land has been allocated to you for Irrigation Purpose?

_______ ____________________ Laterals

ii) On averege how many laterals remain fallow at any time?

_______ ____________________ Laterals.

iii) If some laterals remain fallow in 15(ii), why do you leave them fallow?

Lack of seeds ____________________

Lack of labour ____________________

For rotation Purpose ____________________

Management specification ____________________

Other (Specify) ____________________

16. i) Are you using the two Sprinklers allocated to your farm by the Kibirigwi Irrigation Scheme (KIS)?

Yes ____________

NO ____________

ii) If Yes in 16 (i), describe how often you use them for each of the crops i.e. indicate the number of times per week/month.

PERIOD

CROP	PLANTING		DURING PLANTING		AFTER PLANTING	
	Dry Weather	Wet Weather	Dry Weather	Wet Weather	Dry Weather	Wet Weather
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

iii) How do you know that the crops have had enough water? ______

______

16. iv) If NO in 16 (i) why are you not using the Sprinklers?

Family Disagreement ______
Land Conflict ______
Sickness ______
Lack of Finance ______
Other (Specify ______) ______

v) Would you be willing to rent them out to some other farmers?

Yes ______
NO ______

17. i) Supposing you were charged for the use of this water for Irrigation would you be willing to pay

Yes ______

No ______

ii) If Yes in 17(i), how mcch wohld you be willing and able to pay per month or year.

Ksh ______ Year.

iii) If NO in 17 (i), why wouldn't you like to pay for the water

Can't afford charge ______
That is government property ______
It is not useful ______
Other (Specify ______) ______

FARM INPUT

18 i) Which of the following farm inputs did you get from KIFCO since January this year. Indicate whether you feel they were enough or not?

Type	Quantity	Price Per Kg	Remarks		
			Too Much	Just enough	Not enough
Seeds					
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
Fertilizers					
1.					
2.					
3.					
4.					
Herbicides/Fungicides/ Insectcides					
1.					
2.					
3.					
4.					

ii) What action did you take when the inputs which you were offered were not enough

a) Given more by KIFCO ____________________

b) Bought some fromKKFA ____________________

c) Bought some from other supplier ____________________

d) Did nothing ____________________

e) Used other seeds/chemicals ____________________

f) Other (Specify ____________) ____________________

iii) What did you do with those inputs which were in excess?

a) Stocked for next season ____________
b) Sold to Neighbour ____________
c) Sold elsewhere ____________
d) Gave out freely ____________
e) Other (Specify ________) ____________

18. iv) a) Which of the following Fertilizers do you think is best for use?

a) C.A.N. ____________
b) D.A.P. ____________
c) ____________
d) Other (Specify ________) ____________

b) Why do you think it is best?

____
____
____
____
____

19. i) Of which organizations Co-operative associations are you a member

a) ____________
b) ____________
c) ____________
d) ____________

ii) What official position do you hold in these organizations?

Organization	Position
a) ____________	____________
b) ____________	____________
c) ____________	____________
d) ____________	____________

iii) What improvement do you think these organization need now?

a) ____________
b) ____________
c) ____________
d) ____________

20. i) Do you owe any Co-operative or Rank any loan that you are repaying?

Yes. ______________________

No. ______________________

ii) If yesiin 20(i) state the Organization, Amount, date of aplication, date you received and the date you have to complete repayment

	Source	Amount Ksh.	Date Applied	Date Received	Date of full Repayment
1.	______	______	______	______	______
2.	______	______	______	______	______
3.	______	______	______	______	______
4.	______	______	______	______	______

20 iii) Do you think the Credit Offered by KIFCO is enough for your farm operation

Yes ______________________

No. ______________________

iv) If No in 20(iii), what do you think should be done

____

____

____

21. i) Apart from work on your farm do you also have another job?

Yes ______________________

No. ______________________

ii) If yes in 21(i) what do you do? ______________________

____

iii) How many days per week?

____

iv) How much do you earn from this specific job per day/week/month year? Underline the period.

Kshs. ____________

v) How many family member have jobs outside the holding and where.

Number	Place
One	______
Two	______
Three	______

vi) Are the jobs full time or part time?

Family member	Full-time	part-time
One	___	___
Two	___	___
Three	___	___

23. How many of the following types of livestock do you own at this moment.

Type	Number owned	Total Value KSH.
Oxen	___	___
Bulls	___	___
Heifers	___	___
Calves	___	___
Sheep	___	___
Goats	___	___
Chickkens	___	___
Cow	___	___

(ii) Did you have any cows in lactation last year?

Yes ___________

No ___________

(iii) If yes in 23(ii) how much milk did you get on average

- in the morning --- litres/treetop bottles
- in the evening --- litres/treetop bottles

(iv) What was the price per bottle of treetop/litre?

KSH. ___________

(v) For how long did the loctation last?

___________ month

(vi) Did you sell any manure?

Yes ___________

No ___________

(vii) If yes in 23 (vi) how much did you sell and at what price did you sell it

Quantity_______________ Total value KSH.. _______________

(viii) What other farm product did you sell

Type	Quantity	Total Value
1. ________	________	________
2. ________	________	________
3. ________	________	________

Table I: MONTHLY RAINFALL RECORD 1963 - 1982 (MM)

