DETERMINATION OF OPTIMAL ENTERPRISE MIX AND ALLOCATION OF RESOURCES FOR WEST KANO PILOT IRRIGATION SCHEME.

BY
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DECLARATION

I, Japheth Mulinge Mukumbu declare that this Thesis is my original work and has not been presented for a degree in any other University.

Signed ________________ 27th Oct. 1987
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We declare that this Thesis has been submitted for examination with our approval as university supervisors.

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ABSTRACT

Large scale irrigation systems, especially those requiring pumped water, are costly investments and generally require subsidization. Of all the seven large schemes in Kenya, covering 9,000 hectare, only the gravity-fed Mwea Tabere rice scheme has had positive cash flows. The big losses made by these schemes have cost the Ministry of Agriculture on average, 25 per cent of its total annual budget for the last four years.

To reverse this situation and make irrigation schemes productive, it is important that well tested technology and comprehensive plans are prepared. This study was an effort toward such plans. The main objective of the study was to determine an optimal enterprise mix for West Kano Pilot Irrigation Scheme, which is one of Kenya's large scale irrigation schemes. Determination of such an enterprise mix would help in allocating the available resources optimally and thus maximizing the tenant's income. This is in line with the objectives of the task force set up by the Ministry of Agriculture to look into alternative cost-effective ways of developing Kenya's irrigation potential.

Both primary and secondary data were used in this study. Data on inputs, yields, input-output coefficients and prices was collected between December 1986 and January 1987. Linear programming was chosen as the main tool for data analysis.

A slight modification was done on the ordinary linear programming model in order to fully include the perennial sugar cane crop in the analysis.

Results from this study showed that it is possible to more than double the incomes received by tentants in this scheme from the present KShs.9,Ø33.3Ø to KShs.18,484.67 per annum. If the optimal enterprise mix is adopted the scheme can also save more than KShs.3 million per year in operating capital. This was a clear indication that the scheme can contribute positively to the development of the area. The negative cash flows made in the past can actually be halted. The optimal enterprise mix obtained in this study requires that the tenant allocate 1.92 acres of his plot to rice in the short rains, 2.8 acres to green grams in the long rains season and 1.2 acres to sugar cane. With such a farm plan, marketing capacity for sugar cane and short rains land were found to be the most limiting resources to crop production in the scheme. Green grams was found to be a very profitable enterprise in the scheme, earning the tenant a gross margin of KShs.5,454 per annum as compared to KShs.5,321 from rice. It is thus recommended that green grams should be added to rice and sugar cane as a third scheme crop.

CHAPTER 1

1.1 INTRODUCTION

Increased incomes, increased employment opportunities and general rural welfare are presently Kenya's main rural development objectives (Kenya, 1986). Such objectives make it imperative for researchers and policy makers to shift their attention to rural resource allocation problems. In most of the developing countries, this would imply emphasis on a productive agriculture and livestock economy that provides growing incomes and employment opportunities for rural families. This is because these two form the cornerstone of the rural economies, and therefore of any rural-urban balance, in most of these countries.

Due to the high dependency on agriculture in the Kenyan economy, farmers have the great challenges of:

> "providing food security for a population of about 35 million by the year 2,000, - generating incomes that grow by at least 5 per cent a year for the next 15 years, supplying export crops sufficient for a 150 per cent increase in agricultural export earnings by the year 2,000 absorbing new farm workers at the rate of 3 per cent with rising productivity, and stimulating the growth of productive off-farm activities in the rural areas so that off-farm jobs can grow at 3.5 per cent to 5.0 per cent per year (Kenya, 1986).

These challenges confront the country's agricultural sector at a time when the pressure on Kenya's high potential farmland is so high that landlessness is the sure fate of many children now growing up in the rural areas. The problem of uneconomic subdivision of land which accompanies rapid rural population growth is infact already arousing concern among policy makers (Kenya, 1986). Thus unless more of the country's marginal land is reclaimed and yields per hectare increased, the present rapid decline in land available per capita for food production will necessarily lead to a low rate of increase in food supply against a high rate of growth in food demand in the country. The economic consequences of such a state of affairs are harzadous to the whole economy.

Faced with the above constraints on rainfed agriculture, the Kenyan government, like most other African governments, has seen irrigation as a means towards food self-sufficiency, import substitution, foreign exchange earnings and a solution to the problems of landlessness and unemployment (FAO, 1986). Several state corporations are already involved in irrigation development in the country. These include: the National Irrigation Board, the Tana and Athi River Development Authority, the Lake Basin Development Authority and the Kerio Valley Development Authority. The Ministry of Agriculture, through its irrigation and drainage department also sponsors the establishment of small-scale irrigation projects run by farmers' committees (e.g. Awach Kano in Kisumu, and Kibirigwi in Nyeri).

The National Irrigation Board (N.I.B.) is specifically charged with the responsibility of establishing and running large scale irrigation schemes in the country. Created in 1966, the Board presently operates six schemes (i.e. Mwea, Hola, Perkerra, Ahero, West Kano and Bunyala Irrigation Schemes.) The seventh scheme, Bura Irrigation Project, was recently taken over by a government commission, for rehabilitation. This was necessitated by the great losses it had incurred since its inception.

Due to the National policy of food self-sufficiency, tenants in these schemes have in most cases been required to concentrate on the commercial production of crops given priority by the government or the Board. However, the novelty of modern irrigation and sometimes the remoteness of most irrigation sites causes the costs incurred in establishing and running these schemes to far outstrip the financial returns from such crops. Indeed, the government has had to supplement already costly irrigation works with expensive production, marketing and social support services (e.g. construction of access roads, and provision of health services to tenants). It is reported that the Ministry of Agriculture has had to spend 25 per cent of its budget, yearly, to support irrigation schemes. This is because, out of the seven major schemes, only the gravity fed Mwea rice irrigation scheme has been making positive margins (Kenya, 1986). Table 1.1 shows the annual deficits incurred by the various N.I.B. schemes between 1981 and 1984.

Table 1.1 Annual (surplus)/Deficit carried forward (in Kenya pounds); June 1981 - June 1984

Scheme year	Mwea	Perkerra	Hola	Ahero	West	Bunyala
1981/82	(220,015)	69,115	137,096	54,401	151,896	(12,462)
1982/83	(492,905)	130,151	255,545	99,102	164,768	(21,402)
1983/84	(1354,984)	160,254	306,088	96,822	282,482	38,757

Source: N.I.B. - various annual reports/accounts

1. Figures in bracket indicate that the scheme concerned made some surplus over its total costs of operation for the given year

It is evident from this table that the deficits incurred by these schemes are increasing with time and thus will necessitate bigger government grants. This calls for careful farm planning so as to identity enterprises which would give optimal returns and allocate the schemes' resources optimally. The present study is an attempt to establish such optimal farm plans.

Due to time and money constraints, this study concentrates on only the West Kano Pilot Irrigation Scheme, hereafter referred to as "WKPS". This is not only because the scheme has never broken even since its inception but also because it is the only major Irrigation scheme in the country that produces two principal crops, rice and sugar cane (CBS, 1985). Annual reports from the scheme indicate that most of the problems facing it are closely linked with the production system of the two crops.

1.2 PROBLEM IDENTIFICATION

WKPS was started in 1976. Tenants in the scheme are allocated a 1.6 hectare (4 acres) plot each. According to the farm plan that was adopted at the scheme's inception, half of the tenant's plots should be planted with rice and the other half with sugar cane. These two crop enterprises usually involve many farm operations which often overlap. Thus the adopted farm plan has been observed to demand a very high ability of organization from both the tenants and the scheme management (WKPS, 1978/79).

Due to the nature of the required cropping system, (i.e. 1/2 of the plot under rice and 1/2 under cane), various reasons have been given to explain the scheme's poor performance. These include; labour shortages, lack of enough capital inputs, inability to cope with pests and disease infestation on crops, overmaturity of cane, wastage of harvested cane due to poor organization and poor state of roads, and inadequate financing of crop production. Due to the low incomes accruing from this cropping system, some tenants neglected work on their plots. This forced the Board staff to work overtime in such plots. Thus it (Board) has had to face a problem of accumulated overtime payments for its staff. There is therefore, an urgent need to search for an alternative more profitable farm plan to boost the tenant's incomes and help the scheme to at least break even.

The major reasons, given above for the scheme's poor performance seem to be inherent in the allocation and management of its available resources. Therefore, the critical problem which this study addressed was that of determining a crop or a combination of crops that would optimize the use of resources and thus maximize incomes to the tenants. It was felt that choosing such an enterprise mix would go along way in making WKPS an economically viable project.

1.3 OBJECTIVES OF THE STUDY

The main objectives of this study were to:

(i) Describe the present farming system in the West Kano Pilot Irrigation Scheme,

(ii) Examine the major constraints to crop production in the scheme and,

(iii) Examine whether the present farm plans are optimal or a reallocation of resources is needed to improve the farm incomes.

1.4 HYPOTHESIS TESTED

Given the problem and the objectives of this study, the following hypothesis was postulated.

> The present resource use in the scheme is sub-optimal and hence a reallocation of resources is needed to optimize returns to the tenants.

This hypothesis implies that there are possibilities of other crop enterprise combinations which would yield more income per unit of land than the current one. In order to test it, optimal farm plans were drawn using linear programming technique and compared with the present situation.

1.5 JUSTIFICATION OF THE STUDY

It is generally accepted by most policy makers and scholars that irrigation projects are perhaps the most expensive agricultural investments (Kimani, 1979; Carruthers, 1985; Clark, 1970; Postel, 1985; Biswas, 1985; Kenya, 1986). To pay for such expensive investments, there is need for careful farm planning in order to ensure maximum returns from any irrigation project.

Such planning has not been the case in almost all Kenya's schemes. The government has had to keep them running through big grants. The situation has become so bad that the government has chosen to start no other major scheme until the present ones are rehabilitated and run profitably (Kenya, 1986).

The WKPS seems to have been most hit by this planning problem (N.I.B., reports, C.B.S., 1985) and hence the urgent need for optimal farm planning to raise the tenants' income. Table 1:2 shows the production levels and aggregate returns for the scheme since 1978.

Table 1:2 "WKPS" production statistics 1978 - 85.

Year	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/8
Ha. Cropped	237	857	1,056	1,228	1,172	1,095	450
No. of* Plot. Holders	296	553(259)	553(190)	553(257)	553(113)	553	553
Paddy Output M/tonnes	1,009	2,146	3,379	3,583	3,519	2,935	2,30
Cane Output M/tonnes	-	15,189	20,823	11,395	11,871	5,715	5,594
Gross value (K)	62,861	230,369	341,733	340,784	452,800	396,379	380,72
Payments to plot Holders (K)	29,955	41,078	157,733	100,321	1124,287	118,257	196,53
**Average payment per plot holder (KF)	101.2	74.3	285.2	181.4	2,033	213.8	355.4

Source: Calculated from N.I.B. annual reports & CBS, 198

* The figure in brackets shows the number of tenants who had cane plots out of the given total. In the last two years the Board took over the maintenance of cane plots since most tenants neglected them due to big losses.

** Figures in this row are obtained by dividing the 7th row by the 3rd row.

This table shows, though in an aggregated form, that the schemes low performance has been declining even further. Paddy output fell from 3,379 to 2,302 metric tonnes between 1980 and 1985. Cane output fell from 20,823 to 5594 metric tonnes in the same period. This is an indication that the present farm plan may not be optimal for the tenants and hence there is need to search for an optimal one.

Given the high expenses involved in establishing new irrigation schemes, it is only rational for the country to first utilize to full capacity the potential of its existing schemes if she will have to meet her food self-sufficiency goal. This can only be done if the right enterprises are undertaken on these schemes to utilize their resources optimally.

Undertaking optimal farm plans in these schemes would in addition promote living standards in the rural areas where the irrigation schemes are located. This is in keeping with the national policy on rural development as laid down in the country's fourth and fifth development plans and in the sessional paper No. 1 of 1986.

CHAPTER TWO

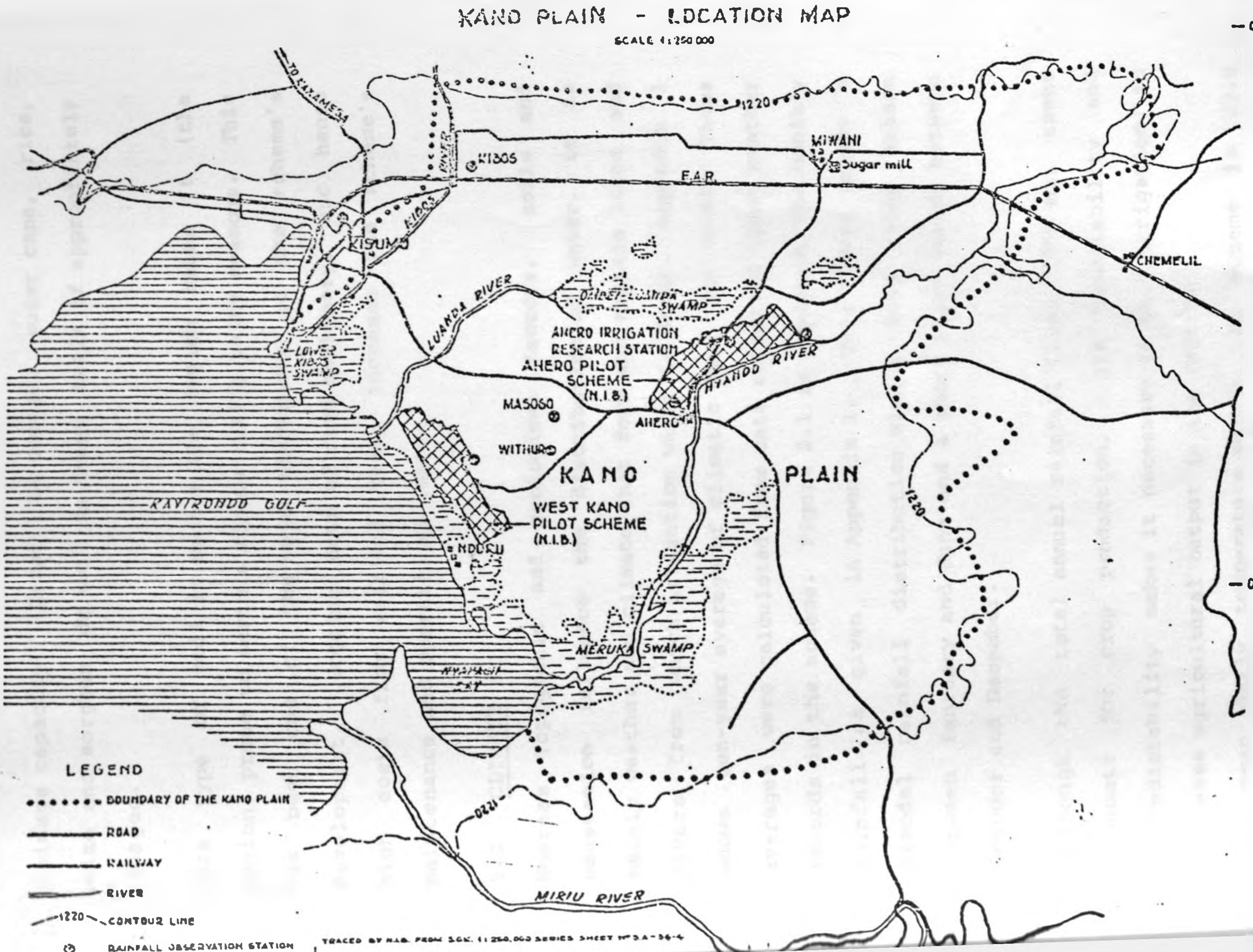
BACKGROUND INFORMATION ON WKPS.

In the year 1970/71, a total area of 1,279 hectares lying along the shores of lake Victoria in the Nyamware and Kawino sub-locations of West Kano, Kisumu district was chosen for a further pilot scheme to complement the Ahero scheme in the Kano plains. Out of the total area, a net irrigable area of about 809 hectares was set aside for irrigation development. Map 1 shows the location of the two schemes in Kano Plains.

Irrigation earthworks and construction started immediately but took a very slow pace due partly to the remoteness of the site and its floody flat topography. This led to high establishment costs which have taken the scheme many years to recover. The first crop production activities were started in 1976, about six years after the start of construction work.

2.1 SOILS AND TOPOGRAPHY

Like the rest of the Kano plains, the area occupied by the WKPS is predominantly flat. Vertsoils (or Black cotton soils) are the main type of soils in the area. Their montmorrilonite quality gives them a characteristic of strong shrinking and cracking during dry seasons and swelling during wet seasons. Though vertisoils are suitable for crop production, they suffer greatly from a poor



KANO PLAIN - LOCATION MAP
SCALE 1:250 000
0°
0°15'
TO KAKAMEGA
KIBOS
KIBOS RIVER
MIWANI
Sugar mill
E.A.R.
KISUMU
CHEMELIL
1220
LUANDA RIVER
OMBEI-LUANDA SWAMP
AHERO IRRIGATION RESEARCH STATION
AHERO PILOT SCHEME (N.I.B.)
NYANDO RIVER
LOWER KIBOS SWAMP
MASOGO
AHERO
WITHURO
KANO PLAIN
KAVIRONDO GULF
WEST KANO PILOT SCHEME (N.I.B.)
NDURU
MERUKA SWAMP
NYAKACH BAY
MIRIU RIVER
LEGEND
BOUNDARY OF THE KANO PLAIN
ROAD
RAILWAY
RIVER
1220 CONTOUR LINE
RAINFALL OBSERVATION STATION
TRACED BY N.A.B. FROM S.O.K. 1:250,000 SERIES SHEET No SA-36-4

MAP 1

drainage capacity. Crops like cotton, sugar cane, rice, maize and sorghum do well on these soils if appropriately managed.

This type of soil in such a flat region makes it (the region) prone to serious floods during rainy seasons. This has been one of the major hindrances to the scheme's development. Bogging down of farm machinery, and hence high costs from wear and tear, increase the scheme's maintenance and operational costs.

