

A LINEAR PROGRAMMING APPROACH TO THE OPTIMAL
ALLOCATION OF RESOURCES AND COMBINATION OF CROP
ENTERPRISES IN THE PERKERRA IRRIGATION SCHEME, KENYA.

BY

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ABSTRACT

The need to study farming at the farm level and to try to improve the welfare and security of the farmer and his family with structural changes effected via the adoption of improved farm plans cannot be over-emphasised in the developing countries. Powerful models to study farming at the farm level and the ways in which it can be adjusted to the advantage of the farming family have been in vogue since the late 1950's. One of these basic models is linear programming which, through the use of high speed computers and due to its ability to handle very complex systems such as are found with subsistence and other small scale farming, has been used in this study.

The study looks at the Perkerra Irrigation Scheme and tries to reorganise the allocation of the existing stock of resources on a typical holding for the maximization of the Gross Margin. It is shown that via rigorous derivations of weights (prices and costs) and by using these in linear programming equations, farm plans can be obtained which yield higher Gross Margins than the existing plan in the P.I.S.

One section of the study has shown that the carry-over of capital from one crop season to another gives the farmer a strong position in the sense that he finds no need of borrowing capital to furnish his operating capital needs. On the whole the study is an eye-opener to planners because it shows the potential that exists in the use of modern programming methods to improve life in Kenya's National Irrigation Schemes.

CHAPTER 1.

INTRODUCTION

1.1 A GENERAL NOTE ON KENYA'S NATIONAL IRRIGATION SCHEMES

The National Irrigation Board (NIB), which is a parastatal body of the Government of Kenya (Republic of Kenya, 1963) is responsible for the construction and running of the "large" irrigation schemes in Kenya. These large irrigation schemes are those which are an important supplier of a nationally important food product. As an example over 90% of all the rice in Kenya comes from NIB schemes (The Weekly Review, June 1979). Also prior to the removal of the quota system on onions in 1973 the NIB was supplying over 60% of the local market needs mainly from the Perkerra Irrigation Scheme (P.I.S) which is one of Kenya's large irrigation schemes. The P.I.S is one of the seven irrigation schemes currently under the organization of the NIB. Table 1.1 gives the names of these irrigation schemes, the districts where they are located, their hectarages as in 1977, the crops grown in each and the approximate date when each of them was opened.

P.I.S is located in Marigat Division of Baringo District in the Rift Valley Province, Kenya.

TABLE 1.1 NATIONAL IRRIGATION SCHEMES UNDER
THE NATIONAL IRRIGATION BOARD, 1977.

	AHERO	BUNYALA	BURA	HOLA	MWEA	PERKERRA	WEST KANO
District	Kisumu	Busia	Tana River	Tana River	Kirinyaga	Baringo	Kisu
Area (ha)	850	381	0 ¹⁾	860	5,700	195	890
Crops	Rice	Rice	in plan	Cotton	Rice	Hort. crops	Rice Suga
Date Started	1969	1970	---	1954	1954	1954	1976

SOURCES: 1) NIB Annual Reports, 1967-68 to 1976-7

2) Assistant Chief Engineer, NIB,
personal communication

Initial developments of irrigation from the Perkerra River were carried out by the African Land Development Board (ALDEV) and the staff of the Department of Agriculture using detainee labour without engineering assistance, (Pereira, 1958). Results of trials with maize, sorghum, groundnuts and sugarcane were ready in 1954. These trials showed the soil to be fertile without immediate salinity problems, (Pereira, 1958, p.246).

1) The Scheme comes into production in 1982.

1.2 PROBLEM FORMULATION AND OBJECTIVES OF THE STUDY

This thesis is based wholly on the P.I.S. Since its inception the P.I.S encountered many problems emanating from its social structure, the erratic flow of the Perkerra River, and most importantly a heuristic effort to find a suitable crop for the scheme. The thesis will contribute to the solution of the crop choice problem using modern planning techniques which have not been used on the problem before. It is felt that choice of a crop or a galaxy of crops suitable to the scheme is central to the solution of most of the scheme's problems which will be discussed below.

Based on the foregoing problem statement the objectives of the study are the following.

- 1) To describe horticultural farming as currently performed in the P.I.S. The P.I.S is presently producing onions, chillies, maize and beans. The production of these crops will be described in detail with special attention being paid to the economics of production.
- 2) To investigate whether farm planning using modern planning techniques can contribute to the improvement of gross margins of individual production units in the scheme.

Optimal plans for production units at various levels of production will be drawn and compared with the status quo. It is hoped that the optimal farm plans developed in the study can be useful in the decision making process by the management of the scheme and the individual farmers.

1.3 THE RELEVANCE OF THE STUDY IN THE CONTEXT OF THE KENYAN ECONOMY.

Compared with other national irrigation schemes P.I.S makes relatively larger losses every year.¹⁾ As a result of these losses the Government of Kenya subsidises the operation and maintenance of the P.I.S. Over and above the Government subsidies the NIB covers the scheme's operating losses at the end of every financial year with what it calls grants. These grants are equivalent to the losses made by the scheme in the year. This flow of Government and NIB grants is shown on Table 2.²⁾

It is clear from the Table that the scheme did not break even in any of the years from 1967 to 1977.

1) See for example NIB Annual accounts 1967/68-1976/77.
2) For additional financial data on the P.I.S see Appendix 3.

The study is therefore relevant in the context of the whole Kenyan economy because it will contribute in making P.I.S an economically viable agricultural venture. If P.I.S realised profits the financial resources that go into its operation and maintenance would be directed to another needy sector of the economy.

TABLE 1.2 GOVERNMENT OF KENYA AND NIB GRANTS TOWARDS THE OPERATION AND MAINTENANCE OF THE P.I.S AND OTHER NIB SCHEMES.

Year	Perkerra Irrigation Scheme		Grants to NIB for distribution to all schemes.	
	2 Government grant K£	3 NIB grant K£	4 ¹⁾	5 3 as % of 4
1967		19,399	---	---
1968		24,401	100,000	24.4
1969		20,305	5,705	355.9
1970		13,707	---	---
1971		14,379	286,370	5.0
1972		17,481	197,171	2.9
1973		17,908	458,123	3.9
1974	15,000	4,398	---	---
1975	10,000	---	---	---
1976	15,000	29,958	1,166,979	2.6
1977	43,000	11,749	---	---

SOURCE: NIB Annual Reports 1966/67-1976/77.

1) This excludes direct grants to various schemes for development purposes.

In absolute terms the P.I.S has received some Kf 256,700 in form of subsidies over the last eleven years. It received the highest grants in 1976 and 1977, suggesting that it made the greatest losses during those two years. This continued low performance of the P.I.S has given it a place in the operational research priority list¹⁾ of the NIB.

A second consideration that renders the study relevant to the economy is that if the Perkerra tenant²⁾ could realise profits he would generally raise his standard of living and he would also invest in development projects which would play an important role in the development of the lower Baringo.

1) The NIB continuously monitors the performance of the schemes under its organization and conducts research to improve the situation.

2) In this study tenant and farmer are used interchangeably

CHAPTER 2.

ENVIRONMENTAL CHARACTERISTICS OF THE STUDY AREA

2.1 GENERAL

This chapter describes the geography of the area where the P.I.S is located and relates the geographical location of the scheme to the urban centres where the bulk of the scheme produce is marketed. The feasibility of farm plans is best decided upon in the light of the possible geographical, social and infrastructural limitations that the area may have. Economic inputs should also be seen in an environmental context.

2.2 LOCATION AND COMMUNICATIONS

The P.I.S lies on the floor of the Rift Valley at co-ordinates 00-28' North and 36-02' East. It falls between Lakes Baringo in the North-East and Bogoria in the South-East at an elevation of 1,000 m above sea level.¹⁾ P.I.S lies in a potentially irrigable stretch of 2,400 ha which is part of the Njemps (Iljamus) flats. This part of Baringo District is termed the low zone and its altitude ranges between 914 m on the shores of Lake Baringo and 1,524 m on the Torgen (Tugen) forest area.

1) Research station building stands at 1,005m ASL.

The scheme is located 100 Km north of Nakuru, the only sizeable shopping centre near to the scheme. A murram road links the P.I.S to Nakuru in the south and Kabarnet, the district headquarters to the west. Northwards the road goes on to Loruk.

A small airstrip two kilometres north of Marigat shopping centre serves the area. Most of the scheme produce finds its way to Nairobi, Mombasa and Kisumu by road.

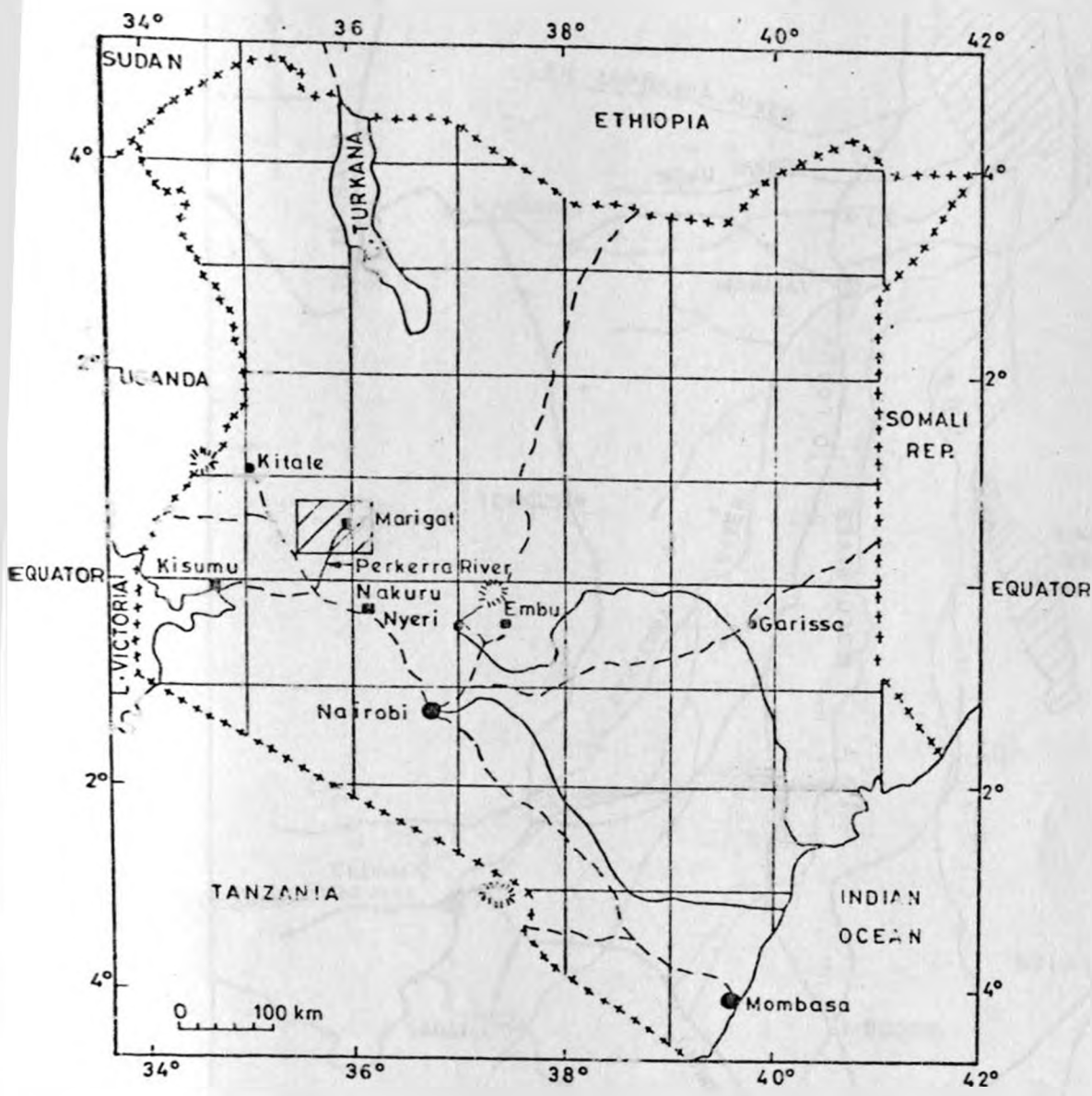
The scheme area is served by Marigat shopping centre. Marigat consists of a few shops, a lodge, a health centre, the office of the District Officer and a Police Post which has played a notable role in stifling the onion black market. Figure 2.1 shows the location of Marigat within the Baringo-Kericho Valley area. Figure 2.2 is a map of South Baringo showing the location of the P.I.S within that zone.

2.3 CLIMATE

2.3.1 PRECIPITATION

Averaged over a ten year period from 1968 to 1977 the P.I.S precipitation data approximated the following:

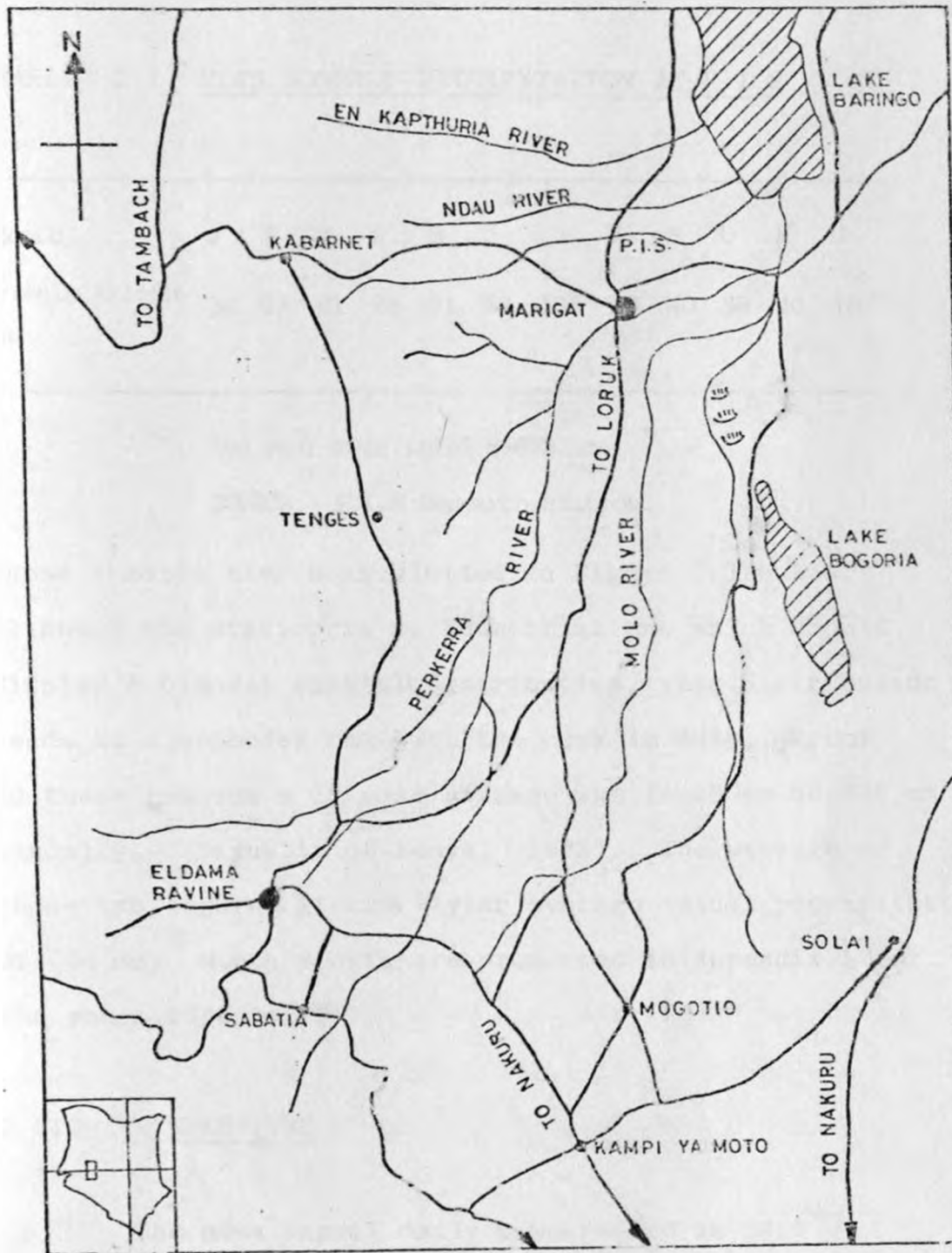
FIG. 2.1 LOCATION MAP OF THE BARINGO - KERIO VALLEY AREA







KEY

- +++ International bound
- ~ Rivers
- Towns
- - - Roads
- ☼ Mountains
- ▨ Baringo - Kerio valley

FIG. 2-2 MAP OF SOUTH BARINGO SHOWING LOCATION OF PERKERRA IRRIGATION SCHEME



- KEY**
-  ROAD
 -  RIVER
 -  TOWN
 -  LAKE

 MARSH

8 0 8 15 24
KILOMETERS

SOURCE: REPUBLIC OF KENYA (1962)

TABLE 2.1 MEAN MONTHLY PRECIPITATION AT P.I.S

Month	J	F	M	A	M	J	J	A	S	O	N	D
Precipitation mm	34	28	61	78	71	68	105	96	40	39	40	18

Ten year mean total = 678 mm

SOURCE: P.I.S Research Station.

These results have been plotted in Figure 2.3 below. Although the station is an Equatorial one which should display a bimodal rainfall distribution, this distribution tends to a unimodal one with the peak in July. Prior to these records a 15 year average was found to be 638 mm annually, (Republic of Kenya, 1962). The average of these two figures gives a 25 year average annual precipitation of 658 mm. Monthly data are presented in Appendix 1 for the years 1968 to 1977.

2.3.2 TEMPERATURE

The mean annual daily temperature is 24.3°C with diurnal maxima ranging between 30.0°C in July and 33.8°C in March. Diurnal minima range between 15.2°C in September and 17.6°C in April. Table 2.2 and Appendix 2 summarise other important climatic data.

TABLE 2.2 TEN-YEAR AVERAGES OF CLIMATIC DATA FOR P. I. S

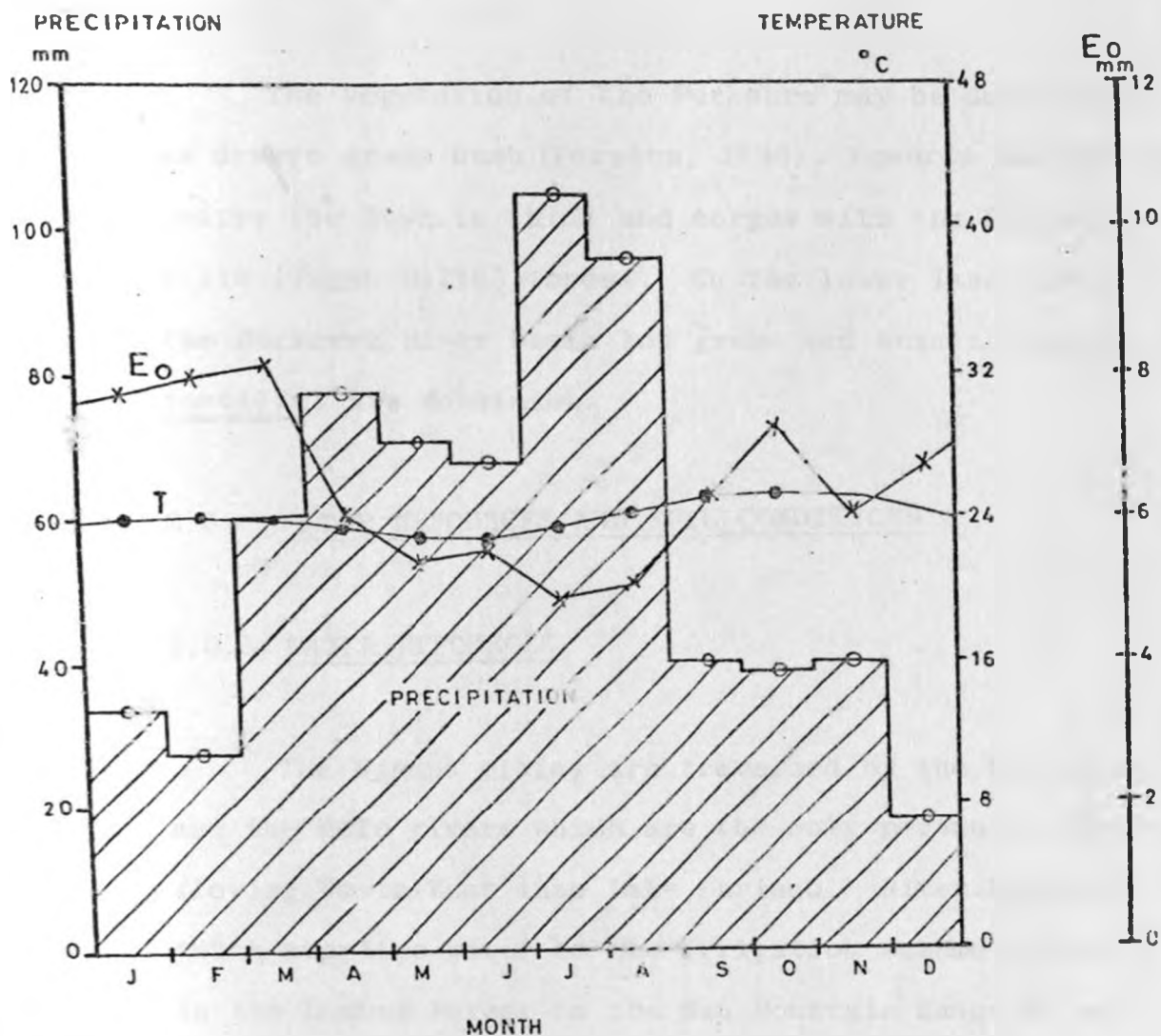
Month	Temperature °C		Mean	Windrun ₁ km day ⁻¹	Sunshine Duration ₁ hrs day ⁻¹	Open pan Evaporation ₁ mm day ⁻¹
	Max.	Min.				
J	33.5	15.5	24.5	113.7	Mean is 8.2 hr with a S.D of 1.5. Maximum is 12.1 hr on Equator.	7.8
F	33.2	17.2	25.2	108.5		8.0
M	33.8	17.3	25.6	126.7		8.2
A	33.0	17.6	25.3	104.2		8.1
M	32.5	16.6	24.6	99.5		5.4
J	31.6	15.8	23.7	95.0		5.6
J	30.0	16.3	23.2	87.7		4.9
A	30.6	15.6	23.1	90.4		5.1
S	32.5	15.2	23.8	94.7		6.3
O	32.8	15.8	24.3	107.4		7.3
N	31.7	17.0	24.4	101.0		6.1
D	31.8	15.7	24.2	113.4		6.7
MEAN	32.3	16.3	24.3	103.5	6.4	

SOURCE: P. I. S Research Station

These data indicate that open pan evaporation is highest when the windrun and the mean monthly temperature are fairly high. A temperature plot appears in Figure 2.3. Open pan evaporation is also plotted on the same diagram so as to depict the relationships between precipitation, temperature and E_o throughout the year.

1) Open pan evaporation is abbreviated as E_o .

FIG. 2.3 MEAN MONTHLY TEMPERATURE, PRECIPITATION AND OPEN - PAN EVAPORATION AT P-I-S.



DATA SOURCES: 1) P-I-S Annual Report 1977/78
2) P-I-S Research Station

2.4 VEGETATION

The vegetation of the Perkerra may be described as desert grass bush (Pereira, 1958). Towards Marigat shopping centre the bush is thick and merges with the Kamasia Hills (Tugen Hills) forest. On the lower land along the Perkerra River basin low grass and acacia (Acacia tortilis) are dominant.