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	MEAN
JAN	40.5	14.8	40	7.2	7.5	-	7.6	60.3	-	40.4	35.9	17.5	15.6	4.5	31.4	71.0	116.8	13.5	3.8	2.1	28.7
FEB	66.3	33.8	8.3	28.3	10.1	173	49.8	11.2	6.6	82.9	53.6	-	-	20.3	10.6	93.6	61.1	7.6	28.3	32.6	39.9
MAR	104.3	152.8	33.1	137.1	51.3	128.5	25.4	180.7	166.8	20.1	-	291.5	40.7	2.6	126.4	177.8	150.8	5.1	144.4	23.1	96.6
APR	613.5	353.7	28[illegible].1	413.3	448.5	279.3	145.5	400.5	256.3	169.4	243.0	307.1	242.1	380.0	315.7	438.3	251.1	229.9	271.4	382.9	321.4
MAY	290.8	50	27[illegible].5	87.4	748.5	201.2	336.9	146.0	250.8	385.9	344	162	106.5	41	440.1	110.4	386.3	293.2	600.2	448.5	285.4
JUN	56	61.7	16.4	15.8	59.5	33.	44.5	31.4	25.1	56.8	45.7	100.4	38	36.4	22.5	35.3	156.7	1.8	51.1	52.3	47.1
JUL	27.5	18.8	15.8	-	56.4	47.	94.1	22.2	27.6	12.1	26.2	174.2	28.4	60.4	31.5	48.3	56.9	13.6	56.1	59.0	39.0
AUG	92.6	57.3	37.2	83.5	76	17.[illegible]	38.4	303	3.0	9.8	25.4	16.4	2	18.7	59	72.8	26.4	63.5	47.2	21.8	39.9
SEP	36.3	8.5	20.5	17.6	68.2	-	25.4	3.8	-	77.8	42	22.5	-	86.9	23.6	65.7	17.3	21.0	73.4	91.2	35.1
OCT	32.8	171.4	118.5	126.1	312.1	135.6	113.6	103.1	26.2	275.9	199.1	59.1	60.6	75.5	219.1	214.9	226.8	178	124.4	5.1	119.9
NOV	72.6	111.0	39[illegible].4	214.1	290.5	303	162.1	108.1	98.6	268.8	129.7	54.6	120.7	147	441.3	111.3	152.4	178	116.9	10.4	174.5
DEC	133	32.5	20.7	74.6	11.2	-	5.6	10	40.4	24.4	-	23.9	38.1	80.6	76.2	179.9	45.2	39.9	67.4	7.2	55.6
TOTAL	1585.7	1086.3	1259.5	1205.0	2139.6	1379.1	1049.1	1107.6	901.4	1367.5	1144.6	926.8	693	953.3	1847.4	1619.3	1647.8	1050.1	1554.4	1146.2	1282.7

Source: Kibirigwi Irrigation Scheme and Kibirigwi Coffee factory Weather records.

Table 2 MONTHLY RAINFALL AS PERCENT OF LONG TERM MONTHLY AVERAGE.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	MEAN
JAN	141	52	140	25	26	0	27	210	0	141	125	61	54	16	284	248	408	47	13	7	100
FEB	216	85	21	71	25	434	125	28	16	208	134	0	0	51	27	235	153	2	71	82	100
MAR	108	158	34	142	53	133	26	187	173	21	0	302	42	3	131	184	156	5	118	24	100
APR	192	110	89	129	139	87	45	125	80	53	76	96	75	116	98	136	71	72	84	119	100
MAY	102	18	96	31	263	70	118	51	88	135	121	57	37	14	154	39	135	104	210	157	100
JUN	119	131	35	34	126	72	95	67	53	121	97	213	81	78	48	75	383	4	109	111	100
JUL	70	48	40	0	145	122	241	57	71	31	67	344	73	155	81	124	146	35	144	151	100
AUG	232	144	93	209	190	43	96	76	8	25	64	41	5	47	148	182	66	159	118	55	100
SEP	103	24	584	502	194	0	72	11	0	222	120	64	0	248	67	187	49	60	209	260	100
OCT	27	143	99	105	260	165	95	86	22	230	166	49	51	63	183	179	189	149	104	13	100
NOV	42	64	229	123	166	174	93	62	56	154	74	31	69	84	254	64	87	102	67	6	100
DEC	292	71	45	164	25	0	13	22	89	54	0	52	84	177	167	395	99	88	148	16	100
TOTAL	124	83	99	94	167	106	82	86	70	107	87	72	54	74	144	126	128	82	121	89	100
MEAN	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source; Calculated from Table I

FARM 1 LP MATRIX APPENDIX 2A

	MIB I	MIB 2	ONS I	ONS 2	TOM I	TOM 2		RHS
MAXIMIZE	90	I00	6800	2043	4900	2400	Z	
LABA	34	0	24	0	I7	0	≤	I60
LABB	90	39	0	0	25	0	≤	I60
LABC	30	20	0	40	8	40	≤	375
LABD	89	20	95	5I	84	30	≤	495
LABE	84	0	95	24	84	I7	≤	375
LABF	24	0	0	24	84	25	≤	I60
LABG	0	0	0	0	0	8	≤	I60
LABH	39	34	0	0	0	84	≤	280
LABI	20	I20	0	95	0	84	≤	I60
LABJ	20	89	40	95	0	84	≤	I60
LABK	0	84	5I	0	40	0	≤	I60
LABL	0	24	24	0	30	0	≤	280
WATA	0	5	5	0	5	0	≤	60
WATB	0	5	6	0	6	0	≤	60
WATC	3	0	3	5	4	I	≤	60
WATD	0	0	0	0	0	0	≤	60
WATE	0	0	0	0	0	0	≤	60
WATF	I	0	0	3	0	4	≤	60
WATG	3	0	0	4	0	4	≤	60
WATH	0	0	0	3	0	3	≤	60
WATI	0	0	0	0	0	0	≤	60
WATJ	0	3	5	0	0	0	≤	60
WATK	0	I	7	0	2	0	≤	60
WATL	0	4	5	0	6	0	≤	60
IRRA	I	0	I	0	I	0	≤	4
IRRB	0	I	0	I	0	I	≤	
UNRA	I	0	I	0	I	0	≤	9
UNRB	0	I	0	I	0	I	≤	
CREA	0	0	50	0	60	0	≤	200
CREB	0	0	0	50	0	60	≤	200
SUBT	I	I	0	0	0	0	≥	3

FARM 2 LP MATRIX APPENDIX 23

	MIB I	MIB 2	ONS I	ONS 2	TOM I	TOM 2		RHS
MAXIMIZA	90	I00	6800	2043	4900	2400	Z	
LABA	34	0	24	0	I7	0	≤	960
LABB	90	39	0	0	25	0	≤	960
LABC	30	20	0	40	8	40	≤	960
LABD	89	20	95	5I	84	30	≤	960
LABE	84	0	95	24	84	I7	≤	960
LABF	24	0	0	24	84	25	≤	960
LABG	0	0	0	0	0	8	≤	960
LABH	39	34	0	0	0	84	≤	960
LABI	20	I20	0	95	0	84	≤	960
LABJ	20	89	40	95	0	84	≤	960
LABK	0	84	5I	0	40	0	≤	960
LABL	0	24	24	0	30	0	≤	960
WATA	0	5	5	0	5	0	≤	60
WATB	0	5	6	0	6	0	≤	60
WATC	3	0	3	5	4	I	≤	60
WATD	0	0	0	0	0	0	≤	60
WATE	0	0	0	0	0	0	≤	960
WATF	I	0	0	3	0	4	≤	660
WATG	3	0	0	4	0	4	≤	60
WATH	0	0	0	3	0	3	≤	60
WATI	0	0	0	0	0	0	≤	60
WATJ	0	3	5	0	0	0	≤	60
WATK	0	I	7	0	2	0	≤	60
WATL	0	4	5	0	6	0	≤	60
IRRA	I	0	I	0	I	0	≤	6
IRRB	0	I	0	I	0	I	≤	6
UNRA	I	0	I	0	I	0	≤	I0
UNRB	0	I	0	I	0	I	≤	I0
CREA	0	0	37	0	44	0	≤	I20
CREB	0	0	0	37	0	44	≤	I20
SUBT	I	I	0	0	0	0	≥	3