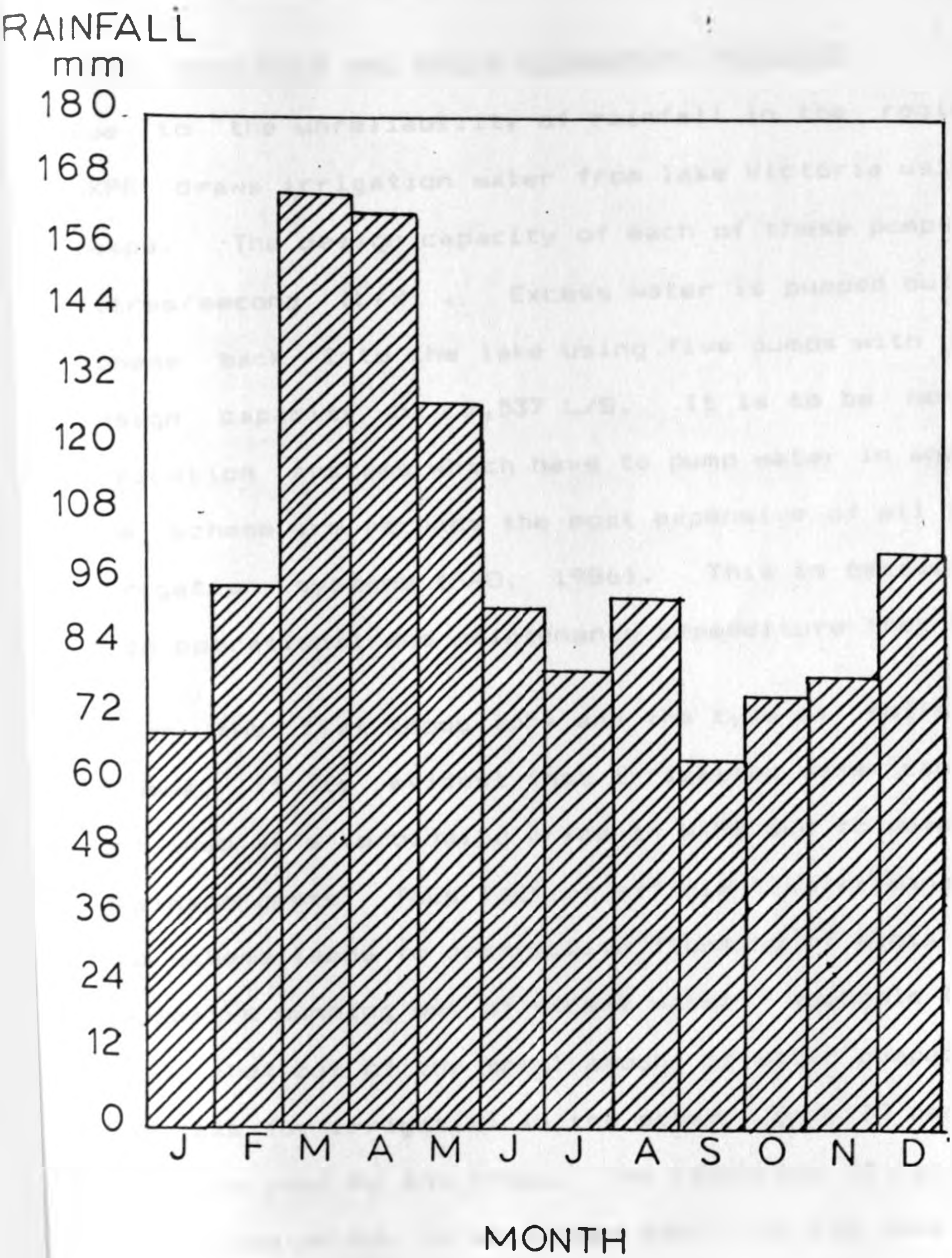
2.3 CLIMATE

Whereas Topograhic and geological factors, soils and vegetation influence the distribution of water, it is mainly weather and climate that form and sustain lakes and rivers from which irrigation water is drawn. Appendix 1 shows ten-year average of climatic data for WKPS. These averages were calculated from data collected from weather records in the scheme. Figure 2.1 is a plot of the monthly rainfall as given in Appendix 1. This figure shows a bimodal rainfall distribution with a long rainy season between February and June and a short rainy season between October and December.

Although the total annual rainfall (i.e. 1206 mm) seems adequate for crop production, its unreliability and unpredictability makes it necessary to use irrigation to increase agricultural output in the region.

The mean daily temperature within the scheme is 22.6 degrees Centigrade with a diurnal maxima ranging between

FIG.1 <u>MEAN MONTHLY RAINFALL FOR WKPS, 1975-1985.</u>



27.54 degrees in July to 30.04 degrees in February. The diurnal minimal ranges between 15.67 degrees Centigrade in September to 17.58 degrees Centigrade in April. Such high temperatures in a humid region makes some farm operations like harvesting sugar cane very unpleasant.

WATER RESOURCES AND WATER MANAGEMENT PROBLEMS

Due to the unreliability of rainfall in the region, the WKPS draws irrigation water from lake Victoria using four pumps. The design capacity of each of these pumps is 425 litres/second (L/S) . Excess water is pumped out of the scheme back into the lake using five pumps with a total design capacity of 2,537 L/S. It is to be noted that Irrigation systems which have to pump water in and out of the scheme are perhaps the most expensive of all types of Irrigation systems (FAO, 1986). This is because of the high operational and maintenance expenditure they incur.

Given the flat topography and the type of soils in the scheme, it is evident that irrigation water can only be obtained at a forbidding price in WKPS due to pumping and drainage costs. Thus lack of efficient water management in the scheme leads to destructive flooding of plots and expensive pumping out of excess water. Ngongolo (1978) found that out of the total amount of water pumped out of the lake for irrigation in the scheme, only 72 per cent is actually used by the crops. The remaining 28 per cent evaporates or has to be pumped back into the lake.

Other water management problems in WKPS include the frequent dangerous floods, which damage both crops and irrigation works, and the fast rate at which the lake is receding. If solutions to these problems are not found soon, then the scheme's very existence is at stake because it might lack a source of irrigation water. Mogaka (1983), argues that if reliable weather data could be obtained and synchronized with fast reactions to weather changes by the scheme management, the present heavy operations and maintenance costs would be reduced greatly.

INFRASTRUCTURE AND SOCIAL INSTITUTIONS

As shown on Map 1, the scheme is linked to Kisumu, 20 Km away, by road., Two murramed roads link the scheme to the tarmaced Nairobi-Kisumu road at Korowe and Rabour. However, only the road from Korowe to the scheme is passable during the rainy season and then only by 4 wheel drive land-rovers. Given that the scheme has not yet been installed with telephone services, the scheme management finds it very difficult to run its (Scheme's) affairs especially during the rainy season. This is because they are forced to commute to Kisumu town almost daily.

This poor communication and transport system has partly been the major cause of the poor performance of the cane crop and also the high operation and maintenance costs in the scheme. Installation of electricity in the scheme grossly cut down these costs since now irrigation pumps are no longer fuel ran. The building of a Jaggery (sugar cane handling factory) next to the scheme is also expected to cut down the costs incurred in transporting sugarcane to factories far away. About 57 per cent of the cost of sugar cane production accrue from harvesting and transporting only (Houtman, 1981).

The area is prone to malaria and Bilharzia diseases. The scheme therefore provides anti-malaria drugs to pregnant mothers and children under 5 years of age. A medical educator is engaged by the scheme to train tenants on maintaining healthy environments so as to reduce the incidence of diseases.

WKPS is served by two primary schools and one nursery school. Tenants are starting a co-operative society which is expected to help them in the marketing of their crops and also give supplementary soft loans for farm operations. However, by the time this study was conducted the society was not operating.

Only one out of the 31 tenants interviewed in this study said he could get a formal loan outside the Board.

2.5: LAND TENURE

The introduction of a large-scale irrigation scheme in West Kano, like in any other place caused a major change in the local land tenure system. Before the scheme started, a complicated system of rights and obligations defined the traditional tenure arrangements. Control over land and access to land rights, whether for grazing or crop cultivation were based on the family lineage principle (Kliest, 1984). This system still prevails to a great extent outside the scheme.

Each tenant in WKPS is allocated a 1.6 hectare plot for scheme crops and about 1/2 to 3/4 acres for his homestead. In addition to this 35 per cent of the tenants interviewed owned, on average, 3.7 acres of land outside the scheme. Houtman (1981), estimated that tenants in WKPS owned 3.6 hectares of land, an average. Outside their scheme land. Land in N.I.B. schemes is provided on tenancy basis hence an individual is not allowed to get a title deed for the allocated plot. However, in case of death, it was observed that traditional procedures are normally followed to determine who will continue the tenancy on the scheme land.

Tenants homesteads are grouped into five villages. This makes it easier for the Board to do mechanized farm operations like land preparation and harvesting of cane without interfering with homesteads.

The tenant in WKPS is supposed to divide his scheme land equally between rice and sugar cane. Although this requirement has remained in principle, only the rice plots have been established for all the 553 tenants. Due to the problems of overmaturity and lack of enough factory capacity for WKPS cane in the existing factories, only less than 762 acres out of the total 1,136 acres set for sugar cane production have been planted. The rest was still fallow. A more detailed discussion on husbandry practises and crop yields for the scheme is given in Chapter five.

CHAPTER THREE

LITERATURE REVIEW

One of the major thrusts to facilitate the achievements stipulated in the last two development plans and the sessional paper No. 1 of 1986, would be to establish a framework of policies that will optimize the allocation of resources to their most productive use. The emphasis placed on this by these three policy documents clearly shows the government's concern over the use of national resources, especially borrowed capital.

Investment in major irrigation projects has often received particular criticism both locally and among aid donors. This is because such projects use the greater portion of borrowed capital allocated to agriculture yet have hardly ever broken-even (FAO, 1986; Kenya, 1986). It is therefore rather surprising that not much has been done to study the resource allocation problems in Kenya's irrigation sector. Much has however been written on irrigation efficiency world-wide. A few of these papers are discussed here below due to their relevance to the local Kenyan situation.

Biswas (1985) argues that the fundamental objective of any irrigation project is to provide efficient water control in order to increase the incomes of the people in the project area. Although this argument is sensible, efficient water management *per se* cannot be taken as a sufficient condition to maximize agricultural production. Other inputs like seeds, fertilizers, pesticides, equipment, energy, extension, credit and marketing facilities are required. Undoubtedly, lack of efficient allocation and monitoring of these resources, plus a continuous evaluation of their use in irrigation projects is one of the major reasons for the current extremes of optimism and pessimism among writers on irrigation development.

Carruthers (1985) contends that, despite its poor performance, irrigation remains the principal means by which climatic constraints are overcome to increase food supplies. Irrigation is thus assuming an increasingly important role in the third world where the World Bank estimates 160 million hectares to be under irrigation Carruthers further highlights some of the criticisms against irrigation as:- huge costs, delays in construction, low yields, poor financial performance and environmental damage to human health and soil fertility. Disregard of these criticisms at the initial planning stages of irrigation projects could be one reason why most of them end up incurring great losses. It is therefore important that detailed feasibility studies be done before any major irrigation project is started. Due to the rising costs of irrigation, governments and international agencies should find ways of making it efficient. Results from this study highlight some resource waste in WKPS which should be avoided.

Postel (1985) points out that better management of existing irrigation systems may be the best near-term prospect of increasing crop production and conserving water supplies. This is especially so in the third world where capital for construction of new irrigation projects is getting increasingly scarce. Biswas (1985) asserts that for some parts of Africa, irrigation should not be promoted until existing schemes are shown to be productive and until well tested technology and comprehensive plans have been prepared. This study was an effort towards making WKPS, one of Kenya's major irrigation schemes, a profitable and productive project.

Though most of the literature referred to above are papers based more on the authors' experience with irrigation development rather than on empirical analysis, they make it clear that financial returns from irrigation need to be improved in order to raise the commitment of irrigators.

The scheme studied was not any exception from the poor performance being referred to above. Most of the past studies done on this scheme have been related mainly to the efficient utilization of the water resource. Such studies are those by Kuria (1977), Ngongolo (1978), and Mogaka (1980). All these studies show the complexity of the water management problem in the scheme. The problem, they argued, is brought about by the operation of the two crop enterprises and the fact that water has to be pumped both in and out of the scheme thus causing very high operation and maintenance costs. Although these are essentially engineering studies, they were useful in illustrating on technical efficiency issues in this study.

Kuria (1977) argued that water efficiency in the scheme was likely to fall with time due to: Pumps breaking down, water checks and gates leaking and the carrying capacity of water channels decreasing due to silting. Such a decline in water efficiency grossly adds to the already high operations and maintenance costs. Although the study was not concerned with technical efficiency from the engineering point of view, it sought to find out whether the tenant should pay such high costs or there are alternative ways of increasing his/her income.

Despite the great concern over its poor performance, little has been done to study the scheme's present enterprise mix. The only economic oriented studies done were those aimed at establishing an agro-economic data base for the scheme. Such studies include one by Houtman (1981) on labour use in the scheme. His study was aimed at describing how labour is deployed by tenants for various farm operations in the scheme. Houtman observed actual farm operations for a full rice crop and hence his study gives the best estimates of the tenant's labour input-coefficients for rice farming in the scheme. His study, however, makes no concrete suggestions as to how labour and other resources should be optimally allocated to the various competing enterprises. Indeed he just reported, using percentages and averages, how much labour went to which activity during the eight months of his study. The present study utilized Houtman's findings to determine the rice input-output coefficients for labour. It however went further to determine how labour and all the other resources could be allocated optimally so as to increase the tenant's income.

A few other studies have been undertaken on resource allocation in other irrigation schemes in the country. Irea (1979) used linear programming to study the allocation of resources and combination of crop enterprises in the Perkerra irrigation scheme. He concluded that it was possible to increase tenant's incomes in the scheme by simply re-organizing the allocation of the existing stock of resources on a typical holding. This conclusion conflicts with Shultz's thesis that farmers are poor but efficient as will be discussed later in this chapter.

On the whole, Irea's study was an eye-opener to planners in that it showed the potential that exists in the use of optimal farm plans to improve life in Kenya's National irrigation schemes. However, the practicability of the optimal farm plan that he recommends remains questionable. This is because he put aside the activity (or croppings) calendar that reflected the status quo of the tenants in the scheme and designed one in which tenants were expected to grow one onion crop each month of the year. Normally the tenants were used to two union crops per annum. They would therefore definitely find it difficult or even impossible to adjust to Irea's farm plan despite the promised returns. In order to help small farmers to adopt new techniques of farming, it is always advisable to start with what they are used to. The present study utilized the practices that tenants in WKPS are used to in order to determine an optimal farm plan which they will not find difficult to adopt.

A study done by Makanda (1984) on Kibirigwi irrigation scheme in Nyeri District utilized detailed information from three randomly chosen farmers to determine the profitability of the scheme. Unlike Perkerra irrigation scheme which is fully under N.I.B., Kibirigwi is a small scale irrigation scheme where farmers are expected to provide their inputs and grow crops of their own choice. Despite this difference in their data base Makanda and Irea reach the same conclusion that it is possible to increase farmers incomes by re-organizing the allocation of the existing stock of resources. Makanda found labour to be the most limiting resource to crop production in the scheme.

In his study, Makanda left out of his analysis the major farming activities carried out in the scheme mainly because they were perennial. He considered horticultural crops which contributed only 8.63 per cent of the total farm income and left out coffee which earned 46 per cent of the total farm income. Livestock activities were also left out mainly for the same reason. Tenants in WKPS grow sugar cane which is a perennial crop with a minimum crop cycle of five years. In order to take into account returns from all the crops grown in the scheme adjustment in crop cycles and discounting of all costs and returns was done. Discounting of cash flow from an enterprise is generally accepted as the best method of combining data to get a measure of the enterprise's profitability over its lifetime (Little and Mirrlees, 1974).

Whereas relatively little has been studied on resource allocation in Kenya's irrigation sector, many studies have been done on this subject within the country's agricultural sector as a whole. This is probably due to the sector's dominance in the national economy and progress.

In a study on the effects of Kenya's Pricing rules on income distribution and resource allocation, Smith (1969) found that the Country's pricing rules did not optimize resource use. He asserted that "If such pricing rules are retained, resources would continue being directed to heavily subsidized commodities and hence sub-optimally used." Alibaruho (1974), in his paper on resource allocation, commodity supply and income distribution aspects of agricultural pricing policy in Kenya shared Smith's views. He used the frequent occurrence of maize shortages simultaneously with excess maize in NCPB stores as evidence that the nature of agricultural commodity pricing may underlie the problems of intercrop and inter-regional resource allocation. He argued that the problems of commodity flow through the whole distribution network could also be a result of the pricing policy. This is not only because of the complexes involved in agricultural input/output markets but also due to the fact that farmers allocate their resources to satisfy more objectives than the profit maximization axiom.

It is important to note that the conclusions drawn in these papers, on crop combinations, are for broad regions and hence their relevance to the individual farmer is very minimal. Nugtere and Bos (1974), pointed out that the operational standard reached by farmers, especially on irrigation schemes have significance only on a regional or local basis. There is therefore a need for more localized studies on resource allocation problems in the country. This implies that the optimal enterprise mix-obtained in this study is applicable to tenants in WKPS and cannot be used effectively by other farmers outside the scheme.

Hunt, (1974), found the pattern of labour allocation in the Mbere area of Embu district, to be varying with the seasons and also with the quantity of rainfall. She distinguished between good and bad seasons and used estimates of returns to labour in various enterprises in different seasons to arrive at her conclusions. Hunt further found that the income a household receives over a given period is predominantly determined by the way they allocate their basic productive resources of land, labour and capital. Similar variations in the allocation of labour are alluded to in Houtman's study on labour utilization in WKPS and were therefore taken into consideration in the present study. The time flow of required labour inputs into different farm enterprises is of key importance in determining the optimal enterprise mix on a given farm. It is because of this reason that the present study gave priority to the timing of farm operations in WKPS as recommended by agronomic research and past practice by tenants and Board staff.

In essence, the ensuing pattern of resource allocation should always be a function of the quantity and quality of resources available to each household, the available opportunities for their use, the degree of risk associated with each opportunity, the range of returns for each and the preference of the household's members. Blagburn (1961) argued in this respect and asserted that the best use of resources is made when a suitable combination of enterprises and an adequate level of total production are persued rather than an efficient management of a particular given enterprise.