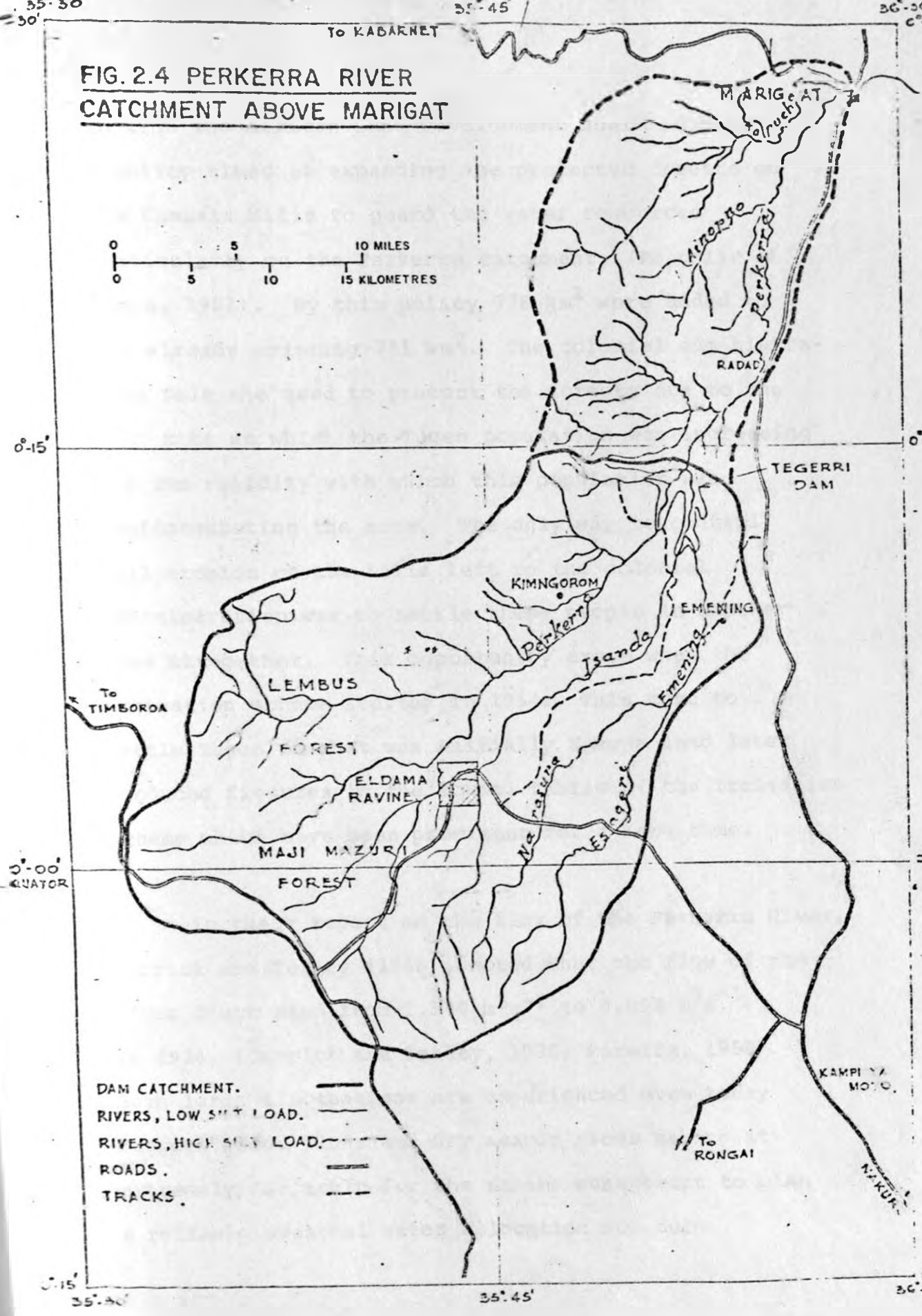
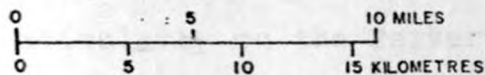
2.5 WATER RESOURCES AND SOIL CONDITIONS

2.5.1 WATER RESOURCES

The Njemps plains are traversed by the Perkerra and the Molo rivers which are the only perennial rivers flowing North-East into Lake Baringo. River Perkerra which supplies water to the irrigation scheme arises in the Lembus Forest on the Mau Mountain Range at an altitude of over 1,800 m. It enters the Rift Valley at Eldama Ravine.

Feeding the Perkerra River is a catchment above Marigat of 1,500 km². This area is estimated from Figure 2.4.

FIG. 2.4 PERKERRA RIVER
CATCHMENT ABOVE MARIGAT



- DAM CATCHMENT.
- RIVERS, LOW SILT LOAD.
- RIVERS, HIGH SILT LOAD.
- ROADS.
- TRACKS.

In 1955 the African Land Development Board adopted a policy aimed at expanding the protected forests on the Kamasia Hills to guard the water resources particularly on the Perkerra catchment, (Republic of Kenya, 1962). By this policy 776 km² were added to the already existing 711 km². The colonial administration felt the need to protect the forests due to the high rate at which the Tugen population was increasing and the rapidity with which this population was deafforestating the area. The only way to control soil erosion on the hills left to the colonial administration was to settle these people in another area altogether. This opportunity arose when the irrigation scheme started in 1954. This move to settle Tugen on what was initially Njiru's land later produced fissures in the social fabric of the irrigation scheme which have been prominent for a long time.

In their report on the flow of the Perkerra River, Carrick and Tetley (1936), noted that the flow of the river fluctuated from 1,540 m³s⁻¹ to 0.098 m³s⁻¹ in 1936, (Carrick and Tetley, 1936; Pereira, 1958). Such large fluctuations are experienced even today between flood flows and dry season flows making it extremely difficult for the scheme management to plan a reliable seasonal water allocation schedule.

For the purposes of irrigation the waters of the Perkerra River are of fairly high quality. The S.A.R.¹⁾ was found to be 1.50 and the electrical conductivity was 168 micromhos cm^{-1} (Mackenzie (K) Ltd, 1978). These values place this water in the class C1-S1 on the USDA diagram for classification of irrigation waters, (USDA, 1954). Such water can be used to irrigate most crops on most soils without fear of causing salinity or alkalinity problems.

2.5.2 SOIL CONDITIONS

The geology of the Perkerra area has been described as Quaternary Sediments (Republic of Kenya, 1963). These cover the whole area south and east of Lake Baringo. Tertiary volcanics are found in several scattered places.

Soils are alluvial deposits and recent lacustrine deposits fading into peaty swamps nearest the Lake. Soils are developed on various alluvial and colluvial deposits. The following quotation summarises the main features of these soils.

1) S.A.R. = Sodium Adsorption Ratio which gives an indication of the suitability of water for irrigation purposes. See USDA, 1954.

The soils of the Perkerra are well drained, moderately deep to very deep, varying in colour, calcareous in places, sand to clay (eutric FLUVISOLS; Ustic Torrifluvent, coarse, loamy, mixed, isohyperthermic family: calcareic FLUVISOLS (saline and sodic phase) Ustic Torrifluvent, fine, mixed, isohyperthermic family: eutric FLUVISOLS (sodic phase); Typic torriorthent, fine loamy over mixed, isohyperthermic family: (Republic of Kenya, 1978).

These soils are found on slopes of 0-5% formally described as level or nearly level to undulating topography. Slopes of this magnitude suggest ease in the use of level basin, graded borderstrips or furrow irrigation systems without involvement of much earth movement, (implying low capital costs on the construction aspect of the irrigation scheme).¹⁾

Under these slopes soils of the foregoing description display fairly high initial infiltration rates, a fact that rules out the use of long borderstrips or long furrows as practical irrigation methods. Calculations done with results obtained from infiltration tests conducted in 1953 give basic infiltration rates ranging between 0.03 and 0.19 cm min⁻¹, (Republic of Kenya 1958). At these basic infiltration rates level basins can only be used efficiently with very high irrigation streams ensuring minimum time of stream advance. For these reasons a short furrow irrigation system is used in the P.

¹⁾ See Pereira, (1958), pp. 247, 249-253 for experimental results on various irrigation methods.

2.6 LAND-USE AND LAND TENURE

2.6.1 LAND-USE

In the ecological zone in which the P.I.S falls (E.z V) the land-use is mainly grazing. This is also true for all the area outside of Perkerra Irrigation Scheme.

2.6.2 LAND TENURE

At the inception of the scheme land inside the present scheme area and outside of it was communally owned. Even todate the people outside of the scheme area graze their livestock indiscriminately over the land indicating that land is still communally owned.

In the scheme area all the land has been declared land for a national irrigation scheme by the Minister for Agriculture in accordance with the Irrigation Act. All the farmers in the irrigation Scheme are tenants who have been licenced to operate in the scheme. Their licences are renewable annually subject to satisfactory adherence to the Irrigation Rules as laid down for all national irrigation schemes (Republic of Kenya, 1962).

The N.I.B. aims at allocating 1.6 ha of land to each tenant in all the schemes. Tenants who are unable

to utilise all their land may often relinquish it to the scheme management to allocate to others. If the scheme management proves that a tenant is incapable of farming efficiently in the scheme, his licence is terminated and a new tenant is admitted into the scheme in his place.

2.7 HISTORY OF CROPPING IN THE PERKERRA IRRIGATION SCHEME

When the scheme started in 1953 maize was the only crop. Raised on virgin land it was possible to obtain 50 bags per hectare, (Chambers, 1962). Irrigation by single heavy flooding was tried on the maize crop as an experiment on flat basins in 1954, (Pereira, 1958, p.247). It was seen to be impossible to use the flood waters of the Perkerra River on a single irrigation application basis.

In 1954 the detention camp which had been placed on the southern bank of the Perkerra River was moved to the present irrigation area. During that year some 283 ha were prepared. The target was to raise the figure to 1,215 ha and later to double it, (Chambers, 1962). The scheme area covers 2,211 ha.

Within two years maize yields began to decline partly as a result of depletion of the soil fertility and partly as a result of vermin damage, (Chambers, 1973, p. 353). In 1956 the first 47 tenants were registered and some 405 ha were prepared. Some of this land was planted with tomatoes.

Tomatoes were plagued with problems. First there were the diseases. Then came mechanical damage as a result of heavy rains. They finally proved to be a failure when transportation to the processing plant at Nakuru turned out to be so rough that the tomatoes arrived in Nakuru in form of pulp. Another crop had to be sought quickly to save the scheme from collapse and onions were suggested.

Onions too, encountered serious problems of diseases and pests. Being a relatively high value crop and falling within the managerial ability of the Perkerra tenant however, the onion became the most important crop in the P.I.S. Table 2.3 summarises the history of onion growing between 1964 and 1978.

	1964	1965	1966	1967	1968	1969	1970	1971	1972
LAND CROPPED, ha	168	158	231	269	272	255	258	188	258
SCHEME YIELD, tonnes	1148	788	2485	2608	2410	2396	2735	1600	1746
MEAN YIELD, ton/ha	6.8	5.0	10.8	9.7	8.9	9.4	10.6	8.5	6.8
NO. OF TENANTS	362	402	403	n.a	481	466	463	465	455
CROPPED LAND PER TENANT, ha	0.46	0.39	0.57	n.a	0.56	0.55	0.56	0.40	0.57

SOURCE: P.I.S. Annual Report

NOTE : The last row is derived by the number

Chilli trials were carried out in the P.I.S. early in the 1960s but the idea was abandoned without a clear reason. Then in 1971 the first 27 hectares of chillies were grown using seed obtained by bulking from the original bushes. This was the birth of the Ex-Perkerra variety which proved an instant success on the British-Asian market. Chillies today are the second most important commercial crop in the P.I.S. Table 2.6 gives a summary of the history of chillies in the P.I.S.

On the relative importance of chillies and onions several points are clear from the tables. It is seen that land cropped with onions has fallen from 269 hectares in 1967 to only 86 hectares in 1978. This shows that the land under onions in 1978 was only 32% of that of 1967. At the same time onion mean yields in the scheme have tended to fluctuate rather heavily, reaching a maximum of 11.3 tonnes ha⁻¹ in 1977 and a minimum of 4.9 t ha⁻¹ in 1978. The period 1964-1978 does not depict any discrete cycle of crop failures. This suggests that droughts, floods, disease outbreaks and other natural disasters have not had a pronounced effect on average onion yields in the scheme.

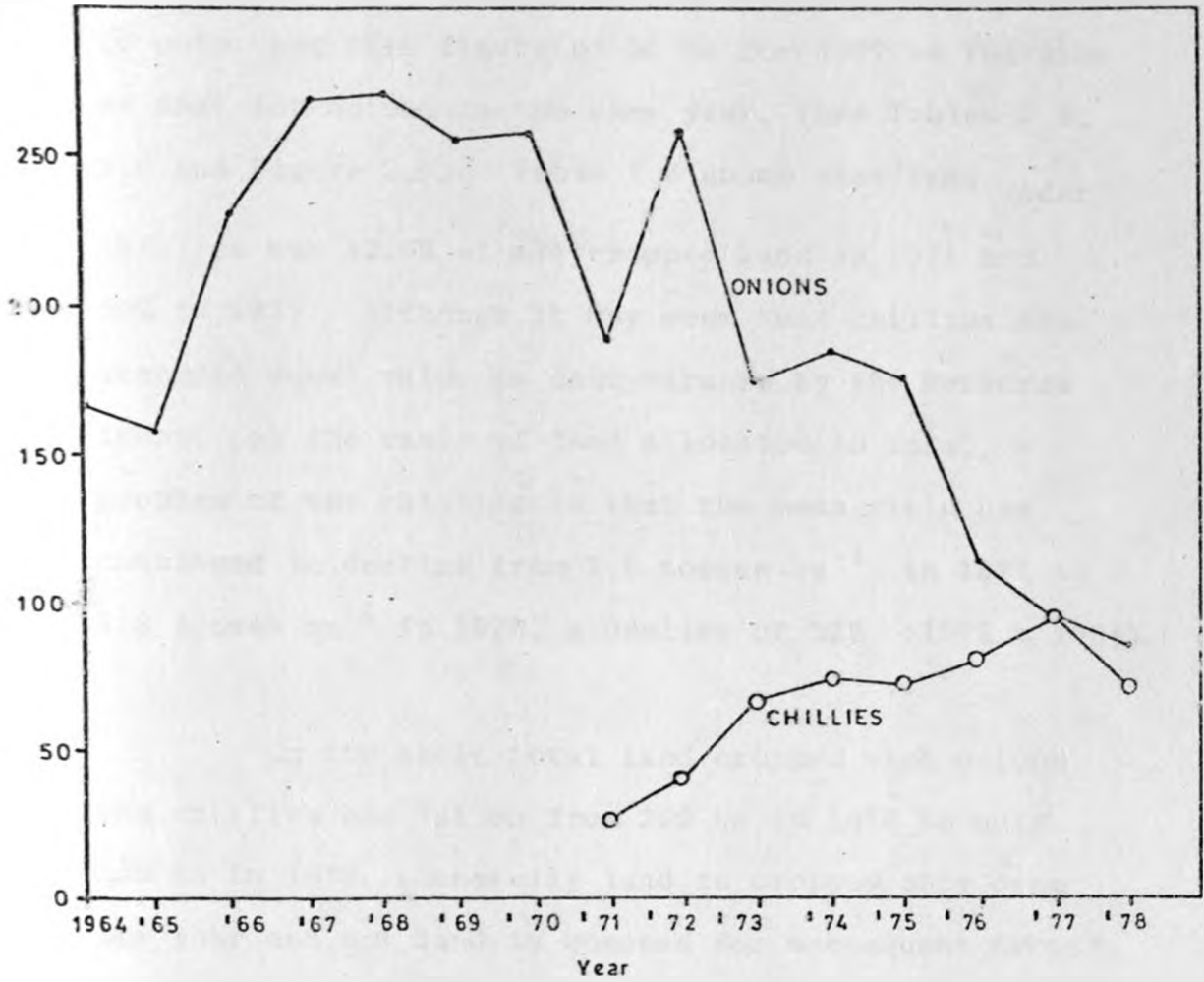
	1971	1972	1973	1974	1975
LAND CROPPED, ha	27	41	67	75	72
SCHEME YIELD, tonnes	70	87	165	186	186
MEAN YIELD ton/ha	2.6	2.1	2.5	2.5	2.6
TOTAL LAND CROPPED ha	215	299	242	260	248
LAND UNDER CHILLIES AS % OF TOTAL	12.6	13.7	27.7	28.8	29.0

SOURCE: P.I.S. Annual Reports, 1

NOTE : Proportion of land under
subtracting the proportion
from 100%.

FIG. 2.5 LAND CROPPED TO ONION AND CHILLIES SHOWING
THE RISING IMPORTANCE OF CHILLIES IN THE CURRENT
FARM PLANS IN THE PERKERRA IRRIGATION SCHEME

Cropped
Land,
ha



DATA SOURCE: Tables 2.5 and 2.6

Chillies hectareages have risen from 27 ha in 1971 when chillies production in the scheme was revived to a maximum of 96 ha in 1977. It is interesting to note that this figure of 96 ha for 1977 is the same as that for onions in the same year, (see Tables 2.5, 2.6 and Figure 2.6). Table 2.6 shows that land under chillies was 12.6% of all cropped land in 1971 and 50% in 1977. Although it may seem that chillies are accorded equal value as cash-earners by the Perkerra tenant (on the basis of land allocated to them), a problem of the chillies is that the mean yield has continued to decline from 2.6 tonnes ha⁻¹ in 1971 to 1.8 tonnes ha⁻¹ in 1978, a decline of 31%, (1971 = 100%).

On the whole total land cropped with onions and chillies has fallen from 299 ha in 1972 to only 158 ha in 1978. (Generally land is cropped only once per year and new land is opened for subsequent crops). During the same period the number of tenants has fallen from 455 to 330. From these figures we see that the average amount of land allocated to these two crops per tenant has dropped from 0.66 ha to 0.48 ha.

Other crops grown today in the scheme are beans

and maize both of which were introduced during the 1977/78 season.

Experiments have been carried out on the following crops to test their suitability for the P.I.S: Capsicums, Soyabeans, Kenaf, Roselle hemp, Cucumber, Melons and Citrus fruits.¹⁾

1) See N.I.R files GM/P/28, GM/P/29 and GM/P/29/A.

CHAPTER 3

LITERATURE REVIEW.

3.1 INTRODUCTION

To underline the problem on the one hand and to substantiate the selected methodology on the other the literature discussion will be divided into two parts.

1. LITERATURE ON THE PERKERRA IRRIGATION SCHEME

This is intended to shed light on the historical perspective of the P.I.S, portray the way the P.I.S is currently placed as a public investment and give an exposition of any lessons the P.I.S may have taught planners of irrigation schemes since it commenced operation.

2. LITERATURE ON POSSIBLE METHODOLOGIES APPLICABLE IN PLANNING IRRIGATION SCHEMES.

Simulation and mathematical models will be briefly surveyed and their relative applicabilities considered in selecting one to be applied as the methodology of this thesis. Among the aspects to be touched in this brief review will be data requirements, computer capacity and time needs, complexity of construction of the

model and the interpretation of the model output. Choice will depend purely on the nature of the problem of the thesis and the advantages of the chosen model over others.

3.2 LITERATURE ON THE P.I.S

Some background to the history of the P.I.S. has already been given in Chapters 1 and 2 of this thesis whereby a history of cropping has been discussed in section 2.7.

Two engineers Carrick and Tetley (1936) reported on the flow of the Perkerra River in detail. They described the flow behaviour of the river so that any plans to develop the Perkerra basin for irrigation agriculture could be done in full view of the eminent difficulties. The report concentrates on the engineering aspects of irrigation scheme developments.

Chambers (1962) has given a rather detailed account of the history of the P.I.S. Chambers describes the forces that clashed before the inception of the scheme and the strains that remained in the organization of the scheme. This report contains also a record of

the selection of crops and the sad story of crop failures which have been characteristic of the P.I.S. In conclusion he puts to the reader the question as to whether the P.I.S should be continued with or whether it should be folded up to save the costs accruing. Chambers does not volunteer an answer to this question

Chambers (1973) once again recounts the events in the modus operandi of the P.I.S that have made it a controversial economic issue as far as public investments are concerned. According to this report by mid-1968 the annual capital costs of the P.I.S were £272,000, the recurrent costs excluding depreciation were £332,000, and the revenue from the scheme some £95,000. He says that the scheme was kept alive by the N.I.B with a direct annual grant of about £24,000, which could be viewed as a direct transfer of funds from the successful Mwea Irrigation Settlement. In a table (see Appendix 3) Chambers presents a breakdown of finance as capital, recurrent expenditure, depreciation, revenue and operating losses upto 1967. Table 1.2 presents similar data for the years from 1967 onwards.

Other original accounts of the history of the P.I.S include that of the Government of Kenya (1962) where an account of the developments in the scheme from

1946 to 1962 are given. Table 3.1 compares the plan drawn by the ALDEV¹⁾ and the present situation.

TABLE 3.1 ALDEV PLAN FOR THE P.I.S COMPARED WITH THE CURRENT PLAN, (1978).

	(1)	(2)
	ALDEV PLAN	CURRENT PLAN
No. of tenants	100	350
Average size of holding (ha)	1.6	1.2
Water rate (K.Shs/ha)	250	750 ²⁾
Main cash crop	Onion	Onion and Chillies
Fence holdings	Yes	No
Grow maize for subsistence	Yes	Yes
Carry soil tests and onion trials	Yes	No

SOURCES: (1) Republic of Kenya (1962)

(2) Author's investigation.

- 1) ALDEV = African Land Development Board. This Board was mainly responsible for land development planning and implementation in the so-called "African areas".
- 2) The water rate is a flat rate set by the W.I.B which is paid by a tenant so long as he puts 1 hectare under crop. It should be known that only the W.I.B has legal rights to divert water from the river and convey it to the fields as far as the schemes are concerned. But there is no relationship between the token fee of Shs.50/- paid by the W.I.B to the water Apportionment Board and the water rate which is designed to cover the operating costs of the water conveyance and distribution structures and any losses due to inefficiencies at conveyance, distribution and field application.

From this table it is clear that the Aldev planners had not anticipated expansion of the scheme using the existing water availability and irrigation structures and had therefore planned to settle only 100 tenants. The number of tenants actually settled is 3.5 times of the Aldev plan; the average cropped area is 25% below the target and the water rates are 3 times higher. Chillies have acquired an equal status with onions as a cash crop in the P.I.S. There is no fencing of tenant's holdings and this facilitates use of heavy machinery in farm operations.

The soil tests suggested in the Aldev plan were started in 1953 and are reported in Pereira, (1958). Pereira also reports on the use of the flood waters of the Perkerra River and the gauging of the flow of the river. Chambers (1973) criticises the initiation of the scheme on the basis of the fact that there wasn't sufficient available information to use in the planning phase. In support of this view Chambers writes:

"To embark upon a major irrigation project with little knowledge of river flows and with what limited knowledge there may be indicating unreliability; --- Without experience of tenants' performance; and without a pilot project --- these are to court disaster."
(Chambers, 1973, p.361).

Lessons that can be learnt from the P.I.S are discussed in Chambers (1973, p.361-365). On the negative side he recognises 'the costs and risks of haste and ignorance; the compounding of problems in complex projects; the irreversibility of the creep of commitment; and the high true costs of poor projects' as the major lessons which P.I.S has taught planners. On the positive side Chambers scores the following benefits:

- (1) introduction of a cash economy to the tenants,
- (2) experience gained by Government officials,
- (3) investment of incomes generated by the scheme,
- (4) indirect Government revenue emanating from the scheme and
- (5) seasonal employment provided in the scheme.

The quoted reports by Carrick and Tetley (1936) Chambers (1962) and (1973), and Pereira (1953) are the only original sources on the scheme in general. Recent information on the scheme is available in annual reports of the N.I.E and the P.I.S but these sources will be used elsewhere in the thesis.

3.3 LITERATURE ON THE METHODOLOGY FOR ECONOMIC PLANNING OF IRRIGATION SCHEMES

3.3.1 POSSIBLE METHODOLOGIES

Heady (1972, p.28) has listed the following methodologies as being appropriate for the determination of the optimal water investment and land development programme in an irrigation project.

(1) Linear Programming. A linear programme can be drawn so that it incorporates equations and variables for both the overall project and its various farms. Where water is scarce and profitable, LP models can simultaneously indicate the optimum allocation of the water resource among farms, soil zones, crops and time periods.

(2) Mixed Integer Models. These are particularly useful for sub-system selections. These models are used where the assumption of infinite divisibility of resources and activities entering the LP model may not be practical, (Agrawal and Heady, 1972). The technique therefore requires that solutions provide quantities in whole units. Integer programming is

essentially an extension of LP. Mixed integer programming means that only some of the variables take integer values. If all the variables take integer values then the model is a pure integer LP.

- (3) Dynamic and Recursive Models. These models are mostly applied in the selection of the optimal plan over time or the most profitable multiple-cropping system. Among their numerous applications are those in the planning of "equipment replacement, crop rotations or crop sequences over time, multiple cropping patterns within a year, sequencing of water among users in a district or village, the optimal growth path of a farm which has many alternatives in plans over successive years, ----." (Agrawal and Heady, 1972, p.104). The cardinal difference between dynamic/recursive models and ordinary LP models is that the former give sequential decisions while the latter deal with a specific point in time.

Weinschenk (1971) defines recursive programming as a "sequence of mathematical programming in which the parameters of a given problem are functionally related to the optimal variables of preceding problems of the sequences," (in Heady (Ed), 1971, p.197). A recursive model does not attempt to devise optimal decision rules such as are contained in an optimal LP solution. So far recursive models have mainly been applied in sectors of the agricultural industry rather than in individual farm planning, (Barnard and Nix, 1973, p.387)

- (4) Non-linear Models to allow demand (market) restraints to be reflected. Baumol (1972) defines non-linear programming "in economic terms" as the analysis of constrained maximization problems in which diminishing or increasing returns to scale are present, (p.136). With diminishing returns (a concave maximization or a convex minimization problem) the number of positive variable values will tend to be greater than the number of constraints. In the increasing returns case the number of positive variable values will generally fall short of the

number of constraints. (see also Agrawal and Heady, 1972, pp.114-120).

- (5) Simulation and Stochastic Programming Model. This model can incorporate variations in rainfall, climate and prices. "Simulation does not require nor typically involve an objective function to be optimized", (Agrawal and Heady, 1972, p.260). Physical systems such as the growth of a plant or economic systems such as the behaviour of a market can be simulated. Simulation models seek to imitate the behaviour of systems over time, (Dorling, 1977, p.2).