FARM 3 LP MATRIX APPENDIX 2C

	MIBII	MIB 2	ONS I	ONS 2	TOM I	TOM 2		RHS
MAXIMIZE	90	I00	6800	2043	4900	2400	Z	
LABA	34	0	24	0	I7	0	≤	480
LABB	90	39	0	0	25	.0	≤	480
LABC	30	20	0	40	8	40	≤	653
LABD	89	20	95	5I	84	30	≤	893
LABE	84	0	95	24	84	I7	≤	653
LABF	24	0	0	24	84	25	≤	480
LABG	0	0	0	0	0	8	≤	480
LABH	39	34	0	0	0	84	≤	720
LABI	20	I20	0	95	0	84	≤	480
LABJ	20	89	40	95	0	84	≤	480
LABK	0	84	5I	0	40	0	≤	480
LABL	0	24	24	0	30	0	≤	720
WATA	0	5	5	0	5	0	≤	60
WATB	0	5	6	01	6	0	≤	60
WATC	3	0	3	5	4	I	≤	60
WATD	0	0	0	0	0	0	≤	60
WATE	0	0	0	0	0	0	≤	60
WATF	I	0	0	3	0	4	≤	60
WATG	3	0	0	4	0	4	≤	60
WATH	0	0	0	3	0	3	≤	60
WATI	0	0	0	0	0	0	≤	60
WATJ	0	3	5	0	0	0	≤	60
WATK	0	I	7	0	2	0	≤	60
WATL	0	4	5	0	6	0	≤	60

APPENDIX 2C CONTINUES

FARM 3 LP MATRIX APPENDIX 2C

	MIB I	MIB 2	ONS I	ONS 2	TOM I	TOM 2	Z	RHS
IRRA	I	0	I	0	I	0	$\leq$	6
IRRB	0	I	0	I	0	I	$\leq$	6
UNRA	I	0	I	0	I	0	$\leq$	6
UNRB	0	I	0	I	0	I	$\leq$	[illegible]
CREA	0	0	25	0	30	0	$\leq$	240
CREB	0	0	0	25	0	30	$\leq$	240
SUBT	I	I	0	0	0	0	$\geq$	3

TABLE 5 : WATER BUDGET FOR MIB I AND MIB 2 IN MILLIMETRES (APPENDIX 4A)

MONTH \ ITEM	EXPECTED RAIN	DEEP PER-COLATION	EVAPO-RATION	TRAN P MIB I	TRAN P MIB 2	DEFICIE-NCY MIB I	DEFICIE-NCY MIB 2	IE REQ MIB I	IE REQ MIB 2
JAN	25	70	I50	0	50	0	-245	0	5
FEB	34	70	I74	0	20	0	-230	0	5
MAR	I00	70	I59	20	0	-I49	0	3	0
APR	305	70	I26	20	0	+89	0	0	0
MAY	285	70	I35	30	0	+50	0	0	0
JUN	42	70	99	40	0	-28	0	I	0
JUL	37	70	78	20	0	-I3I	0	3	0
AUG	36	70	93	0	0	0	0	0	0
SEP	32	70	I35	0	0	0	0	0	0
SEP	I25	70	I50	0	20	0	-II5	0	3
NOV	I56	70	III	0	20	0	-45	0	I
DEC	37	70	I26	0	30	0	-I89	0	4

TABLE 6 WATER BUDGET FOR ONS I AND ONS 2 IN MILLIMETRES (APPENDIX 4B)

ITEM / MONT	EXPECTED RAIN	DEEP PER-COLATION	EVAPO-RATION	TRANS P. ONS I	TRANS P. ONS 2	DEFICIE-NCY ONS I	DEFICIE NCY ONS 2	IE. REQ ONS I	IE. REQ ONS 2
JAN	25	70	I50	60	0	-255	0	5	0
FEB	34	70	I74	60	0	-270	0	6	0
MAR	I00	70	I59	30	I00	-I59	-225	3	5
APR	305	70	I26	0	I00	0	+9	0	0
MAY	285	70	I35	0	60	0	+20	0	0
JUN	42	70	99	0	60	0	-I58	0	3
JUL	37	70	78	0	60	0	-I7I	0	4
AUG	36	70	93	0	30	0	-I57	0	3
SEP	32	70	I35	0	0	0	0	0	0
OCT	I25	70	I50	I25	0	220	0	5	0
NOV	I56	70	III	300	0	325	0	7	0
DEC	37	70	I26	60	0	2I9	0	5	0

TABLE 7 WATER BUDGET FOR TOM I AND TOM 2 IN MILLIMETERS (APPENDIX 4C)

ITEM / MONTH	EXPECTED RAIN	DEEP PERCOLATION	EVAOPRATION	TRAN P TOM I	TRAN P TOM 2	DEFICIENCY TOM	DEFICIENCY TOM 2	IE REQ TOM I	IE REQ TOM 2
JAN	25	70	I50	30	0	-225	0	5	0
FEB.	34	70	I74	60	0	-270	0	6	0
MAR	I00	70	I57	60	50	-I89	-50	4	I
APR	305	70	I26	20	I00	+89	+9	0	0
MAY	285	70	I35	0	30	0	+50	0	0
JUN	42	70	99	0	60	0	-I87	0	4
JUL	37	70	78	0	60	0	-I7I	0	4
AUG.	36	70	93	0	20	0	-I47	0	3
SEP.	32	70	I35	0	0	0	0	0	0
OCT.	I25	70	I50	0	0	0	0	0	0
NOV	I56	70	III	I25	0	-I25	0	2	0
DEC	37	70	I26	300	0	-300	0	6	0

Table 8 Activity Analysis APPENDIX I

ITEM / ACTIVITY	Ourput Per Lateral (KG)	Price Per Kilogram (KSH)	Total Per Laterral (KSH)	Variable Costs Per Lateral (KSH)	Net Rev. Per Lateral KSH
MAIZE & BEANS I	258	2.60	666	573	90
MAIZE & BEANS 2	260	2.60	676	573	100
ONIONS I	2018	5	10,090	3290	6800
ONIONS 2	1912	2.50	4780	2737	2043
TOMATOES I	2430	3.50	8505	3605	4900
TOMATOES 2	2295	2.50	5737	3337	2400