It can be argued that a part from the studies by Irea and Makanda, most of the studies referred to above seemed descriptive or broad based and thus do not establish activities and activity levels to be operated by the individual farmer in order to maximize income. Chris Doyle (1975) in his review of literature on agricultural resources use in East Africa brings out this defect more clearly. He and others (Gatere, 1982; Randal, 1981; Heyer, 1971), emphasize the importance of determining a combination of enterprises and enterprise levels for optimal resource use in agriculture.

In more recent years, studies on resource allocation in Kenyan agriculture have tended to use more definite economic and scientific tools of analysis to arrive at definite recommendations on how best to optimize resource use by the individual farmer. Matovu (1979). Studied the efficiency of resource utilization in small scale farming in Meru and Machakos districts. He used Cobb Douglas production functions and marginal value product comparisons to conclude that small scale farmers in these areas were efficient in their allocation of resources. His study, like most others that have used production functions as analytical tools, confirm Shultz's (1964) hypothesis that peasant farmers are poor but efficient (Dittrich and Myers, 1979; Fernado, 1982). However, Yotopolaus and Nugget (1975) have criticized the use of production functions in studies on efficient resource allocation, for biased and contradicting results. This blame can be associated with the general criticisms in the realism of the marginal analysis of neo-classical economics. Such criticisms include:- lack of knowledge about the firm's production function unrealistic assumptions of the state under which a firm operates and the fact that a firm may seek to maximize utility or minimize risk rather than the profit maximization axiom of neo-classical economics. To seal these flaws, other tools of analysis have been developed for decision making. These include network analysis (or organizational theory, CPM & PERT etc), Game theory, Budgeting and programming techniques. Linear programming was used in the present study as is explained in the next chapter.

Shultz hypothesis has led to the present emphasis on the expensive policy of providing complementary inputs in order to improve crop production. This is because it makes policy makers believe that there is hardly any room for improving production by simply reallocating the existing stock of resources. Conceptually, there are two possible alternatives for increasing production. The first involves expanding the production surface through innovation while the second involves re-organizing the present stock of productive inputs within a given production possibility curve. The use of production functions in resource allocation problems tends to emphasize the former which is obviously more expensive than the latter because it involves innovation. One would think it is wiser to exhaust all the possibilities of the second alternative before recommending the first one. The two could as well complement one another as would be te case if innovation are considered in LP model formulation.

Studies exist that show that there are possibilities of increasing agricultural output and incomes by simply re-organizing the existing stock of resources (Irea, 1979; Makanda, 1980; Heyer, 1971; Asemenew, 1980; Kange, 1980). All these studies used linear programming models to determine both optimal farm plans and major constraints to crop productions in their respective regions of study. They all agree that labour and working capital are generally the most common constraints to peasant agriculture in Kenya. The present study had close similarity to these studies, in its objectives and hypothesis.

CHAPTER FOUR

4.1 METHODOLOGY

In order to test the postulated hypothesis and achieve the objectives of this study, Linear programming (LP) was adopted as the major tool of data analysis. The gross margins from the resulting optimal plan of the linear programme were compared with the present income of an average tenant in the scheme to judge whether the hypothesis was to be rejected or not. If the former is higher than the latter then the hypothesis would not be rejected and vice versa.

Gross margin comparisons were also used to determine the best activity calendar for the scheme. Three possible activity calendars were drawn for the scheme using agronomic and climatic data. Based on each calendar, a linear programming model was developed for the scheme. Out of the three Models, the model that gave the optimal plan with the highest total gross margin was adopted as the best for the tenants in the scheme. The activity calendars are given as appendices 2 to 4. Shadow prices (or marginal value products) resulting from the dual programme of the linear programming model were used to determine the most limiting resources to agricultural production in the scheme.

4.1 DATA

To facilitate this study, data were required and generated on the following:

(i) tenant resource endowments of land, labour and capital

(ii) input-output coefficients for all the farm activities done in the scheme;

(iii) Crop yields per acre for all the crops that have been recommended to the scheme by the Ahero Irrigation Research station (A.I.R.S.).

(iv) Unit prices of both inputs used and outputs produced by tenants in the scheme and

(v) The amount of output the tenant needs from the scheme for his family's subsistence per year.

4.1.1. SAMPLING

In order to collect primary data on tenant family labour resource availability and subsistence requirements, a sample of 40 tenants was randomly chosen from the 553 tenants registered in the scheme. In case of high homogeneity of the economic charateristics of respondents, as was the case in this study, even a smaller sample could be used without much harm to the study (Irea, 1979; Heyer, 1972; Bagazonzya, 1979). This is because there would be little variation from the optimal farm plan obtained for the model (or average) farm in the study.

Out of the selected tenants, only 31 turned up for the interviews that were carried out at the scheme's offices. Efforts to contact the remaining nine through the field assistants were fruitless.

4.1.2. DATA COLLECTION

Although most of the required data were available from secondary sources like Board reports and Research station records, primary data had to be collected for family labour availability and family subsistence requirements. Since the study intended to analyze what exactly takes place in the tenant's plots, counter checking of information collected from secondary sources was done where necessary. This involved for example, collecting data from tenants' farm records to check whether the Board actually gives all the tenants an equal amount of capital inputs as stipulated in its policy.

The questionnaire used for data collection in this study is given in appendix 5. It had two sections. Information in section A was collected through formal interviews which were administered to the selected tenants at the Scheme's offices. Information from section B was intended for counter checking information on capital inputs as stated above. Answers to questions in this section were very identical and hence implied tenants in WKPS actually received the same amounts of inputs from the Board.

Houtman's (1980) study on labour utilization in WKPS was found most reliable for labour data. This is because he observed the actual farm operations done in the scheme for a full rice crop cycle (i.e. 8 months). His report was therefore used for calculating input - output coefficients for rice crop labour requirements and for information on hired labour.

Very little information could be obtained on sugar cane production from either the tenant farm records in Kisumu Head Office or the tenants themselves. This is because most tenants had actually abandoned their cane plots by 1984 and the Board had not reached a decision on what to do with these plots (WKPS, 1984). Faced with this problem, the study had to rely on information obtained from records that the Head field assistant incharge of cane production in the scheme, keeps on the operations that are done on cane plots. This information was supplemented with cane input recommendations from the Ahero Irrigation research station to analyze the cane crop.

Reports from the research station were used as the sole source for information on the three dryland crops which have been recommended to replace the double cropping system of rice production. This is because these crops have nct been adopted fully in the scheme and hence tenants know very little about their production.

4.2 LINEAR PROGRAMMING MODEL SPECIFICATION

Linear programming is a special case of mathematical programming in which functions are linear. It can be considered as a linear production function, formed from a combination of linear production activities homogeneous of degree one. Thus it exhibits constant return to scale.

In its ordinary form, linear programming has three quantitative parts, that is, the objective function, a set of constraints and a non-negativity condition for all activities involved. Thus in its standard form, it can be expressed as:

Max $Z = CX$ -- objective function

Subject to $AX \leq r$ -- constraint set

and

$X \geq 0$ -- non-negativity condition

Where Z is the total net returns from the farm

X is an n x 1 vector of activity levels in the farm

C is an n x 1 vector of net returns per acre of activity

A is an M x N matrix of input - output coefficients or technology matrix

and r is an M x I vector of farmers resource endowments.

Stated as above, the problem becomes that of maximizing the total net returns from the farmer's farm subject to some resource constraints. It has however been often argued that the farmers objective may not necessarily be to optimize or maximize income but utility (Heyer 1972). Thus in every study one has to investigate whether the programme's objective function is similar to that of the farmers. In the present study, maximization of net returns for the tenant farmers is taken as the objective since the overriding goal of the Board in all its schemes is to increase farm incomes.

When used as a planning tool, linear programming lends itself to the determination of combinations of enterprises, resources and techniques that maximize gross margins, net returns or profits for a particular set of fixed resources. In its formulation for this purpose, It is thus able to handle the intricacies involved in a given farming system in a more comprehensive, systematic and rigorous manner than the techniques of programme planning and budgeting could do. Development and use of linear programming techniques for planning and decision making has been greatly enhanced by the advent of modern computer technology.

Because of the possibility of performing sensitivity analysis, one other principal advantage of linear programming as a tool of analysis is that it provides a means of analysing a variety of alternative decisions.

These two qualities (i.e. comprehensiveness and sensitivity analysis) are among the major factors that have made LP popular in farm management studies. Being able to handle a large number of interrelated variables, it copes well with peasant farming systems which are characterized by a high degree of interdependence between production and consumption, consumption and investment, investment and resource availability, and socio-cultural constraints.

4.2.1. LIMITATIONS OF LINEAR PROGRAMMING MODELS

Most of the limitations of this model are closely related to its basic assumptions. The assumption of linearity for example renders the model inadequate in analysing situations where economies or diseconomies of scale exist or where non-linearity is the realistic functional relationship.

Programming is also of little help in situations where the manager wants to formulate price expectations or estimate input-output relationships. It can only proceed after judgement has been made on these, thus assuming them to be equally reliable for all enterprises in the farm. This is because of the assumption of single value expectations in linear programming. This limitation can however be overcome by performing sensitivity analysis.

The problem of obtaining the data required for LP analysis has also been sighted often as another drawback in its use as a planning tool (Heyer, 1972; Irea, 1979).

This problem was encountered in this study especially for the cane crop and was dealt with in the manner already explained in section 4.1.2.

Despite these limitations, the method fits well with the setting of the present study (i.e. its hypothesis) and hence will be utilized. It has been particularly acknowledged as a guide to farmers in the best use of resources in a manner compatible with social welfare (Bagazonzya, 1983). This is because it provides a fundamental analysis of the efficiency of farm resource combination which can serve as a basis for bettering the public administration of resources where agricultural policy or institutions which condition production efficiency are concerned.

4.3 PLANNING PERIOD PROBLEM

In any study on planning, the specification of the planning period and the forming of input-output coefficients are singled out to be the most difficult (Beneke, 1973). This is especially so in cases where perenial crops are included in the analysis. Infact, all the past studies in Kenya, that were discussed in the previous chapter as having used linear programming preferred using a one year planning period even where an important perennial activity was involved.

The present study involved sugar cane which agronomically requires a minimum of five years for a complete crop cycle.

This obviously presented a major problem in the choice of the methodology for data analysis. In cases where more than one time period is needed for decision making, scholars have proposed the use of dynamic linear programming models instead of the static one (Merril, 1965; Heady, 1959; Hutton, 1965). Although the theoretical principles and framework for dynamic programming have been developed to some advanced state, its application to actual decision making problems has been very minimal even in developed countries. White (1969), explored the main reasons for this as those involving its severe computational problems, misunderstanding of its advantages over other methods and its large number of redundant computations. These reasons plus the lack of an adequate computer package for its analysis necessitated the choice of a slightly modified linear programming model for this study.

The normal practice in WKPS is one where once the initial decision to plant cane is made no subsequent decisions are required on the enterprise mix for at least the next five years. Thus it becomes more realistic, in the scheme's setting, to consider the five year period as a single decision period rather than as five subsequent decision periods which would have been the case in dynamic programming.

To synchronize the difference in crop cycles between sugar cane and the other crops in the scheme, five rice crops and five dry land crop periods are considered in the analysis. This suggestion is given by Harsh (1981). Maximizing the total net returns from the cane crop and the other crops for the whole five year period therefore becomes the objective function. Although market prices for both inputs and outputs will definetely change within this period, it is assumed that relative prices will remain constant and hence such price changes will not affect the optimal plan.

To capture the effect of time on the value of money, all incomes and expenditures have been discounted at an interest rate of 14 per cent. This is the average interest rate given by commercial banks on deposits and hence is considered as the opportunity cost of investing the tenants capital (CBK, 1986). Details on discounting procedures are given in Gittinger (1982). Discounting table values used in the study are those from Gittenger (1982) and are given in Appendix VI.

With the Specified planning period and the consequent discounting process, a linear programming model was specified for each activity calendar. Each of these LP models has an objective function and a set of seven types of constraints (Appendix VII to IX). Formally these LP models can be expressed as:

Max $\bar{P}_i X_i$ -- objective function

Subject to:-

(i) $\sum_{i=1}^{5} m_{ij} X_i \leq M_j$, j = [1,2,-----,60] - labour constraints

(ii) $\sum_{i=1}^{5} C_i X_i \leq K$ -- Capital constraints

(iii) $\sum_{i=1}^{2} X_i \leq L$)

(iv) $\sum_{i=3}^{5} X_i \leq L - X_2$)-- land constraints

(v) $X_2 \leq T$ -- Marketing constraint for sugar cane.

(vi) $\sum_{i=1}^{5} P_i X_i \geq S$ -- Subsistence constraints

(vii) $X \geq O$ Non-negativity constraints

Where:- P is an n x 1 vector of the total discounted gross margins from one unit of activity X for the five years planning period.

X - is X_i's activity level in acres.

M - is labour input requirement of activity X_i in Month

M - is the total amount of labour available in month j

C - is the total discounted expenditure on capital items for activity X_i in the five year period.

S - is the total discounted value of the tenant's family subsistence requirement for five years.

T - is the total crashing capacity for cane that is available to the tenant and

L - is total scheme crop land available to tenant.

Footnote 1: This figure is given in acres after dividing the available crashing by 50metric tonnes which is the average yield of cane per acre.

In addition to the assumption of constant relative prices, this model also assumes that the Board will continue to provide the capital items equally to all tenants as it has been doing and that the family set up will not undergo any significant changes within five years so as to affect the labour or the subsistence constraints.

The model as formulated above violates none of the basic assumptions of the ordinary linear programming model (i.e. additivity, linearity, divisibility, finiteness and single value expectations) and hence possesses the same qualities. A more detailed derivation of its quantitative components is explained in the sections that follow.

4.3.2 THE OBJECTIVE FUNCTION

The objective function in the present study is to maximize the tenant's farm income by adopting optimal farm plans and hence allocating tenant resources optimally. To do this, gross margins per acre of activity were calculated. Five activities were identified. These are rice, sugar cane, sorghum, green grams and beans production. The unit of measurement is one acre of activity. Thus in full the objective function can be expressed as:

$$\text{maximize } Z = \bar{P}_1 X_1 + \bar{P}_2 X_2 + \bar{P}_3 X_3 + \bar{P}_4 X_4 + \bar{P}_5 X_5$$

Where $P_1 X_1$ ......, $P_5 X_5$ are the discounted gross margins from rice, sugar cane, green grams sorghum and Beans respectively. To obtain $\bar{P}_i$, which is the discounted gross margin from a unit of activity i , the ordinary gross margin calculations were used for activities 1,3,4 and 5, per annum i.e.

$GM_i = Q_i P_i - U_i$

Where GM is the gross margin per acre for activity i .

Q_i is the quantity of output of activity i

P_i is the price of the product per unit for activity i (1986 prices are used throughout)

U_i is the total variable cost per acre for activity i

Once the value of the GM is obtained, then the enterprise is expected to earn that each year for the next five years since the prices and yields are assumed to be constant throughout the period. $\bar{P}_i$ therefore is obtained by discounting a cash flow of the calculated GM for the next five years. For sugar cane enterprises (i.e. activity 2), the same procedure is followed except that the first output is expected after the second year. The mean yield of the cane crop is obtained by adding the expected yields of the plant cane and the subsequent three ratoons then dividing by four. This is because we are considering the total net returns from the cane crop regardless of its ratoon stage. Houtman (1980) adopts the same method in order to calculate the break-even point for the cane crop. Details on the crop yields are given in chapter five.

4.3.3 RESOURCE CONSTRAINTS

(i) The land Constraints

Each tenant in WKPS is allocated a 4 acre (1.6 hectares) plot of land. Under the existing farm plan, the tenant is expected to divide this plot equally between rice and sugar cane growing. These are considered to be scheme crops and hence the Board is directly involved in their farm operations. However, since the introduction of single cropping of rice in 1984, the tenants have been encouraged to plant dryland crops on the rice plots during the long rains. Though the study considered the season factor, all the crops were regarded equally in planning. Thus no preference was given to present scheme crops.

Due to the fact that the dryland crops are grown only during the long rains season and rice only during the short rains, two land constraints were used. One for short rains land and another for the long rains land. Since sugar cane remains on the plot all the seasons, the long rains land constraint becomes:

$\sum_{i=3}^{5} X_i \leq L - X_2$, where X_2 is the cane activity and X_3 to X_5 are the dryland crops.

The short rains land constraint can formally be written as:

$\sum_{i=1}^{2} X_i \leq L$. L is equal to four acres, the total amount of land available to a tenant according to the Board's policy.

(ii) Labour Constraints

Labour was analysed on monthly basis. The three activity calendars were thus utilized to get the initial sixty monthly labour constraints. However, some of these were similar or obviously unbinding and hence were disregarded. The arising smaller matrices are given in tables 5B: 1 to 3 in chapter five. Houtman's report was used to obtain rice labour input coefficients. Field assistants' records and Ahero irrigation research reports were used for cane and dryland crops. This is because tenants have never fully participated in the production of those crops and hence neither Houtman's study nor the present study could get reliable primary data on these crops. The Field Assistants' records were considered the most reliable source for cane data. Both Family labour and hired labour are added to obtain the total labour available in a given month. The average family was found to have approximately 3 adults and 5 children. From Houtman's report, an adult is expected to work for six hours a day in 25 days a month. Thus in a month one adult works for about 6 x 25 = 150 man-hours. 3 x 150 = 450 man-hours are the total adult labour in man-hours available to the average family in the scheme. Child labour was considered at 0.5 adult equivalent hence providing a total child labour of 75 x 5 = 375 man-hours to the average family.

Since most children were found to be of school age, their labour is considered only during school holiday months (i.e April, August and December). Hired labour is added only to those months during which activities for which tenants usually hired labour occur. Figures on the amount of labour hired by the tenants are given by Houtman. Labour hired by the Board with the tenants' consent was included under operating capital and hence not analysed as part of tenants' available labour.