In a simulation model variables are not linked by explicit mathematical functions and this characteristic makes the model suitable for handling very complex systems.

Stochastic programming is a form of risk programming with each variable subject to risk variation taking a range of possible values specified as a probability distribution, (Barcard and Nix, 1973, p.390).

This type of model has been applied very little since its discovery in the 1950s which is an indication that it is fairly difficult to apply. The major task is estimating probability distributions for all the variables in the matrix subject to random variation, which may be most or all of them. Another major constraint in applying this model is its high demand of computer time.

(6) Agro-economic models for examining specific questions of physical sub-optimizations relative to water-use.

(7) Certain behavioural models to account for response of farmers based on their social, economic and cultural conditions.

Of all these different types of models only simulation and ordinary linear programming (and to an extent some of the extensions of the ordinary LP model) have been widely used to solve practical farm problems with some success, (Mukhebi, 1977, p.1). Linear programming can be taken as the most widely applied methodology of planning at the micro-level.

The analytical demands of this thesis are partly discernible from the objectives of the study stated above. In addition to that the relatively less complicated data requirements of the ordinary linear programming model, and its potential usefulness for practical advisory purposes (see Barnard and Nix, 1973, p.371) this study will be based on ordinary linear programming models. An additional argument in favour of the ordinary LP is that the setting of this study is such that only a limited amount of data analysis and computer time are available.

3.3.2 DEVELOPMENTS OF THE LP TECHNIQUE

The ground-work on the theoretical constructs upon which LP is based was done by Dantzig, (see Koopmans, 1951, pp. 19-32, 339-347). Koopmans' book generally deals with the various aspects of a fundamental problem of normative economics: the best allocation of limited means towards desired ends. Dantzig discovered the simplex method of solving a linear programming problem during the Second World War and published it in 1947. Later he was the first one to use the "Objective Function" in linear technology analysis. Koopmans (1951) gives the basic mathematics used in the early development of the LP method and the authors who played notable roles in those developments.

Linear programming is an optimization technique.¹⁾ Optimization can refer to a polyperiod (intertemporal) farm plan, the plan of a single year, decisions on the amount of feed or fertilizer inventories to be carried or the choice of strategies to meet uncertain weather and prices, (Agrawal and Heady, 1973, p. 5). Given the end and the means by which to achieve it, operations research methods indicate the pattern of resource allocation, the nature of investment which will maximise profit or rate of return, and the selection among strategies which will minimise unfavourable outcome from the vagaries of nature or the market.

One of the earliest applications of LP to agriculture was that of Hildreth and Reiter, (see Koopmans, 1951, pp. 177-188). They applied the method to choose a crop rotation plan. Other pioneering applications of LP in agriculture are those of Heady and Love (1954), quoted in Heady and Candler (1953).

1) Unfortunately space does not permit a complete discussion of the assumptions underlying LP but these can be found in a good LP text such as Agrawal and Heady, 1972, p. 31-34; Heady and Candler, 1969, p. 17-18 where other useful references may be found.

Since this time many publications came out on LP in Europe and North America. In Kenya more recently several studies have applied LP in studying peasant-farmer behaviour. Clayton (1963) demonstrated by a study in Nyeri District, Kenya, that labour could be a limiting resource when planning for improvements of currently existing farm plans. Labour was shown to be seasonally limiting although some seasonal unemployment of some of the family labour also existed. Otim (1978) and McArthur (1963) criticise Clayton (1963) on the grounds that he used research station data rather than actual on-farm-observation data and so involving too much imagination far drawn from actual real-world behaviour of farmers.

Odero-Ogwel and Clayton (1963) constructed an aggregate LP model of Nyeri District, Kenya, by which they showed that optimal plans provided only a small marketable surplus of potatoes. The model also showed that maize and beans production only remained at a level barely sufficient to meet subsistence needs. A further fact the study revealed was that there was potential for expansion of rural labour employment.

Heyer (1972) working in Masii Division of Machakos District, Kenya, showed that LP analysis could be used in connection with introduction of major crop innovations in peasant farming. Heyer (1972) concludes that the constraints to improvement of farm incomes in Masii area are land and labour.

Mukhebi (1977) has presented a case study of a real co-operative farm in Kenya. In this study Mukhebi uses the available data in a LP to optimise on the combination of enterprises for the maximization of the Gross Margin. The constraining variables are identified and remedies are suggested.

3.3.3 POSSIBLE LP VERSIONS AND MODIFICATIONS

Farrington (1976) basing his work on Heyer (1972) compared maximising plans and observed actual performance for good and bad years for Mangulenje and Mulomba in Malawi. Farrington found that at Mangulenje on a predominantly cotton hectarage, the good year maximising plan was approx. 2.5% above observed performance. (Observed = 100%). The value for the poor year was 23% above observed performance. At Mulomba the corresponding figures were 32% and 4% on a predominantly maize hectarage. Farrington concludes

that farmers' behaviour is consistent with a policy of long-term profit maximization although we cannot test this hypothesis. If farmers could predict input and output prices and the State of Nature they would select the best enterprise or parcel of enterprises early in the season.

Owing to the fact that the farmer is a producer faced with great uncertainty or account of the variety of the possible States of Nature, LP model builders (McInerney, 1969; Heyer, 1972; Low, 1974) have incorporated game-theoretic considerations in LP models, a step first advanced by Dorfman (in Koopmans, 1951, p348-357). Pay-off matrices on good, bad and standard (average) States of Nature outcomes have aided in maximising the expected maximum (maximax), and the expected minimum (maximin). The majority of authors are working with averages although Palmer-Jones (1977) criticises this approach. Palmer-Jones argues that peasant farmers may alter their technical coefficients under different environmental conditions and that there is no theoretical reason to believe that average inputs will give rise to average outputs. But Low (1978) underlines the power of the LP technique in studying peasant farmer behaviour because of its ability to handle a large number of interrelated variables. LP copes well with peasant farming systems which are characterised by a high degree of "interdependence between production and

consumption, consumption and investment, investment and resource availability, and resource availability and social and cultural constraints." (p.190). It is concluded therefore that so long as the assumptions of the LP remain within farm production logic it is the most appropriate method of optimization to use under P.I.S conditions.

Most of the other extensions of the LP model including Integer and Dynamic programming have been given elsewhere early in this chapter.

An important variant of LP is sensitivity analysis, (Agrawal and Heady, 1972). Sensitivity analysis are the techniques which are used to study how an optimal solution is affected by changes in individual numerical values of the right hand side (resource restraints) and objective row elements. It is used to study the effect of tightening or slackening a constraint, changing a price or cost, and so on. It allows the user to check the dependence of the final solution accuracy on the original data (ICL, 1969, p.213). The major processes of sensitivity analysis are Right hand Side Ranging and Objective Ranging and these will be carried out in this thesis.

3.3.4 DATA REQUIREMENTS FOR THE LP MODEL

The data requirements for the formulation of a LP problem are as follows:

1. Unit prices for the activities in the objective function and the levels of these activities (yields).
2. Technical coefficients for each of the inequations.
3. Restraint levels which are the levels beyond which a particular resource cannot be used for production. (See also Barnard and Nix, 1973, p.348-359).

Problems have been encountered in collecting data for a LP problem under conditions of peasant agriculture, (Heyer, 1972). Heyer writes that researchers may attempt to draw probabilities and effect planning decisions from a risk rather than an uncertainty basis thus using statistical instead of game theoretic criteria, but the information to do this is very scarce. Upton and Casey (1974) and Upton (1976), have sounded warnings against the use of expected yields as if they were actual yields. Expected prices should also

It should be borne in mind therefore that because of the wide possible range of values of each variable encountered in a farm business setting it is impossible to make decisions on the maximization of actual profits (actual Gross Margins). Averaged data obtained from actual observations have to be used but distributions for each variable should be shown. as will be done in this thesis.

3.3.5 LIMITATIONS OF THE LP APPROACH

This section exposes some of the shortcomings of LP solutions. LP solutions should not be taken as prima facie economic goals but rather as mere guidelines on possible courses of action that the farm operator may take in improving the economic efficiency of his farming.

Waugh (1961) has written:

The present organization of a farm
is known to be feasible. The only problem is
to find improvements, if there are any. (p.404.)

An important fact to bear in mind when formulating policy decisions based on LP solutions to practical farm problems is that several solutions exist which are almost as profitable as the 'best' solution obtained by the LP method (McPherson and Faris, 1958). Likely alternatives to the best solution should be well pointed out in the suggestions and recommendations

forwarded by the analyst. The superiority of the best solution over the alternative solutions (one of which may be the current farm plan) depends on proper handling of the following sources of error which are inherent in LP model formulation.

- (1) Mathematics: The mathematical source of error applies to the linearity imposed on resource restrictions. "Linearity is the price we have paid for a method that is an absolute improvement on functional analysis ... allowing for more realistic statements about certain aspects of the farmers' environment", (Edwards, 1961, p.303).
- (2) Statistics: Programmers have not used statistics enough in arriving at reliable input-output coefficients. The value of programmed solutions to practical farm problems could be greatly enhanced if, with every solution, the analyst provided statements about the statistical significance of the results, (Edwards, 1961, p.304). A programmed solution is no more trustworthy than the accuracy with which one arrives at the input-output relationships, prices and

- (3) Economics: Shortcomings are inherent in our assumption of perfect knowledge on a static economic model. In considering dynamic problems shortcomings depend on the reliability of our guesstimates of futural values and on the difficulties of allowing for intertemporal interaction between decision variables and exogenous variables. (Edwards, 1961, p.395).
- (4) Programmers: When the model differs significantly from the facts, the programmer or analyst must state the assumptions clearly and refer to these when interpreting the results. Restrictions must be clearly formulated (Edwards, 1961, p.397):

On the application of linear programming by Agricultural Economics Departments, Eisgruber and Reisch (1961) recognise the following shortcomings:

- (1) Lack of availability of sufficiently detailed input-output data, and
- (2) difficulty of constructing a linear programming model which realistically represents relevant relationships and alternatives.

It should not be forgotten however that models are simplifications of real-world situations and that there is little use in drawing a model which becomes so complex and time consuming that its benefits are exceeded by the costs. As much as possible, however, one should state clearly the assumptions underlying a statement in the model.

CHAPTER 4.

METHODOLOGY4.1 INTRODUCTION

The need to draw plans for the holdings in the P.I.S arises because it is thought that the current plans there are not optimal, and secondly (partly as a corollary), the farmers could improve their welfare with higher incomes and increase their investments with greater surpluses with production above basic need. This was explained in earlier chapters.

Since land is fixed in quantity increased output can only result from a higher intensity of farming (Factor-Product relationship), or from better use of land by selecting better crops or crop combinations, (Product-Product relationship). This thesis will entirely focus on the optimal combination of enterprises using a simple LP approach as outlined in the literature review.

4.2 HYPOTHESES

The study is based on the following hypotheses.

This hypothesis simply states that there are possibilities for other crop combinations existing which would yield more per unit of land than the current ones. This hypothesis is restricted to investigating land-use. Optimal plans will be drawn and be compared with the existing situation (1977-78 cropping season). If the optimal plans obtained by the LP are better than current ones i.e. they give higher Gross Margins per hectare (or per cubic metre of water), the hypothesis will be accepted.

- (2) The main constraint in any future contemplated expansion of the scheme is the lack of operating capital inputs in the present system of limited advance payments to tenants remains unaltered.

This hypothesis will look at the use to which the estimated available operating capital per tenant is put. It will be investigated whether estimated savings plus advance cash payments are sufficient to furnish all the tenant's operating capital needs. If the tenants are required to hire capital to implement improved plans the hypothesis will be accepted. Otherwise the hypothesis will be rejected.

- (3) Water is not a constraint in putting the originally planned 2,400 hectares of land under crop.

Water flow as gauged at the offtake (headworks) will be allocated to the crops obtained by the optimal plan. If this water is sufficient to raise these crops on the current scheme hectarage then the optimal plans will be expanded to the total scheme land level of 2,400 ha. in aggregated models. If the canal flow is still sufficient for this amount of land the hypothesis will be accepted.

These three hypotheses on land, capital and water use will be investigated by use of the LP method.

4.3 DATA

As outlined in the literature review no systematic data survey was done prior to this study. Therefore the study had to be entirely based on primary data collected in the survey.

4.3.1 SAMPLING AND FIELD SURVEY

a) SAMPLING OF TENANTS

The survey was carried out from November 1978 until January 1979. It considered the cropping season July 1977 until June 1978. At the time of the survey there were 350 tenants in the scheme. Two possibilities of sampling were open: a large sample of 30 or more tenants could have been taken and the theoretical sampling distribution of the mean could be approximated with a normal distribution according to the Central Limit Theorem, (Freund and Williams, 1970, p. 179). The second possibility was to use small sampling theory and assume that the population distribution could be approximated closely with a normal curve, (Freund and Williams, 1970 p. 179).

Due to the constraints of time and money and the homogeneity of farm inputs in the scheme small sampling theory was applied and a sample of 22 tenants was selected at random. Further to the reasons for adopting small sampling theory was the fact that all farm operations in the scheme go on simultaneously and this made it possible to cross-check questionnaire information against actual field observations. "Historical"

While the survey lasted the following operations were observed: canal clearing, cross-bunding, transplanting, weeding and harvesting as carried out by the farmers. Ploughing, harrowing, spraying and transportation by the scheme organization were also empirically studied.

Farmers were either visited in the fields or were interviewed in the office of the scheme management. The author conducted all the interviews personally. The author always started with an introduction of the work and the importance of the exercise so as to create a good atmosphere for the interview and to make the interviewer aware of the vital role he was playing.

Except for one interview where a lady farmer could not understand well the author's Kiswahili and the interview had to be conducted with the aid of an interpreter, all the questionnaires were ran using Kiswahili. An enumerator who was a son of one of the farmers rendered invaluable service in the creation of rapport. Out of the sample of 22 there were 16 respondents. Six farmers avoided being interviewed for various reasons beyond the control of the author.

(b) SAMPLING BY IRRIGATION BLOCKS.¹⁾

For purposes of comparing farmers in the sample with others in the same irrigation block, the blocks where the sample occurred were taken to form the sample of blocks. For example if a farmer holding in the relevant period was R1 T2 then all the farmers in block R1 had their relevant data recorded so as to compare them with farmer No R1 T2. These comparisons appear in Chapter 5 below:

In summary we can say that this stratified sampling was carried out in two stages, one a random stage, the other a purposive stage, respectively.

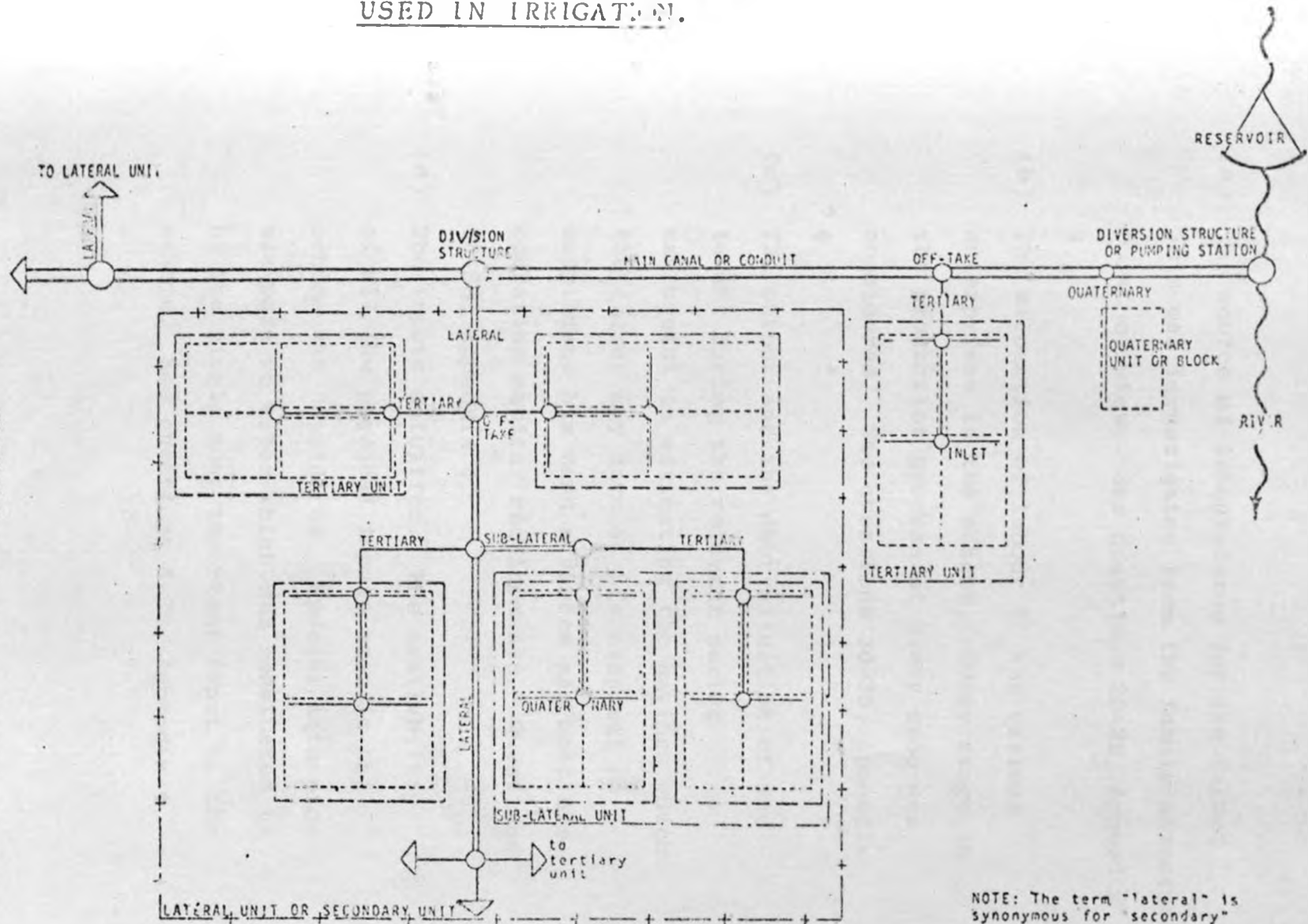
All relevant data in the scheme office were collected to ease the interviews.

4.3.2 QUESTIONNAIRE FORMAT

The questionnaire used in this survey is displayed as Appendix . There were the following aspects to look into when constructing the questionnaire:

-
- 1) A Block is defined as an "area that can be irrigated efficiently by one man if he were to receive the flow continuously". (ICID, January 1988, p.91) For clarification see Figure 4.1.

FIG. 4.1 SCHEMATIC PRESENTATION OF TERMINOLOGY USED IN IRRIGATION.



SOURCE:

ICID BULLETIN, JANUARY 1974, VOL. 27, 44

NOTE: The term "lateral" is synonymous for "secondary"

- (a) The source of labour-force for the farmer
This was investigated from the family structure point of view. See questions 20-29, Appendix 4.
- (b) The allocation of labour to the various enterprises in the scheme. Every stage in the production process of every crop was considered. See questions 30-35, Appendix 4.
- (c) The output and the debt situation of the tenant during the relevant period was useful in estimating the savings which the farmer may have at his disposal to supplement his cash advances and meet his operating capital requirements. Questions 36-38, Appendix 4.
- (d) The inputs situation. The availability of all the physical inputs used in the scheme was considered. Special attention was paid to water which was considered to be the single most important input in the scheme. See questions 4-12, Appendix 4.

4.4 LP MODEL FORMULATION

4.4.1 GENERAL FORMAT

In a normative approach the first step is to select a typical (representative) farm from a sample of farms which may be stratified by size, resources available and other physical characteristics.

For the purpose of this thesis a typical farm is any individual farm, the average, or the modal farm because complete homogeneity in physical inputs (including inputs in natura) is assumed.

The basic problem of linear programming is a special conditional extreme value problem. It exists if and only if there are limited resources or other restrictions which limit the extent to which production can be taken. A LP problem has three quantitative components: an objective function, alternative methods or processes for attaining the objective, and resources or other restrictions.

The normal form of the LP problem can be presented as follows:¹⁾

$$\text{Maximise: } Z = C'X \quad \text{-----}(I)$$

subject to

$$AX \leq B \quad \text{-----}(II)$$

$$\text{and } X \geq 0, B \geq 0. \quad \text{-----}(III)$$

where

A is an $m \times n$ canonical¹⁾ matrix of technical coefficients,

C is an $n \times 1$ row vector of prices or other weights for the objective function,

X is an $n \times 1$ row vector of activities (commodities to produce),

B is an $m \times 1$ column vector of resource or other restraints, and

$C'X = Z$ is the objective function.

In the expanded form the problem can be written as

$$\text{Maximise: } Z = c_1x_1 + c_2x_2 + \dots + c_nx_n \quad \text{-----}(IV)$$

subject to:

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq b_1 \quad \text{-----}(V)$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \leq b_2 \quad \text{-----}(VI)$$

$$\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n = b_m \quad \text{-----}(VII)$$

$$x_1 = 0, x_2 = 0, \dots, x_n = 0. \quad \text{-----(VIII)}$$

$$b_1 = 0, b_2 = 0, \dots, b_m = 0. \quad \text{-----(IX)}$$

Equations (I) and VI) are of course similar i.e. they contain the same information. Equation (II) gives the complete range of the possible relationships which the LP can handle. Equation (III) ensures non-negativity of resources and activities.

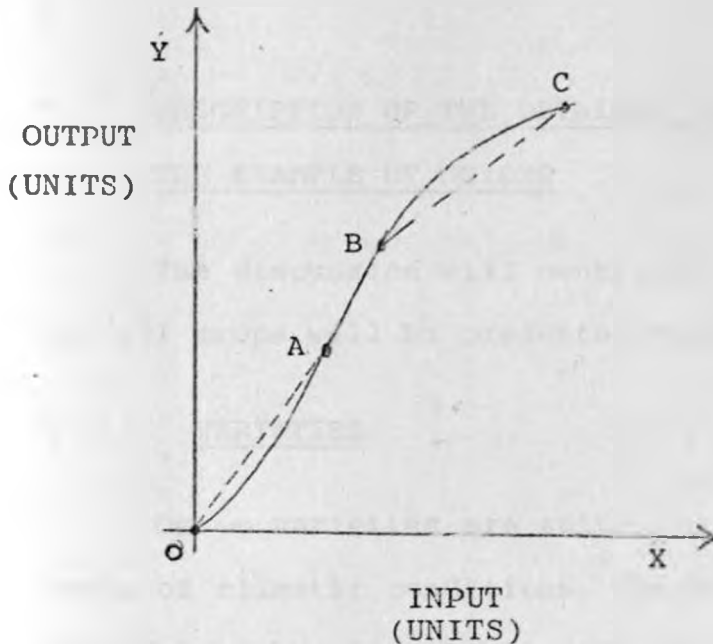
4.4.2 A NOTE ON THE DISTORTION OF THE NEOCLASSICAL PRODUCTION FUNCTION BY THE LINEARITY ASSUMPTION

The neoclassical production function is encountered frequently in agricultural production by virtue of its nature. (See Fig. 4.2).

It is clear from the inequations (V) to (VII) that each of those inequations represents a linear process of the form $Y = a + bx$.

(The models of this thesis were computed using the ICL LP MARK 3 package on an ICL 2950 K17 computer.)

Fig. 4.2 LINEAR APPROXIMATION OF THE NEOCLASSICAL PRODUCTION FUNCTION.



This linear relationship describes a straight line once particular values are assigned to a and b . The essential feature of this relationship is that, no matter how large x is, the change in it of one unit always leads to a change in Y of b units. This means that constant returns are assumed, a fact that dictates certain distortion of the neoclassical production function which describes agricultural production systems. Therefore linearity has to be approximated by the method of Weinschenk, (1971, p.181). Each of the sections OA , AB and BC is then taken as an activity and entered in the LP as such.

CHAPTER 5.

PRESENTATION AND GENERAL DISCUSSION

OF THE COMPILED PLANNING DATA

5.1 DESCRIPTION OF THE OBTAINED RESULTS:

THE EXAMPLE OF ONIONS

The discussion will centre on onions but data for all crops will be presented where appropriate.

5.1.1 VARIETIES

Onion varieties are suited to only a narrow range of climatic conditions, therefore great care should be taken in selecting the variety so as to prevent unnecessary losses. Day length and temperature are the main determining factors. The minimum day length and the minimum temperature should be reached before bulbing can commence. Temperatures higher than varietal requirements lead to hastened bulbing and maturity resulting in low yields because bulbs do not attain their potential size, (Jones, p.3).

The P.I.S. grows the onion variety "Tropicana F 1 Hybrid" only. Trials on (1) Bombay Red, (2) Red Creole, (3) Yellow Granex, (4) White Granex, (5) White Mexican, (6) White Creole and (7) Burgandy have been carried out in the past.

Varieties 1 and 2 were abandoned because they were low yielding and the rest were rejected by the producer because they were unacceptable to the local consumers.

5.1.2 AGRONOMY

In addition to the variety other onion performance determinants are stand, soil type, moisture supply and soil fertility.