Source

Table FARM INCOME Ksh (1982/83)

SERIAL NUMBER	HORT. PRODUCTS	COFFEE	MAIZE	BEANS	MILK	TOTAL
I	2657	-	340	400	-	3397
2	578	343	1530	1600	-	6795
3	169	-	1530	800	-	2499
4	3160	1806	680	1600	-	21697
5	0	-	-	-	8760	8760
6	1490	1800	3060	800	900	22450
7	615	-	170	400	-	1185
8	100	-	170	2400	2920	5590
9	1819	840	170	400	-	9949
IO	5540	922	1700	800	2190	18528
II	4411	90	1700	1200	-	8121
12	2583	300	170	400	1920	7773
13	2518	-	850	1200	-	4568
14	2100	-	510	400	-	26IO
15	5119	-	680	800	-	6599
16	5029	70	5IO	1600	-	7769
17	13685	IOI7	5IO	800	2920	27068
18	8605	300	850	800	-	12955
19	11332	-	-	-	-	11332
20	6960	-	850	1200	-	9010
21	5086	I000	340	400	11040	25866
22	54853	1710	1700	800	-	72743
23	14657	-	5IO	400	-	15567
24	17159	2631	340	400	4320	45912
25	16129	1800	510	1600	12977	47416
26	56012	105	510	400	3285	61152
27	15760	2000	2720	400	6600	43480
TOTAL	258126	150623	22610	22040	57832	5I0791
Percent of Total	50	29.5	4.4	4.3	11.3	IOO

SOURCE : Own Survey (1983

FIG. I ADMINISTRATIVE HIERACHY

NATIONAL IRRIGATION FRAME WORK

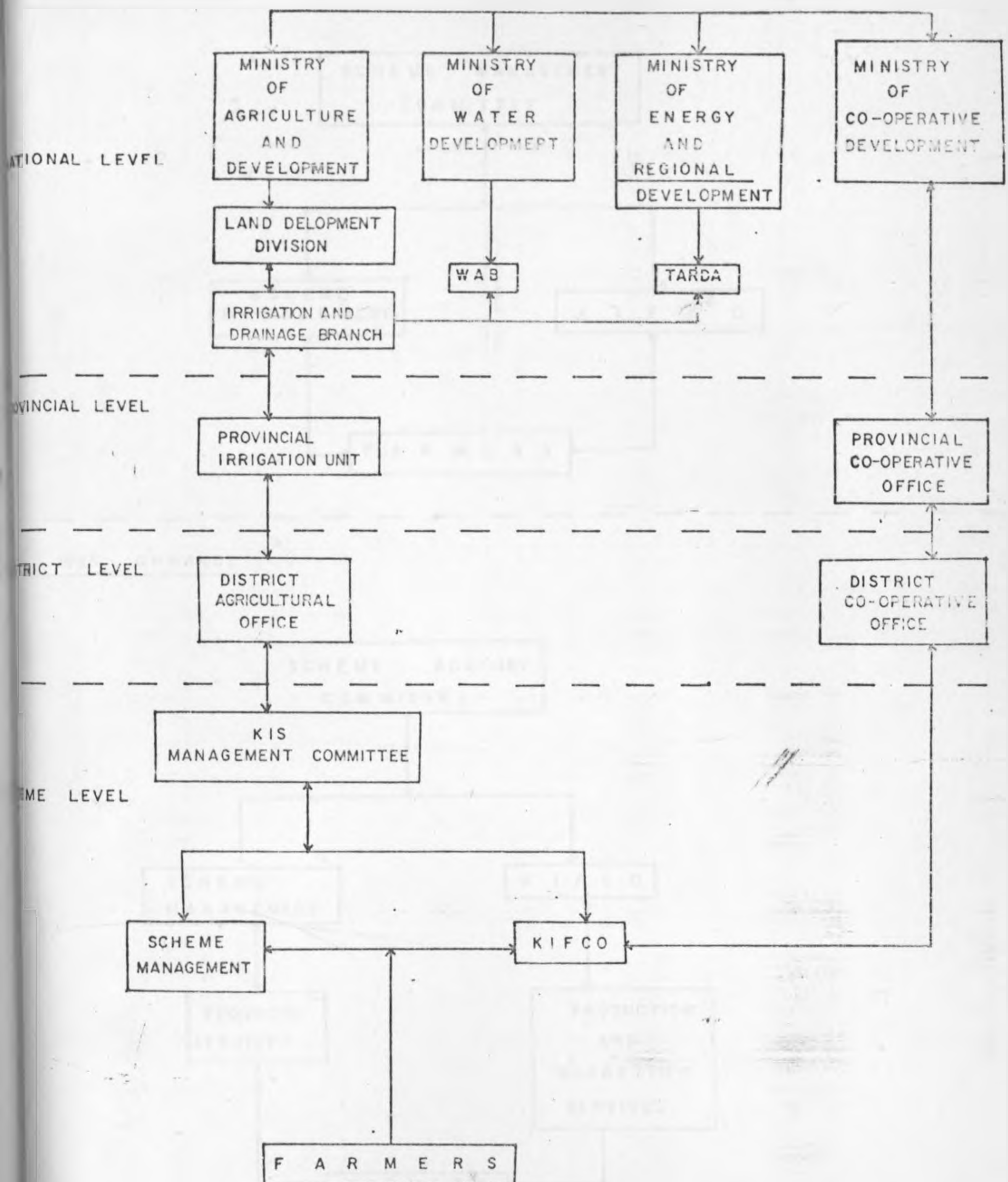
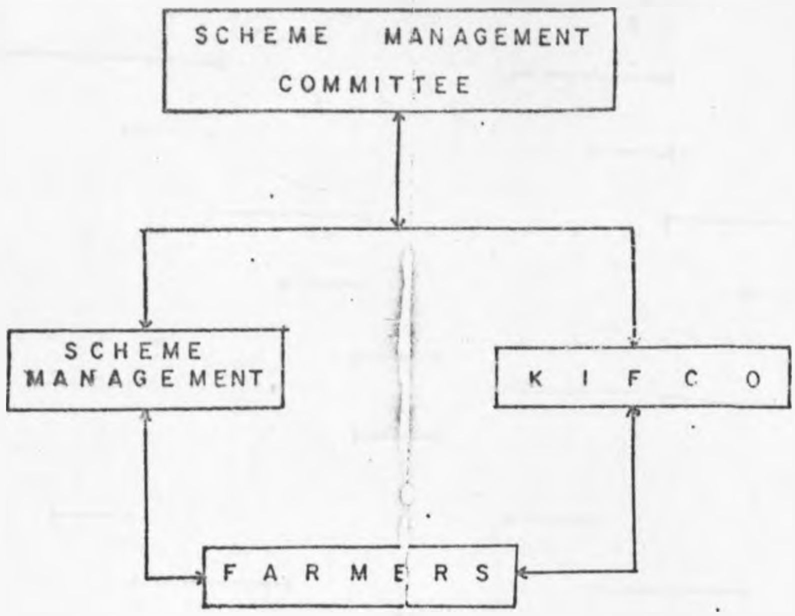
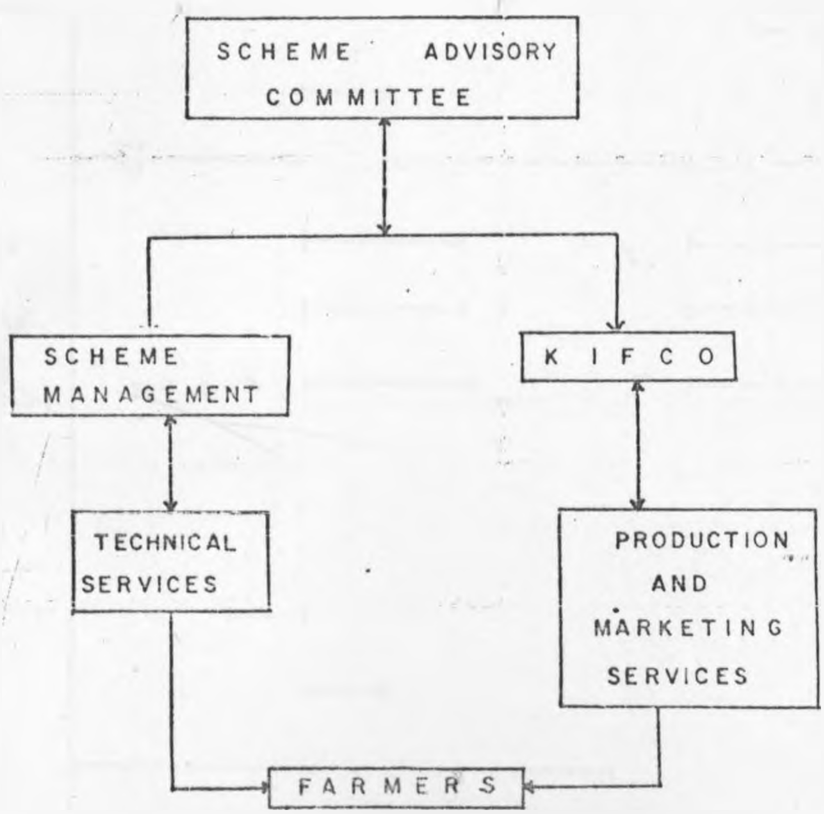