(iii) Operating Capital Constraint

All the capital used on the scheme crops by the farmer was taken to be the amount of capital available. This figure was not hard to obtain since the scheme management gave equal amounts of capital inputs to tenants and debited them when they sold their output. The figure was added up and discounted for five years as required by the model for analysis. Capital input coefficients for the various crops were also not hard to obtain due to the availability of farm records and the close supervision of farm operations by the field staff. It may, however, be worth noting that most of the input-output coefficients used in this study differ significantly from those recommended by the Ahero research station. This is because the study aimed at using the tenant's practical setting in analysing his decision making behaviour.

Expenditure on inputs required for each given activity are added up and discounted for five years so as to obtain the figure that is entered into the programme (i.e. Ci in section 4.3.1) as the capital input coefficient.

OTHER CONSTRAINTS

Since the scheme was started, it has suffered a serious problem of lack of enough market for its sugar cane. This is partly because it is situated outside the Nyanza sugar belt and hence it is not well served by the factories within the belt. Infact the Board had stopped planting cane in the scheme from 1979 upto 1985 due to lack of markets for it. In 1985, the proprietors of the jaggery factory, recently constructed next to the scheme, promised to build a factory which would crash all the cane from the scheme. The design capacity for this factory was given as 100 metric tonnes per day (i.e. the output of a 2 acre cane plot). Due to this cane marketing problem, it was found necessary to establish a marketing constraint for cane in this study.

Establishing a marketing constraint was not easy due to lack of data. However, discussions with the irrigation officer in charge of the scheme showed that the only reliable market for the scheme's cane was the recently build jaggery factory. He argued that the factories in the sugar belt do not normally take the scheme's cane, unless it is a government directive, because of the high transport costs involved. Thus the cane market constraint was set using an estimate of the amount of cane the jaggery factory could be expected to crash per day. Although its design capacity is 100 metric tonnes per day, it would be superfluous for one to expect a firm to operate at its design capacity. A study by Odhiambo (1978) showed the three big sugar factories in the sugar belt (i.e. Chemilil, Miwani and Muhoroni) as utilizing only 57,52 and 45 per cent of their design capacities respectively. Given its proximity to its major source of cane, it is estimated that the jaggery factory would be able to crash 60 metric tonnes of cane a day (i.e. 60% of its design capacity). This figure was used as the marketing constraint for cane in the LP model. Since the decision unit in the study was an acre of land, the figure was divided by 50 metric tones (i.e. average yield per acre of cane) to convert it into acres for use in the model. Sensitivity analysis was used to bring out the full effect of the market constraint on the optimal enterprise mix.

The subsistence constraint used in the study referred to the amount, in money terms, that the tenant would require from scheme farm activities, to subsist for a year. Tenant's main food requirements per week were valued using the prices given during the questionnaire interviews and then multiplied by 52 weeks in a year. Estimated income from activities other than on scheme crops was subtracted from the resultant figure since most of all this income was said to be used for subsistence purposes. The result was added up and discounted for the five year period so as to obtain the figure that is used in the LP model. Using monetary values was thought to be the best way of approximating the tenant's subsistence requirements because none of the scheme crops is used as a staple food by the tenants and hence has to be sold in order to by the traditional dish, (i.e. maize flour and fish).

Lastly the non-negativity constraints require that none of the activities takes a negative value.

CHAPTER FIVE

DATA PRESENTATION, ANALYSIS AND DISCUSSIONS

The first part of this chapter presents the compiled data in a manner that will help in understanding the present farming system, in WKPS. It deals with husbandry practices, yields and incomes of the present farm plan and will be presented cropwise. The second part includes the linear programming analysis and a discussion of the results obtained from it.

PART A: HUSBANDRY PRACTICES AND INCOMES

5A: Paddy Rice Production

By 1979, all the 553 tenants in WKPS had established their 2 acre (0.8 ha.) rice plots. Rice production can be considered as the only crop enterprise that has been fully adopted by tenants in this scheme. The other enterprises that have been recommended have met with limited acceptance by tenants due to various reasons that will be given under their sections in this chapter.

Paddy rice production is a labour intensive enterprise which involves a number of farm inputs and operations. Land preparation on the rice plot is normally done in two phases. First, harrowing is done using Board tractors. Charges on this are combined with charges on irrigation water to form the service charges that the Board staff .pa records in a tenant farm account record. The tenant has to pay for these services together with all other inputs given to him by the Board.

After the Board harrows a tenant's plot, he/she is expected to do paddling either by oxen or manually. This is in preparation for the transplanting of rice seedlings into the plot. He is supposed by this time, to have his/her seedlings ready in a small nursery at one corner of his plot. Tenants in WKPS prefer paddling their plots manually instead of using oxen. On average a tenant would need 155.5 man-hours per acre for land preparation. As noted earlier, all rice labour input data in this study were calculated from Houtman's (1981) report.

After a tenant has prepared his/her plot to the satisfaction of the Field Assistant in charge of rice, the water guards are supposed to allow enough irrigation water into the plot. If the seedlings in the nursery are ready for transplanting, the tenant is supposed to transplant them or hire labour to do it. This requires, on average, 173 man-hours of labour.

Although agronomic research recommends three weedings for a rice crop, tenants in WKPS normally do only two. Each weeding was found to require about 235 man-hours per 2 acre plot. Thus a tenant needs 470 man-hours of weeding labour for his rice crop in the present farming system. This makes weeding the second major labour consuming farm operation in rice plots in WKPS. Harvesting takes the greatest amount of labour.

Once the rice ears start emerging, then bird scaring becomes an important activity. This can be done manually or using a reflective wire. Most tenants in WKPS scare birds manually (i.e. by staying at the plot from 6 a.m. to 6 p.m. and shouting to scare birds when they come upon the rice ears). In bird scaring both child and adult labour could be given the same weight. However from the activity calendars developed for this study, this activity falls on the month of November when children are in school. Hence adult labour was found to be mostly used. On average 373 man-hours were required for this exercise, per 2 - acre plot.

When the rice crop is ready, harvesting commences guided by the Board staff. This is normally 155 days after transplanting. Five activities are involved in rice harvesting in WKPS. These are cutting, stucking, threshing, winnowing and transporting to the drying floor. Since normally the same people do all these activities, it was easier to establish the total amount of labour for harvesting than for each of the activities. On average, 500 man-hours are required for harvesting a 2 - acre rice plot in WKPS.

Tenants labour is also required for other activities like maintenance of irrigation systems and clearing and burning of rice trash after harvesting. Maintenance of irrigation systems was found to require 100 man-hours while clearing and burning of trash required 41 man-hours per 2 acre plot Labour used for activities like fertilization and seed broadcasting was found insignificant and hence was not considered in this study. Spraying labour is normally provided by the Board and hence it is considered as part of the working capital. It is important to note that all the farm operations in the scheme are closely supervised by the Board's staff even when done by the tenants themselves. This results in a high degree of homogeneity in input requirements and farming methods.

Unlike labour, all capital inputs required by the tenants, for paddy rice production, are provided by the Board. These include 37.5 Kg of seed paddy rice, 16 1/2 Kg of ferdum, gunny bags, spray labour, irrigation and harrowing services. Table 5A.1 gives the capital and labour input requirements for paddy rice production. The prices quoted here are those of 1986. Price for labour was that paid to casual labourers by the Board. In addition to these, each tenant received an advance of Kshs. 200 from the Board and an average of Kshs. 1,295 from NCPB to hire labour or for subsistence.

Table 5A: 1, WKPS RICE INPUT REQUIREMENTS

INPUT	AMOUNT/ACRE (IN KG/MAN-HOURS)	PRICE (KSHS)	TOTAL COST PER ACRE (KSHS)
Seed	18.75 Kg	8.32/Kg	156.00
Fertilizer Sulphate of Amonia	107.5 Kg	3.00/Kg	322.50
Water, Rotavation & other service charges	-	-	1,638.00*
Ferdum (pesticide)	8.75 Kg	34.66 Kg	285.95
Gunny Bags	-	-	1,070.00*
NIB spray labour	-	-	27.00*
Nursery labour	26.5 man- hrs	1.70/man-hr	45.05
Land preparation	154.5 man-hrs	1.70/man-hr	262.65
Transplanting Labour	173 man-hrs	1.70/man-hr	294.10
Weeding labour	235 man-hrs	1.70/man-hr	399.50
Bird scaring	186.5 man-hrs	1.70/man-hr	317.05
Harvesting	250 man-hrs	1.70/man-hr	425.00
Maintenance of irrigation system	50 man-hrs	1.70/man-hr	85.00
Clearing trash	20.5 man-hrs	1.70/man-hr	34.85

Source: Author's Survey data.

*These figures were obtained from tenant's farm records.

5A.1.1 RICE YIELDS

The first fourteen rice crops in WKPS were double cropped as required by the Board. Due to the problems arising from this cropping system, rice yields fell to as low as 9.9 bags/acre (75 Kgs/bag). The rice variety planted in the scheme has had to be changed thrice in an effort to fight pests and disease incidence and also increase yields. However, rice yields have registered a gradual increase in the last three years. This was after the introduction of the single cropping system. Table 5A:2 shows the average paddy rice yields per acre for the scheme since its inception.

As can be seen in table 5A:2, rice yields fell to their lowest in 1978/79. It is worth noting that this is the same year when commercial production of cane commenced in the scheme. This is an indication of the effect that the present farm plan had on the tenants. Pest and disease incidence on the crop were said to have been so high at this time that the rice variety had to be changed from Sindano to Basmati. This was expected to increase yields because of basmati's greater tolerance to pest and diseases (N.I.B., 1978/79). The rice variety was changed again in the scheme from Basmati to IR54 in 1983 when single cropping was introduced.

Yields have increased upto 31.8 bags per acre for the seventeenth crop. This study used 31 bags per acre as the average yield for the rice enterprise in the five year

Table 5A:2 WKPS PADDY RICE AVERAGE YIELD (IN BAGS*)/SCRE, 1976-198

Year	Crop1	Crop2	Total/year	Average/Acre
1976/77	26.4	39.4	72,774.8	32.9
1977/78	12.1	14.1	28,977.2	13.1
1978/79	9.9	12.4	14,663,8	11.2
1979/80	20.2	21.8	46,452.0	21.0
1980/81	19.6	22.9	47,005.0	21.3
1981/82	21.3	20.4	46,120.2	20.8
1982/83	19.2	18.8	42,028.0	19.0
1983/84	27.6	-	30,525.6	27.6
1984/85	24.8	-	27,428.8	24.8
1985/86	31.8	-	35,170.8	31.8

Source: WKPS Annual Reports
*1 bag = 75Kgs.

Note: Figures in columns 2 and 3 show the Average yield/acre/crop and hence are of vital importance to this study. Counting from crop 1 of 1976/77 one can identify the trend of crop yields for the 17 rice crops, that had been planted in WKPS upto 1986. The effects of the various changes as explained in preceeding sections can also be seen in the yield variations in these columns if analysed in a serial form (i.e from crop1 to crop 17) planning period. An average over many crops (or years) could not be used because of the changes in the rice variety used in the scheme and the change in the cropping system.

5A:1.2 RICE GROSS MARGIN

The conventional formular for obtaining enterprise gross margins was given in chapter 4 section 4:3:2 as $GM_i = Q_iP_i - U_i$. Q_iP_i gives the gross returns from enterprise i while U_i is the total variable costs incurred in the ith enterprise. Normally, U_i includes all the costs on working capital and hired labour.

Since all the analysis in this study was based on 1986 prices for outputs and inputs, the average yield for the seventeenth rice crop (i.e. 31 (75 kg) bags/acre) was used for rice gross margin calculations. From table 5A:1 the total variable cost of rice production per acre (excluding costs of tenants' hired labour) is given as Kshs. 3,499.45. Given the 1986 rice price of Kshs. 200 per 75 Kg. bag, then the tenant received Kshs. 2701.00 per acre from the Board. This meant that the average tenant in WKPS received a total of Kshs. 5,402.00 (i.e. 2701 x 2 acres) from the Board as income from his/her rice enterprise.

The average cost of hired labour for rice production was estimated to be Kshs. 1.70/man-hour regardless of the kind of farm operation. The total amount of hired labour used on a 2 acre rice plot was 693 man-hours. Thus the total cost of hired labour on rice was Kshs. 589.05 per acre (i.e. 693 ÷ 2x 1.70). Substracting this from Kshs. 2,701.00, we get the rice gross margin as Kshs 2,113.03.

In this study, reliable data on tenant's hired labour was available only for the rice enterprise. Problems encountered in obtaining data on sugar cane have already been highlighted and the three recommended dryland crops had not yet been adopted by tenants. For the sake of gross margin comparisons between the various enterprises, costs of hired labour were not considered in the gross margins calculated for use in the linear programming models. Although this meant slightly overestimated gross margins, it was found more reliable than using the actual gross margin for rice (i.e. Kshs. 2113) and overestimating gross margins for the other enterprises. Thus Kshs 2,701 was used as the gross margin for the rice enterprise in this study. Sensitivity analysis showed that the optimal solution would however not change even if Kshs, 2113 was used as the gross margin.

In section 4:2:2, a five year planning period was chosen for this study. Thus, assuming the tenant received Kshs. 2701.00 from an acre of rice each year for the next five years, the aggregate discounted rice gross margin for the whole planning period was obtained using the discounting procedure given in Table 5A:3 (see Appendix 5 for Discounting Table values).

TABLE 5A:3, WKPS DISCOUNTED RICE GROSS MARGIN

Year	Gross margin (Kshs)	Discount factor (14 %)	Present Value (Kshs)
1	2701	.877	2,369
2	2701	.769	2,077
3	2701	.675	1,823
4	2701	.592	1,599
5	2701	.519	1,402
Total	13505	3.432	9,270

NOTE: All figures in column 4 were rounded up to the nearest whole number.

The aggregate discounted rice gross margin used for analysis in this study was thus Kshs. 9,270.00. This figure includes all the proceeds from the rice enterprise within the five year planning period. Discounting was found necessary because the effect of time on money is not costless.

5A:2 SUGAR CANE PRODUCTION

Unlike in rice, only 259 tenants had their cane plots ready for cane growing by 1980. This figure fell considerably in later years as was shown in Table 1:2. Infact, if the jaggery factory that has been constructed next to the scheme were not built, cane production in WKPS would have reached a standstill (WKPS, 1983/84).

Sugar cane growing is far more capital intensive than rice growing. It involves a number of farm operations in which items like tractors are used. Due to the problems that have faced this enterprise in WKPS, the Board staff has had to perform almost all the farm operations on the cane plot. These problems include:- limited factory capacity, long distance between the scheme and the cane crashing factories, poor roads and the overmaturity of cane which arises from these problems.

Agronomically, successful sugar-cane growing requires firstly, land clearing and rough levelling using bull-dozers and scrapers. After this, heavy cultivation is done using heavy crawler tractors usually hired from a contractor. Light soil cultivation and final levelling are then done using normal Board's tractors. This involves ridging and making cross-furrows in preparation for seed cane planting.

If seed cane is to be planted directly after ridging, triple super phosphate fertilizer at the rate of 50 Kg/acre is broadcast over the plot. A ridger works the fertilizer into the soil. The tenant is then expected to arrange the tops and ends of furrows and make plant furrows 5cm deep facing the morning sun. Three-bud seed cane sets are then planted in a head-to tail arrangement without overlap. Experience in WKPS shows that this would need about 208 man-hours of labour per acre. After planting, covering of seed cane sets is done after irrigation or rainfall. This would require 104 man-hours of the tenant's labour.

First weeding is supposed to be done 3 weeks after planting. Although agronomic research recommends 4 weedings for plant cane, the Board has been doing only two. The Head Field assistant in charge of cane argued that they have not only found these sufficient but it also helps reduce the labour costs. The first weeding is normally done the second month after planting while the second weeding is done after the seventh month. After the second weeding, the cane plants form a canopy that retards weed growth and hence no need for more weeding. Each weeding requires about 104 man-hours of weeding labour per acre.

A second fertilizer application is done 3-4 months after planting. This is also the time of banking-up soil on the cane stands. Both the fertilization and banking-up exercise take a total of 124 man-hours of labour on average. Sulphate of ammonia is applied this time at the rate of 100 Kg/acre.

When cane is ready for harvesting, 18-24 months after planting, irrigation is stopped 6 weeks before the scheduled harvesting date. Brix reading or determination of maturity is done by analysing a sample. A bridge is put across the drain so that the trailers can enter the field. Cane harvesting in WKPS is normally done by a subcontractor who charges Kshs. 104.10 per tonne of harvested cane.

Most of the activities done on plant cane after planting are repeated for all the three ratoon crops. Tables 5A: 4 and 5A:5 give a summary of the input requirements for sugar cane production in WKPS. The same farming operations are done on all the ratoon cycles hence the variable costs are the same for all the three ratoons in one cane life cycle.

It is important to note here that land preparation and harvesting activities on cane can not be done during the rainy season due to the nature of soils and the topography of the Kano plains. The three activity calendars for WKPS were based on this factor and the fact that rice can only be grown during the short rains.

5A:2:1 SUGAR CANE YIELDS

Sugarcane yields for the present farming system are hard to establish. This is because the major constraint to the enterprise's performance is not within the farm. Lack of enough market for the scheme's sugar cane output has been cited as the major drawback to its cane production (WKPS, annual reports 1979/80).

TABLE 5A:4, WKPS PLANT CANE INPUT REQUIREMENTS

INPUT	AMOUNT PER ACRE (KG/MAN-HOURS/ LITRES)	PRICE (KSHS)	TOTAL COST PER ACRE (KSHS)
Seed	1.25 tons	392.00	490.00
Fertilizer			
TSP	50 Kg	170.00/ 50 Kg	170.00
Sulphate	100 Kg	150.00/ 50 Kg	300.00
Water plus Service charges	-	-	1,460.00
Ferdum (pesticide)	5.5 Kg	34.Kg	190.63
Herbicides			
Gessapax Combi	4 litres	78.50/lt.	314.00
Estamine 2-4-D	0.75 cc	100.00/cc	75.00
Nata TCA	3.25 Kg	34.50/Kg	112.13
Harvesting charges	-	104.10/ tonne	5,205.00
Cutting furrows	52 man - hours	1.70/ man-hour	88.40
Improvement of furrows	52 man - hours	1.70/ man-hour	88.40
Planting	208 man hours	1.70/ man-hour	353.60
Cutting of grass furrows & fertilization	32 man-hours	1.70/ man-hour	54.40
Weeding	208 man-hours	1.70/ man-hour	353.60
Banking-up	52 man-hours	1.70/ man-hour	88.40

Sources: A.I.R.S., Field Assistants reports and WKPS stores clerk records.