At the P.I.S onion seedlings are raised in nurseries irrigated at 3 - day intervals until germination is complete. The irrigation is at 5 - 6 day intervals until 10 or so days before transplanting when irrigation is stopped to harden the seedlings. Onion seedlings require much care at transplanting, (Knott, 1957). A well spaced hectare on onion seedbed fills 10 hectares. If heavily seeded the bed fills more than these.

Onions are transplanted at slightly less than pencil size; at about 60 days from seeding. Transplants are spaced at 10 cm within rows with 2 rows per ridge one on either side. Ridges are 30 cm apart; and this

However, field observations by the author have revealed that spacings are on average 15 x 15 cm resulting in a population of 444,400 plants per ha. Under irrigated conditions heavy populations often lead to higher yields but may lower bulb size. Plant population studies have shown that plants suffer interference from their neighbours in their growth and development, and yields may drop as a result, (Harper, 1977. p.151 - 194). There is no reason to believe that onion populations depart from the reciprocal yield law which essentially means that the higher the plant population the lower the contribution of each plant to the yield (weight) per unit area. This statement implies smaller onion bulbs and hence poor quality onions at high population densities.

Land preparation entails two ploughings and one harrowing run. Then land is machine-ridged and hand-cross-banded before transplanting.

Weeding is carried out by hand before weeds are 5 cm tall (about once per week) and more frequently during bulbing.

Fertilizer (Sulphate of ammonia for N, S) is

At P.I.S it has been observed that split applications tend to improve yield and bulb quality.

The first 3 - 4 irrigations after transplanting are given at 3 - 4 day intervals and subsequent ones at 7 day intervals. The crop remains in the field for about 90 days after transplanting. Towards the end of the growing season the crop is given a dry spell of 15 - 20 days before harvesting.

The main pest is thrips. Thrips is controlled by spraying Malathion 50% at the rate of 4.25 l ha⁻¹ or Rogor 40E at 0.75 l ha⁻¹, or Sevin 85% at 2.5 kg ha⁻¹. The spray schedule is once in 2 - 3 week intervals until the crop is mature.

The main disease is purple blotch (Alternaria porii). Preventive spraying is carried out at 10 - 14 day intervals with Dithane M45 at the rate of 2.5 kg ha⁻¹.

Once harvested the crop is dried for about 3 days in the shade and then graded by machine. The crop is then packaged in 13.6 kg nets and sealed to identify the source. It is then ready for marketing.

Over a period of 12 years upto 1978 Perkerra averaged a yield of 8.8 t ha^{-1} ; the world average is 11.0 t ha^{-1} .

The agronomy of other scheme crops is given in the Appendices, (see Appendices 6 - 10).

5.1.3 GROSS MARGIN CALCULATION FOR ONIONS

All calculations of gross margins will be done in a form of "GROSS MARGIN CALCULATION". The remarks which follow each calculation will explain the necessary derivations leading to a gross margin.

(1) YIELDS

Table 5.1 shows the yields of the 1977/78 crop for the various enterprises.

To substantiate onion yields the sample yields were compared with yields recorded by the P.I.S. Management. For onions the yields have been collected for the year 1976 whose records looked more complete than those of other years and these have been plotted as Figure 5.1.

TABLE 5.1 YIELDS REALISED BY PERKERRA TENANTS DURING
THE 1977/78 CROP SEASON.

Tenant Number	Onions kg/ha	Chillies kg/ha wet wt.	Maize 90 kg bags/ha	Beans 90 kg bags/ha
1	8,390	7,410	10	15
2	6,580	7,065	10	15
3	4,135	7,410	12	-
4	2,520	6,175	20	-
5	5,005	8,330	25	-
6	7,020	4,170	15	12
7	8,960	4,525	20	8
8	6,720	3,555	30	-
9	2,950	6,420	-	-
10	6,880	10,370	15	-
11	5,600	4,940	10	8
12	7,550	7,905	10	17
13	10,720	6,430	-	15
14	6,720	2,160	2	-
15	5,610	5,140	20	-
16	6,105	8,400	15	-
MEAN	6,340	6,970	15	13
Standard Deviation	2,110	1,940	7	3

SOURCE: Author's investigation.

FIG. 5.1 DISTRIBUTION DIAGRAMS FOR ONION
YIELD REALISED BY PERKERRA TENANTS IN 1976

(a)

LEGEND

F --- Frequency

14 --- Tenant Number

Notes:

For panel (a)

$n = 116$ tenant hectares

$\bar{X} = 925$ kg/ha

S.D = 726 kg/ha

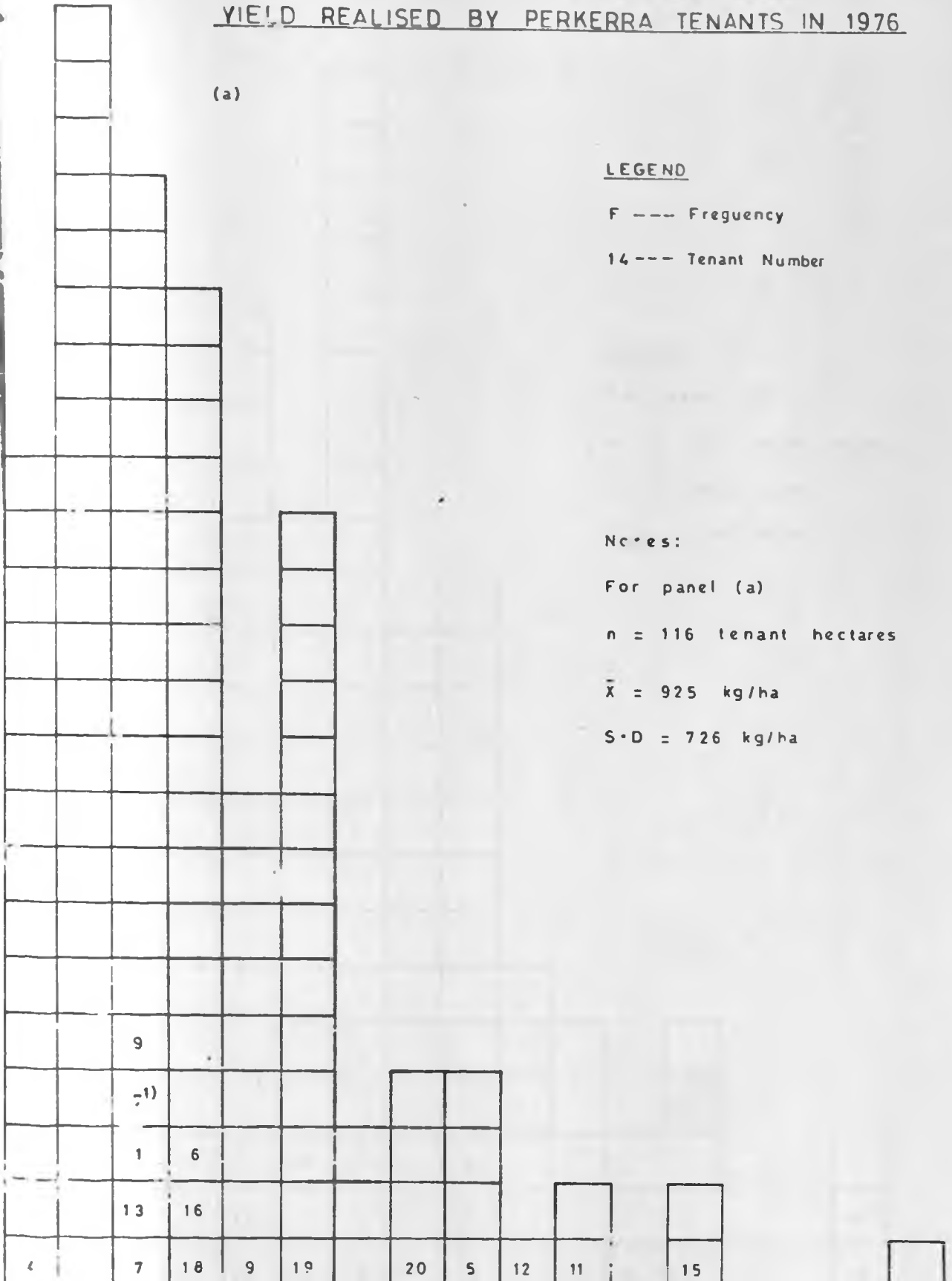


FIG. 5.1 (CONTINUED)

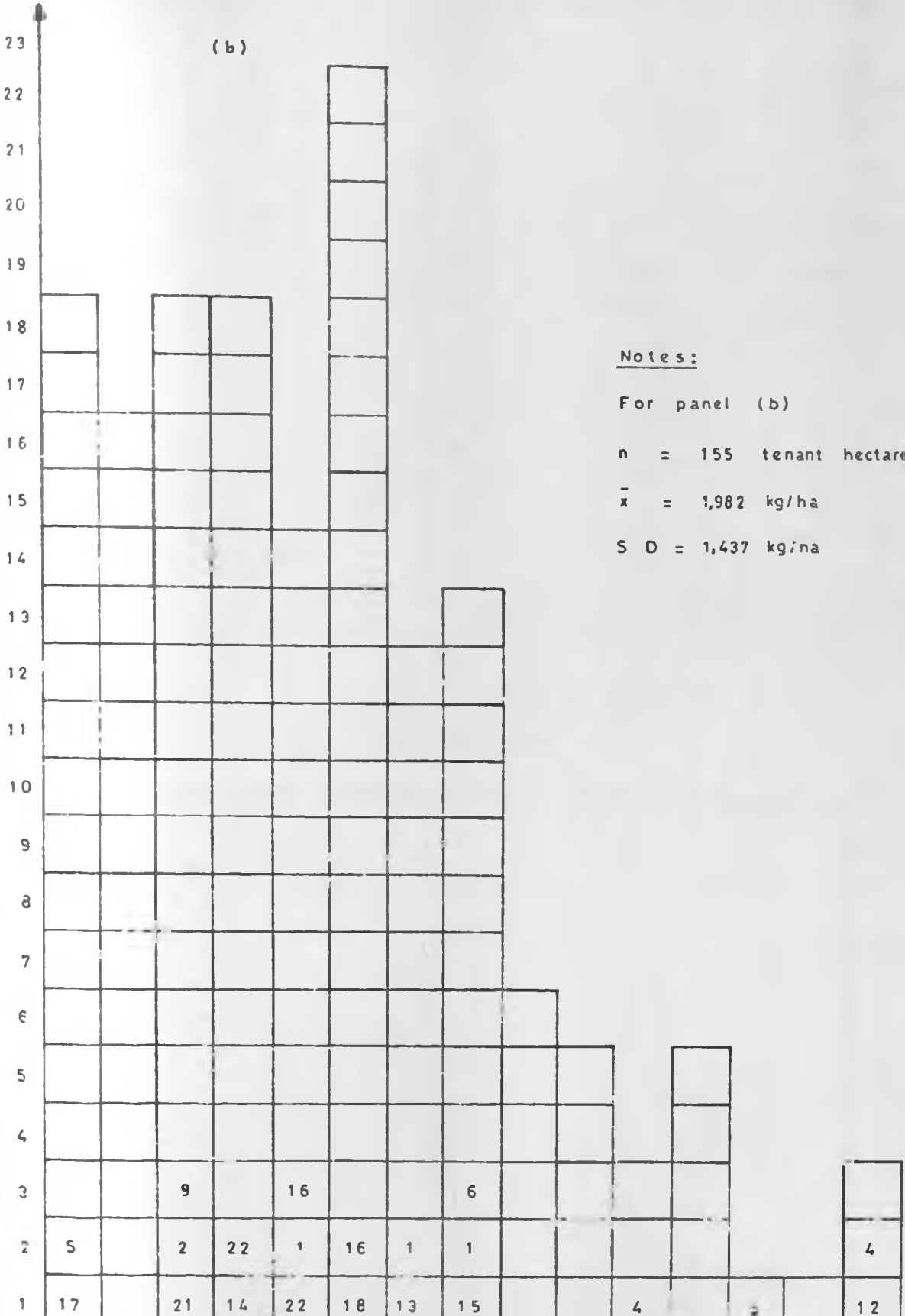
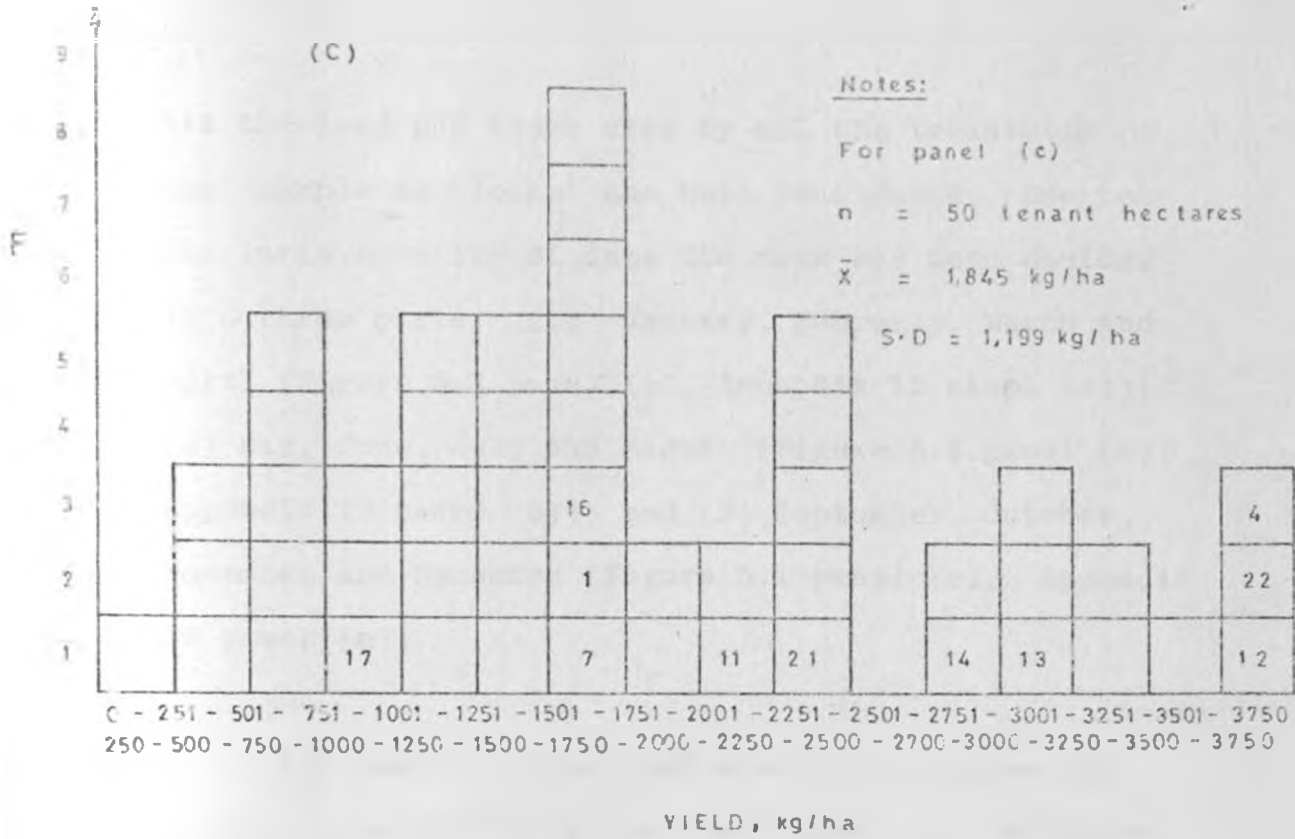
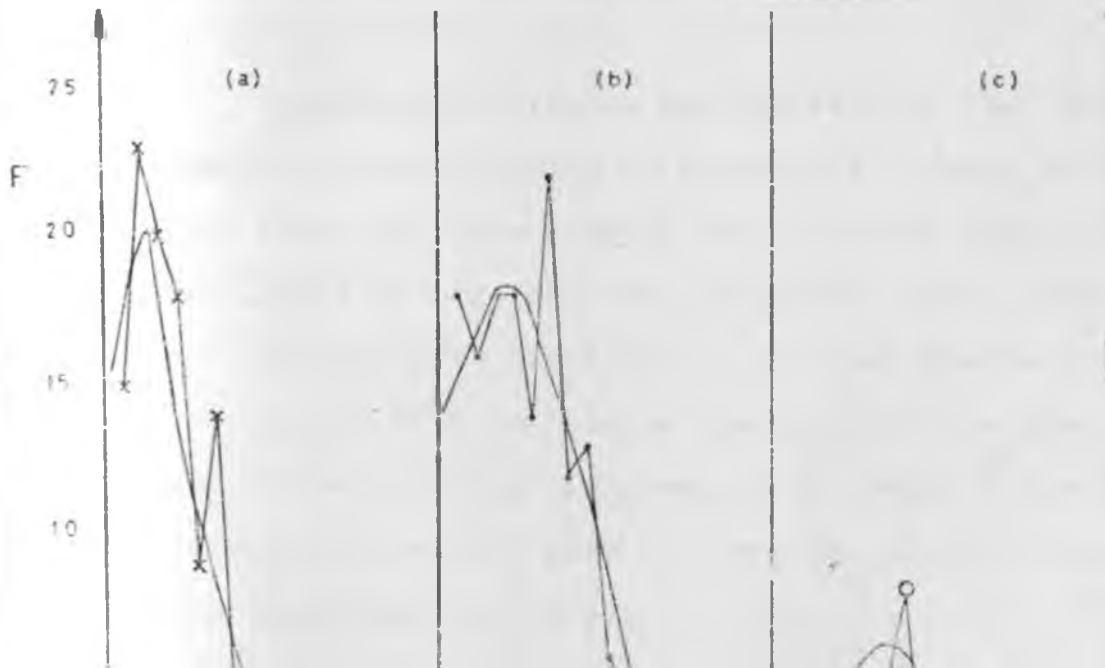


FIG. 5.1 (CONTINUED)



SOURCE: Appendix 13 panel (c)

FIG. 5.2 CURVI-LINEAR APPROXIMATIONS OF THE COLUMN GRAPHS OF FIGURE 5.1



All the land put under crop by all the tenants in the 'sample of blocks' has been considered. Due to the large quantity of data the year has been divided into three parts: (1) January, February, March and April (Figure 5.1 panel (a), Appendix 13 panel (a)); (2) May, June, July and August (Figure 5.1 panel (b), Appendix 13 panel (b)); and (3) September, October, November and December (Figure 5.1 panel (c), Appendix 13 panel (c)).

Any member of the sample of 22 may or may not appear in any of the plots. Each panel of the Figure only gives those of the sample of blocks who harvested and delivered during that part of the year.

Seasonality effects are discernible from the frequency distributions of Figure 5.1. First the means show that the January-April mean is lower than the May-August and the September-December means. Secondly the January-April distribution is clearly skewed to the left, a fact that means that most of the observations are concentrated on the lower yield levels. Smooth curves plotted in Figure 5.2 show the distribution approximations more clearly.

A third observation is that the yields obtained in May-September are generally higher than those obtained at any other time in the year. This necessitated the change in the yield classes so as to incorporate all yields in the season. (The interval of yields has been changed from 250 to 400 kg). The 1976 yields were very low compared with the 1977 recorded yields. These 1977 yields will be used for planning. They have been divided into high, average and low levels and average yields will be used to draw optimal plans. High yields are defined as the average of the 5 highest yields realised by the sample of 16 in the 1977/78 season. Low yields are the average of the 5 lowest yields, and average yields are the average of all the 16 records.

TABLE 5.2 P.I.S. YIELD CLASSES

Class	Onions Kg/ha	Chillies Kg/ha	Maize 90 Kg	Beans bags/ha
High	8,530	9,080	23	17
Average	6,340	6,970	15	13
Low	4,040	4,690	8	8

Source: Table 5.1 (of Author's investigation).

56.25% of all the tenants have higher than average yields for onions; 56.25% realise higher than average chillies yields and 31.25% realise higher than average maize yields. Only tentative figures are available for beans because the records from which they are obtained are too few to draw conclusions from.

The table of gross margin calculation for onions is presented as Table 5.3 and those of other crops are in the appendices. Superscripts 1 and 2 on A and B on every GROSS MARGIN table refer to low and average yields, respectively. Following is a discussion of the footnotes of Table 5.3.

(2) PRICE DETERMINATION (footnote 3)

The onion price was derived by a time series analysis of historical price data presented in Appendix 11. It is assumed that future developments in the market can be estimated by a trend extrapolation into the future. The trend was fitted via the following steps.

STEP 1: CALCULATION OF MONTHLY AVERAGE PRICES

Onion price data were obtained for grades I and II from 1969 August to 1978 November. The prices were recorded per net of 13.6 kg and their

Table 5.3

GROSS MARGIN CALCULATION 1.

(Irea, Form 1)

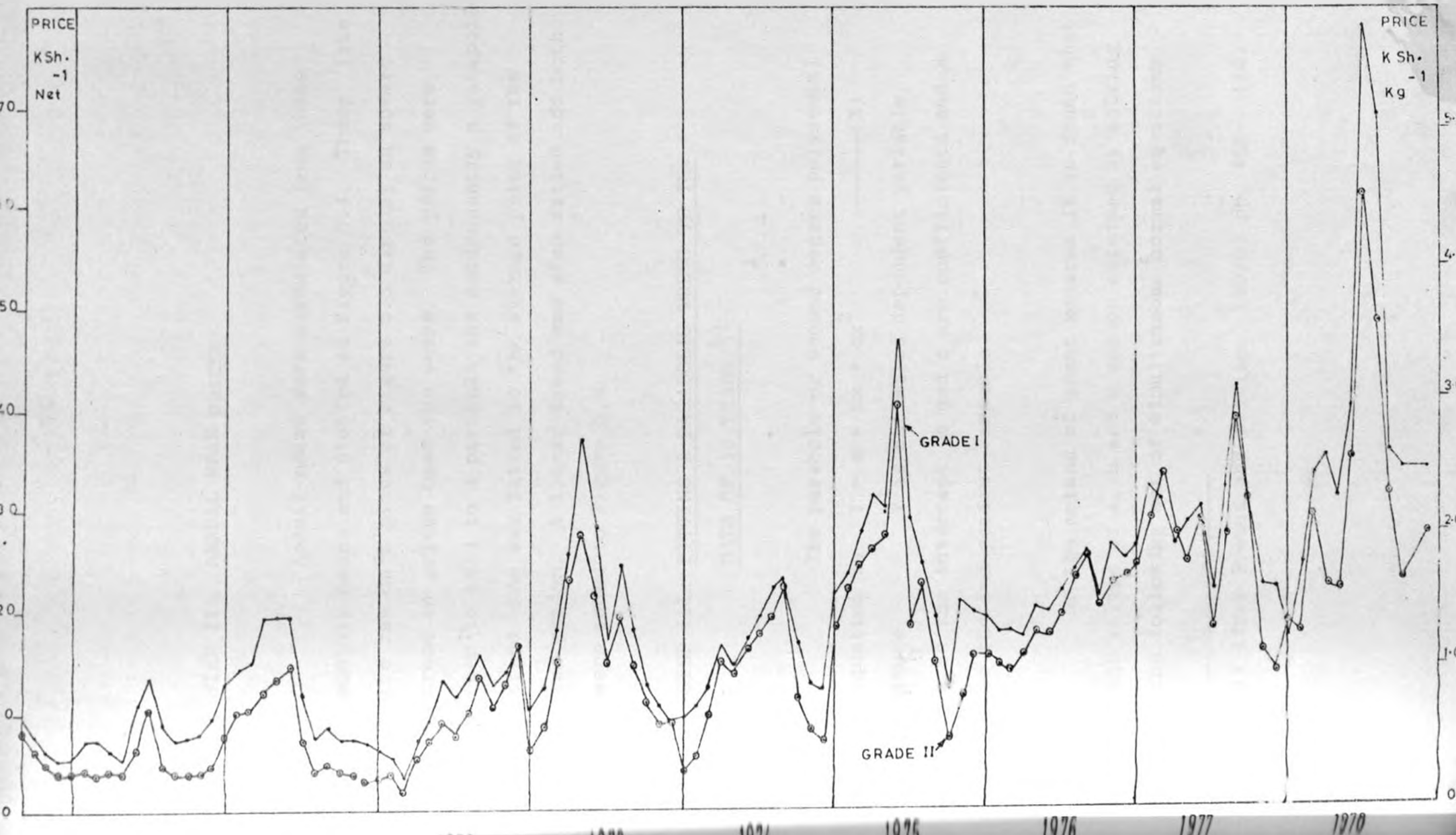
Location: P,I,SEnterprise: ONIONSVariety: TROPICANA F1 Hybrid

Level of Production

		A ¹⁾				B ²⁾	
		Units	Unit price K sh. ³⁾	Units per ha.	Value per ha. K sh.	Units per ha.	Value per ha. K sh.
I Yield	Grade I	KG	3.05	3,030	9,242	4,755	14,503
	Grade II	kg	2.40	1,010	2,424	1,585	3,804
Gross Output		Ksh			11,666		18,307
II Allocable Costs							
1.	Water	m ³	0.063 ⁴⁾	11,900	745	11,900	745
2.	Land Preparation						
	2.1 Ploughing x 2	hr	20.00	10	200	10	200
	2.2 Harrowing	hr	28.75	4	115	4	115
	2.3 Ridging	hr	32.50	2	65	2	65
	2.4 Other						
3.	Seed/Seedlings ⁵⁾	kg	450.00	4	1,300	4	1,800
4.	Fertilizer						
	4.1 Sulphate of Ammonia	kg N	7.10	500 =105N	745	750 =158N	1,122
	4.2						
	4.3						
5.	Pesticides ⁶⁾						
	5.1 Malathion 50 % x 2	l	58.82	8.5	500	8.5	500
	5.2 Rogor 40E x 3	l	35.56	2.25	80	2.25	80
	5.3 Dithane M-4 ⁻ x 2	kg	95.00	5	475	5	475
6.	Grading	net	0.10	295	30	495	50
7.	Bags	net	1.50	295	443	495	743
8.	Transport (Internal) ⁷⁾	ha	65.00	1	65	1	65
9.	Transport (External)	kg	0.02	4,040	890	6,340	1,395
10.	Other Material Costs						
	Sum 1-10 Allocable Costs				6,153		7,355
	Less Labour						
GROSS MARGIN I					5,513		10,952
11.	Labour						
	1. Clearing Canals	hr	1.60	40	64	40	64
	2. Planting	hr	1.70	50	85	50	85

Fig. 5.3 MEAN MONTHLY SCHEME - GATE PRICES FOR ONIONS

AT P.I.S. (KSh), 10 YEARS DATA.