FIG. 2 MANAGEMENT STUCTURE

977 — JUNE 1983

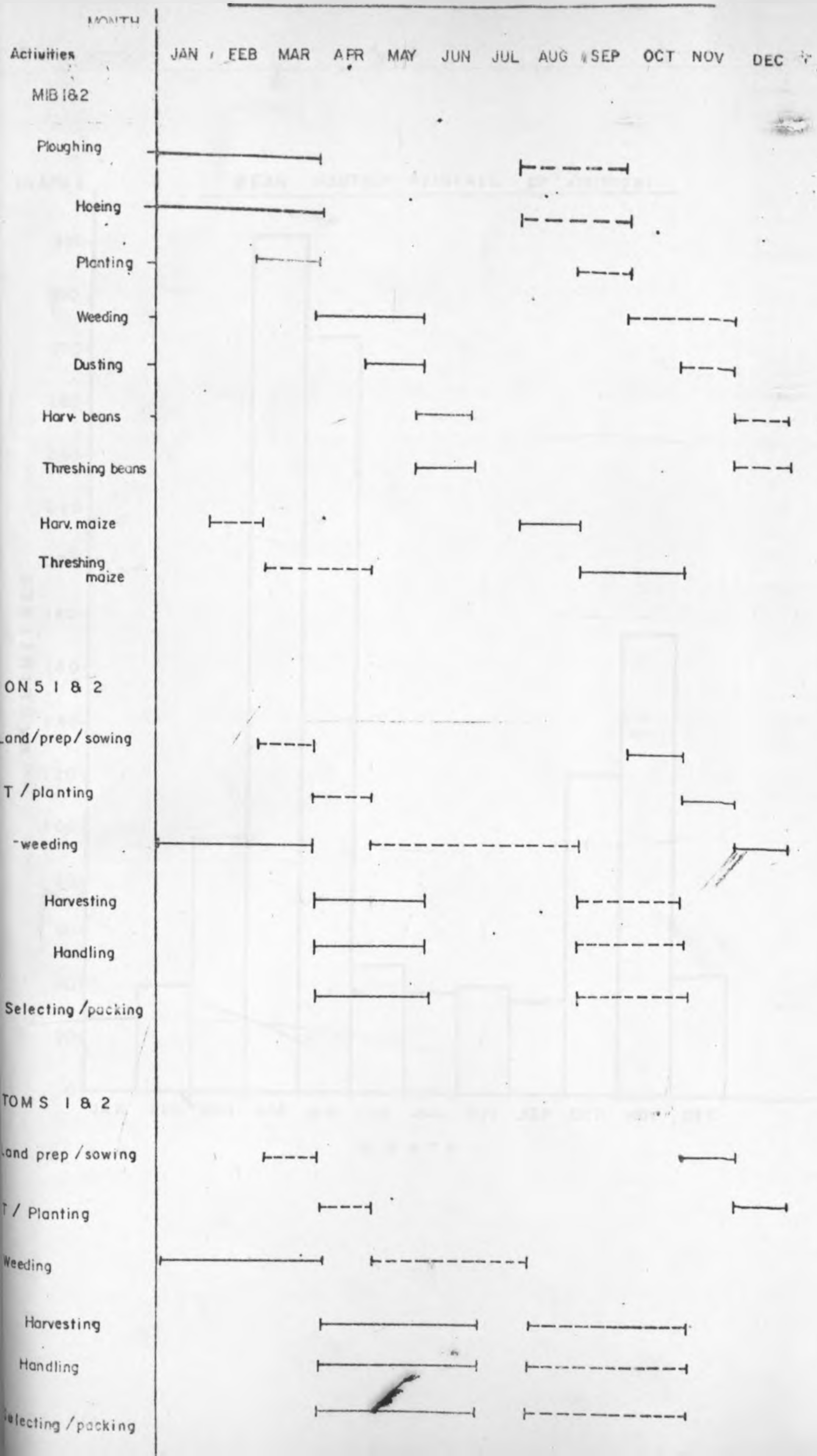


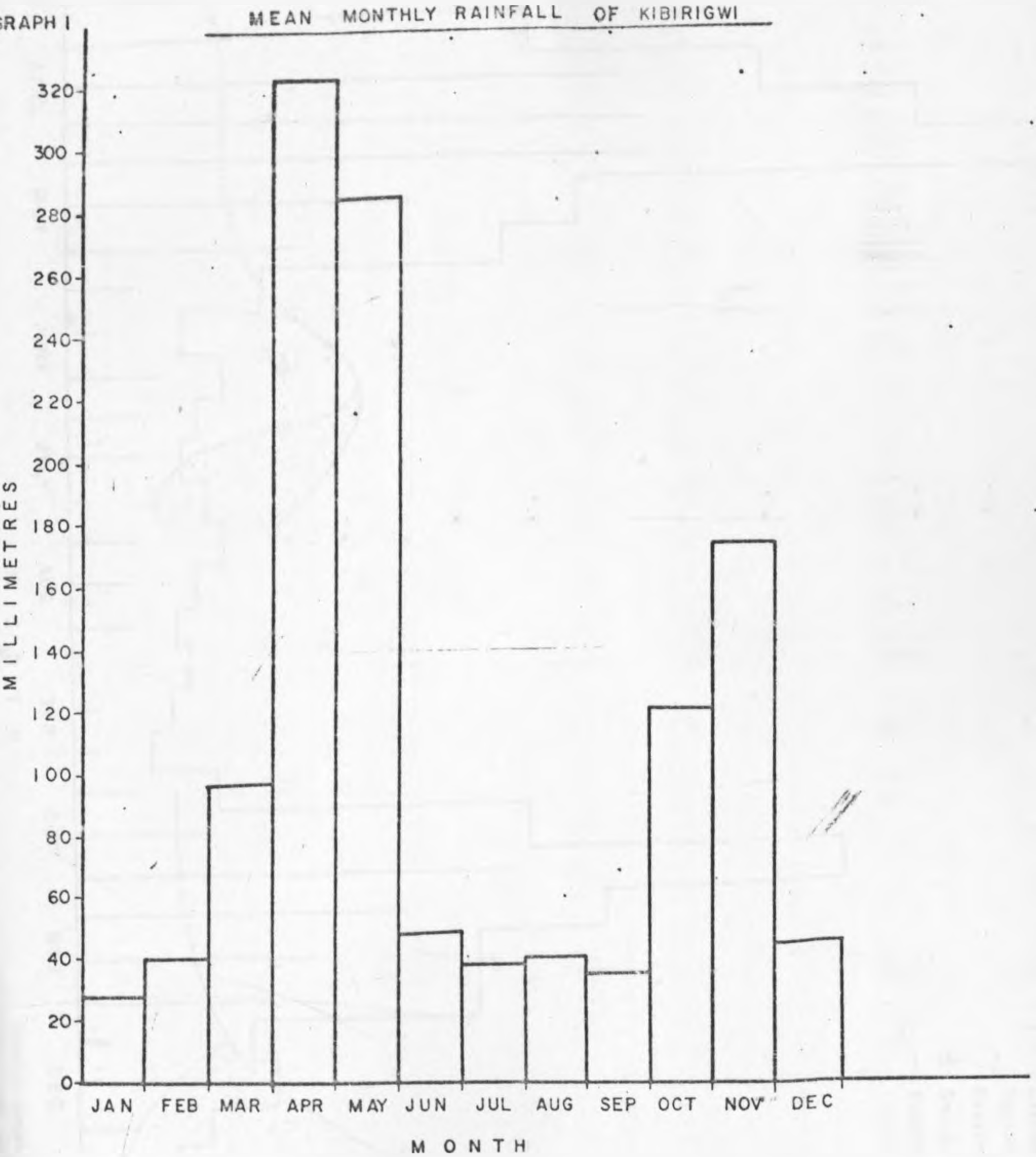
Y 1983 ONWARDS



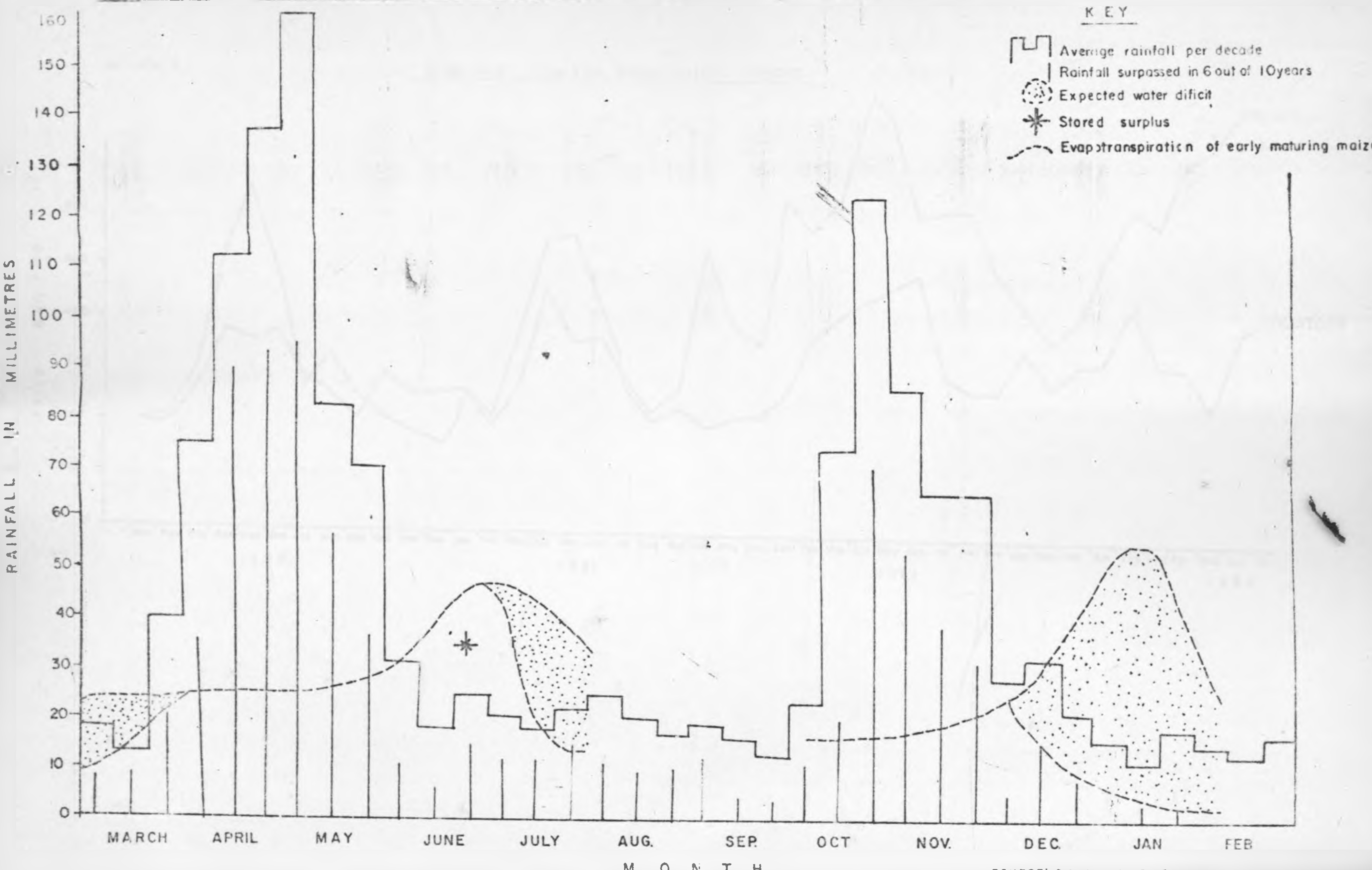
APPENDIX 3

THE FARMING CALENDER FOR SIX ACTIVITIES