TABLE 5A:5, WKPS RATOON CANE INPUT REQUIREMENTS

INPUT	AMOUNT PER ACRE (LITRES/KG/MAN-HOURS ETC.	PRICES (KSHS)	TOTAL COST PER ACRE (KSHS)
Fertilizer Sulphate	100Kg	150.00/ 50 Kg	300.00
Water & Service Charges	-	-	1,460.00
Herbicides			
Gessapax Combi	4 litres	78.50/ litre	314.00
Estamine 2-4-D	0.75 cc	100.00/cc	75.00
Nata TCA	3.25 Kg	34.50/Kg	112.13
Harvesting charges	-	104.10/ton	5,205.00
Weeding	208 man-hours	1.70/man-hour	353.60
Furrow improvement	18 man-hours	1.70/man-hour	30.60
Banking up + Fertilization	124 man-hours	1.70/man-hour	204.00

Sources: A.I.R.S., Field Assistants' reports and WKPS stores clerk records.

Houtman (1981) estimated the yields per acre plot of plant cane and the ratoons to be:

* Plant cane crop --- 180 tons (break even point:64 tons)

* 1st ratoon crop --- 108 tons (break even point:42 tons)

2nd ratoon crop --- 72 tons (break even point:42 tons)

3rd ratoon crop --- 48 tons (break even point:42 tons)

Total: 408 tons (break even point:190tons)

*These yields were achieved in the first years of operation. The yields for the 2nd and 3rd ratoon crops are Houtman's own projections. From these yield figures, Houtman estimates the average cane farmer to receive a total net farm income of Kshs 17,000 in five years or Kshs. 3,400 per annum.

If the figures given in the scheme's annual reports are taken to be more realistic, Houtman's estimates turn out to be highly exagerated. Table 5A:6 gives the sugar cane statistics for WKPS from 1978 to 1983.

TABLE 5A: 6 WKPS SUGAR CANE PRODUCTION STATISTICS 1978 - 1983

Year (1)	Area Under cane (acres) (2)	Area Harvested (acres) (3)	No. of Growers Harvested (4)	Total output Metric tonnes (5)	Mean cane yield/acre plant (6)	Mean cane yield/acre Ratoon (7)	Mean Net Income/ acre (Kshs) (8)
1978/79	825	223	-	15,227	86	44	4,121
1979/80	825	530	259	20,822	41	35.6	1,209
1980/81	825	385	190	11,395	-	30	763
1981/82	680	515	257	11,871	-	23	631
1982/83	680	183	113	5,760	-	31	715

Source: WKPS Annual Reports.

Figures in table 5A:6 were calculated from statistics presented in WKPS annual reports. Since these annual reports did not indicate for which ratoon stage the production statistics represented, it was not possible to establish from them the respective mean yield/acre for the 3 - ratoon stages. However, Table 5A:6 can be used to approximate cane yields since other sources proved unhelpful. Since sugar cane in WKPS can only be harvested if handling factories ask for it, column 1 and 2 can give one a hint on the extent to which available factory capacity affects cane production. For example, out of the 825 acres that were under cane in 1978/79, only 223 acres were harvested for crashing thus leaving about 6Ø2 acres of cane unharvested.

Given the difficulties encountered in establishing past yields of sugar cane from the available data, it was not easy to determine the mean incomes received from cane plots by tenants. Houtman (1981) estimated the mean net farm income from a Ø.8 ha (2 acre) plot to be Kshs. 3,ØØØper annum. Calculations from the 8th column of Table 5A: 6 gave a mean net farm income of Kshs. 2,975.2Ø per 2 acre plot per annum. Thus a difference of about Kshs. 25.

Note that the income reffered to here is that which the tenant received after the Board subtracted the costs of all the inputs it had provided to him. This meant that the costs of tenant's hired labour and family labour were not considered in its calculation. Although tenants used to hire some labour for their cane plots before they started abandoning them due to low returns, none of the 19 tenants in the study sample whose cane plots had once been cultivated could recall the amount of hired labour they had used per farm operation on cane. The field work for this study was done about three years after most of them had abandoned their cane plots.

5A: 2:2 SUGAR CANE GROSS MARGIN

The gross margins calculated in this study for sugar cane and the three dry land crops were not considered as part of the tenants total farm income for the present farming system. They were solely derived for determining the optimal farm plan in part B of this chapter.

The same procedure used to get the rice gross margin was used for all the other enterprises. However, in section 5A:2:1, It was found difficult to establish the average cane yields either for plant cane or for the ratoons. Table 5A:7 gives estimates of mean cane yield from three different sources.

TABLE 5a: 7 WKPS Estimates of Mean cane yields from three sources (in metric tonnes)

Source / Crop	*Table 5A:6	Houtman (1981)	** Field Assistant's Records
Plant crop	64	90	50
1st ratoon	33	54	65
2nd ratoon	33	36	65
3rd ratoon	33	24	55
Total	163	204	235
Mean per crop	41	51	59

* Figures in this column were calculated from Table 5A: 6 columns 6 and 7 with the assumption that yields are equal for all ratoon crops.

** Figures in this column are the projections that the Head Field Assistant had given in his records for the present cane crop.

This table shows the discrepancies on mean yield per acre of cane from the three sources available to the author. Faced with similar discrepancies, the designers of the jaggery factory mentioned earlier, in collaboration with the scheme management, chosed to use 50 metric tonnes per acre per crop as the mean yield for cane (N.I.B., 1984). Thus the factory was designed to crash 100 tonnes of cane per day, which is the expected output from a 2 acre plot. This figure, 50 metric tonnes, was also chosen as mean yield per acre of cane per crop for this study.

Given the 1986 producer price of cane (i.e. Kshs. 300.00 per metric tonne), the tenant would therefore be expected to receive a gross return of Kshs. 15,000 (i.e. 300 x 50) for each of the four crops. The variable costs of each of the crops were calculated from Tables 5A:4 and 5. Thus the enterprise gross margins for cane crops at 1986 producer prices are:-

Plant crop	Kshs. 15,000	- 8,242	=	Kshs. 6,758
1st ratoon crop	Kshs. 15,000	- 7,391	=	Kshs. 7,609
2nd ratoon crop	Kshs. 15,000	- 7,391	=	Kshs. 7,609
3rd ratoon crop	Kshs. 15,000	- 7,391	=	Kshs. 7,609
Total	Kshs. 60,000	-30,415	=	Kshs.29,585

The aggregate net returns from the full cane cycle would therefore be Kshs. 29585. Spreading this income over the five year period, this would be equivalent to an annual return of Kshs. 5,917.00. Discounting this figure the same way we did for rice, the aggregate discounted gross margin per acre of sugar cane would be Kshs. 5,917x 3.432 = Kshs. 20,307.14. However, no income is received from cane until the end of the second year, hence the discounting procedure had to take this into consideration. This resulted to Kshs. 18,784.00 as the aggregate discounted gross margin per acre of sugar cane for the five year planning period.

5A:3 DRYLAND CROPS PRODUCTION

Under the present farming system, dryland crops are expected to be grown in the rice plots during the long rains season. Agronomic research by the Ahero Irrigation research Station (A.I.R.S) staff has recommended green grams, sorghum and beans as the most suitable dryland crops for WKPS. However, not many tenants have grown these crops since the scheme started single cropping rice. Only six of the 31 interviewed said they had grown green grams. Two of these had also grown sorghum on their plots. The crops are referred to as dryland because they do not require irrigation.

Both within and without the scheme, growing of green grams seemed to be gaining pupularity among farmers. This was indicated by the number of plots, especially outside the scheme,that one could see under the crop. Table 5A:8 gives the input requirements and their estimated local prices. All the information on these crops had to be collected from the research staff and their reports since the crops are not yet fully adopted by the tenants in the scheme. Their expected yields were given as 3, 6, and 3 bags per acre for green grams, sorghum and beans respectively. Their local producer prices were Kshs. 700, 240 and 480 per bag respectively.

TABLE 5A:8 INPUT REQUIREMENTS FOR DRY LAND CROPS

Crop	Input	Amount @ acre Kg/m-hrs/ml	Price Kshs.	Total Cost @ acre Kshs.
Green grams	Seed	3Kg	18.00	54.00
	Pesticides	80 ml	80.00/80ml	80
	Land preparation	24 man-hrs	1.70/m-hr	40.8
	planting Labour	32 man-hrs	1.70/m-hr	54.40
	Weeding Labour	128 man-hrs	1.70/m-hr	217.60
	Harvesting	80 man-hrs	1.70 m-hr	116.00
Sorghum	Seed	2 kg	16.00	32.00
	Fertilizer	50	150.00/50kg	150.00
	- Simithion 50	40ml	80.00/80ml	40.00
	Furdum	2Kg	34.66	69.32
	planting Labour	32 man-hrs	1.70/m-hr	54.40
	Wedding	192 man-hrs	1.70/m-hr	626.40
	Harvesting	64 man-hrs	1.70/m-hr	108.80
	Fertilization & Spraying	16 man-hrs	1.70/m-hr	27.20
Beans	Seed	15	15.00	225.00
	Fertilizer T.S.P.	25 kg	3.40	85.00
	Simithion 50'	40 ml	1.00	40.00
	Planting Labour	32	1.70	54.40
	Weeding Labour	192 man-hrs	1.70	326.00
	Harvesting	64 man-hrs	1.70	108.00
	Fertilization & Spraying	16 man-hrs	1.70	27.20

Source: A.I.R.S. records

5A:3:1 DRYLAND CROPS GROSS MARGINS

Using the information on inputs, output and prices given in Table 5A:8 and section 5A:3, the enterprise gross margins for the three dryland crops were calculated. These are given in Table 5A:9.

Table 5A:9, WKPS Enterprise Gross Margins for Dryland Crops

Crop (1)	Gross return/ acre Quantity x price (2)	Total variable costs (Kshs.) (3)	Gross margin (Kshs) (4=2-3)	Total Discounting factor (5)	Aggr. Discounted gross margins (Kshs.) (6)
Green grams	700x3=2100	152	1,948	3.432	6,686
Sorghum	240x6=1440	251	1,189	3.432	4,081
Beans	480x3=1440	350	1,090	3.432	3,741

Source: Author's Survey.

The figures in column 6 were the ones used in the objective function for their respective crops. This was because, these figures take into consideration all the returns from a given enterprise for the whole planning period.

5A: 4 TOTAL FARM INCOME FROM PRESENT FARMING SYSTEM

Total farm income in this study means the income a tenant receives from the Board after it has deducted all the monies advanced to him/her, in the form of inputs, during the production of his crops. This does not include cost of the tenant's hired labour.

The total annual income from rice was given in section 5A: 1:2 as Kshs. 5402. Income from the cane crop was given as Kshs. 2975 in section 5A:2:1. A problem arises because the rice income was calculated at 1986 prices while cane income was derived using 1983 prices. To synchronize this price difference, it was thought necessary to inflate the cane income using the National lower Income consumer price Index (CPI) with 1983 as the base year. CPI is the most commonly used figure to approximate the effect of inflation on prices (Mcdougall, 1976). Using the figures given in the quarterly economic review for September 1986 (CBK, 1986) the CPI for 1985 would be 122, if 1983 is chosen as the base year. Thus the cane income becomes Kshs. 3,629.50 (i.e. 2975 x 1.22).

The total annual farm income from the present farming system thus becomes Kshs. 9,031.50 (i.e. 5402 + 3629.50). If this income were to be received annually for the next five years, then the tenant would receive a total discounted farm income of Kshs. 30,996.11 (i.e. 9,031.50 x 3.432). These are the figures that were used in the comparisons between the present farming system and the optimal farm plans obtained in this study.

PART 5B: RESULTS OF LINEAR PROGRAMMING (LP) ANALYSIS

The results of this study were based on the enterprise gross margins defined in part 5A and constraints determined in the way explained in chapter 4. The three activity calendars in appendices 2 to 4 were used to determine monthly labour constraints for the whole planning period. The original matrices, given in appendices 7a to 7c, were found to have similar constraints or some which were obviously not limiting crop production. Elimination of such constraints resulted in the three smaller matrices given in Tables 5B: 1a to 1c.

The objective function is given as the top row in each of the matrix. It is stated as the optimization of gross margins when cane is planted during the given month. For example, WKPSOPTJY means that gross margins are being optimized when cane was planted in July. The three models were developed in order to determine whether the time of planting cane affects the way enterprises compete for various resources and the optimal income to the tenant.

5B:1 PRESENT AND OPTIMAL FARM PLANS

Details of the present farming system and the incomes accruing from it have been given in previous sections. The optimal farm plans and their corresponding total gross margins obtained after the application of the LP technique

TABLE 5B: Ia LP Model I for WKPS OPT FEB

	RICE	SUGARCANE	GREENGRAMS	SORGHUM	BEANS		
OBVJ. FN.MAX	9270	18786	6685	4081	3741		
SUBJECT TO:							
JAN 1	0	0	24	24	24	LE	450
JAN 5	0	104	24	24	24	LE	450
FEB 1	0	208	12	48	72	LE	450
FEB 2	0	0	32	48	72	LE	450
FEB 4	0	124	32	48	72	LE	450
MARCH	0	136	64	64	72	LE	450
MARCH 2	0	50	64	64	72	LE	450
MARCH 3	0	0	64	64	72	LE	450
APRIL 1	0	104	64	64	64	LE	925
APRIL 2	0	0	64	64	64	LE	925
MAY 1	0	0	80	64	64	LE	450
MAY 3	0	50	80	64	64	LE	450
MAY 4	0	104	80	64	64	LE	450
JUNE 1	155	124	0	0	0	LE	512
JUNE 2	155	0	0	0	0	LE	512
JUNE 4	155	104	0	0	0	LE	512
JULY 5	27	50	0	0	0	LE	464
AUGUST 1	173	0	0	0	0	LE	987
SEPT 1	168	104	0	0	0	LE	532
SEPT 2	168	24	0	0	0	LE	532
SEPT 3	168	0	0	0	0	LE	532
OCT 1	118	50	0	0	0	LE	506
OCT 2	118	89	0	0	0	LE	506
OCT 3	118	24	0	0	0	LE	506
NOV 1	187	0	0	0	0	LE	484
NOV 2	187	104	0	0	0	LE	484
NOV 3	187	59	0	0	0	LE	484
NOV 4	187	24	0	0	0	LE	484
DEC 2	250	125	0	0	0	LE	1105
DEC 3	250	104	0	0	0	LE	1105
DEC 4	250	59	0	0	0	LE	1105
WK-CAPITAL	12005	19503	522	861	1200	LE	68447
LR-LAND	0	1	1	1	1	LE	4
SR-LAND	1	1	0	0	0	LE	4
MKT-CONSTA	0	1	0	0	0	LE	1.2
SBS.CONSTR	9274	18786	6685	4081	3741	GE	36371

NOTE = ABBREVATIONS;

OBJ.FN.MAX: This means a maximization problem.
LE: Less or equal to
GE: Greater or Equal to
WK-CAPITAL - WORKING CAPITAL
LR-LAND - LONG RAINS LAND
SR- LAND -SHORT RAINS LAND
MKT-CONSTR - MARKETING CONSTRAINT
SBS-CONSTR - SUBSISTENCE CONSTRAINT

TABLE 5B: Ib. LP Model 2 for WKPS OPT JY

	RICE	SUGARCANE	GREENGRAMS	SORGHUM	BEANS		
OBVJ. FN.MAX	9270	18786	6685	4081	3741		
SUBJECT TO:							
JUNE 1	155	0	0	0	0	LE	512
JUNE 3	155	124	0	0	0	LE	512
JUNE 5	155	104	0	0	0	LE	512
JULY 1	27	208	0	0	0	LE	464
JULY 5	27	124	0	0	0	LE	464
AUGUST 1	173	136	0	0	0	LE	984
AUGUST 2	173	50	0	0	0	LE	984
SEPT 1	168	104	0	0	0	LE	532
SEPT 2	168	0	0	0	0	LE	532
OCT 3	118	50	0	0	0	LE	506
OCT 4	118	104	0	0	0	LE	506
NOV 1	187	50	0	0	0	LE	484
NOV 2	187	0	0	0	0	LE	484
NOV 4	187	50	0	0	0	LE	484
NOV 5	187	104	0	0	0	LE	484
DEC 5	250	50	0	0	0	LE	1105
JAN 1	0	0	24	24	24	LE	450
FEB 1	0	104	32	48	72	LE	450
FEB 3	0	24	32	48	72	LE	450
FEB 4	0	0	32	48	72	LE	450
MARCH 1	0	50	64	64	72	LE	450
MARCH 2	0	59	64	64	72	LE	450
MARCH 3	0	24	64	64	72	LE	450
MARCH 4	0	0	64	64	72	LE	450
APRIL 1	0	0	64	643	72	LE	825
APRIL 2	0	104	64	64	64	LE	825
APRIL 3	0	59	64	64	64	LE	825
APRIL 4	0	24	64	64	64	LE	825
MAY 1	0	0	80	64	64	LE	450
MAY 3	0	104	80	64	64	LE	450
MAY 4	0	59	80	64	64	LE	450
WK-CAPITAL	12005	19503	522	861	1200	LE	68447
LR-LAND	0	1	1	1	1	LE	4
SR-LAND	1	1	0	0	0	LE	4
MKT-CONSTA	0	1	0	0	0	LE	1.2
SBS.CONSTR	9274	18786	6685	4081	3741	GE	36371

NOTE = ABBREVATIONS AS MODEL 1

TABLE 5B: Ic. LP Model 3 for WKPS OPT DC

	RICE	SUGARCANE	GREENGRAMS	SORGHUM	BEANS		
OBVJ. FN.MAX	9270	18786	6685	4081	3741		
SUBJECT TO:							
JUNE 1	155	0	0	0	0	LE	512
JULY 2	27	104	0	0	0	LE	464
JULY 3	27	24	0	0	0	LE	464
AUGUST 2	171	50	0	0	0	LE	984
AUGUST 3	173	59	0	0	0	LE	984
AUGUST 4	173	14	0	0	0	LE	984
SEPT 1	168	0	0	0	0	LE	532
SEPT 3	168	104	0	0	0	LE	532
SEPT 4	160	59	0	0	0	LE	532
SEPT 5	168	24	0	0	0	LE	532
OCT 3	118	124	0	0	0	LE	506
OCT 4	118	104	0	0	0	LE	506
OCT 5	118	59	0	0	0	LE	506
NOV 1	187	0	0	0	0	LE	484
NOV 5	187	104	0	0	0	LE	484
DEC 1	250	208	0	0	0	LE	1105
DEC 4	250	124	0	0	0	LE	1105
JAN 1	0	136	24	24	24	LE	450
JAN 2	0	50	24	24	24	LE	450
JAN 3	0	0	24	24	24	LE	450
FEB 1	0	104	32	48	72	LE	450
FEB 2	0	0	32	48	72	LE	450
MARCH 1	0	0	64	64	72	LE	450
MARCH 3	0	50	64	64	72	LE	450
MARCH 4	0	104	64	64	72	LE	450
APRIL 1	0	124	64	64	64	LE	825
APRIL 2	0	0	64	64	64	LE	825
APRIL 4	0	50	64	64	64	LE	825
MAY 1	0	0	80	64	64	LE	450
WK-CAPITAL	12005	19503	522	861	1200	LE	68447
LR-LAND	0	1	1	1	1	LE	4
SR-LAND	1	1	0	0	0	LE	4
MKT-CONSTA	0	1	0	0	0	LE	1.2
SBS.CONSTR	9274	18786	6685	4081	3741	GE	36371

NOTE = ABBREVATIONS AS MODEL 1

are presented in Table 5B:2. From this table, the total acreage utilized by the optimal enterprise mix seems to exceed the actual allocation of 4 acres. It should however be noted that under the two land constraints adopted in the LP model specification for this study, rice and green grams do not compete for land. Thus only upto 3.312 acres of short rains land and 4 acres of long rains land are being used in the optimal farm plans.