STEP II: ANNUAL MEAN PRICES

Annual means were calculated from these monthly means and plotted as Figure 5.4. These, like the raw data plots of Figure 5.3 display an upward trend in prices over the years. The prices were seen to tend to a parabola and consequently a parabolic trend line was fitted to the average price of the two grades. A linear trend was also fitted and both were added to Figure 5.4.

STEP III: FITTING A PARABOLIC TREND TO THE DATA OF 10 YEARS.¹⁾

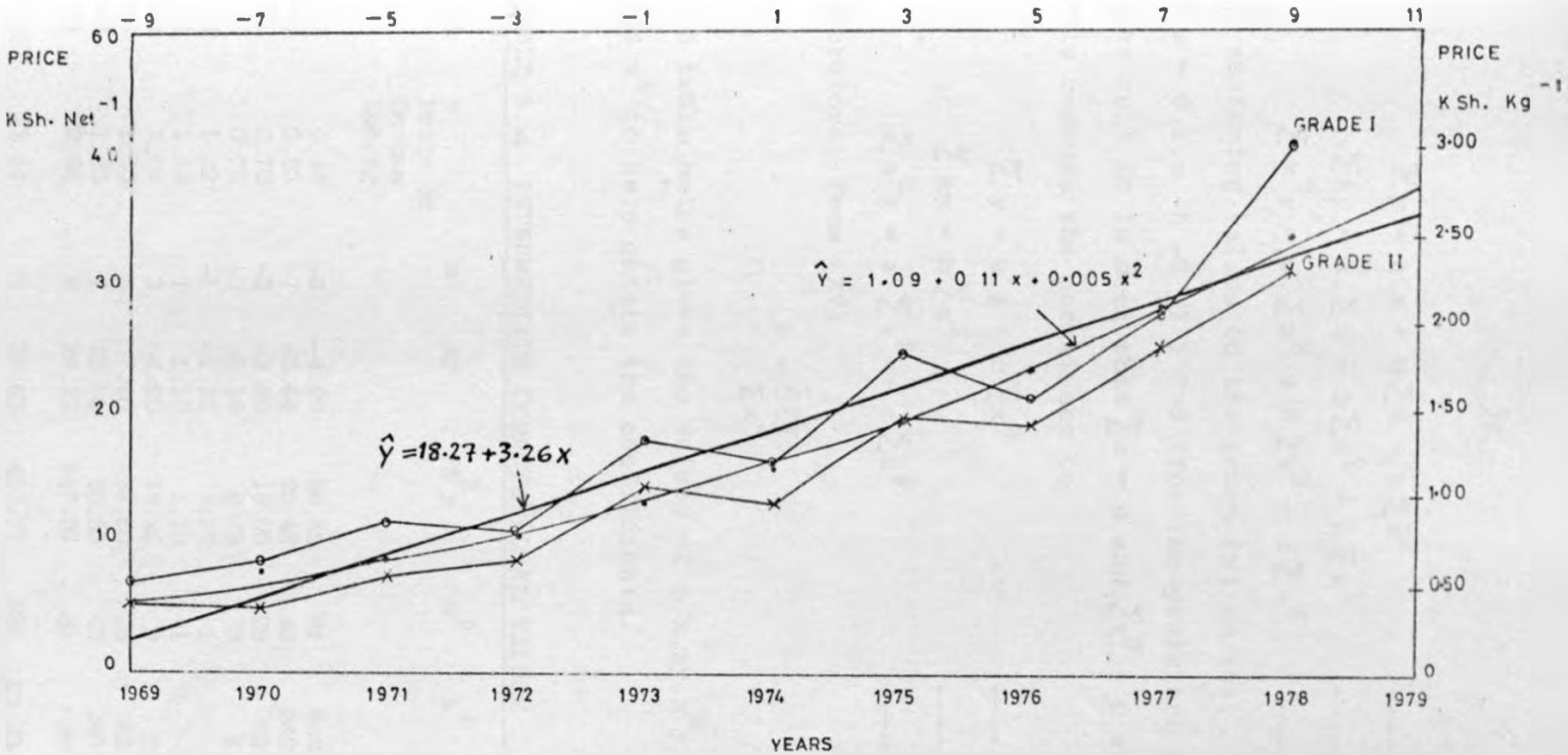
The parabola or second degree polynomial equation is $Y = a + bx + cx^2$ -----(X)
where Y is estimated dependent variable,
a is the intercept, b and c are coefficients and x is the independent variable.

By the method of least squares it is found that the values of a, b and c can be obtained by solving the following set of simultaneous normal equations.

1) After Freund and Williams, (1970) pp. 412 - 416.

PRICES.1969 - 1978

T = CODED TIME



$$\sum y = n.a + b \sum x + c \sum x^2 \quad \text{-----(XI)}$$

$$\sum xy = a. \sum x + b \sum x^2 + c \sum x^3 \quad \text{-----(XII)}$$

$$\sum x^2 y = a. \sum x^2 + b \sum x^3 + c \sum x^4 \quad \text{-----(XIII)}$$

By assigning values to the years (x) so that

$\sum x = 0$ i.e. -5 -3 -1 1 3 5 (for the years are an even set) it is seen that $\sum x = 0$ and $\sum x^3 = 0$ and this reduces the normal set to

$$\sum y = n.a + c \sum x^2 \quad \text{-----(XIV)}$$

$$\sum xy = b \sum x^2 \quad \text{-----(XV)}$$

$$\sum x^2 y = a. \sum x^2 + c \sum x^4 \quad \text{-----(XVI)}$$

Therefore, from (XV)

$$b = \frac{\sum xy}{\sum x^2}$$

The table below gives the values of $y, x, xy, x^2 y, x^2$ and x^4 to help obtain the coefficients.

TABLE 5.4 INTERMEDIATE COMPUTATIONAL VALUES

YEAR	y Price of Onions Ksh/kg	x	xy	$x^2 y$	x^2	x^4
1969	0.45	-9	-4.05	36.45	81	6561
1970	0.52	-7	-3.64	25.48	49	2401
1971	0.72	-5	-3.60	18.00	25	625
1972	0.72	-3	-2.16	6.48	9	81
1973	1.22	-1	-1.22	1.22	1	1
1974	1.10	1	1.10	1.10	1	1
1975	1.65	3	4.95	14.85	9	81
1976	2.50	5	7.50	37.50	25	625
1977	1.95	7	13.65	95.55	49	2401
1978	2.30	9	20.70	186.30	81	6561

n = 10

Substituting

$$b = \frac{36.65}{330} = 0.11$$

a = 1.09

c = 0.005

The equation of the parabolic trend becomes

$$Y = 1.09 + 0.11X + 0.005x^2 \quad \text{-----(XVII)}$$

(Origin 1969; x units, 1 year; Y mean price Kshs kg.⁻¹)

From the estimated trend the following values were obtained and plotted in Figure 5.4.

TABLE 5.5: TREND VALUES FROM THE PARABOLIC FUNCTION OF EQUATION XVII.

YEAR	Y, in Kshs kg ⁻¹	Kshs net ⁻¹
1969	0.50	6.85
1970	0.56	7.70
1971	0.66	9.00
1972	0.80	10.95
1973	0.98	13.40
1974	1.20	16.40
1975	1.48	19.90
1976	1.70	24.00
1977	2.10	28.60
1978 ¹⁾	2.48	33.80
1979	2.70	41.55

by substituting the value of x for 1979 in the function of equation XVII the estimated onion price

Since grade I prices are on average 13% above average, and grade II prices are 11% below average (for both grades), grade I price for 1979 will approximate Kshs 3.05 and grade II price will approximate Kshs. 2.40, ceteris paribus. These prices have been used in the onion Gross Margin calculation.

STEP IV: THE LINEAR TREND AND THE SEASONAL INDEX FOR ONION PRICES.

For purposes of checking whether the parabola is the best fit a linear trend was fitted. This has been incorporated in Figure 5.4. The procedure is shown below.

In an effort to make it possible to make statements on how much the farmer can expect during any month for his onions, a price index has been constructed. The procedure for this calculation also appears below.

The first step is to fit a linear function to the 2-year price data of Appendix II. (1969 has been left out because it has incomplete data).

The linear function takes the form¹⁾

$$y' = a + bx \quad \text{-----}(XVIII)^2)$$

To obtain the values of a and b for a least squares fit the following normal set of equations is useful.

$$\sum y = n \cdot a + b \cdot \sum x \quad \text{-----}(XIX)$$

$$\sum xy = a \cdot \sum x + b \cdot \sum x^2 \quad \text{-----}(XX)$$

Assigning values to x and using the annual price means as y's the table below gives the values of the unknown entities in XIX and XX.

TABLE 5.6: SOLUTIONS FOR a AND b IN EQUATION XVIII

YEAR	x	y	xy	x ²	y'
1970	-4	7.00	-28.00	16	5.28
1971	-3	9.80	-29.40	9	8.49
1972	-2	9.95	-19.90	4	11.75
1973	-1	16.50	-16.50	1	15.01
1974	0	14.90	0	0	18.27
1975	1	22.65	22.65	1	21.53
1976	2	20.55	41.10	4	24.79
1977	3	26.60	79.80	9	28.05
1978	4	36.45	145.80	16	31.31
1979	5	-	-	25	-
TOTAL		164.40	195.55	60	34.57

Substituting n = 9, and knowing that $a = \frac{\sum y}{n}$, and $b = \frac{\sum xy}{\sum x^2}$

the following linear equation is obtained:

$$y' = 18.27 + 3.26x \quad \text{-----}(XXI)$$

This equation has then been used to estimate the values of y' in the last column by substituting the corresponding values of x.

NOTE: The following legend goes with the equation XXI: Origin 1974; x units, 1 year; y mean annual onion prices in Ksh per 13.6 kg net.

The plot of this function appears in Figure 5.4 where it is easily compared with the parabolic trend line fitted earlier on. Estimation for 1979 by a linear trend is Sh.2.54. This is lower than the estimation by the parabolic trend. However, the parabolic trend will be used in models while for seasonal index the linear estimation is enough.

Substituting $x = 0, 1, 2, 3, \dots$ and 11 the figures of Appendix 12 are obtained from the linear function. See Appendix 12 panel (b).

The original data of Appendix 12 panel (a) are then divided month by month by the corresponding trend values and multiplied by 100. These values are given in Appendix 12 panel (c). They are the percentages of trend.

The mean of the percentage of trend is then found for each of the months and the sum of these obtained.

See page 11. Now the seasonal index for each month

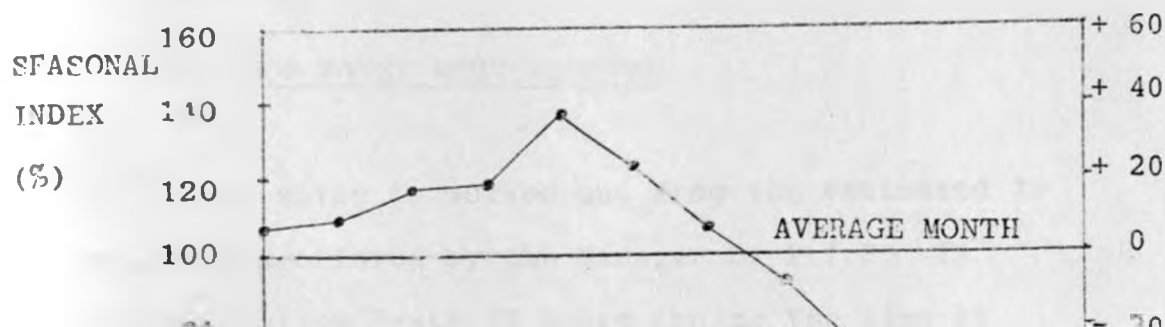
Since the 12 means totalled 130.4, we adjust for this by multiplying each of the means by $1200/130.4 = 9.202$, thus getting the seasonal index shown in row 12 and below.

TABLE 5.7: PERKERRA ONION PRICE INDEX BASED ON A LINEAR TREND OF NINE-YEAR SCHEME-GATE PRICES, (1970 - 1978).

<u>MONTH</u>	<u>SEASONAL INDEX</u>
January	106.7
February	107.7
March	116.9
April	117.8
May	137.1
June	123.3
July	106.7
August	92.0
September	73.6
October	70.8
November	72.7
December	74.5

This seasonal index has been plotted as Figure 5.5.

FIG. 5.5 ONION SEASONAL PRICE INDEX



STEP V : INTERPRETATION OF THE PRICE INDEX

A figure of 106.7 for January means that typical January prices are 106.7% of those of the average month, or in other words they are 6.7% above those of the average month. It is seen from the figures that prices are above average in January, rise to a maximum in May and fall below average after July and remain so for the rest of the year.

This price index would be useful to Perkerra farmers because it tells them when to expect higher than average prices or lower than average prices throughout the year. Except where institutional restraints do not allow any farmer could synchronise his harvest with the month of May when onion prices are at their highest.

(3) CROP WATER REQUIREMENTS AND RETURNS TO WATER
(Footnote 4)

a) CROP WATER REQUIREMENTS

This value is worked out from the estimated 19 irrigations offered by the Manager of P.I.S. If each irrigation lasts 22 hours (being the time it

This value differs from the author's estimate of 3 l s^{-1} , which was found to be quite common in the scheme. However, the management's estimate will be used henceforth.

Table 5.8 depicts the availability of water from the Perkerra River as gauged in the main canal at the river diversion from 1968 to 1977 and averaged on a monthly basis. The data from which these averages are obtained are recorded as Appendix 5.

b) RETURNS TO WATER

The returns to water can only be given on the basis of a crop. The higher the value of the crop the greater will be its return to water relative to other crops. It is for this reason that irrigation is mostly used in many parts of the world to raise only high value crops such as fruits and vegetables where water is scarce.

Onions have been shown to have a Gross Margin of Sh. 5,452 after deduction of all the costs of production including labour. It has been shown also that the amount of water required per hectare of onions is $11,900 \text{ m}^3$. If the Gross Margin is divided by the amount of water then the return per m^3 of water is Sh. 0.458 (approx, 50 cents).

TABLE 5.8 PERKERRA RIVER MEAN FLOW AS GAUGED AT
CANAL NEAR RIVER DIVERSION.

Month	Days	Mean Diurnal Flow Rate $M^3 s^{-1}$	Flow per 9-hr Day m^3	Flow per Day Less ¹⁾ 40%	Monthly Supply ²⁾ $m^3 \times 1000$
January	31	0.50	16,200	9720	301.3
February	28	0.43	13,930	8360	228.3
March	31	0.37	11,990	7190	222.9
April	30	0.43	13,930	8360	250.8
May	31	0.48	15,550	9330	289.2
June	30	0.50	16,200	9720	291.6
July	31	0.49	15,880	9530	295.4
August	31	0.49	15,880	9530	295.4
September	30	0.68	22,030	13220	396.6
October	31	0.66	21,330	12830	397.7
November	30	0.62	20,090	12050	361.5
December	31	0.52	16,850	10110	313.4
MEAN	30.4	0.51	16,660	10000	304.2

SOURCE: Appendix 5.

1) Represents estimated total losses which include conveyance, distribution and application losses. Irrigation efficiencies differ at all three stages of the system. For clarification of terminology and definitions of efficiencies see ICID, ICID Bulletin, January 1978, Vol. 27 No. 1, pp. 91-101.

Since all tenants use approximately equal amounts of water on their holdings it is to be expected that the returns to water must differ with the level of production. As an example, from the Gross Margin Calculation for onions on Table 5.3 we see that the low level production Gross Margin of Sh. 213 gives a return to water of only 2 cents per m^3 . When Gross Margin 1 is considered the returns to water improve tremendously.

As far as chillies are concerned it has been reported that in 36 irrigation applications a total of 22,540 m^3 are applied. (See Appendix 6.) Since a flat rate is paid on water irrespective of the crop that is being irrigated, chillies water costs are lower per unit than those of onions. An average chillies hectare yielding a Gross Margin of Sh. 2142 approximates a return to water of 10 cents per m^3 . This shows that onions are of a higher value as far as returns to water are concerned. On the low production level chillies depict a negative value of returns to water.

Onions and chillies are the only high value crops grown in the scheme. Maize and beans are

The discussion considers net returns to water since the cost of water has already been deducted to get the Gross Margin. It is difficult to say whether on the basis of these values the water has low or high returns since only one user of water, the P.I.S has been considered. It is worthwhile for other users of the waters of the Perkerra River to be considered before one can state whether or not the P.I.S takes the priority of water apportionment. However, it has been shown that for the average yielder it is economical to farm by irrigation in the P.I.S although the margin of net benefits is rather low.

Crop Coefficient (K_c) values for onions and chillies at similar stages of development are the same, (Doorenbos and Pruitt, 1975, p.66) and this suggests similar ET (crop) values, (Doorenbos and Pruitt, 1975, p.83). This in effect suggests that except for the longer season of the Perkerra chillies the water demands for chillies and onions remain the same. Beans also have comparable K_c values, (Doorenbos and Pruitt, 1975, p.65).

In summary, we can conclude that unless further experiments prove otherwise the water demands of the

(4) SEED (Footnote 5)

Onion seed costs KSh. 450 per kg. Since seedlings are supplied to the farmers from scheme communal nurseries this cost takes into account all the necessary nursing costs that the scheme management incurs.

(5) FERTILIZER INPUTS

Contrary to what the Manager of the P.I.S reports on the application levels of fertilizers¹⁾, the average rate of application on onions is not 52 kg ha⁻¹ but in fact more than double that rate. The following data support this statement.

1) Manager P.I.S to Chief Agriculturist, M.I.B, official communication, November 1978

TABLE 5.9 : FERTILIZER APPLICATION LEVELS IN THE
P.I.S, ¹⁾ kg ha⁻¹

TENANT NUMBER	ONIONS	CHILLIES	MAIZE
1	500	250	125
2	750	500	125
3	375	250	125
4	500	250	125
5	500	250	125
6	250	250	125
7	500	500	125
8	750	500	250
9	250	250	0
10	500	250	250
11	500	250	125
12	374	500	62
13	500	250	0
14	250	500	0
15	500	250	250
16	500	500	125
MEAN	470	340	120
S.D ²⁾	148	125	80

SOURCE: Author's investigation.

Note: If zero applicatic levels are removed from
the maize fertilizer values, the S.D drops to 60 kg.

- 1) The fertilizer is Sulphate of Ammonia which is 21% N.
2) This is sample standard deviation.

(6) PESTICIDES (Footnote 6)

Details of the application of pesticides appear in the agronomy section. Another pesticide used is Sevin 85% at the rate of 2.5 kg ha⁻¹. Malathion, Rogor and Sevin are often sprayed alternatively in a bid to evade thrips resistance to any of them. Dithane M45 is the only fungicide used in the scheme.

(7) GRADING

The tenant meets the costs of grading. 10 cents is paid to the scheme organization per net of onions for use of the grader. Labour for grading is provided by the farmer and is included in the column "HARVESTING" of Appendix 14 (a).

(8) BAGS

The packaging material recommended for Kenyan conditions are well aerated plastic nets which cost the tenant Sh. 1.50 a piece. The standard weight for onion packages in Kenya is 13.6 Kg. The costs of nets is defrayed from net earnings.

hectare to the reception centre. No consideration is given to the number of trips made to one farmer's holding or to whether or not one trip serves more than one farmer.

(10) EXTERNAL TRANSPORT

Rongai Transport Company Limited has undertaken the contract to transport P.I.S produce to Nairobi. The average charges are 0.1 cent per kilometre per kg. For onions the charges are Sh.3 per net of 13.6 kg over a distance of 270 km i.e from Perkerra to Nairobi; and for chillies a consignment of 300 bags of 20 kg each is charged Sh.1,500 over the same distance.

(11) LABOUR REQUIREMENT AND CALENDER OF OPERATIONS

As similar crops start and end at different dates, the labour data had to be standardised. This was done by developing a calender of operations spanning a period of 12 months. The data used in the calender of operations approximate closely those obtained from the interviews, (see Appendix 14 to 17.

In drawing a calender of operations as displayed on Table 5.10, for crops grown in the P.I.S

(a) FACTORS AFFECTING THE TENANT

a1) At any time in the year the Perkerra tenant is busy with at least three plots of crops of 0.4 ha each. Each of these plots is under a different crop. These crops are onions, chillies, maize and beans.

a2) It is convenient and economical to transplant when there is an adequate flow of water. Lack of water during the first 3-4 irrigations after transplanting can lead to heavy crop mortalities. Moreover, sufficient water flow rates save time at transplanting.

(b) FACTORS AFFECTING THE WHOLE SCHEME

b1) Major farm operations such as ploughing, harrowing, ridging and spraying are easiest during a dry weather spell when heavy machinery can penetrate the fields.

b2) An attempt is made to have the sensitive stage of a crop escape the rainy season when fungal diseases prevail consequent to favourable weather.

If the maximum of water demand for the cropped area would correspond with the maximum water supply the economics of water-use would improve

5.10: A SUGGESTED P.I.S FARMER'S ANNUAL CALENDAR OF OPERATIONS.

MONTH	ONIONS	CHILLIES	MAIZE	BEANS	KENAF	R. HEMP
1	CC Tr Irr x 6 Weed x 3 Bund	Bund CC				Irr x 4 Weed
2	Irr x 4 Weed x 3	Tr Irr x 6 Weed x 2				Irr x 2
3	Irr x 4 Weed x 4 CC	Irr x 4 Weed x 3				Harv. (calyces)
4	Irr x 2	Irr x 3, CC Weed x 3 Pick x 2				
5	Harv.	Irr x 3 Weed x 3 Pick x 4	Bund	Bund Plant		
6	Bund Tr CC Irr x 6 Weed x 3	Irr x 3 Weed Pick x 4	Plant Irr x 4 CC Weed	Irr x 4 CC Weed		
7	Irr x 4 Weed x 3	Irr x 2 Pick x 4	Irr x 4 Weed	Irr x 4 Weed		
8	Irr x 4 Weed x 3 CC		Irr x 2	Irr x 2 Harv.	Bund CC	
9	Irr x 2		Harv.		Weed x 2 Plant Irr x 6	
10	Harv.				Irr x 4 Weed	L. Prep. Plant Irr x 6
11					Irr x 4 Weed	Irr x 4 Weed
12						

LEGEND TO TABLE 5.10

Tr	Transplant
Irr	Irrigate
CC	Clear Canal
Harv.	Harvest
L. Prep.	Land Preparation

Paying attention to all these factors would lead to the development of the ideal calendar of operations for the P.I.S. The major shortcoming is that it is the aim of the scheme management of the P.I.S. to make horticultural production continuous even as the demand is. What the scheme can rely on to improve the calendar of operations is a thorough monitoring system for market price and consumer behaviour for the whole range of scheme produce. The price analysis given above has shown how historical commodity prices can be used to predict future prices. Once a future price is found supply can then be adjusted to the benefit of the farmer.

Based on this calendar of operations is a calculation of the labour demand throughout 12 months for the Perkerra farmer.

TABLE 5.11: LABOUR DEMAND SCHEDULE FOR THE PERKERRA FARMER
BASED ON THE SUGGESTED CALENDAR OF OPERATIONS
MAN-HOURS.

MONTH	COTONS	CHILLIES	MAIZE	BEANS	KENAF	R. HEMP	TOTAL
1	1550	85				225	1860
2	1030	625				60	1715
3	1040	600				360	2000
4	60	985					1045
5	840	1340	40	140			2360
6	1550	1050	350	320			3270
7	1030	865	250	315			2460
8	1080		50	130	90		1350
9	840		130		440		1430
10					220	650	870
11					220	320	540
12					440	220	660

SOURCE: Calculated from author's investigation on labour demand per farm operation.

It should be borne in mind that this demand schedule represents the status quo.

We can see from this schedule that peak labour demand, if we take month 1 to be January, occurs

5.2 THE STRUCTURE OF THE TENANT FARMS

5.2.1 LABOUR AVAILABILITY

The following results were obtained about the farmer's source of labour.