GRAPH I
MEAN MONTHLY RAINFALL OF KIBIRIGWI
MILLIMETRES
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

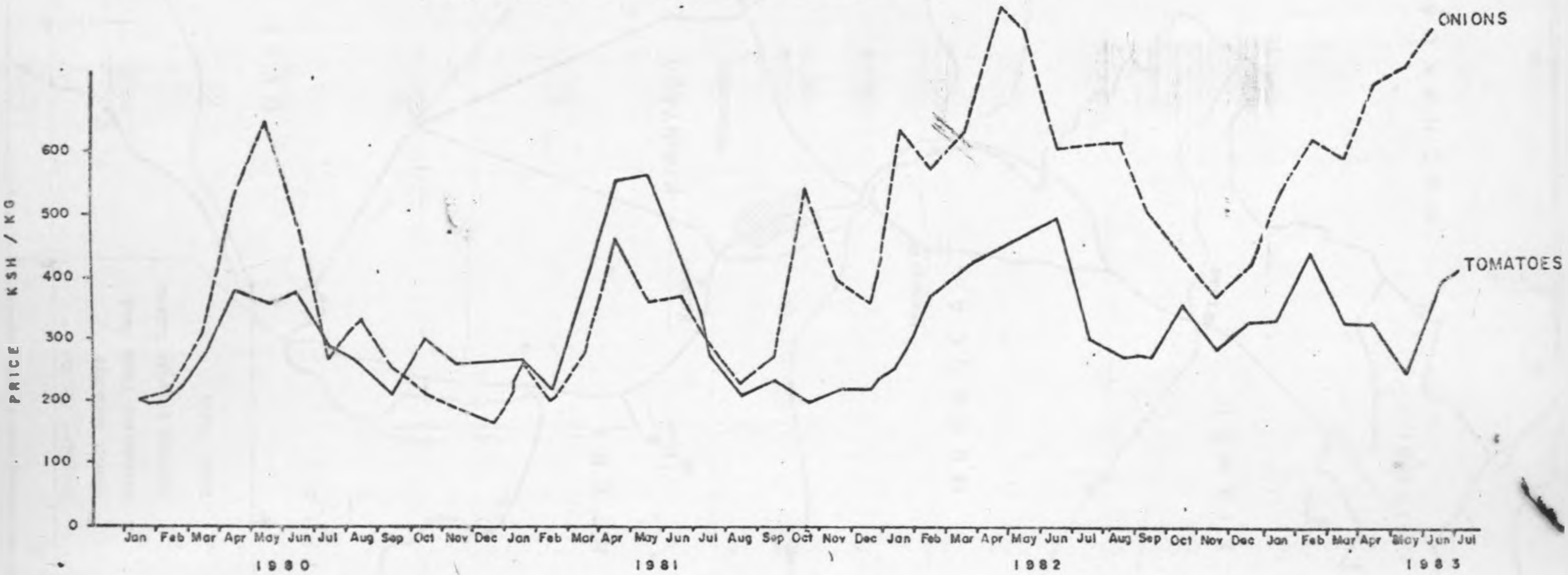
GRAPH 2 MONTHLY RAINFALL AND ESTIMATED EXPECTED EVAPOTRANSPIRATION OF MAIZE AND BEANS