TABLE 5B:2. WKPS PRESENT AND OPTIMAL FARM PLANS

ENTERPRISE	PRESENT FARM PLAN (Acres)	OPTIMAL MODEL I WKPSOPT FEB	FARM PLANS MODEL 2 WKPSOPT JY	MODEL 3 WKPSOPT DEC
Rice	2	1.92	1.792	1.92
Sugar cane	2	1.2	1.2	1.2
Green Grams	-	2.8	2.8	2.8
Soghum	-	-	-	-
Beans	-	-	-	-
Optimal Sol. 5 - yrs. total Discounted gross Margin (Kshs)	30,996.11	63,439.40	57,327.60	63,439.40
*Mean annual Income (Kshs)	9,031.50	18.484.67	16,703.85	18.484.67
Optimal Sol. 5-yr total Gross margin without green grams (Kshs.)	30,996.11	44,771.40	39,109.60	44,771.40

Source: Linear programming computer print out.

* Figures in this row were obtained by dividing the preceding row by 3.432 which is the total discount factor used in previous sections.

Table 5B:2 shows a significant increase in total gross margins when optimal farm plans are adopted. In all the three optimal farm plans, only rice, cane and green grams are included in the enterprise mix. This means that sorghum and beans should not be grown in WKPS under the present conditions.

Models 1 and 3 give identical results and hence there will be no difference in incomes whether the tenant plants his cane in February or in December. However, it will be shown that the competition by enterprises for November labour differs in the two models. Model II gives a lower total gross margin than the other two optimal farm plans though its resultant income is 84.9 per cent higher than the income resulting from the present farming system.

It is important to note that a higher portion of the increase in income in all the three models is due to the inclusion of green grams which have not been fully introduced in the present farming system. The assumed sugar cane marketing capacity is also a little higher than that which has been available in the past. This has had to be so because the jaggery factory started its operations this year (i.e. 1987) and hence its added capacity had to be taken into consideraiton in the present study.

5B:2 RANGE OF FEASIBILITY FOR OPTIMAL FARM PLANS

Linear programming has the added advantage of showing the range within which the obtained optimal farm plan will remain optimal. This is defined by the ranges of the coefficients, of both the objective function and the constraints, within which the basic variable (i.e. the enterprises in the optimal plan) will remain in the basis. Such ranges are also given to indicate at what level of gross margin a non-basic enterprise can enter the basis and hence the optimal plan. Table 5B:3 gives such ranges for the basic enterprises for all the three optimal farm plans.

TABLE 5B: 3 RANGE OF FEASIBILITY FOR BASIC ENTERPRISES

MODEL I ENTERPRISE	LOW RANGE	CURRENT VALUE	HIGH RANGE
Rice	Ø	9,27Ø	28,226.22
Sugar cane	11,935.77	18,786	9.958959E+10*
Green grams	4112.999	6,685	17,238.23
Model 2 ENTERPRISE			
Rice	Ø	9,27Ø	23,673.6Ø
Sugar cane	12,935.35	18,786	9.958957E+1Ø*
Green grams	4112.999	6,685	16,238.65
Model 3 ENTERPRISE			
Rice	Ø	9,27Ø	28,226.21
Sugar cane	11,935.78	18,786	1E + 38*
Green grams	4113	6,685	17,238.22

Source: Linear programming computer print out.

* This figure is enormous and can be considered as infinite.

Table 5B: 3 gives the range of the enterprises gross margin within which a given basic enterprise remains in the basis. All the figures are expressed in Kenya shillings. It is important to note that these are also the stability limits of the optimal farm plans developed. For example, consider the rice production enterprise in models I and 3 under ceteris paribus conditions. If the gross margin obtained from an acre of rice goes below the lower limit of zero Kenya shillings, the rice enterprise will leave the optimal plan in favour of one of the two non-basic enterprises (i.e. sorghum or beans). Alternatively, if the gross margin for the rice enterprise exceeds the upper or high range of Kshs. 28,226.22, land will be released from other basic enterprises to the production of rice. What really determines how much land will be released to rice production is how much of the other resources, labour and capital, are needed from sugar cane and green grams in order to produce an extra acre of rice.

5B:2:1 <u>ENTERING VALUE FOR NON-BASIC ENTERPRISES</u>

Table 5B:4 shows the value at which an enterprise which is not in the optimal farm plan can enter and thus change the combination of enterprises therein. The table gives the relevant figures for all the three models since the same enterprises, sorghum and beans are non-basic in all of them.

TABLE 5B:4 ENTERING VALUES FOR NON BASIC ENTERPRISES

Enterprise	Current Value	Entering Value Model 1	Model 2	Model 3
Sorghum	4081	6738.001	6738.002	6738
Beans	3741	6738	6738	6738

Source: Linear programming computer print out.

These figures indicate that, the non-basic enterprises will enter the optimal farm plan if their gross margins/acre reach a level of Kshs. 6738. This figure is close to the present gross margin for green grams. A close observation of the activity calendars given in appendices 2 to 4 shows that these three activities utilize almost the same amounts of the labour resource and are planted during the same season.

5B:2:2 RANGE OF FEASIBILITY FOR RESOURCE CONSTRAINTS

This range of feasibility gives the lower and upper limits for each constraint, within which the enterprises in the optimal farm plan will remain basic though their values may change. It also defines the range over which the shadow price or the marginal value product (MVP) of a limiting resource will remain constant. Beyond the relevant limits, the MVPs will change with changes in the optimal plan.

Only model I is discussed here because results for model 2 and 3 have similar interpretations. The latter are given in appendices 8 and 9. Table 5B:5 shows the range of feasibility for model 1 with respect to the resources.

TABLE 5B: 5

THE RANGE OF FEASIBILITY FOR MODEL 1

CONSTRAINT	LOW RANGE	UNITS OF RESOURCE	UPPER RANGE
1) JN1	67.20001	450	1E+38
2) JN5	192	450	1E+38
3) FB1	339.2	450	1E+38
4) FB2	89.60001	450	1E+38
5) FB4	208.3999	450	1E+38
6) MR1	342.4	450	1E+38
7) MR2	239.2	450	1E+38
8) MR3	179.2	450	1E+38
9) AP1	104	825	1E+38
10) AP2	179.1998	825	1E+38
11) MY1	224	450	1E+38
12) MY4	348.80001	450	1E+38
13) MY3	284	450	1E+38
14) JE1	446.5127	512	1E+38
15) JE2	297.7325	512	1E+38
16) JE4	357.7327	512	1E+38
17) JE5	422.5025	512	1E+38
18) JY5	111.8631	464	1E+38
19) AG1	332.308	987	1E+38
20) ST1	447.5036	532	1E+38
21) ST2	351.5037	532	1E+38
22) ST3	22 .7036	532	1E+38
23) OT1	286.6609	506	1E+38
24) OT2	297.4609	506	1E+38
25) OT3	255.4609	506	1E+38
26) NV1	359.2	484	1E+38
27) NV2	124.8	484	588
28) NV3	430	484	1E+38
29) NV4	387.9999	484	1E+38
30) DC2	630.2138	1105	1E+38
31) DC3	605.314	1105	1E+38
32) DC4	551.0139	1105	1E+38
33) WKC	47967.07	68447	1E+38
34) LRL	1.2	4	5.264999
35) SRL	3.120855	4	1E+38
36) MKC	0	1.2	1.829546
37) SBC	9000.082	36371	1E+38

THE RANGE IN WHICH THE SAME VARIABVLES REMAIN IN SOLUTION.

SOURCE: LINEAR PROGRAM COMPUTER PRINTOUT.

Only three resources were found to be limiting in this case. These are long rains land, (LRL), marketing capacity for cane and November labour for the second year (NV2) of the planning period. The values for the marketing capacity can be converted into tonnes by multiplying them by 50 which is the assumed average yield per acre of sugar cane. If the amount available of any of these resources goes beyond the given limits, the optimal farm plan will change and consequently some of the presently unlimiting resources are likely to become limiting.

Unlike limiting resources, when a resource is non-limiting in the optimal solution a lower range for it is defined beyond which there will be an outgoing enterprise or constraint in the basic solution. The upper range limit for such a resource is always infinity as shown in Table 5B:5. Consequently no increase in a non-limiting resource can change the optimal basis under ceteris paribus.

5B:3 SHADOW PRICES OF RESOURCES

The shadow prices or the marginal value product (MVPs) of resources in optimal solutions indicate their productivity, at the margin, on the farm. They show the increase or reduction in total gross margins that would occur if one unit more or one unit less of a resource were used, all other constraints and activities in an optimal plan remaining constant. In linear programming, only limiting resources in the optimal plan take positive MVPS. Table 5B:6 shows the limiting resources in the adopted three models, and their shadow prices.

TABLE 5B: 6 SHADOW PRICES (OR MVPS) FOR ALL OPTIMAL PLANS

LIMITING RESOURCE	MODEL I WKPSOPFEB (KSHS)	MODEL II WKPSOPTJY (KSHS)	MODEL III WKPSOPTDC (KSHS)
NVI	0	50	0
NV2	50	0	0
NV5	0	0	50
LRL	6738.001	6738.001	6,738
MKC	10500.23	9500.653	10500.23

Source: LP computer print out.

From Table 5B:6, one can deduce that, in all the three models, marketing capacity for cane is the most limiting constraint to cane production in West Kano pilot irrigation scheme. An addition of one unit (i.e. 50 tonnes) of sugar cane crashing capacity per tenant would increase his total gross margin by Kshs 10,500 for model 1 and 3 and by Kshs 9,500.70 for model 2.

The second most binding constraint is long rains land. An additional one acre of long rains land would increase the total gross margin of the tenant by about Kshs 6,738 in all the three Models. This goes a long way to indicate the importance that should be attached to the development of dryland crops, especially green grams in the scheme. These are the crops grown during the long rains.

November labour is limiting in the first year for model 2. According to the relevant activity calendar this is the month when bird scaring is done on rice and banking up and fertilization are done on sugar cane. Availability of an extra man-hour during this period would add Kshs. 50 to the total gross margin. November labour is also limiting for the second and fifth years of the planning period in model 1 and 3 espectively. The shadow price in each case is Kshs. 50. Similar interpretations as given for model 2 are applicable, in these other cases. This difference in the time November labour will be limiting for a given model can be taken to explain the effect that the timing of plant cane has on the way enterprises will compete for the labour resource. However, the fact that the shadow price for November labour is the same in all the models indicates the insignificance of the time cane is planted in relation to the way enterprises compete for resources. Nevertheless, the effect of the time cane is planted on the total gross margins has already been shown in Table 5B:2 to be significant. Combining the information from these two tables (i.e. 5B:2 & 5B:6), one can conclude that the best time for planting cane in WKPS is between the months of December and February.

5B:4 SLACKS AND SURPLUSES

In linear programming, a slack occurs when the available amount of resource is not completely used in the optimal farm plan. A surplus arises when more is earned by the optimal plan than was required by a certain constraint (e.g. the subsistence constraint). Table 5B:7 shows the slacks and (surplus) of working capital, short rains land and tenant's subsitence requirements. These are chosen because of their economic and policy implications. Otherwise, apart from the November labour that has already been discussed, all the other labour constraints were found to be unlimiting and hence in slacks. Under the present assumptions and the corresponding optimal plan, the tenant is required to hire labour only during the November months when labour is limiting production.

TABLE 5B: 7 WKPS SLACKS AND SURPLUS

RESOURCE	MODEL 1 (KSHS/ACRE)	MODEL 2 (KSHS/ACRE)	MODEL 3 (KSHS/ACRE)
WORKING CAPITAL	-20,479.93	-22,020.68	-20,479.93
SRL	- .8791449	-1.007487	- .8791443
SBC	+ 27,370	26,171.43	27,370

Source: LP computer print out.

(NB: Negative and positive signs stand for slack and surplus respectively).

Since the optimal farm plan for model 2 has already been shown to be inferior to those from models I and 3 in income, discussion here is given for only slacks and surpluses in models 1 and 3.

In both the optimal plans of these models, a slack of Kshs. 20,479.93 is left unused on the available capital. Bearing in mind that the capital constraint in this study was obtained by adding the value of all the capital items that the National Irrigation Board has been giving the average tenant in the scheme, this means that if the optimal farm plans are adopted for the scheme, the Board will be saving Kshs. 20,479.93 per tenant within five years in discounted value terms. In undiscounted terms, this is the same as Kshs. 5,967.35 per year per tenant (= 20,479.93/3.432). If this figure is multiplied by the total number of tenants in the scheme (i.e. 553), adoption of the optimal farm plans will make the Board save a total of Kshs. 3,299,944.55 per year. This is inform of capital input that could have been given in the present system but are not needed in the optimal plan. This is in addition to increasing the individual tenant's income by Kshs. 9,453.70 per annum (i.e. 18,484.67 - 9,031.50).

In collaboration with the Government, the Board can use these enormous savings to establish a sugar cane processing factory for the scheme. This would help increase the acreage under sugar cane which has turned out to be the most profitable enterprise for the scheme given a readily available market. An increase of this nature would definitely increase tenant incomes even further.

There is a second slack of 0.8791449 acres of short rains land. This would mean such an amount of land as this to be left fallow during the short rains. Such a situation would most likely be welcome by the scheme management since lack of enough rest for the land was one of the main reasons for choosing single cropping. It was argued that continuous irrigation of land led to soil instability hence high rate of bogging down of machines resulting in high maintenance costs. However, the tenants might find such a situation unrealistic due to tradition or erroneously thinking that using this slack land would boost their income. Since green grams can also do well in the scheme during the short rains and require little or no irrigation water as compared to rice, the scheme may need to consider putting this slack short rains land under green grams. However, this depends on how much of the other resources. Labour and capital, have slacks in the optimal farm plan during that period. From table 5B:5 most of these resources are in slacks thus are available for production of greengrams.

The total gross margin resulting from the optimal plan gives a surplus of Kshs. 27,370 above the subsistence requirement. This means that if the optimal farm plans are adopted, the tenant will have an income far above his/her subsistence requirements. This is in contrast to the present farming system where the income earned by the farmer, Kshs. 30,996.50, is far below his/her subsistence requirements of Kshs. 36,371. Infact almost all the interviewed tenants cited hunger and lack of finances to pay for their childrens' school fees as their major problems.

A five year discounted surplus of Kshs. 27,370 will result to a mean annual surplus of about Kshs. 7,974.94 for the typical tenant in WKPS. This means that farming can actually be a very paying business in this scheme despite past failures.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

This study was undertaken to determine an optimal enterprise mix and allocation of resources for the West Kano Pilot Irrigation Scheme. The study was based on data collected between December 1986 and January 1987. It was prompted by the past poor performance of this large scale irrigation scheme and the important role that agric ulture has to play in the development of the national economy.

The main objectives of this study were:

i) To describe the present farming system in the West Kano Pilot Irrigation Scheme.

ii) To examine the major constraints to crop production in the scheme.

iii) To determine whether the present farm plans are optimal or a reallocation of resources is needed to improve the tenants gross margins and incomes.

In order to achieve these objectives, linear programming was chosen as the main tool for data analysis but gross margin comparisons were used as decision criteria. Both secondary and primary data were used in the study. Primary data were specifically needed to determine the amount of family labour available to the average tenant and how much the average family in the scheme requires for subsistence. Tenants' farm accounts, available at N.I.B.'s Kisumu office, were a major source of data on capital. Other sources of data were the Field assistants' records, A.I.R.S. reports and Houtman's (1981) report on labour use in the scheme.

To take into account all the returns from sugar cane, a five-year planning period was adopted for the study. The life cycles of all other crops were adjusted accordingly and all costs and returns were discounted to take care of the effect of time on the value of money.

Arising from the objectives of this study, one main hypothesis was postulated for testing. This was that the present resource use in the scheme is suboptimal and hence a reallocation of resources is needed to optimise returns to the tenants. This hypothesis in essence means that there is a possibility of increasing the tenant incomes by just reorganizing the present stock of resources. It was to be tested by comparing the present tenant farm incomes with the income that accrue from the optimal farm plans after applying the LP technique.

Discussions in chapter five showed that the optimal farm plan resulted in a total gross margin which is at least 84.9 per cent higher than the income from the present farm plan. Thus the hypothesis is not rejected.