TABLE 5.12: PERKERRA FARMER'S PERMANENT LABOUR STRUCTURE

TENANT NUMBER	SELF	NUMBER OF WIVES	CHILDREN OVER 15YR	PERMANENT HIRED LABOUR	TOTAL	TOTAL MAN-HRS/MONTH
1	1	1	0	1	3	390
2	1	1	4	2	4	1,050
3	1	1	3	0	2	660
4	1	3	3	1	8	1,050
5	1	1	4	0	6	790
6	1	2	0	1	4	520
7	1	3	0	0	4	520
8	1	2	4	1	8	1,050
9	1	3	0	1	5	660
10	1	1	0	1	3	390
11	1	0	0	0	1	130
12	1	2	0	0	2	390
13	1	2	4	2	9	1,170
14	1	0	1	1	3	390
15	1	1	1	1	4	520
16	1	3	0	1	5	560
MEAN	1	2	2	1	5	640
S.D					2	301

SOURCE: Author's investigation.

1; All investigations refer to the 1977/1978 crop season.

The total man-hours available are on average 640 man-hrs/month. The models later are based on this average. However the table indicates that some farms have only 390 hours/month for disposal when others can plan production with more than 1000 hours a month.

Tenant's ages average 41 years with a range between 25 and 58 years. Each tenant is taken as one man-equivalent irrespective of whether it is a man or a woman. All permanently available labour of age 15-59 years be it male or female is also taken to be equivalent to one man-equivalent. Discussions occur in Clark and Haswell (1964) and Srinivasan (1957, quoted in Clark and Haswell) on classification of farm labour, but there is no agreed system among social scientists on how to value child and female labour in man-equivalents. The author contends that the system of allocation depends on the nature of the farm operations that the labour is engaged in. For the P.I.S. the output of a man for an operation such as transplanting onions may fall short of the 'man-equivalent', whereas for a girl of 15 years it may somewhat exceed this non-standardised measure of physical human output.

In calculating the man-hours available per month each man-equivalent is taken to be involved in irrigation agricultural activities for 6 hours a day for 22 days a month. This estimate allows a total of 260 days a year which is below the 300 days estimate used by Clayton (1961) for a similar study but under more favourable climatic conditions, (also cited in Clark and Hoswell, 1964, p. 133). Figures of total available labour have been rounded.

5.2.2 LAND AND LAND-USE

Land was found to have been allocated as follows during the 1977/78 season, (ending in June 1978).

TABLE 5.13: LAND SIZE AND ALLOCATION BY ENTERPRISES
DURING THE 1977/78 CROPPING SEASON AT P.I.S,HA

Tenant Number	Onions	Chillies	Maize	Beans	Total ¹⁾
1	0.4	0.4	0.4	0.4	1.6
2	0.4	0.4	0.2	0.4	1.4
3	0.4	0.4	0.2	0	1.0
4	0.4	0.4	0.2	0	1.0
5	0.8	0.4	0.2	0	1.4
6	0.4	1.2	0.4	0.4	2.4
7	0.4	0.4	0.2	0.4	1.4
8	1.2	0.4	0.2	0	1.8
9	0.4	0.4	0	0	1.8
10	0.4	0.4	0.4	0	1.2
11	0.4	0.4	0.2	0.4	1.4
12	0.4	0.4	0.2	0.4	1.4
13	0.4	0	0.4	0.4	1.2
14	0.4	0.4	0.2	0	1.0
15	0.8	0.4	0.2	0	1.4
16	0.8	0.4	0.2	0	1.4
MEAN	0.5	0.4	0.2	0.2	1.4

SOURCE: Author's investigation.

1) Presently the amount of land a farmer can allocate to one crop is institutionalised at a minimum level of 0.4 ha for all the cash crops and maximum of 0.4 ha for the others.

5.2.3 CAPITAL AVAILABILITY

Although 50% of all the interviewees were found to be in debt, with debts ranging between KShs.600 and KShs.5,000, this did not affect the capital availability estimates because these debts did not limit the level of credit advanced to farmers during a crop season. The capital available consisted of a farmer's liquidity, which might come from a source other than the scheme, and the advance cash payments provided by the scheme management.

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CHAPTER 6

DISCUSSION OF RESULTS OF ORGANIZATION FOR FARM LEVEL MAXIMUM PROFITABILITY, AND AGGREGATION TO WHOLE PROJECT PROFITABILITY

6.1 General Introduction

At this point it is necessary to recall that the two objectives of this study are firstly, to describe farming as is currently carried out in the Perkerra Irrigation Scheme, and secondly, to seek reorganization of the system with a view to increasing gross margins. These objectives, which form the backbone of the thesis have already been stated in section 1.2 page 3.

The description of farming as is currently carried out started with a geographical and historical statement of the study area as is contained in Chapters 1 and 2. Further description of the current P.I.S. activities appears in Chapter 5, which above all else is a presentation of the data to be used in the planning process.

Chapter 5 establishes the main resources as land, labour, capital and water. Their levels are established and these are aimed to act as the constraints in the subsequent models. Current average gross margins are calculated so as to show the situation as it is currently. On the basis of the various levels of yields obtained by the farmers, classes are drawn to show that

Of particular importance in Chapter 5 (see pages 73 - 84), is the derivation of prices to be used in the models. As adjustment of time series trends using the Laspeyres criterion leads to an upward bias on the trend and the Paarsche adjustment has the opposite effect, Freund and Williams (op. cit) apply time series analysis using nominal prices which leads to no enhancement of effect in either direction. This has been applied here and the application by Freund and Williams (op. cit) has been meticulously followed.

Another important section of Chapter 5 is the discussion on returns to water and crop-water requirements. This section lays the foundation upon which water can be entered into the model as one of the constraining resources.

From the foregoing we see that the first objective of the thesis has been satisfied. Chapter 6 therefore deals with the second objective.

Chapter 6 will present its results in two parts viz., results of optimization of individual holdings and aggregation to whole-scheme-optimization.

Chapter 6 is the culmination of the preparation to modelling as discussed in Chapters 3 and 4. The literature review on Chapter 3 prepares the reader in the understanding of Chapter 6 by delineating from a large

Section 4.4 in Chapter 4 is particularly relevant to Chapter 6 as this explains the nature of a linear programming problem formulation. However, in the computer solution of this problem one cannot observe the actual arithmetical mechanics since a 'package' has been used. Suffice it to say that the computer solves the problem iteratively whereby one additional step in the calculation leads towards the best answer. Eventually, through a number of iterations, the optimal solution is obtained. The problem formulation presented on pages 59 and 60 is incorporated in the problem matrices.

6.2 Introduction to the Models

As already stated, there are individual holding models and aggregated models. The gross margin for individual holdings will form the basis for the aggregated model as the latter is only the sum total of all the optimum solutions in the scheme.

Optimum solutions on individual holdings will be obtained for the following situations:-

- (i) A situation based on the derived farming calender of Tables 5.10 and 5.11 which represents the status quo. The first model in this category will consider optimization given the existing stock of resources of the individual average holding and all possible crop enterprises (Model 1). The second will consider only the crops that are currently grown in the scheme (therefore excluding roselle

- (ii) A situation where there is borrowing or hiring to augment the existing stock of family labour and capital resources. This model will include all crops considered to be feasible enterprises in the P.I.S., (Model 3).
- (iii) A parametric state of the resource levels whereby a dynamic situation is generated by altering the value of the resource by a pre-determined magnitude so as to observe the effect on the previous optimal solution. This model will attempt to determine the resource package necessary for a farmer to break-even and to improve on the current plan, (Model 4).
- (iv) Model 5 will use the matrix shown as Table 6.8 based on the feasible assumption that it is possible to plant a crop every month. Resource levels will also be stated on a monthly basis. The model will also incorporate the possibility of hiring labour to supplement available family labour as well as the carry-over of capital from one crop to another as this has been observed in the field. (See Table 6.8).
- (v) An aggregated model based on the best individual holding plan to determine a

In addition to these, several sensitivity analyses will be carried out with a view to determining the stability of the various models. As has been mentioned on page 44, sensitivity analyses are the techniques which are used to study how an optimal solution is affected by changes in individual numerical values of the resource levels and objective row elements (prices and costs of production). Mostly sensitivity analysis is used to study the effect of tightening or slackening a constraint, changing a price or cost etc. The main difference between sensitivity analysis and parametric modelling is that in the latter pre-determined 'jumps' are made on any desired element of RHS (resource levels) or objective row elements. In the former a general range on all rows is built around each optimal value of the RHS or objective row element. As discussion of the results progresses these differences will become more and more pronounced.

6.3 Introduction to the Problem Matrices

Two problem matrices have been drawn. One of these is based on the calender of operations which represents the status quo of the scheme. This matrix, presented as Table 6.1 considers two onion crops per annum and one crop of each of the other five enterprises viz., chillies, maize, beans, kenaf and roselle hemp.

TABLE 6.1

LP PROBLEMA MASYARAKAT PERKERAJAAN

CRIS.	INPUT						SALARIO								HIRING LABOUR								HIRING				
	1 F01	2 F02	3 F03	4 F04	5 PKE	6 PMH	7 S01	8 S02	9 S03	10 S04	11 S05	12 S06	13 L01	14 L02	15 L03	16 L04	17 L05	18 L06	19 L07	20 L08	21 L09	22 L10	23 L11	24 L12	CAPITAL CAP	FIX	
C	-7355	-9375	-1780	-1630	-1895	-1.40	2.70	2.0	80	200	2.70	6.0	-1.80	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-0.20	-
P01	1	1	1	1	1	1																					1.4
P02	1550	85				225							-1														1.4
P03	1030	625				60							-1														6.20
P04	1040	600				60								-1													1.4
P05	10	985													-1												6.20
P06	140	1340	37	149												-1											1.4
P07	1520	1050	354	316													-1										5.10
P08	1030	865	250	315														-1									6.20
P09	1000		46	130	94														-1								1.4
P10	700		130	130	460															-1							6.20
P11					222	650																-1					6.20
P12					222	320			8	10																	1.4
P13					400	222																					6.20
P14	7355	9375	1780	1630	1895	1440						1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
P15	-6340						1																				
P16		-6970						1																			
P17			-15						1																		
P18				-13						1																	
P19					-1520						1																
P20						-670						1															

SOURCE: AUTHOR'S INVESTIGATION

Several models have been drawn by altering certain aspects of this matrix e.g. removing 'hiring labour' columns which removes casual labour leaving the farmer with only his permanently hired and family labour.

The other problem matrix, Table 6.8, presupposes the possibility of planting a crop each month and so having a possibility of 12 crops of each enterprise in a year. This is possible under irrigated conditions.

The expanding of symbols used in these problem matrices are explained in Appendices 18(a) and 18(b).

6.4 Basic Farm Models

MODEL 1: ALL CROPS, AVERAGE YIELDS, NO HIRING ACTIVITIES

The optimal organization as obtained by this model is compared with the current organization in Table 6.2.

In this model the constraining variables were land, January Labour and Operating Capital which attained shadow prices of KShs. 1,107, 2.80 and 0.60 per unit, respectively.

The Table shows that less onion hectareage would be preferred in the new model, at a level of 0.31 ha instead of the current 0.4 ha yielding a gross margin of KShs. 3,025.

The three factors which were constraining on this model were shown to be quite sensitive when so analysed. Land, for example was ranged only between 0.92 ha and 1.49 ha for the optimal plan to remain so. This is shown on Table 6.3.

TABLE 6.2: MODEL 1 OUTPUT COMPARED WITH THE CURRENT PLAN

OPTIMAL ORGANIZATION			CURRENT ORGANIZATION		
Enterprise	Amount of Land (ha)	Gross Margin (KSh)	Enterprise	Amount of Land (ha)	Gross Margin (KSh)
Onions	0.31	3,025	Onions	0.4	3,905
Kenaf	0.36	795	Chillies	0.4	1,826
R. Hemp	0.73	1,883	Maize	0.4	-232
			Beans	0.2	194
	1.4	5,703		1.4	5,693

SOURCE: COMPUTER OUTPUT AND TABLES
5.2 AND 5.13

(1)

TABLE 6.3: SENSITIVITY ANALYSIS AND
CONSTRAINING VARIABLES OF MODEL

Constraint	Right Hand Side	Lower Limit of R.H.S.
Land	1.4	0.92
Jan. Labour	642.0	474.88
Capital	4000.0	3767.40

SOURCE: COMPUTER OUTPUT

Right Hand Side Ranging also showed that March and October labour were fairly sensitive. Below 584.6 and 556.2 man-hours for these two months, respectively, the optimal plan ceases to be optimal. Note that the RHS gave 640 man-hours, (Table 6.1).

Objective ranging showed that at the current chilli prices, chillies entered the plan if the price of onions fell to KShs. 2.30/kg⁻¹. If the price of chillies rises to KShs. 2.32/kg⁻¹, they enter the plan even with the current prices prevailing but other constraints come into play. Maize enters the optimal organization if its price rises to KShs. 261.50 per 90-kilogram bag. This price of maize is unrealistic as the price of maize in Kenya is controlled at a low KShs. 85 - 100 per 90-kg. bag. May be if the price of maize was left to be determined by open market conditions that price would be reached.

On the whole this model improves the current plan by a mere KShs. 10. Considering the food issue which is controversial in the P.I.S. it can be concluded that the current organization is comparable to the optimal organization of model 1. Inclusion of maize and beans in the plan means that the farmer wouldn't have to purchase them, so saving himself certain costs and inconvenience.

MODEL 2: NO KENAF AND ROSELLE HEMP, AVERAGE YIELDS,
NO HIRING ACTIVITIES

The enterprises considered in this model are onions, chillies, maize and beans which were found planted during the field survey.

This model gave an optimal plan of KShs. 4,080 with onions at 0.41 ha and chillies at 0.01 ha, leaving a slack on land of 0.98 ha (approx. 1.0). January and June labour supplies were exhausted and labour attained shadow prices of KSh. 4.20 during those two months, respectively.

The solution to this model does not improve on the current plan in any way and may be considered to be inferior to it. The one most important feature about it however, is that it acts as a control to the other models; it shows that without some structural change in the resource availabilities, there is no way gross margins in the P.I.S. can be improved with the utilization of all the land.

6.5 Extended Models

There is no reason why a programmer should consider any resource fixed a priori. A programmer should introduce buying and selling activities for resources so as to determine the limit endogenously, (Edwards, 1961). Hiring activities will be introduced for these variables because it is assumed that a peak labour demand period affects most of the scheme, and tenants are forced by circumstances to hire casual labour from outside. Such a situation may be observed during chilli picking or onion land preparation and planting season. Hiring activities for labour and capital will ensure that all the available land is cropped, as land allocation is controlled.

MODEL 3: ALL CROPS, AVERAGE YIELDS, HIRING ACTIVITIES ON LABOUR AND CAPITAL

By making allowance for a farmer to hire labour to supplement his family and permanent labour, the solution on Tables 6.4 and 6.5 was output.

It is immediately clear from Table 6.4 of the solution that the KShs. 6,400 gross margin of this solution is superior to that of the current plan and that all the land has been utilised. The model however,

TABLE 6.4: COLUMN INFORMATION FOR SOLUTION OF MODEL 3

COLUMN INFORMATION		SOLUTION			
		RIGHT HAND SIDE OBJECTIVE		LIMITS PROFIT	
ACTIVITY IN OPTIMAL BASIS	NAME		VALUE	OBJECTIVE	REDUCED COST
✓	PON	+	0.5881	-7355.0000	0
	PCH	+	0	-9375.0000	-1092.7409
	PMA	+	0	-1780.0000	-3033.5112
	PBE	+	0	-1630.0000	-1508.7112
✓	PKE	+	0.2407	-1895.0000	0
✓	PRH	+	0.5712	-1440.0000	0
✓	SON	+	3728.4574	2.7000	0
✓	SCH	+	0	2.7000	0
✓	SMA	+	0	80.0000	0
✓	SBE	+	0	200.0000	0
✓	SKE	+	3365.8697	2.7000	0
✓	SRH	+	382.7117	6.0000	0
✓	LJA	+	400.0540	-1.2000	0
	LFE	+	0	-1.2000	-1.0040
✓	LMA	+	177.2443	-1.2000	0
	LAP	+	0	-1.2000	-1.2000
	TMA	+	0	1.2000	-1.2000

TABLE 6.4: COLUMN INFORMATION FOR SOLUTION OF MODEL 3

COLUMN INFORMATION		SOLUTION			
		RIGHT HAND SIDE OBJECTIVE	VALUE	LIMITS OBJECTIVE	PROFIT REDUCED COST
✓	PON	+	0.5881	-7355.0000	0
	PCH	+	0	-9375.0000	-1092.7409
	PMA	+	0	-1780.0000	-3033.5112
	PBE	+	0	-1630.0000	-1508.7112
✓	PKE	+	0.2407	-1895.0000	0
✓	PRH	+	0.5712	-1440.0000	0
✓	SON	+	3728.4574	2.7000	0
✓	SCH	+	0	2.7000	0
✓	SMA	+	0	80.0000	0
✓	SBE	+	0	200.0000	0
✓	SKE	+	3365.8697	2.7000	0
✓	SRH	+	382.7117	6.0000	0
✓	LJA	+	400.0540	-1.2000	0
	LFE	+	0	-1.2000	-1.0040
✓	LMA	+	177.2443	-1.2000	0
	LAP	+	0	-1.2000	-1.2000
	LMA	+	0	-1.2000	-1.2000
✓	LJU	+	259.7697	-1.2000	0
	LJY	+	0	-1.2000	-1.2000
✓	LAU	+	17.7577	-1.2000	0
	LSE	+	0	-1.2000	0.8979
	LOC	+	0	-1.2000	-1.2000
	LNO	+	0	-1.2000	-1.2000
	LDE	+	0	-1.2000	-1.2000
✓	CAP	+	1604.0416	-1.2000	0
	OBJECTIVE		6400.3127		

SOURCE: COMPUTER OUTPUT

GENERAL COLUMN INFORMATION OF THE SOLUTION OF MODEL 3

- ME = See page 8.
- LUE = This is the level at which the activity of the given NAME has entered the optimal plan.
- OBJECTIVE = For each activity described under NAME this is the cost (or gross revenue) accruing per unit of that activity. For buying and producing activities costs are given as negative revenues while for selling activities revenues are positive.
- REDUCED COST = The reduced cost of a variable is the increase in the objective function per unit increase in the value of the variable whilst the current basis remains feasible. Alternatively the reduced cost of a variable may be regarded as the minimum reduction required in the objective value of the variable in order for it to become eligible, in terms of the complex algorithm, to

TABLE 6.5: ROW INFORMATION FOR SOLUTION OF MODEL 3

SOLUTION

ROW INFORMATION		RIGHT HAND	SIDE	LIMITS	
ACTIVITY	NAME	OBJECTIVE		PROFIT	
IN OPTIMAL	PROFIT	Z	SLACK	R.H.S.	
BASIS			6400.3127	0	
	R01	+	0	1.4000	-1576.2399
	R02	+	0	640.0000	-1.2000
	R03	+	0	640.0000	-0.1960
	R04	+	0	640.0000	-1.2000
✓	R05	+	604.7149	640.0000	0
✓	R06	+	146.0088	640.0000	0
	R07	+	0	640.0000	-1.2000
✓	R08	+	34.2727	640.0000	0
	R09	+	0	640.0000	-1.2000
	R10	+	0	640.0000	-0.3071
✓	R11	+	215.2763	640.0000	0
✓	R12	+	403.2761	640.0000	0
✓	R13	+	407.2814	640.0000	0
	R14	+	0	4000.0000	-0.2000
	R15	+	0	0	-2.7000
	R16	+	0	0	-2.0000
	R17	+	0	0	-80.0000
	R18	+	0	0	-200.0000
	R19	+	0	0	-2.7000
	R20	+	0	0	-6.0000

SOURCE: COMPUTER OUTPUT

LEGEND ON ROW INFORMATION FOR SOLUTION OF MODEL 3

- NAME = Name of the row as shown on page 9.
- SLACK = This is the amount of resource which, out of the initial amount, (R.H.S.), has been left unutilized. Where extra units of the activity were hired to be used in obtaining the optimal solution the slack is zero.
- R.H.S. = LIMITS = Resource levels made available. No limits were placed on hired resources i.e. after exhausting these LIMITS one could hire the resource indefinitely.
- PRICE = In a linear programming problem a value associated with each constraint when an optimal solution has been found. It gives the change that will occur to the value of the objective if a unit change is made to the right hand side of the constraint providing the current basis remains feasible. The range over which the price applies is limited and can be ascertained by the process of right hand side ranging. The reduced cost has an analogous role with respect to the

LEGEND ON ROW INFORMATION FOR SOLUTION OF MODEL 3

- NAME = Name of the row as shown on page 9.
- SLACK = This is the amount of resource which, out of the initial amount, (R.H.S.), has been left unutilized. Where extra units of the activity were hired to be used in obtaining the optimal solution the slack is zero.
- R.H.S. = LIMITS = Resource levels made available. No limits were placed on hired resources i.e. after exhausting these LIMITS one could hire the resource indefinitely.
- PRICE = In a linear programming problem a value associated with each constraint when an optimal solution has been found. It gives the change that will occur to the value of the objective if a unit change is made to the right hand side of the constraint providing the current basis remains feasible. The range over which the price applies is limited and can be ascertained by the process of right hand side ranging. The reduced cost has an analogous role with respect to the objective function.

From the tables of output it has been shown that a total of 855 man-hours (Table 6.4), should be hired to raise the GM to KSh. 6,400. The amount of labour lying idle throughout the year is a total of 1,811 man-hours most of which falls idle in April, November and December. The 855 extra man-hours a tenant requires during his peak labour demand period are hired at a total cost of KSh. 1,030.

Right hand side ranging shows that the optimal solution of model 4 remains optimal between 0.8 ha and 1.7 ha. Table 6.6 summarises other important features of this model as obtained by sensitivity analysis. Fairly narrow ranges are discernible for land, February, July and September labour as is shown by Right Hand Side Ranging.

6.6 Parametric Model

To accommodate any changes which may occur in the restraint levels, and to investigate the effects of proportional increments in all the resource levels, a parametric model was drawn. Only the right hand side (resource restraints) was parameterized. The objective function was not parameterized because it was not possible to forecast price behaviour of all the commodities and inputs. Secondly, it was not possible to accurately relate these price changes to the stepwise changing resource levels designed to be used in the parametric models. An increment in resources may or may not affect the scheme's unit production costs.

TABLE 6.6: SENSITIVITY ANALYSIS AS APPLIED TO MODEL 3

(a)

ROW INFORMATION		RIGHT HAND SIDE RANGING		LIMITS			PROFITS
ROW NAME (Constraint)	TYPE	R.H.S.	LOWER LIMIT OF R.H.S.	OUTGOING AT LOWER LIMIT	UPPER LIMIT OF R.H.S.	OUTGOING AT UPPER LIMIT	
Land	+	1.4	0.8	July Labour	1.7	Oct. Labour	
Feb. Labour	+	640.0	618.0	LAU	676.0	July Labour	
July Labour	+	640.0	606.0	July Labour	+INF		
Sept. Labour	+	640.0	583.0	LAU	917.0	July Labour	

SOURCE: COMPUTER OUTPUT

TABLE 6.6: SENSITIVITY ANALYSIS AS APPLIED TO MODEL 3

(b) COLUMN INFORMATION		OBJECTIVE RANGING		LIMITS PROFITS		
		RIGHT HAND SIDE OBJECTIVE				
VARIABLE	TYPE	OBJECTIVE	LOWER LIMIT OF OBJ.	INCOMING AT LOWER LIMIT	UPPER LIMIT OF OBJ.	INCOMING AT UPPER LIMIT
PON	+	-7355.00	-7508.00	Feb. Labour	-6263.00	Feb. Labour
PKE	+	-1895.00	-2050.00	Sept. Labour	-1786.00	Feb. Labour
PRH	+	-1440.00	-1662.00	Feb. Labour	-1293.00	Sept. Labour
SON	+	2.70	2.67	Feb. Labour	2.87	Feb. Labour
SCH	+	2.00	0	Chilli	2.16	Prod. Chillies
SMA	+	80.00	0	Maize	282.23	"
SBE	+	200.00	0	Beans	316.05	Prod. Beans
SKE	+	2.70	2.60	Sept. Labour	2.77	April Labour
SRH	+	6.00	5.67	Feb. Labour	6.22	Sept. Labour
LJA	+	-1.20	-1.32	"	-0.58	Op. Capital
LMA	+	-1.20	-1.35	"	-0.71	Sell Beans
LJU	+	-1.20	-1.34	"	-0.49	Feb. Labour
LAU	+	-1.20	-1.44	"	0	Sell Maize
CAP	+	-0.20	-0.24	"	0	Op. Capital

SOURCE: COMPUTER OUTPUT

For these reasons it would have been fallacious (with the available data) to make assumptions of relationships between the objective and the resource restraints.

MODEL 4: ALL CROPS, AVERAGE YIELDS, RIGHT HAND
SIDE PARAMETRIC

The model therefore starts to output solutions at:

RHS = 0.4 ha land
 = 260 man-hours labour
 = 1,000 shillings operating capital

CHANGE = 0.4 ha, 260 man-hours and 1,000 shillings
 for land, labour and operating capital,
 respectively. Column 3 is the first
 basic optimal solution as it is
 output with minimum resources.