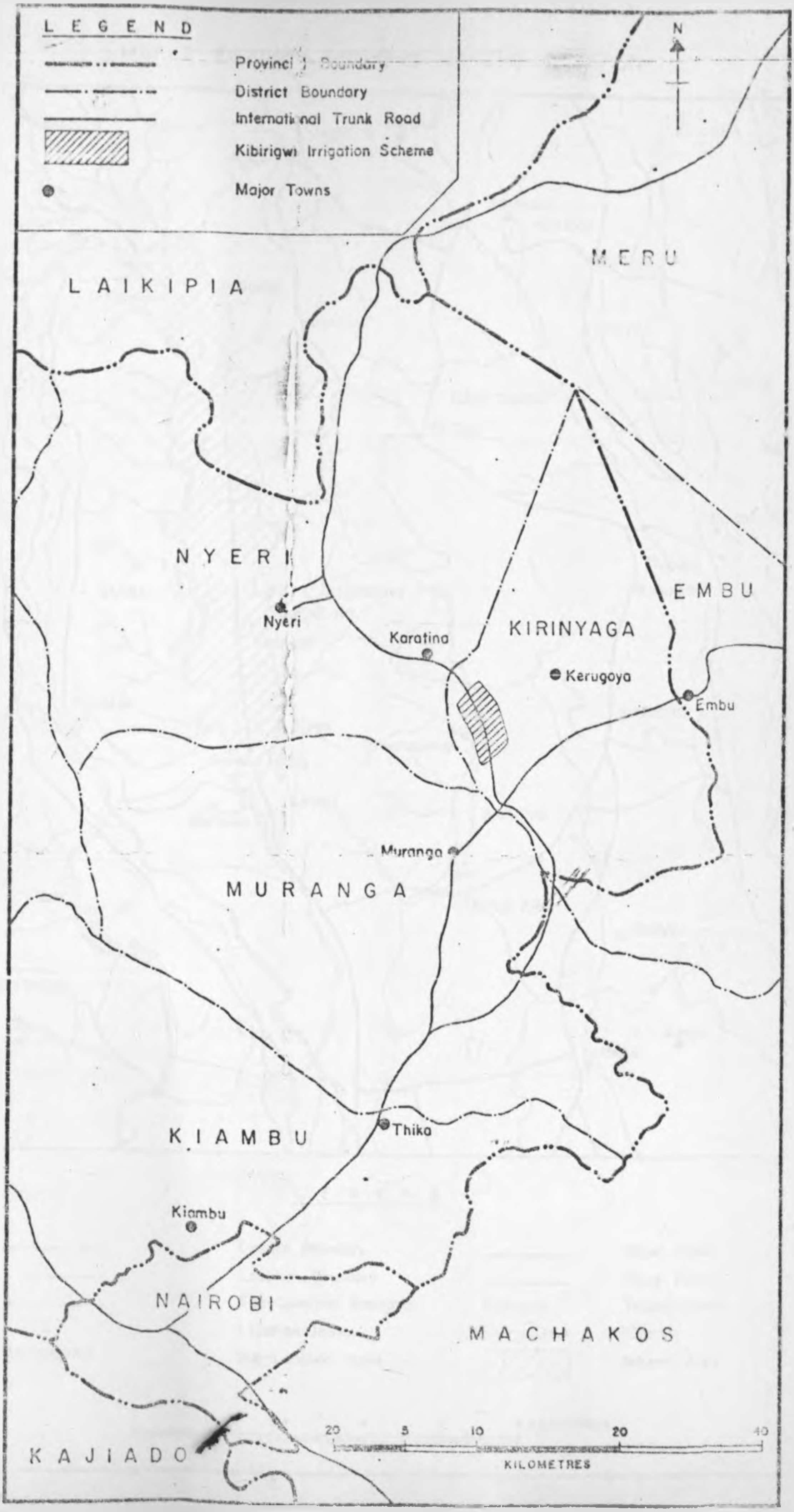
SOURCE: Schmidt H. & Swobodr Op. Cit page 640

GRAPH 3

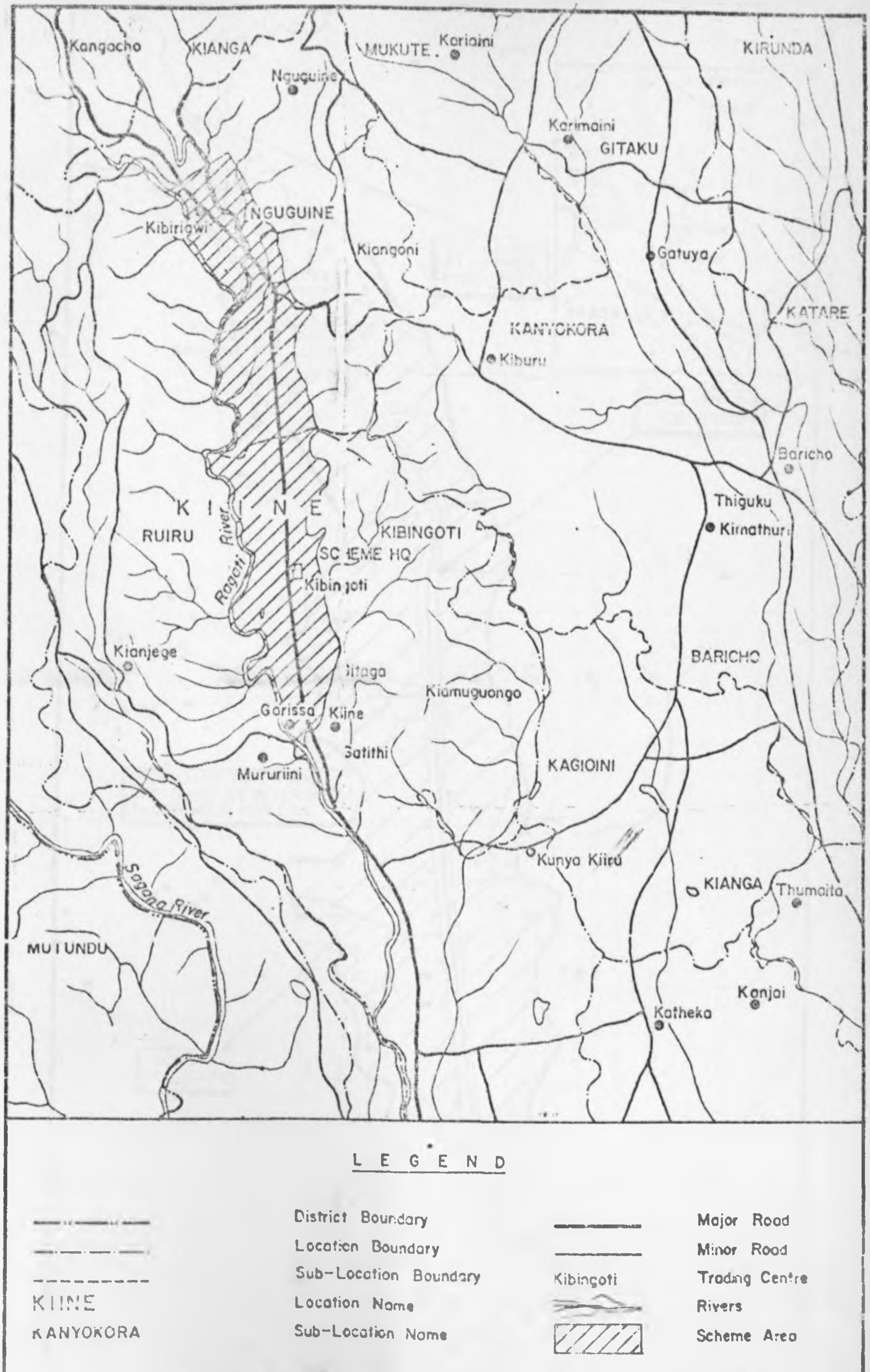
MONTHLY TOMATO AND ONION PRICES



MAP I SCHEME'S REGIONAL SETTING



MAP 2 KIBIRIGWI IRRIGATION SCHEME SITUATION



MAP 3 KIBIRIGWI IRRIGATION SCHEME : GENERAL LAYOUT