6.2 CONCLUSION

From this study, a number of important conclusions can be drawn about irrigation farming in WKPS.

Firstly, it has been shown that the present farming system and its allocation of resources is sub-optimal and to a great extent wastes an enormous amount of money in form of working capital. Incomes to tenants can be more than doubled from the present Kshs. 30,996.11 to Kshs. 63,439.40 by adopting the optimal enterprise mix developed in this study. This requires that the tenant grow rice in 1.92 acres of land during the short rains, green grams in 2.8 acres during the long rains and sugar cane in 1.2 acres. This enterprise mix will remain optimal as long as the marketing facilities for cane allow the tenants to produce upto 90 tonnes of cane and all the other resource constraints are fulfilled. Ninety tonnes of cane are the upper limit, allowed by the sensitivity analysis, above which the optimal farm plan will cease to be optimal.

If adopted, this enterprise mix will save the Board about Kshs. 5,967.35 per year per tenant in form of unused capital. These savings can be used by the Board to deal with other problems that are confronting the scheme (e.g. floods, limited marketing capacity for cane and draught affecting green grams). These problems normally increase the risk in the cane and green grams enterprises and hence have resulted in the tenants reluctance in growing these crops.

Thirdly, it was found that marketing capacity for sugar cane and short rains land are the most limiting resources to crop production in the WKPS. The shadow prices or MVPs of these resources were found to be Kshs. 10,500 and Kshs. 6,738 respectively. November labour (i.e. labour for bird scaring in rice and banking up in cane plots) was also limiting but not to as high a degree as that of the former two resources. The MVP for this labour is Kshs. 50. This is also the month in which the tenant would need the highest amount of hired labour. The amount of family labour available then is 450 man-hours while the amount of labour required by the tenant for his farming operations is 507.84 man-hours. This means that the tenant has to hire a minimum of 57.84 man-hours assuming all the present family members are fully engaged in farm work at the rate of 6 hours a day, 6 days a week.

This study has also shown that the best time for planting sugar cane in WKPS would be between the months of December and February. If cane is planted any other time, the incomes accruing to the tenants will be lower than the optimal. This would be because some operations like land preparation and cane harvesting cannot be done well due to heavy rains or the resulting enterprise mix is just inferior to the optimal alternatives.

From the results obtained in this study, the present bias towards rice production, by tenants in WKPS, can be explained only by the higher degree of risk associated with cane and green grams production in the scheme. Cane has in the past faced a high risk of lacking market outlets while green grams have been reported to suffer adversely from floods or draught. Otherwise these two enterprises have been shown, in this study, to be more profitable than rice production. Table 6:1 shows the incomes for each of the three enterprises in the optimal enterprise mix.

TABLE 6:1 TOTAL GROSS MARGIN PER ENTERPRISE

OPTIMAL ENTERPRISE MIX (MODELS 1 & 3)				
ENTERPRISE	ACREAGE (Acres)	SEASON	TOTAL DISCOUNTED GROSS MARGIN (KSHS)	MEAN ANNUAL INCOME (KSHS)
Rice	1.92	Short rains	17,798.40	5,230.86
Green grams	2.8	Long rains	18,718.00	5,453.96
Sugar cane	1.2	Perennial	22,543.20	6,568.53

Source: LP computer print out.

It is evident from this table that sugar cane is the most profitable enterprise in WKPS followed by green grams. The Board should therefore endeavour to develop these enterprises by solving the problems presently confronting their development.

6:3 RECOMMENDATIONS

From the findings of this study, the following recommendations are made in order to achieve increased incomes to both the tenants and the Board:

i) The present enterprise mix should be changed to the optimal one obtained in this study.

ii) The Board should seek ways of increasing the marketing capacity for sugar cane which will in turn increase tenant incomes. This can be done through more cooperation between the Board, the scheme management and the cane crashing factories, especially the jaggery factory recently built next to the scheme. The Board, or a tenants' cooperative society, can if possible buy shares in this factory so as to increase the scheme's influence on the factory's decision making.

iii) The scheme should add green grams to the present two scheme crops. This would mean offering services like extension, supervision of farm operations and other necessary inputs to tenants for green grams production.

iv) The Board should monitor the provision and utilization of capital inputs by tenants so as to avoid unnecessary waste of these resources. This would help reduce the present high operation cost and their accompanying government subsidies, thus releasing funds for other development purposes.

v) Cane should be planted between the months of December and February for efficiency of farm operations and optimal returns.

In addition to these recommendations, it is the author's view that the Board should consider the following:-

i) Finding more staple markets for green grams so as to ensure the tenants of a market for their produce. Presently, there is no organized market for this crop and hence tenants have had to look for a green grams market for themselves. This way the tenants have a very low bargaining power against the rich buyers of this product and hence stand a high chance of being exploited.

ii) The Board should look into ways of solving the flooding problem which happens to be a great hindrance to farming in this scheme. An engineering study would be recommended to find ways in which this problem can be solved.

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APPENDIX 1 TEN YEAR AVERAGES OF CLIMATIC DATA FOR WKPS, 1975-1985

Month	Temparature deg. C max	min	Mean	Rainfall (mm)	Open pan evaporation
Jan	29.74	16.02	22.88	67.86	6.73
Feb	30.04	16.34	23.19	96.79	6.88
March	30.02	17.08	21.55	165.96	6.77
April	28.18	17.58	22.88	159.17	5.57
May	28.11	16.92	22.52	126.40	5.14
June	27.94	15.59	21.51	82.82	4.93
July	27.54	15.59	21.57	82.82	4.93
August	28.14	15.59	21.87	95.46	5.36
Sept	29.39	15.47	22.43	66.31	6.43
Oct.	29.45	16.33	22.89	73.86	6.19
Nov.	28.81	10.48	22.66	72.85	5.72
Dec.	29.41	15.98	22.70	97.95	6.04
Total	346.79	195.46	271.14	1206.58	71.51
Mean	28.90	16.29	22.60	100.55	5.96

SOURCE: WKPS ANNUAL REPORTS

JUNE1	Land.Prep	Land.PRep*			
JULY1	NurseryWork	Planting			
AUGUST1	Transplanting	Cover.Sets&Fert			
SEPT1	Weed&Clear.Irr.	FirstWeeding			
OCT1	SecondWeeding				
NOV1	BirdScaring	BankUp&Fert			
DEC1	Harvesting				
JAN1			Land.Prep.	Land.Prep.	Land.Prep.
FEB1		SecondWeeding	Planting&Fert	Planting&Fert	Planting&Fert
MARCH1		ClearIrr.System	FirstWeeding	FirstWeeding	FirstWeeding
APRIL1			SecondWeeding	SecondWeeding	SecondWeeding
MAY1			Harvesting	Harvesting	Harvesting
JUNE2	Land.Prep				
JULY2	NurseryWork				
AUGUST2	Transplanting	ClearIrr.System			
SEPT2	Weed&Clear.Irr				
OCT2	SecondWeeding				
NOV2	BirdScaring				
DEC2	Harvesting				
JAN2		Harvesting*	Land.Prep.	Land.Prep.	Land.Prep
FEB2		BurningTrash	Planting&Fert.	Planting&Fert	Planting&Fert
MARCH2		Re.Ridging&Fert	FirstWeeding	FirstWeeding	FirstWeeding
APRIL2		FirstWeeding	SecondWeeding	SecondWeeding	SecondWeeding
MAY2			Harvesting	Harvesting	Harvesting
JUNE3	Land.Prep	BankUp&Fert.			
JULY3	NurseryWork				
AUGUST3	Transplanting				
SEPT3	Weed&ClearIrr.	SecondWeeding			
OCT3	SecondWeeding	CearIrr.System			
NOV3	BirdScaring				
DEC3	Harvesting.				
JAN3			Land.Prep	Land.PREep.	Land.Prep
FEB3		Harvesting*	Planting&Fert	Planting&Fert	Planting&Fert.
MARCH3		BurningTrash	FirstWeeding	FirstWeeding	FirstingWeeding
APRIL3		Re.Ridging&Fert	SecondWeeding	SecondWeeding	SecondWeeding
MAY3		FirstWeeding	Harvesting	Harvesting	Harsting '
JUNE4	Land.Prep.	BankUp&Fert.			
JULY4	NurseryWork				
AUGUST4	Transplanting				
SEPT4	Weed&ClearIrr.				
OCT4	SecondWeeding	SecondWeeding			
NOV4	BirdScaring	ClearIrr.System			
DEC4	Harvesting				
JAN4			Land.Prep.	Land.Prep	Land.Prep
FEB4			Planting&Fert	Planting&Fert	Planting&Fert
MARCH4		Harvesting*	FirstWeeding	FirstWeeding	FistWeeding
APRIL4		BurningTrash,	SecondWeeding	SecondWeeding	SecondWeeding
MAY4		Re.Ridging&Fert	Harvesting	Harvesting	Harvesting
JUNE5	Land.Prep.	FirstWeeding			
JULY5	NurseryWork	BankUp&Fert.			
AUGUST5	Transplanting				
SEPT5	Weed&ClearIrr.				
OCT5	SecondWeeding				
NOV5 .	BirdScaring	SecondWeeding			
DEC5	Harvesting	ClearIrr.System			
JAN5			LandPrep.	Land.Prep	LandPrep
FEB5			Planting&Fert	Planting&Fert.	Planting&fert.
MARCH5			FirstWeeding	FirstWeeding	FirstWeeding
APRIL5		Harvesting *	SecondWeeding	SecondWeeding	SecondWeeding
MAY5			Harvesting	Harvesting	Harvesting

	RICE.	SUGARCANE	GREENGRAMS	SORGHUM	BEANS
JUNE1	Land.Prep				
JULY1	NurseryWork				
AUGUST1	Transplanting				
SEPT1	Weed&ClearIrr.				
OCT1	SecondWeeding				
NOV1	BirdScaring	Land.Prep*			
DEC1	Harvesting	Planting			
JAN1		Cover.Sets&Fert	Land.Prep	Lnad.Prep.	Land.Prep.
FEB1		FirstWeeding	Planting	Planting	Planting
MARCH1			FirstWeeding	FirstWeeding	FirstWeeding
APRIL1		BankUp&Fert.	SecondWeeding	SecondWeeding	SecondWeeding
MAY1			Harvesting	Harvesting	Harvesting
JUNE2	Land.Prep.				
JULY2	NurseryWork	SecondWeeding			
AUGUST2	Transplanting	ClearIrr.System			
SEPT2	Weed&ClearIrr.				
OCT2	SecondWeeding				
NOV2	BirdScaring				
DEC2	Harvesting				
JAN2		ClearIrr.System	Land.Prep	LandPrep.	Land.Prep.
FEB2			Planting	Planting	Planting
MARCH2			FirstWeeding	FirstWeeding	FirstWeeding
APRIL2			SecondWeeding	SecondWeeding	SecondWeeding
MAY2			Harvesting	Harsting	Harvesting
JUNE3	Land.Prep.	Harvesting*			
JULY3	NurseryWork	BurningTrash			
AUGUST3	Transplanting	Re.Ridge&Fert.			
SEPT3	Weed&ClearIrr.	FirstWeeding			
OCT3	SecondWeeding	BankUp&Fert.			
NOV3	BirdScaring				
DEC3	Harvesting				
JAN3			LandPrep.	Land.Prep.	Land.Prep.
FEB3		SecondWeeding	planting	planting	Planting
MARCH3		ClearIrr.System	FirstWeeding	FirstWeeding	FirstWeeding
APRIL3			SecondWeeding	SecondWeeding	SecondWeeding
MAY3			Harvesting	Harveting	Harvesting
JUNE4	Land.Prep.				
JULY4	NurseryWork.	Harvesting*			
AUGUST4	Transplanting	BurningTrash			
SEPT4	Weed&ClearIrr.	Re.ridge&Fert.			
OCT4	SecondWeeding	FirstWeeding			
NOV4	BirdScaring				
DEC4	Harvesting	BankUp&Fert.			
JAN4			Land.Prep.	Land.Prep.	Land.Prep.
FEB4			Planting	Planting	Planting
MARCH4		SecondWeeding	FirstWeeding	FirstWeeding	FirstWeeding
APRIL4		ClearIrr.System	SecondWeeding	SecondWeeding	SecondWeeding
MAY4			Harvesting	Harvesting	Harvesting
JUNE5	Land.Prep.				
JULY5	NurseRyWork				
AUGUST5	Transplanting	Harvesting*			
SEPT5	Weed&ClearIrr.	BurningTrash			
OCT5	SecondWeeding	Re.Ridge&Fert.			
NOV5	BirdScaring	FirstWeeding			
DEC5	Harvesting	BankUp&Fert.			
JAN5			Land.Prep.	Land.Prep.	LandPrep.
FEB5			Planting	Planting	Planting
MARCH5		SecondWeeding	FirstWeeding	FirstWeeding	FirstWeeding
APRIL5		ClearIrr.System	SecondWeeding	SecondWeeding	SecondWeeding
MAY5			Harvesting	Harvesting	Harvesting

This..Ratoon..

Will..be..Harvested..in..AUGUST6

APPENDIX 5

QUESTIONAIRE: SECTION A:

RESPONDENTS NAME ....

AGE............

PLOT NO.............

1. When did you become a tenant in this scheme?

....

2. How many people do you have living in your home?

....

3. How many of these are available for farm-work?

Family member	No.	Average No. of hours worked/day	Av. No. of months available for farm work per year
Husband	...	....	....
Wife(s)	...	....	....
Children	...	....	....
Relatives	...	....	....

4. How many permanent farm labourers do you have? ......

5. How much do you pay each per month? Kshs ....

6. How many casual labourers do you employ for various crop activities?

Crop	Activity	Av. No. of employees	Rate of of pay/day	Av. No. Of days worked
Rice	Planting	......	.....	......
	Weeding 1st	......	.....	......
	2nd	......	.....	......
	Feeder & Drainage	......	.....	......
	Clearing	......	.....	......
	Harvesting	......	.....	......
	Cutting	......	.....	......

Crop	Activity	Av. No. of employees	Rate of pay/day	Av. No. Of days worked
	Stucking	......	.....	......
	Thresning & winnowing	......	.....	......
	Transport	......	.....	......
Sugar cane	Weeding	......	.....	......
	Feeder & Drainage	......	.....	......
	Clearing	......	.....	......

7. Do you own a farm outside this scheme? Yes/ No

8. How far and how big? .... Km, ...acres

9. What do you normally grow on that land?

	Enterprise	acres	output
a.	....	......	....
b.	....	......	....
c.	....	......	....

10. What off-farm activities do you do and how much money do you earn from them per day (month or year)?

	Activity	Kshs
a.	....	....
b.	....	....

11. What enterprises do you grow in your homestead and how much do you get out of them?

	Enterprise	Output	Kshs/annum
a.	....	......	....
b.	....	......	....

12. After harvesting rice, what dryland crops did you plant in your rice plot last season?

	Crop	Output	Kshs.
a.	....	....	....
b.	....	....	....
c.	....	....	....

13. What other sources of credit do you have a part from the Board?

	Source	Amount /yr	Interest rate
a.	....	....	....
b.	....	....	....
c	....	....	....

14. What are the major problems tenants face in this scheme? ....

....

....

15. What other enterprises do you wish the board should allow tenants to keep in their plots? ....

....

16. a) How much rice did you receive from the board for consumption last season? ..... bags.

b) How much of this was consumed at home ....

c) How much did you sell and at what price?

.... bags, at ....Kshs/kg or bag.

17. What other food stuffs does your family use and at what rate?

	food stuff	rate/week	Cost
a.	....	....	....
b.	....	....	......

Section B (From tenants farm Records)

INFORMATION ON TENANTS INPUT USE ON THE SCHEME

1. Amounts of fertilizer used by the tenant.

Crop	Name of Fertilizer	Amount Applied -Kg
1. Rice	....	....
2. Plant cane	....	....
3. 1st Ratoon	....	....
4. 2nd "	....	....
5. 3rd "	....	....

2. Current price of the various fertilizers: per kg.

1. ....

2. ....

3. ....

3. Water application to crops by tenants.

Crop	Frequency of water Application times/wk	Estimated intake MM
Rice	....	....
Plant cane	....	....
1st Ratoon	....	....
2nd Ratoon	....	....
3rd Ratoon	....	....

....

4. Pesticides applied by tenant:-

Crop	Names of Pesticides	Rate of application
1.	....	....
2.	....	....
3.	....	....
4.	....	....

5. Current prices of the various pesticides used.

Pesticide	Cost
....	....
....	....
....	....
....	....
....	....
....	....

6. Seed use in the last season:-

	Crop	Amount of seed	Cost of seed
1.	....	....	....
2.	....	....	....
3.	....	....	....
4.	....	....	....
5.	....	....	....

7. Tractor hours spent in land preparation:-

	Crop	Type of machine	Machinery time
1.	....	....	....
2.	....	....	....
3.	....	....	....
4.	....	....	....

8. Harvest and transport costs for cane.

Amount of hired labour for harvesting ....

No. of trips to factory ....

Total cost ....

9. LABOUR INPUT USE

Crop	Activity	Number of workers	No. of Days worked	Charge/ person/ Day	Total charge

10. <u>INFORMATION</u> <u>CONCERNING</u> <u>OUTPUTS</u> (Mean over last five yrs)

Crop	Amount harvested	Amount consumed	Amount sold	per unit price	Gross income
1.	....	......	.....	......	.....
2.	....	......	.....	......	.....
....	....	......	.....	......	.....

N.B. Information in section B will be compared with the corresponding recommeded input levels from the research station which will be filled in the table below.