As the model involves stepwise variation of the RHS, the following assumptions were incorporated in its structure:

- (i) That 260 man-hours are the minimum available each month of the year.
- (ii) That KSh. 1,000 are available as operating capital at the start.
- (iii) That the minimum land allocation to any tenant was 0.4 ha and the maximum was 2.0 ha.

The parametric model starts to output solutions at the levels of resources given in assumptions (i) to (iii).

Four increments were considered each taking the values 260,1000 and 0.4 for labour, capital and land, respectively. Each increment was called CHANGE and was multiplied by the PARAMETER to give the level of the resources to be added to RHS for optimization at that stage. The PARAMETER took the values 0, 1, 2, 3, and 4.

Solutions were output at $\text{RHS} + 0 * \text{CHANGE}$, $\text{RHS} + 1 * \text{CHANGE}$, etc., where RHS was the name of the right hand side. RHS + 0, where the first solution is output is the point described by the initial resource levels as defined in assumptions (i) to (iii), above. The results obtained are shown on Table 6.7.

It is seen that food crops do not enter the model at any of the considered levels of inputs, a clear indication that the economics of food production in the P.I.S. does not justify the recent trend towards maize and beans production.

In order to give a visual realization to the changes that parameterization introduces, Figure 6.1 plots the results of model 4.

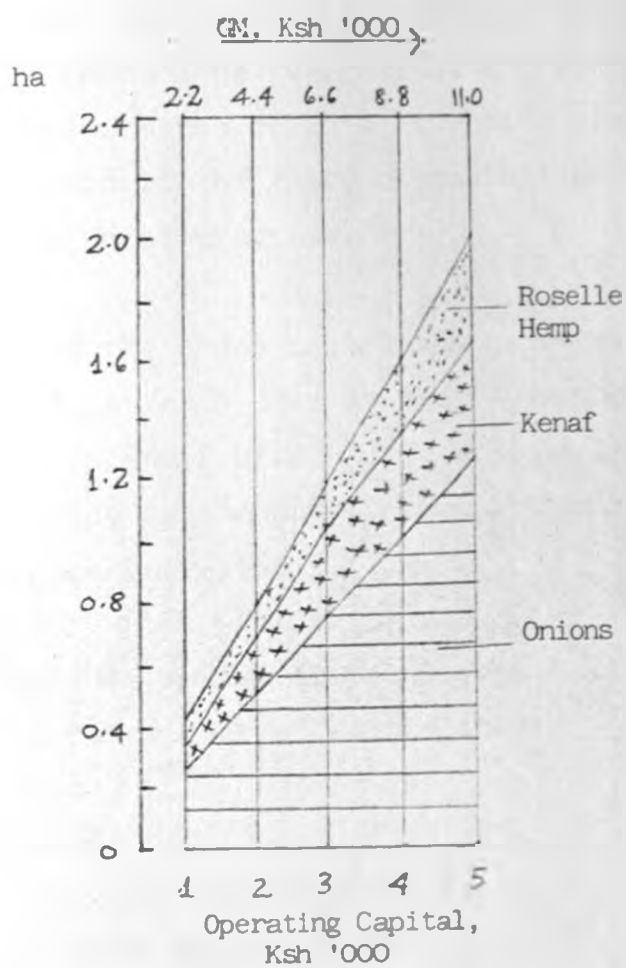
TABLE 6.7: MODEL 4 SUMMARY OF OUTPUT

1	2	3	4	5	6	7
Value of Parameter		0	1	2	3	4
Total GM (Sh)		2210	4420	6630	8835	11040
Enterprise(s)	On	0.25	0.5	0.75	1.0	1.25
	Ke	0.10	0.16	0.24	0.32	0.4
	Rh	0.10	0.15	0.22	0.29	0.36
Total Land (ha)		0.4	0.8	1.2	1.6	2.0
Initial Labour (man-hours/month)		260	520	780	1040	1300
Hired Labour	LJA	141	282	423	564	705
	LMA	25	49	73	97	121
	LJU	120	240	340	480	601
	LAU	16	32	47	63	78
Initial Op. Capital (Sh.)		1000	2000	3000	4000	5000
Borrowed Capital (Sh.)		1080	2160	3240	4320	5400

NOTE: Rh = Roselle hemp, Ke = Kenaf On = Onions

Fig. 6.1:

DIAGRAMMATIC REPRESENTATION
OF THE PARAMETRIC MODEL SOLUTION



6.7 The Expanded Model Developed on an Annual Rotation Programme

6.7.1 Changes on Original Model Concepts

It was recognised that there was a possibility of having a crop starting each month over the whole year. This possibility engendered the expansion of the cropping calendar upon which the models so far discussed are based to include twelve real activities on each enterprise. The essence of this is that a crop can be planted in any month of the year, a possibility limited to irrigated horticultural practice.

In addition to the above modification, water demand was estimated for each crop by the FAO method as discussed in Doorenbos and Pruitt (1975, p. 4 et seq). These have been entered in the model, thus introducing an additional resource restraint.

A third important modification was the introduction of the carry-over of earned income from one month to the next.

Besides being more complex than the other models, this one introduces a stringent rotation programme which, if not followed, would render the idea meaningless. As one crop is harvested other crops at various hectarages on the same holding are expected to be at various stages of growth.

6.7.2 Results of Model 5

After solving the model using the computer package as used for the other models, the solution shown on Table 6.9 was output. This solution has been shown together with its monthly water needs.

This model did not hire any capital because operating capital needs were furnished by the income carried over from one month to another. A capital level of KSh. 6,000 has been allowed for in January, and during the other months rotation dynamics make the carry-over of capital from one month to the next a possibility.

The results show that no irrigation water is needed in July. The crop water requirements are satisfied by rain during that month. During the month of July there are 5 crops in the scheme all at various stages of growth. Among these is a crop that is close to harvest, one that has just been transplanted, and three crops which are at various stages of growth with varying water requirements. All these have been considered in the calculation for total crop water requirements.

The optimum plan of this model would be a suitable rotation programme for the whole scheme (as will be discussed later). Among other things the plan ensures continuity of onion supply in the local horticulture market and reduces the farmer's reliance on borrowed capital to furnish his needs.

The gross margin of KSh. 21,050 is at least 300% the gross margin of the existing programme which is a clear improvement but the managerial ability of the farmer is put to test by the intensiveness of the system. These issues will be discussed in a later section.

TABLE 6.9: SOLUTION OF MODEL 5 WITH MONTHLY WATER NEEDS

Month	Enterprise	Land Allocation To Enterprise ha	Irrigation Water Needs m ³ /month
JANUARY	ON01	0.2	1344
FEBRUARY	ON02	0.4	1538
MARCH	ON03	0.2	2000
APRIL	ON04	0.4	1398
MAY	ON05	0.4	698
JUNE	ON06	0.2	350
JULY	ON07	0.4	0
AUGUST	ON08	0.2	1190
SEPTEMBER	ON09	0.4	1848
OCTOBER	ON10	0.4	1568
NOVEMBER	ON11	0.2	826
DECEMBER	ON12	0.4	1160
Total Gross Margin		=	KSh. 21,050

SOURCE: CIMPUTER OUTPUT

6.8 An Aggregated Model (MODEL 6)

Looking at the models which have been presented so far it is clear that model 5 is the most superior. The financial implications in aggregating the results of this model would be greater than any other for the scheme. It would be expected also that as the model presupposes a high level of management to cope with the monthly operations, this model more than any other presents the managerial challenge which has hitherto lacked in the scheme. For these reasons the aggregated model adopts the results of model 5.

Table 6.10 is the summary of the aggregation exercise. To establish whether it is feasible to aggregate these results given the average flow (Appendix 5) columns 3, 4 and 7 present water demand results.

The aggregated model uses 350 farmers at an average holding of 1.4 ha. It has been shown that this kind of aggregated model would be free of aggregation bias (Odero-Ogwel and Clayton, 1973). The results of this model are tabulated on Table 6.10.

TABLE 6.10: RESULTS OF THE AGGREGATED MODEL BASED ON THE OPTIMAL PLAN OF MODEL 5

1 Month	2 Cropped Land (ha)	3 Water Requirement Per Farmer (m ³)	4 Total Water Required (m ³ x1000)	5 Scheme Revenue From Water (KShx1000)	6 Available Irrigation Flow (m ³ x1000)	7 Land Irrigated With Given Flow (ha)
JAN	70	1344	94	5.6	304.2	226
FEB	140	1538	19.6	1.2	304.2	2172
MAR	70	200	140	8.4	304.2	152
APR	140	1398	195.7	11.7	304.2	217
MAY	140	698	97.7	5.9	304.2	436
JUN	70	350	24.5	1.5	304.2	869
JUL	140	0	0	0	304.2	0
AUG	70	1190	83.3	5.0	304.2	256
SEP	140	1148	258.7	15.5	304.2	164
OCT	140	1568	219.5	13.2	304.2	194
NOV	70	826	57.8	3.5	304.2	368
DEC	140	1160	162.4	9.7	304.2	262
TOTAL				81.2		

SOURCE: AUTHOR'S COMPUTATION

6.9 General Discussion of Results

A certain amount of discussion of results of the various models has tended to follow the tabulation of these results. This section presents a generalised discussion of the results of all the models. The discussion will start with the relatively easy models and end with the more complex ones.

Section 6.4 presented the basic farm models which are based on the existing cropping calendar. Model 1 shows that little is to be gained by rejecting the current plan and adopting the plan of this model as the GM is not improved to any significant extent. The plan has further proved itself inadequate as the current plan contains beans and maize which are important food crops. From the comparison of the current plan and the plan obtained from Model 1 it is clear that the heuristic effort used by the farmer and the scheme management has arrived at a commendable plan which compares well with an LP optimum one.

The results of Model 2 give a plan that is inferior to the current one. This emanates from the exclusion of kenaf and roselle hemp which have relatively higher gross margins than maize and beans. The large slack on land, approximately 1.0 ha on a 1.4 ha holding is an indication that without the hiring of some production resources all the land cannot be utilized. On the grounds that this model does not improve the gross margin in any way it cannot be recommended for adoption in the scheme.

Model 3 shows that with the option of hiring labour and capital at unit costs of KSh. 1.20 per man-hour and KSh. 0.20 per shilling, respectively, a plan is obtained which improves the current one by at least KSh. 400 per season per holding. This flexibility also ensures that all the land is cropped. The plan however, excludes all food crops.

Sensitivity analysis of this model shows that the model is fairly sensitive to changes in the production costs of onions, kenaf and roselle hemp and the prices of onions and chillies. The analysis however, shows that the model is fairly insensitive to changes in the prices of maize and beans as the model remains stable within very wide ranges of maize and beans prices - KSh. 0-282 and KSh. 0-316, respectively. If the price of maize rose above KSh. 282 per 90-kg. bag and that of beans rose above KSh. 316 per 90-kg. bag, then these would probably enter the basis. Given the Government producer price control restrictions on maize and beans it is unlikely to expect these prices to be reached in the open market. Therefore, in considering whether or not to adopt this plan the food production criterion cannot be taken as overruling.

The parametric model (Model 4) is designed to investigate the effect on the GM and enterprise combination of changing resource restraints. Optimal solutions output at the various stages show that the proportion of onions in the plan remains unaltered but that of kenaf declines while more roselle hemp enters the model (see Figure 6.1)

The fifth model drawn incorporates the possibility of having 12 crops per year, i.e planting a crop each month. The results of this model show that only onions enter the optimal plan (see Table 6.9). Earning a gross margin of KSh. 21,050 this is the most superior of all the others and earns three times better than the current plan. This would be a suitable rotation programme to adopt except for the fact that it suggests a monoculture, an idea likely to be opposed by P.I.S. farmers who have in the past lost whole onion crops due to diseases and pests. From a purely GM improvement standpoint this plan would be recommended for adoption in the whole scheme. As a result of this recommendation this plan is used to draw an aggregated model to show what would be the result of adopting it on 350 holdings.

The results of aggregation as shown on Table 6.10 which summarises the outcome of Model 6, indicate that by adopting the optimal plan of Model 5 in the scheme, an annual scheme revenue of K£4,060 could be generated in water rates. This attribute and the fact that farmers would earn much higher incomes make this plan an attractive one.

In general, it has been shown that plans exist which are much superior to the current plan. A reorganization of farming in the P.I.S. by adopting some of these plans basing decisions on farmers' preferences such as provision for food and the need for diversification, is feasible. The main problems are that some of these plans lay heavy demands on hired resources, except Model 5 which adopts a method of carrying-over income

from one crop to use as operating capital on another. Further, to adopt any of them successfully, a higher level of management is necessary.

CHAPTER 7
HYPOTHESES TESTING

7.1 GENERAL

It was earlier stated that all the hypotheses would be tested by use of the results obtained from the LP solutions. All the hypotheses tested here have been stated in section 4.2 of this study.

7.2 TESTING HYPOTHESIS 1.

Hypothesis 1 states that "the present land-use in the P.I.S. is sub-optimal and a reallocation of resources is required to optimise land-use".

Results of "LP Perkerra 1" have shown that it is possible to raise the GM of the current plan by about 300%. Inevitably this has been achieved by a reorganization of the existing resources - factor - factor relationship. Plans 1 and 3 are also better than the current plan. The hypothesis is therefore accepted.

7.3 TESTING HYPOTHESIS 2.

The results of Plan 3 show that besides the farmers initial capital of KSh.4,000 an extra KSh.2,398 is required to furnish the farmers' operating capital needs. The hypothesis cannot be rejected therefore because more than KSh:4,000 are required through the season.

However, the results of "LP Perkerra 1" have shown that the carry-over of revenue from one crop to the next leads to an optimal plan that doesn't require any hired capital.

For these two reasons judgement is reserved on hypothesis 2.

7.4 TESTING HYPOTHESIS 3.

The statement of hypothesis 3 reads: "water is not a constraint in putting the originally planned 2,400 ha under crop". This hypothesis is tested using Table 6.10. It is shown on Table 6.10 that 304,200 m³ of water are available per month. The monthly scheme water demand does not exceed this figure. It is also shown that a total of 3,203 ha can be put under crop between January and May. The hypothesis is accepted.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

The study has shown that there are ways of reallocating the existing production resources in the P.I.S. to generate higher incomes for the farmers. It has been shown also that this reorganization is feasible. The study therefore arrives at the conclusion that a reorganization of the P.I.S. cropping pattern is an apt proposition for the present time.

With the ever-rising cost of living it is important that the N.I.B. institutes measures to aid in the implementation of the following recommendations:

1. That the cropping pattern be altered to conform to the solution of "LP Perkerra 1" (Model 5).
2. That the technical personnel at the P.I.S. be increased by (a) a graduate agriculturalist to act as the field officer and (b) an entomologist.
3. That strict supervision be carried out to ensure that the recommended fertilizer levels are applied.
4. That a study be carried out to determine the main causes for low yields.
5. That the N.I.B. initiate a study with the objective of determining whether water storage in the river or night storage in the scheme would be the most appropriate method of increasing the farmed hectarage. This will involve a feasibility study of the Perkerra river catchment.

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APPENDIX 1: MONTHLY AND ANNUAL PRECIPITATION FOR 1968 TO 30TH JUNE
1978 AT P.I.S. (mm)

MONTH	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
JANUARY	-	54.9	88.9	25.7	1.8	18.4	1.8	1.5	0.7	89.3	52.8
FEBRUARY	77.7	24.4	2.0	-	59.7	11.8	13.8	12.8	6.6	1.0	74.3
MARCH	60.9	134.9	131.8	1.5	1.5	-	127.3	24.5	3.3	0.8	122.3
APRIL	108.5	2.8	46.0	76.9	43.2	8.5	44.1	149.9	61.7	281.6	33.6
MAY	69.6	96.5	36.8	138.2	67.3	7.3	31.5	199.8	101.8	121.9	8.8
JUNE	45.5	2.0	79.3	174.2	134.9	30.1	35.6	66.4	47.8	89.4	37.1
JULY	74.4	66.0	76.7	53.8	28.5	109.8	134.8	186.7	99.7	224.0	
AUGUST	64.3	15.8	115.3	150.3	68.3	100.2	106.4	126.1	51.2	56.8	
SEPTEMBER	6.1	63.8	16.8	52.2	37.9	21.6	43.8	71.0	37.6	44.5	
OCTOBER	52.0	51.1	31.5	31.8	67.8	7.4	41.8	42.8	10.8	55.2	
NOVEMBER	53.9	20.3	27.2	13.5	30.9	34.9	52.7	9.9	16.8	139.1	
DECEMBER	5.6	0.8	25.9	51.0	19.7	-	3.3	1.0	39.5	14.0	
TOTALS	618.5	533.3	678.2	769.1	561.5	350.0	736.9	792.4	477.3	1117.6	328.9

Annual Mean = 676.53 mm

SOURCE: P.I.S. 1978 Annual Report

APPENDIX 2: MONTHLY WINDRUN AVERAGES AT P.I.S. (km/day).

MONTH	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	MEAN
MONTH												MEAN
J	113.5	136.0	110.6	116.7	116.3	119.2	130.8	132.6	126.4	93.8	55.3	113.7
F	118.4	99.9	112.6	113.6	104.0	120.6	91.6	122.8	123.2	103.1	84.2	108.5
M	105.7	117.0	117.0	145.1	133.2	146.7	129.6	133.5	142.7	137.6	85.7	126.7
A	90.5	-	105.2	112.9	129.2	126.4	98.5	111.0	100.4	87.6	80.0	104.2
M	100.2	-	109.0	94.3	92.2	121.5	109.3	96.7	104.6	66.6	100.4	99.5
J	108.4	-	106.4	78.6	86.0	98.5	102.3	82.1	97.4	-	97.0	95.0
J	103.8	-	95.9	80.3	86.6	89.8	92.0	91.4	90.4	73.8	72.9	87.7
A	103.9	-	102.2	102.2	96.8	93.9	88.2	74.2	83.4	81.4	77.3	90.4
S	120.2	-	107.2	92.7	108.9	108.2	95.0	84.7	100.7	53.2	75.0	94.7
O	123.7	108.4	115.4	107.9	104.3	114.0	113.9	95.0	122.9	88.6	87.2	107.4
N	110.4	108.2	105.6	81.6	98.8	115.6	113.6	95.0	108.5	74.8	98.5	101.0
D	-	120.4	116.6	116.0	116.7	119.1	117.0	114.0	115.7	84.9	-	113.4

NOTE: Based on the average number of days in a month = 30.4167 for a normal year and 30.3 for a leap year.

SOURCE: P.I.S. Research Station.

:

APPENDIX 3: FINANCE FIGURES ON THE P.I.S.

	(1) Capital £	(2) Recurrent £	(3) Depreciation £	(4) Revenue £	(5) Operation Losses in £ (2)+(3)-(4)
1954					
1955	86,336	21,588	1,727	Nil	23,315
1956	33,546	16,490	2,398	Nil	18,888
1957	55,016	11,213	3,498	500	25,211
1958	32,777	16,145	4,153	800	19,498
1959	9,675	31,060	4,347	2,100	33,307
1960	2,771	16,313	4,402	2,640	18,075
1961	3,045	14,460	4,463	2,405	16,518
1962	7,221	10,218	4,608	2,021	11,805
1963	14,241	31,906	4,892	13,232	23,566
1964	6,198	35,580	5,017	7,114	33,483
1965	10,940	44,790	5,236	33,197	16,829
1966	8,447	27,156	7,788	15,545	19,399
1967	3,202	34,464	6,357	15,420	25,401
Totals	273,415	332,383	58,886	94,974	296,295

NOTE: A continuation of this appendix is to be found in Table 1.2 of the thesis.

SOURCE: Chambers (1973), p. 350.

APPENDIX 4.

QUESTIONNAIRE USED IN SURVEY.¹⁾

1. Name of farmer..... Plot Number.....
2. Name of enumerator.....
3. Date of survey.....

INFORMATION CONCERNING ALLOCATION OF
LAND TO THE VARIOUS ENTERPRISES

4. How many different crops did you grow last year and how many hectares of each crop did you plant?²⁾

<u>Crop</u>	<u>ha</u>
1.
2.
3.
4.
5.

5. Size of land in hectares
6. Do you have land elsewhere? Yes..... No:.....
7. What did you grow on that land last year and how much of your land did you allocate to each of the crops grown or animals kept?

	<u>Enterprise</u>	<u>ha</u>
1.
2.
3.

8. Besides farming in this irrigation scheme, are you involved in any other money-making activities? Yes..... No.....

9. What are these activities? 1.
2.
3.

10. Approximately how much money do you get from these other activities per month? Kshs.....

INFORMATION CONCERNING LAST SEASON'S INPUTS ON THE SCHEME.

11. How much fertilizer did you apply to each of your crops last season?

	<u>Crop</u>	<u>Name of fertilizer</u>	<u>Amount applied, kg.</u>
1.
2.
3.
4.
5.

12) Current price of the various fertilizers

- (per kg as at Baringo) 1.
2.
3.

13. How many times a week do you apply water to your crops?

<u>Crop</u>	<u>Frequency of water application, times/week.</u>	<u>Estimated³⁾ Intake, m³</u>
1.
2.
3.
4.
5.

14. Estimated application rates for the various crops through the growing season.

<u>Crop</u>	<u>Estimated application rate m³</u>	
1.
2.
3.
4.
5.

15) Did you apply any pesticides to your crops last season?

Yes No

16) Please, tell me the pesticides you used on the various crops and how much of each you used

	<u>Crop</u>	<u>Name of pesticide</u>	<u>Rate of application</u>
1.
2.
3.
4.
5.

17) Current prices of the various pesticides used.

	<u>Pesticide</u>	<u>Cost</u>
1.
2.
3.
4.
5.

18) How much seed of each crop did you buy and what was the cost of it?

	<u>Crop</u>	<u>Amount of seed</u>	<u>Cost of seed</u>
1.
2.
3.
4.
5.

19) How many hours did the scheme tractors spend on your land during land preparation?⁴⁾

	<u>Crop .</u>	<u>Machinery time</u>
1.
2.
3.
4.
5.

INFORMATION CONCERNING SOURCES OF LABOUR AND
THE ALLOCATION OF LABOUR TO THE VARIOUS ENTERPRISES

20) Husband....., Approx. ageyrs.

21) Number of wives.... Approx. age(s)yrs.

22) How many permanent labourers had you during the last season and how much were you paying each of them?

<u>Labourer</u>	<u>Monthly salary, Kshs.</u>
1.
2.
3.

23) How many children do you have? -

24) How many of your children are over 15 years of age? - - - - .

25) Do you have any sons who are married?
Yes No

26) Do you have any daughters who are married?
Yes No

27) Do any of your married children help you with farm work?

Sons: Yes ... No ... Their wives: Yes ... No ...

Daughters: Yes ... No ... Their husbands Yes ... No

28) How much on average do you pay your casual labourers per day? Kshs.

32) Planting

	Crop	No of workers	Days worked	M. hrs per day	Charge per day	Total charge
1.
2.
3.
4.
5.

33) Irrigating

.....
.....
.....
.....
.....

34) Weeding

.....
.....
.....
.....
.....

35) Harvesting

	Crop	No of workers	Days worked	M. hrs per day	Charge per day	Total charge
1.
2.
3.
4.
5.

INFORMATION CONCERNING OUTPUTS

36)	Crop	Amount harvested	Amount consumed at home	Amount sold	Price per unit	Gross income, Kshs.
1.	G1.....
		G2.....
2.
3.
4.
5.

37) Did you have any debts outstanding at the beginning of the season we are talking about on any of the crops you had grown the season before?
 Yes No

38) How much are these debts?⁵⁾

	Crop	Debts	Total costs	Gross income less debts and costs	Comment
1.
2.
3.
4.
5.

39) What do you think are the major problems tenants face in this scheme?

1.
2.
3.
4.

40) I have found that generally the yields of maize are very low, what do you think should be done about growing maize in the scheme?⁶⁾

- A. Increase ha to B. Leave it as it is
- c. Remove maize

FOOTNOTES TO APPENDIX 4

- 1) This questionnaire relates to the 1977/78 cropping season.
- 2) Since areas in the scheme are still in imperial units tenants were asked questions in those units (acres) and these were then translated to metric units (ha).
- 3) The average stream size had earlier on been estimated at 3.8 l s^{-1} .
- 4) If tenants cannot recall these values the values will be obtained from the workshop records.
- 5) This question was found necessary in view of the fact that a new tenant takes over the debts of the evicted tenant whom he is replacing. The general feeling of the tenants in the scheme is that these debts should be scraped as bad debts because in many cases the new tenant can operate this holding for more than two seasons without realising a net benefit from his plot. This poses a serious hunger threat for the tenant and his family.

- 6) This question is important from the point of view of food for the tenant and his family, especially if they have no land elsewhere from where they get their food.