Crop	Activity	Input	Research St. Recom.	Mean applied	Difference

COMPOUNDING AND DISCOUNTING TABLES

APPENDIX 6 — 6. *Three-decimal Table for Discount Factor, Various Rates*

DISCOUNT FACTOR—How much 1 at a future date is worth today

Year	1%	3%	5%	6%	8%	10%	12%	14%	15%	16%	18%
1	990	971	952	943	926	909	893	877	870	862	847
2	980	943	907	890	857	826	797	769	756	743	718
3	971	915	864	840	794	751	712	675	658	641	609
4	961	888	823	792	735	683	636	592	572	.552	516
5	.951	863	784	.747	681	621	567	.519	497	476	437
6	942	837	746	705	630	564	507	456	432	410	370
7	.933	.813	711	665	583	.513	452	400	.376	.354	.314
8	.923	789	677	627	.540	467	404	351	327	.305	266
9	.914	766	645	592	.500	424	.361	.308	.264	.263	.225
10	.905	.744	.614	.558	463	386	.322	270	.247	.227	.191
11	896	.722	585	527	429	350	.287	237	.215	195	.162
12	.887	701	[illegible]	497	397	319	257	208	.187	168	137
13	.879	681	530	469	368	290	229	182	.163	145	.116
14	870	661	505	442	340	263	205	160	141	.125	099
15	861	642	481	417	.315	239	.183	140	123	.108	084
16	853	623	458	394	292	218	163	123	107	093	071
17	844	605	436	371	270	198	146	108	093	080	060
18	836	587	416	350	250	180	130	095	081	069	051
19	828	570	396	331	232	164	116	083	070	060	043
20	820	554	377	312	215	149	104	073	051	051	037
21	811	538	359	294	199	135	093	064	053	044	031
22	803	522	342	278	184	123	083	056	046	038	026
23	795	507	326	262	170	112	074	049	040	033	022
24	788	492	310	247	158	.102	066	043	035	028	019
25	780	478	295	233	146	092	059	038	030	024	016
26	772	464	281	220	135	084	053	033	026	021	014
27	764	450	268	.207	125	076	047	029	023	018	011
28	[illegible]	[illegible]	[illegible]	[illegible]	110	[illegible]	042	[illegible]	[illegible]	[illegible]	[illegible]
29	749	424	243	185	107	063	037	022	017	014	005
30	742	412	231	174	099	057	033	020	015	012	007
35	706	355	181	130	068	036	019	010	008	006	003
40	672	307	142	097	046	022	011	005	004	003	001
45	639	264	111	073	031	014	006	003	002	001	001
50	608	228	087	054	021	009	003	001	001	001	000

Year	20%	22%	24%	25%	26%	28%	30%	35%	40%	45%	50%	Year
1	.833	.820	806	800	794	781	769	741	714	690	667	1
2	.694	.672	.650	640	.630	610	592	549	510	476	444	2
3	.579	.551	524	512	500	477	455	406	364	328	296	3
4	482	451	423	410	397	.373	350	301	260	226	198	4
5	402	370	.341	328	.315	.291	.269	223	186	156	132	5
6	.335	.303	.275	262	.250	.227	.207	165	133	108	088	6
7	.279	.249	.222	.210	.198	.178	.159	122	095	074	059	7
8	.233	.204	.179	.168	.157	.139	.123	091	068	051	039	8
9	.194	.167	.144	.134	.125	.108	.094	067	048	.035	.026	9
10	.162	.137	.116	.107	.099	085	.073	050	035	.024	.017	10
11	.135	.112	.094	.086	.079	066	.056	.037	025	.017	012	11
12	.112	092	076	.069	062	052	043	027	018	012	008	12
13	093	.075	061	.055	050	040	033	020	013	008	005	13
14	.078	.062	049	044	039	032	025	015	009	006	003	14
15	.065	.051	040	.035	.031	.025	.020	011	006	004	002	15
16	054	042	.032	028	025	.019	015	008	005	003	002	16
17	045	034	026	023	020	015	012	006	003	002	001	17
18	038	028	021	018	016	.012	009	005	002	001	001	18
19	031	023	.017	.014	012	.009	007	003	002	001	000	19
20	026	019	.014	012	010	.007	005	002	001	001	000	20
21	022	015	011	009	008	006	004	002	001	000	000	21
22	018	013	009	007	006	004	003	001	001	000	000	22
23	015	010	007	006	005	003	002	001	000	000	000	23
24	013	008	006	005	004	003	002	001	000	000	000	24
25	010	007	005	004	003	002	001	001	000	000	000	25
26	009	006	004	003	002	002	001	000	000	000	000	26
27	007	005	003	002	002	001	001	000	000	000	000	27
28	[illegible]	004	002	002	002	001	001	000	000	[illegible]	[illegible]	28
29	005	003	002	002	001	001	000	000	000	000	000	29
30	004	003	002	001	001	001	000	000	000	000	000	30
35	002	001	001	000	000	000	000	000	000	000	000	35
40	001	000	000	000	000	000	000	000	000	000	000	40
45	000	000	000	000	000	000	000	000	000	000	000	45
50	000	000	000	000	000	000	000	000	000	000	000	50

Source: Gittinger (1982)

	RICE	SUGARCANE	GREENGRAMS	SORGHUM	BEANS	
OBJ.FN.MAX	9274	18786	6685	4081	3741	
Subject.To						
JAN1	0	0	24	24	24LE	450
FEB1	0	208	32	48	72LE	450
MARCH1	0	136	64	64	72LE	450
APRIL1	0	104	64	64	64LE	825
MAY1	0	0	80	64	64LE	450
JUNE1	155	124	0	0	OLE	512
JULY1	27	0	0	0	OLE	464
AUGUST1	173	0	0	0	OLE	987
SEPT1	168	104	0	0	OLE	532
OCT1	118	50	0	0	OLE	506
NOV1	187	0	0	0	OLE	484
DEC1	250	0	0	0	OLE	1105
JAN2	0	0	24	24	24LE	450
FEB2	0	0	32	48	72LE	450
MARCH2	0	50	64	64	72LE	450
APRIL2	0	0	64	64	64LE	825
MAY2	0	0	80	64	64LE	450
JUNE2	155	0	0	0	OLE	512
JULY2	27	0	0	0	OLE	464
AUGUST2	173	0	0	0	OLE	987
SEPT2	168	24	0	0	OLE	532
OCT2	118	59	0	0	OLE	506
NOV2	187	104	0	0	OLE	484
DEC2	250	124	0	0	OLE	1105
JAN3	0	0	24	24	24LE	450
FEB3	0	0	32	48	72LE	450
MARCH3	0	0	64	64	72LE	450
APRIL3	0	104	64	64	64LE	825
MAY3	0	50	80	64	64LE	450
JUNE3	155	0	0	0	OLE	512
JULY3	27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AUGUST3	173	0	0	0	OLE	987
SEPT3	168	0	0	0	OLE	532
OCT3	118	24	0	0	OLE	506
NOV3	187	59	0	0	OLE	484
DEC3	250	104	0	0	OLE	1105
JAN4	0	0	24	24	24LE	450
FEB4	0	124	32	48	72LE	450
MARCH4	0	0	64	64	72LE	450
APRIL4	0	0	64	64	64LE	825
MAY4	0	104	80	64	64LE	450
JUNE4	155	50	0	0	OLE	512
JULY4	27	0	0	0	OLE	464
AUGUST4	173	0	0	0	OLE	987
SEPT4	168	0	0	0	OLE	532
OCT4	118	0	0	0	OLE	506
NOV4	187	24	0	0	OLE	484
DEC4	250	59	0	0	OLE	1105
JAN5	0	104	24	24	24LE	450
FEB5	0	124	32	48	72LE	450
MARCH5	0	0	64	64	72LE	450
APRIL5	0	0	64	64	64LE	825
MAY5	0	0	80	64	64LE	450
JUNE5	155	104	0	0	OLE	512
JULY5	27	50	0	0	OLE	464
AUGUST5	173	0	0	0	OLE	987
SEPT5	168	0	0	0	OLE	532
OCT5	118	0	0	0	OLE	506
NOV5	187	0	0	0	OLE	484
DEC5	250	0	0	0	OLE	1105
WK.CAPITAL	12005	19538	522	861	1200LE	60447
LR.LAND	0	1	1	1	4LE	4
SR.LAND	1	1	0	0	OLE	4
[illegible]	0	1	0	0	OLE	1.2

36371

OBJ;MN.MAX	9274	18786	6685	4081	3741	
Subject.To						
JUNE1	155	0	0	0	0LE	512
JULY1	27	208	0	0	0LE	464
AUGUST1	173	136	0	0	0LE	987
SEPT1	168	404	0	0	0LE	532
OCT1	118	0	0	0	0LE	506
NOV1	187	124	0	0	0LE	484
DEC1	250	0	0	0	0LE	1105
JAN1	0	0	24	24	24LE	450
FEB1	0	104	32	48	72LE	450
MARCH1	0	80	64	64	72LE	450
APRIL1	0	0	64	64	64LE	825
MAY1	0	0	80	64	64LE	450
JUNE2	155	0	0	0	0LE	512
JULY2	27	0	0	0	0LE	464
AUGUST2	173	50	0	0	0LE	987
SEPT2	168	0	0	0	0LE	532
OCT2	118	[illegible]	0	0	0LE	506
NOV2	187	0	0	0	0LE	484
DEC2	250	0	0	0	0LE	1105
JAN2	0	0	24	24	24LE	450
FEB2	0	24	32	48	72LE	[illegible]
MARCH2	0	59	64	64	72LE	450
APRIL2	0	104	64	64	64LE	825
MAY2	0	0	80	64	64LE	450
JUNE3	155	124	0	0	0LE	512
JULY3	27	0	0	0	0LE	464
AUGUST3	173	0	0	0	0LE	987
SEPT3	168	104	0	0	0LE	532
OCT3	118	50	0	0	0LE	[illegible]
NOV3	187	0	0	0	0LE	484
DEC3	250	0	0	0	0LE	1105
JAN3	0	0	24	24	24LE	450
FEB3	0	0	32	48	72LE	486
MARCH3	0	24	64	64	72LE	450
APRIL3	0	59	64	64	64LE	825
MAY3	0	104	80	64	64LE	450
JUNE4	155	124	0	0	0LE	512
JULY4	27	0	0	0	0LE	464
AUGUST4	173	0	0	0	0LE	987
SEPT4	168	0	0	0	0LE	532
OCT4	118	104	0	0	0LE	506
NOV4	187	50	0	0	0LE	484
DEC4	250	0	0	0	0LE	1105
JAN4	0	0	24	24	24LE	450
FEB4	0	0	32	48	72LE	450
MARCH4	0	0	64	64	72LE	450
APRIL4	0	24	64	64	64LE	825
MAY4	0	59	80	64	64LE	450
JUNE5	155	104	0	0	0LE	512
JULY5	27	124	0	0	0LE	464
AUGUST5	173	0	0	0	0LE	987
SEPT5	168	0	0	0	0LE	532
OCT5	118	0	0	0	0LE	506
NOV5	187	104	0	0	0LE	484
DEC5	250	50	0	0	0LE	1105
JAN5	0	0	24	24	24LE	450
FEB5	0	0	32	48	72LE	450
MARCH5	0	0	64	64	72LE	450
APRIL5	0	0	64	64	64LE	825
MAY5	0	0	80	64	64LE	450
WK.CAPITAL	12000	19538	322	861	1200LE	60447
LR.LAND	0	1	1	1	1LE	4
SR.LAND	1	1	0	0	0LE	4
MKT.CONSTR	0	1	0	0	0LE	1.2
[illegible]	9274	18786	6685	4081	3741GE	35371

RICE	SUGARCANE					
OBJ.FN.MAX	9274	18786	4685	4081	3741	
Subject.To						
JUNE1	155	0	0	0	OLE	512
JULY1	27	0	0	0	OLE	464
AUGUST1	173	0	0	0	OLE	987
SEPT1	168	0	0	0	OLE	537
OCT1	118	0	0	0	OLE	506
NOV1	187	0	0	0	OLE	484
DEC1	250	208	0	0	OLE	1105
JAN1	0	136	24	24	24LE	450
FEB1	0	104	32	48	72LE	450
MARCH1	0	0	64	64	72LE	450
APRIL1	0	124	64	64	64LE	825
MAY1	0	0	80	64	64LE	450
JUNE2	155	0	0	0	OLE	512
JULY2	27	104	0	0	OLE	464
AUGUST2	173	50	0	0	OLE	987
SEPT2	168	0	0	0	OLE	532
OCT2	118	0	0	0	OLE	506
NOV2	187	0	0	0	OLE	484
DEC2	250	0	0	0	OLE	1105
JAN2	0	50	24	24	24LE	450
FEB2	0	0	32	48	72LE	450
MARCH2	0	0	64	64	72LE	450
APRIL2	0	0	64	64	64LE	825
MAY2	0	0	80	64	64LE	450
JUNE3	155	0	0	0	OLE	512
JULY3	27	24	0	0	OLE	464
AUGUST3	173	59	0	0	OLE	987
SEPT3	168	104	0	0	OLE	532
OCT3	118	124	0	0	OLE	506
NOV3	187	0	0	0	OLE	484
DEC3	250	0	0	0	OLE	1105
JAN3	0	0	24	24	24LE	450
FEB3	0	104	32	48	72LE	450
MARCH3	0	50	64	64	72LE	450
APRIL3	0	0	64	64	64LE	825
MAY3	0	0	80	64	64LE	450
JUNE4	155	0	0	0	OLE	512
JULY4	27	0	0	0	OLE	464
AUGUST4	173	24	0	0	OLE	987
SEPT4	168	59	0	0	OLE	532
OCT4	118	104	0	0	OLE	506
NOV4	187	0	0	0	OLE	484
DEC4	250	124	0	0	OLE	1105
JAN4	0	0	24	24	24LE	450
FEB4	0	0	32	48	72LE	450
MARCH4	0	104	64	64	72LE	450
APRIL4	0	50	64	64	64LE	825
MAY4	0	0	80	64	64LE	450
JUNE5	155	0	0	0	OLE	512
JULY5	27	0	0	0	OLE	464
AUGUST5	173	0	0	0	OLE	987
SEPT5	168	24	0	0	OLE	532
OCT5	118	59	0	0	OLE	506
NOV5	187	104	0	0	OLE	484
DEC5	250	124	0	0	OLE	1105
JAN5	0	0	24	24	24LE	450
FEB5	0	0	32	48	72LE	450
MARCH5	0	104	64	64	72LE	450
APRIL5	0	50	64	64	64LE	825
MAY5	0	0	80	64	64LE	450
WK.CAPITAL	12005	19538	522	861	1200LE	60447
LR.LAND	0	1	1	1	1LE	4
SR.LAND	1	1	0	0	OLE	4
MKT.CONSTR	0	1	0	0	OLE	1.2
	[illegible]	[illegible]	4685	4081	3741GE	36371

APPENDIX 8 THE RANGE OF FEASIBILITY FOR MODEL 2

CONSTRAINT		LOW RANGE	UNITS OF RESOURCE	UPPER RANGE
1)	JE1	277.8395	512	1E+38
2)	JE3	426.6396	512	1E+38
3)	JE5	402.6394	512	1E+38
4)	JEI	297.9979	464	1E+38
5)	JY5	197.1979	1E+38	1E+38
6)	AG1	473.3048	984	1E+18
7)	AG2	370.1049	984	1E+38
8)	ST1	425.9421	532	1E+38
9)	ST2	301.1421	532	1E+38
10)	OT3	271.5164	506	1E+38
11)	OT4	336.3165	506	1E+38
12)	NV1	148.8	484	508.0001
13)	NV2	335.1999	484	1E+38
14)	NV4	195.1998	484	1E+18
15)	NV5	459.9999	484	1E+38
16)	DC5	508.1282	1105	1E+38
16	JN1	67.20001	450	1E+38
18)	FB1	214.1	450	1E+38
19)	FB2	118.3999	450	1E+38
20)	FB3	89.60001	450	1E+38
21)	MR1	239.2	450	1E+38
22)	MR2	160.4	450	1E+38
23)	MR3	207.9999	450	1E+18
24)	MR4	179.2	450	1E+38
25)	AP1	179.1998	825	1E+38
26)	AP2	304	825	1E+38
27)	AP3	250	825	1E+38
28)	AP4	208.0002	825	1E+38
29)	MY1	224	450	1E+38
30)	MY1	348.800-	450	1E+18
31)	MY4	294.8	450	1E+38
32)	WKC	46426.32	68447	1E+38
33)	LRL	1.2	4	5.264999
34)	SRL	2.992513	4	1E+38
35)	MKC	0.[illegible]	1.2	2.073253
36)	SBC	10199.57	36371	1E+38

THE RANGE IN WHICH THE SAME VARIABLES REMAIN IN SOLUTION.

SOURCE: LP COMPUTER PRINT OUT

APPENDIX 9 : THE RANGE OF FEASIBILITY FOR MODEL 3

CONSTRAINT		LOW RANGE	UNITS OF RESOURCE	HIGH RANGE
1)	JE1	297.7326	512	1E+38
2)	JY2	176.6631	464	1E+38
3)	JY3	80.66309	464	1E+18
4)	AG2	392.308	984	1E+38
5)	AG3	403.108	984	1E+38
6)	AG4	361.108	984	1E+18
7)	ST1	322.7037	532	1E+38
8)	ST3	447.5017	532	1E+38
9)	ST4	393.5037	532	1E+38
10)	ST5	351.5037	512	1E+38
11)	OT3	375.4609	506	1E+38
12)	OT4	351.4609	506	1E+38
13)	OT5	297.4609	506	1E+38
14)	NV1	359.2	484	1E+38
15)	NV5	124.8	484	578.0524
16)	DC1	729.8138	1105	1E+38
17)	DC4	629.0139	1105	1E+38
18)	JN1	230.4	450	1E+38
19)	JN2	127.2	450	1E+38
20)	JN3	67.20001	450	1E+38
21)	FB1	214.4	450	1E+38
22)	FB2	89.60001	450	1E+38
23)	MR1	179.2	450	1E+38
24)	MR2	2[illegible]9.2	450	1E+38
25)	MR3	239.2	450	1E+38
26)	MR4	304	450	1E+38
27)	AP1	328	825	1E+38
28)	AP2	179.2	825	1E+38
29)	AP4	239.2	824	1E+38
30)	MY1	224	450	1E+38
(31)	WKC	47967.07	68447	1E+38
32)	LRL	1.2	4	6.28125
(33)	SRL	3.120856	4	1E+38
34)	MKC	1.192091E-07	1.2	2.859716

THE RANGE IN WHICH THE SAME VARIABLES REMAIN IN SOLUTION

SOURCE: LP COMPUTER PRINT OUT