APPENDIX 5: PERKERRA RIVER FLOW, 1968-1977 (m³/ sec)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
JAN		0.53	0.45	0.61	0.57	0.66	0.29	0.35	0.46	0.54
FEB		0.56	0.44	0.46	0.55	0.54	0.27	0.26	0.42	0.35
MAR		0.54	0.43	0.38	0.48	0.30*	0.25	0.25	0.33	0.36*
APR		0.54	0.55	0.59	0.38	0.32*	0.45	0.27	0.55	0.21*
MAY		0.53	0.60	0.45	0.47	0.34		0.47	0.52	0.30*
JUN		0.52	0.47	0.41	0.50	0.44		0.64	0.58	0.48
JUL	0.48	0.48	0.48	0.47	0.46	0.43		0.52	0.53	0.48
AUG	0.56	0.52	0.50	0.37	0.67	0.57		0.41	0.76	0.48
SEP	0.56	0.48	0.75	0.65	0.83	0.74				0.48
OCT	0.55	0.50	0.74	0.64	0.71	0.71				0.48
NOV	0.41	0.46	0.74	0.64	0.78	0.67				0.48
DEC	0.40	0.41	0.64	0.54	0.76	0.40				0.48
MEAN	0.49	0.50	0.56	0.52	0.60	0.51				0.48

NOTE: For purposes of planning irrigation development records are required over periods shorter than a month. See text. Consequently annual means are of limited value.

* = controlled flow at the river diversion. Otherwise most of the river flow is diverted leaving only a trickle.

SOURCE: P.I.S. Annual Reports 1968/69-1976/77.

APPENDIX 6:

AGRONOMY: CHILLIES¹⁾

Chillies (Capsicum frutescens) trials were carried out in the P.I.S in the 1950s but were abandoned and chillies were a relatively forgotten crop until 1968 when its production in the scheme started. The reason for this revival was diversification as onions were the only crop raised in the scheme upto that time. The variety, which came to be known as Ex-Perkerra was obtained by bulking from the original bushes. It is of the long red Cayenne type.

Land preparation comprises of disc-ploughing two times to a depth of 15 to 20 cm, harrowing and ridging. Seedling is raised in a nursery 160 m² broadcast or drilled to a medium density.²⁾ At 42 days when seedling are 10 to 15 cm tall they are transplanted at 45 cm within rows and 90 cm between rows.

1) Adapted from Mohdhar, A. A, January, 1976 and Knot, J. E, 1957

2) This is sufficient to fill one hectare at the spacing given. Heavier densities may fill more than one hectare of land.

Sulphate of ammonia is applied in a split dressing at 14 days after transplanting and at flowering time. Application levels range between 52 kg N and 105 kg N ha⁻¹. The transplanted crop is hand-weeded 3 to 4 times before a complete canopy is formed.

Irrigation in the nursery is by sprinkler at one day intervals before emergence and 4 day intervals after. Generally the crop is irrigated at seven day intervals in the field.

Main diseases are seedling dumping-off and powdery mildew. Dumping-off is controlled by seed-dressing with Dithane M-45 at 0.2 kg per 50 kg seed.¹⁾ Powdery mildew is prevented by spraying at high volumes with Karathane, Dithane M-45, Benlate or Afugan at their recommended rates. Major pests and their chemical controlling agents can be tabulated as follows:

<u>Pest</u>	<u>Chemical Control</u>	<u>Rate</u>
American bolworm	Endosulphan	2.8 l ha ⁻¹
Yellow teamite	Kelthane	1.7 l ha ⁻¹
Aphids	Rogor 40E	0.6 l ha ⁻¹
Termites	Aldrin 40% (W.P)	3 kg ha ⁻¹

1) Other methods of control are crop rotation of seedbed and hot water treatment of seeds for 30 minutes at 52°C by cerasan treatment.

GROSS MARGIN CALCULATION 2.

(Irea, Form 1)

Location: P.I.S
 Crop: CHILLIES

Variety: EX-PERKERRA

Level of Production		A1)				B2)	
		Units	Unit price K sh.	Units per ha.	Value per ha. K sh.	Units per ha.	Value per ha. K sh.
Yield	Grade I	kg	2.30	4690	10,790	6,970	16,030
	Grade II						
Gross Output		Ksh			10,790		16,030
<u>Allocable Costs</u>							
1	Water ⁴⁾	m ³	0.033	22540	745	22540	745
2	Land Preparation						
	2-1 Ploughing x 2	hr	20.00	10	200	10	200
	2-2 Harrowing	hr	28.75	4	115	4	115
	2-3 Ridging	hr	32.50	2	65	2	65
	2-4 Other						
3.	Seed/Seedlings ⁵⁾	kg	110	1	110	1	110
4.	Fertilizer						
	4-1 Sulphate of ammonia	kgN	7.10	250 =52N	370	345 =72N	510
	4-2						
	4-3						
5.	Pesticides						
	5-1 Dithane M-45 x 4 ⁶⁾	kg	95.00	10	950	10	950
	5-2 Rogor 40E x 4	l	35.56	3	107	3	107
	5-3 Aldrin x 1	kg	47.50	3	143	3	143
6.	Grading						
7.	Bags	Buyer provides gunny bags.					
8.	Transport (Internal)	ha	65.00	1	65	1	65
9.	Transport (External)	kg	0.25	4690	1,175	6,790	1,745
10.	Other Material Costs ⁷⁾				3,485		4,620
Sum 1-10 Allocable Costs					7,530		9,375
Less Labour							
GROSS MARGIN I					3,260		6,655
11	Labour						
	1. Clearing Canals	hr	1.20	72	86	72	86
	2. Planting	hr	1.90	48	91	48	91
	3. Cross Bunding	hr	0.80	100	80	100	80
	4. Irrigating	hr	1.10	824	906	824	906
	5. Weeding	hr	1.60	1,750	2,800	1,750	1,800
	6. Harvesting	hr	0.20	1,570	315	2,750	550
	7. Other Labour						
Sum 11, Total Labour Cost					4,278		4,513

REMARKS ON GROSS MARGIN CALCULATION FOR CHILLIES

- 1) This refers to a low level yield of $4,690 \text{ kg ha}^{-1}$.
- 2) This refers to an average sample yield of $6,970 \text{ kg ha}^{-1}$.
- 3) This is the present national economic farm-gate producer's price related to fresh exports as used by the Ministry of Agriculture for their computations.¹⁾
- 4) The flat water rate paid on any crop should mean that water is valued differently for the various crops. The irrigation stream was found to be 7.82 l s^{-1} .
- 5) One kg of seed will provide seedling sufficient to fill one hectare and for any subsequent gapping. The price given is the price of seed only.
- 6) Dithane M-45 required for seed dressing is included in this amount. It is taken that the whole range of chemicals may or may not be used in one cropping season especially when proper sanitation has been practiced in the past.

1) Republic of Kenya, 1978.

7) These include the following:

Handling charges (including drying of chillies, grading or sorting, packaging and loading onto trucks)	A ¹⁾ -----1060/=	B ¹⁾ 1060/=
Packaging material (bags)	----- 75/=	75/=
Sales Commission at 30 cts kg ⁻¹	-----1410,	2090/=
Interest charges at 20 cts kg ⁻¹	----- 940,	1395/=

1) As on "GROSS MARGIN CALCULATION" table.

APPENDIX 7: AGRONOMY: MAIZE

In the P,I,S maize is presently grown to meet the food needs of the tenant and his family and not, strictly speaking as a cash crop. Maize was reintroduced during the 1977-78 season for the first time since its removal as a scheme crop in the sixties.

P,I,S has not settled on one maize variety but instead it is trying out several varieties include the Embu short season varieties and Katumani synthetics.

Land preparation is the same as for onions and chillies. Where new land is being opened 3 - 4 ploughings may be needed to break the soil sufficiently. After harrowing and ridging maize is planted by hand with 2 seeds per hill at an approximate spacing of 75 x 30 cm giving a population of 44,000 plants per hectare.

Maize is irrigated at weekly intervals over a growing season of approximately 150 days.

Dusting with 5% DDT when maize is Knee-high protects maize from stalk-borer infestations.

Over the last season yields averaged 15 bags (1350kg) per hectare. The GM calculation shows that it is uneconomical to grow maize by irrigation in the P.I.S. In recent times local politics has played a notable role in sustaining maize among the scheme crops in the P.I.S.

GROSS MARGIN CALCULATION 3

(Irea, Form 1)

Location: P.I.S
 Crop: MAIZE

Variety: KATUMANI HYBRID

Level of Production	Units	Unit price K sh.	A		B	
			Units per ha.	Value per ha. K sh.	Units per ha.	Value per ha. K sh.
Yield Grade I Grade II	Kg	0.90	900	810	1350	1215
Gross Output				810		1215
<u>1. Allocable Costs</u>						
1. Water	m ³	0.063	11900	745	11900	745
2. Land Preparation						
2.1 Ploughing x 2	hr	20.00	10	200	10	200
2.2 Harrowing	hr	28.75	4	115	4	115
2.3 Ridging	hr	32.50	2	65	2	65
2.4 Other						
3. Seed/Seedlings	Kg	1.85	50	93	50	93
4. Fertilizer						
4.1 Double superphosphate	Kg P ₂ O ₅	6.0	40	240	40	240
4.2 A.S.N.	Kg	2.25	100	225	100	225
4.3						
5. Pesticides						
5.1 5% D.D.T. Dust	Kg	11	3	33	3	33
5.2						
5.3						
6. Grading	-	-	-	-	-	-
7. Bags	Bag	3	10	30	15	45
8. Transport (Internal)	ha	15	-	15	-	15
9. Transport (External)	-	-	-	-	-	-
10. Other Material Costs						
Sum 1-10 Allocable Costs				1761		1776
Less Labour				-951		-561
GROSS MARGIN I						
11. Labour						
1. Clearing Canals	hr	1.30	37	48	37	48
2. Planting	hr	1.90	37	70	37	70
3. Cross Bunding	hr	1.20	66	80	66	80
4. Irrigating	hr	1.00	235	235	265	265
5. Weeding	hr	1.90	310	590	310	590
6. Harvesting	hr	0.80	100	80	128	102
7. Other Labour						
Sum 11. Total Labour Cost				1103		1155

APPENDIX 8: AGRONOMY: BEANS

Growing beans is optional for P.I.S tenants. Beans, like maize, are grown to meet the food needs of the tenant and his family. Only local varieties have been grown in the P.I.S hitherto.

Land preparation is the same as for onions and maize and the spray schedule is the same as that of maize.

Seeding is aimed at producing 110,000 to 145,000 plants per hectare.

No fertilizer has been recommended for Perkerra's irrigated conditions. However, it is proposed that a mixed fertilizer of

100 kg CAN,

100 kg Single superphosphate, and

150 kg Muriate of potash,

is suitable when applied at a rate of 100 kg per hectare.

No serious pests or diseases have been detected on Perkerra beans.

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GROSS MARGIN CALCULATION 4

(Irea, Form I)

Location: P.I.S

Commodity: BEANS

Variety: INDIGENOUS

Level of Production

		A		B			
		Units	Unit price K sh.	Units per ha.	Value per ha K sh.	Units per ha.	Value per ha K sh.
Yield	Grade I Grade II	Kg	2.20	900	1980	1170	2574
Gross Output					1980		2574
1. Allocable Costs							
2	Water	m ³	0.063	11900	745	11900	745
2	Land Preparation						
2-1	Ploughing x 2	hr	20	10	200	10	200
2-2	Harrowing	hr	28.75	4	115	4	115
2-3	Ridging	hr	32.50	2	65	2	65
2-4	Other						
3.	Seed/Seedlings	Kg	2.20	112	250	112	250
4.	Fertilizer						
4-1	Mixture	Kg	1.70	100	170	100	170
4-2							
4-3							
5.	Pesticides						
5-1	Aldrin dust	Kg	15	2	30	2	30
5-2							
5-3							
6.	Grading						
7.	Bags	Bag	3	10	30	13	39
8.	Transport (Internal)	ha	15	-	15	-	15
9.	Transport (External)						
10.	Other Material Costs						
Sum 1-10 Allocable Costs Less Labour					1620		1629
GROSS MARGIN I					360		945
11	Labour						
1	Clearing Canals	hr	0.90	52	46	52	46
2.	Planting	hr	1.70	39	67	39	67
3.	Cross Bunding	hr	1.20	104	128	104	128
4.	irrigating	hr	1.20	194	236	194	236
5.	Weeding	hr	1.30	322	418	322	418
6.	Harvesting	hr	0.90	190	166	200	180
7.	Other Labour						
Sum 11, Total Labour Cost					1061		1075

Over the last season yields of beans in the P.I.S averaged 13 bags (1170 kg) per hectare. See GM calculation for beans below.

APPENDIX 9: AGRONOMY: KENAF

Kenaf (Hibiscus cannabinus) is one of the fibre crops which the NIB has experimented on and has contemplated entering in its diversification program in some of its schemes.

Seedbed preparation operations do not deviate from those required for maize and beans.

The irrigation schedule is also similar to that of beans.

The GM computation is based on the works of Jahadhmy (1969)¹⁾, and Mohdhar (1968 - 69)²⁾. Only averaged data can reliably be used in this computation as the author relied wholly on the reports of these two authorities.

-
- 1) Jahadhmy, A. A, Kenaf - Its production, processing and Potential, in the Kenya Sisal Board Bulletin, Nairobi, February, 1969.
 - 2) Mohdhar, A. A; Galole Kenaf trials results, N.I.B, 1969.

GROSS MARGIN CALCULATION 5

(Irea, Form 1)

Location: P.I.S
 Price: KENAF
 Area of Production: _____

Variety: _____

	Units	Unit price K sh.	A		B	
			Units per ha.	Value per ha K sh.	Units per ha	Value per ha K sh.
Yield <u>Grade I</u>	Kg	2.70	950	2565	1520	4104
<u>Grade II</u>						
Gross Output				2565		4104
<u>Allocable Costs</u>						
1. Water	m ³	0.063	11900	745	11900	745
2. Land Preparation						
2-1 Ploughing x 2	hr	20.00	10	200	10	200
2-2 Harrowing	hr	28.75	4	115	4	115
2-3 Ridging	hr	32.50	2	65	2	65
2-4 Other						
3. Seed/Seedlings	Kg	83	3	250	3	250
4. Fertilizer						
4-1 Compound 15:15	Kg	2.00	100	200	100	200
4-2						
4-3						
5. Pesticides						
5-1						
5-2						
5-3						
6. Grading						
7. Bags						
8. Transport (Internal)	ha	15	-	15	-	15
9. Transport (External)	Kg	0.20	950	190	1520	304
10. Other Material Costs						
Sum 1-10 Allocable Costs Less Labour				1780		1894
GROSS MARGIN I				785		2210
11. Labour						
1. Clearing Canals						
2. Planting						
3. Cross Bunding						
4. Irrigating						
5. Weeding						
6. Harvesting						
7. Other Labour (Baling)	hr	1.25	80	100	96	120
Sum 11, Total Labour Cost				2400		2600

APPENDIX 10: AGRONOMY: ROSELLE HEMP

Roselle hemp (Hibiscus subdariffa) has been experimented upon by the NIB with a view to using it in its crop diversification programme. Production of roselle calyces was tried in 1968 in the P.I.S and the results obtained that time form the basis of the GM calculation below.

The agronomic details are similar to those of maize. The crop requires nitrogen upto 500 kg per hectare. Under the management level of the average Perkerra tenant however, only about 250 kg/ha would be applied.

On the GM table labour has been valued at an average of Kshs.1.20 per man-hour which was the average found for the P.I.S.

The yields on the GM table are average yields reported for the 1968 trials.

Price P, I, S
ROSELE PET
of Production

Variety:

		A		B			
		Units	Unit price K sh.	Units per ha.	Value per ha K sh.	Units per ha	Value per ha K sh.
Yield	Grade I	Kg	6.0			670	4020
	Grade II						
Gross Output							
Allocable Costs							
	Water	m ³	0,063			11900	745
Land Preparation							
	2-1 Ploughing	hr	20.00			10	200
	2-2 Harrowing x 2	hr	28.75			4	115
	2-3 Ridging	hr	32.50			2	65
	2-4 Other						
Seed/Seedlings							
Fertilizer							
	4-1 Ammonium Sulphate	Kg N	6.0			52	312
	4-2						
	4-3						
Pesticides							
	5-1						
	5-2						
	5-3						
Grading							
Bags							
Transport (Internal)							
Transport (External)							
Other Material Costs							
Sum 1-10 Allocable Costs							1437
Less Labour							2583
GROSS MARGIN I							
Labour							
	1 Clearing Canals						
	2. Planting						
	3. Cross Bunding						
	4. Irrigation						

APPENDIX 11 (a): AVERAGE MONTHLY ONION SCHEME-GATE PRICES
(P.I.S) FOR GRADE 1, 1969-1978. (Sh)

MONTH	1969	1970	1971	1972	1972	1973	1974	1975	1976	1977	1978
JAN.		7.50	14.60	5.50	12.30	10.30	23.30	17.50	32.00	24.30	147.3
FEB.		7.40	15.20	3.50	18.00	12.20	27.40	17.40	31.00	33.30	165.4
MAR.		6.40	19.40	7.50	25.70	16.20	31.10	16.80	25.90	35.00	184
APR.		5.70	19.50	9.20	37.00	14.20	30.00	20.20	28.70	31.10	195.6
MAY		10.90	19.60	13.10	27.80	16.90	46.60	19.40	30.00	39.50	223.8
JUN		13.30	11.90	11.60	17.20	19.30	29.00	21.60	21.60	78.30	223.8
JUL		8.80	7.70	13.20	24.40	21.80	24.40	23.80	32.10	69.50	225.7
AUG	9.80	7.60	8.40	15.60	17.90	23.10	19.10	25.50	41.90	35.50	204.4
SEP.	8.00	7.70	7.50	12.80	12.50	16.50	12.00	21.10	30.00	33.80	161.9
OCT.	6.40	8.10	7.50	14.00	10.50	12.40	20.70	26.00	21.80	n.a	127.4
NOV.	5.50	9.60	6.80	16.70	8.90	12.00	19.30	24.70	21.70	33.60	158.8
DEC.	5.60	12.90	6.40	10.20	9.20	21.30	19.20	25.80	17.40	n.a	128
MEAN	7.06	8.82	12.04	11.08	18.45	16.35	25.18	21.65	27.80	41.39	
NET	7.10	8.80	12.0	11.10	18.40	16.40	25.20	21.60	27.80	41.40	
KG ⁻¹	.50	.65	.90	.80	1.35	1.20	1.85	1.60	2.05	3.05	

NOTE: The prices net⁻¹ are the ones from which the prices kg⁻¹ are obtained for use in the analysis. A net=13.6 kg.

SOURCE: P.I.S. Accounts records.

APPENDIX 11 (b): AVERAGE MONTHLY ONION SCHEME - GATE PRICES
(P.I.S.) FOR GRADE 2, 1969 - 1978 (Sh).

MONTH	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	
JAN		4.40	10.20	3.90	8.40	5.30	21.70	14.30	29.70	17.40	115.
FEB		3.80	10.20	2.10	14.80	9.30	24.10	13.40	33.50	29.30	120.
MAR		4.30	12.10	5.50	22.70	14.70	25.90	15.00	27.30	21.90	149.
APR		4.00	13.40	7.30	27.30	13.50	26.70	17.40	24.50	21.50	155.
MAY		6.60	14.80	9.00	21.30	15.90	40.00	16.90	28.70	34.80	186.
JUN		10.50	7.30	7.90	14.80	17.40	18.10	19.10	17.60	61.10	173.
JUL	.	4.80	3.90	10.00	19.10	19.10	22.20	23.10	26.90	48.60	177.
AUG	8.30	3.80	5.00	13.30	14.50	22.00	14.20	24.80	38.80	31.00	175.
SEP	6.70	3.90	4.00	10.60	10.80	11.00	6.90	20.00	30.30	22.40	126.
OCT	5.10	4.00	3.70	12.60	8.50	7.80	11.10	22.40	15.40	n.a	90.
NOV	3.80	4.90	3.00	16.70	8.90	7.00	15.10	22.90	13.30	27.30	122.
DEC	3.90	8.00	3.40	6.40	4.10	18.40	14.90	24.00	18.40	n.a	101.
MEAN	5.56	5.25	7.58	8.78	14.60	13.45	20.08	19.44	25.37	31.33	
NET ⁻¹	5.60	5.20	7.60	8.80	14.60	13.40	20.10	19.40	25.40	31.50	
KG	0.40	.40	.55	.65	1.10	1.00	1.45	1.40	1.85	2.30	

NOTE: The note under Appendix 11 (a) applies.

SOURCE: P.I.S. Accounts records.

APPENDIX 12 (a) AVERAGE MONTHLY ONION SCHEME - GATE PRICES, P.I.S

(NET = 13.6 kg)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1970	6.00	5.60	5.35	4.85	8.75	11.90	6.60	5.70
1971	12.40	12.70	15.75	16.50	17.20	9.60	5.80	6.70
1972	4.70	2.80	6.50	8.25	11.05	9.75	11.60	9.45
1973	10.35	16.40	24.20	32.15	24.55	16.00	21.75	16.20
1974	7.80	10.75	15.45	13.85	16.40	18.35	20.45	22.55
1975	22.50	25.75	28.50	28.35	43.30	23.55	23.30	16.65
1976	15.90	15.40	15.90	18.80	18.15	20.35	23.45	25.15
1977	29.85	32.25	26.60	26.60	29.35	19.60	29.50	40.35
	20.85	31.30	28.45	26.30	37.15	69.70	59.05	33.25
	17.00	18.50	19.50	22.90	22.10	22.40	19.60	
	10.65	8.90	9.50	11.75	18.50	16.00	11.90	

APPENDIX 12 (a) AVERAGE MONTHLY ONION SCHEME - GATE PRICES, P.I.S; KSHS. NET ⁻¹

(NET = 13.6 kg)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1970	6.00	5.60	5.35	4.85	8.75	11.90	6.60	5.70	5.80	6.05	7.25	10.45	7.00
1971	12.40	12.70	15.75	16.50	17.20	9.60	5.80	6.70	5.75	5.60	4.90	4.90	9.80
1972	4.70	2.80	6.50	8.25	11.05	9.75	11.60	9.45	11.70	13.30	16.70	8.30	9.95
1973	10.35	16.40	24.20	32.15	24.55	16.00	21.75	16.20	11.60	9.50	8.90	6.65	16.50
1974	7.80	10.75	15.45	13.85	16.40	18.35	20.45	22.55	13.75	10.10	9.50	19.85	14.90
1975	22.50	25.75	28.50	28.35	43.30	23.55	23.30	16.65	9.45	15.90	17.20	17.05	22.65
1976	15.90	15.40	15.90	18.80	18.15	20.35	23.45	25.15	20.55	24.20	23.80	24.90	20.55
		32.25	26.60	26.60	29.35	19.60	29.50	40.35	30.15	18.60	17.50	17.90	26.60
		31.30	28.45	26.30	37.15	69.70	59.05	33.25	28.10	-	30.45	-	36.45
			8.50	19.50	22.90	22.10	22.40	19.60	15.20	12.90	15.15	13.75	
				9.50	11.75	18.50	16.00	11.90	9.60	6.40	8.35	7.15	

APPENDIX 12(b)

TREND VALUES FROM THE LINEAR FIT $Y = 18.27 + 3.2x$ OF APPENDIX 12 (a).

(see text)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	118.3	21.5	24.8	28.1	31.3	34.6	37.8	41.1	44.4	47.6	50.9	54.1
1971	57.4	60.6	63.9	67.2	70.4	73.7	76.7	80.2	83.5	86.7	90.0	93.2
1972	96.5	99.8	103.0	106.3	109.5	112.8	116.1	119.3	122.6	125.6	129.1	132.4
1973	135.6	138.9	142.2	145.4	148.7	151.9	155.2	158.4	161.7	165.0	168.2	171.5
1974	174.8	178.0	181.3	184.5	187.8	191.0	194.3	197.6	200.8	204.1	207.4	210.6
1975	213.9	217.1	220.4	223.6	226.9	230.2	233.4	236.7	239.9	243.2	246.5	249.7
1976	253.0	256.2	259.5	262.8	266.0	269.3	272.6	275.8	279.1	282.3	285.6	288.8
1977	292.1	295.4	298.6	301.9	305.2	308.4	311.7	314.9	318.2	321.4	324.7	328.0
1978	331.2	334.5	337.8	341.0	344.3	347.5	350.8	354.0	357.3	360.6	363.8	367.1

APPENDIX 12 (c): PERCENTAGE OF TREND AND SEASONAL PRICE INDEX (see text)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	32.8	26.0	21.6	17.2	28.0	34.4	17.5	13.9	13.1	12.7	14.2	19.3	
1971	21.6	20.9	24.6	24.6	24.4	13.0	7.5	8.3	6.9	6.4	5.4	5.2	
1972	4.9	2.8	6.3	7.8	10.1	8.6	10.0	7.9	9.5	10.6	12.9	6.3	
1973	7.6	11.8	17.0	22.1	16.5	10.5	14.0	10.2	7.2	5.8	5.3	3.9	
1974	4.5	6.0	8.5	7.5	8.7	9.6	10.5	11.4	6.8	4.9	4.6	9.4	
1975	10.5	11.9	12.9	12.7	19.1	10.2	10.0	7.0	3.9	6.5	7.0	6.8	
1976	6.3	6.0	6.1	7.2	6.8	7.6	8.6	9.1	7.4	8.6	8.3	8.6	
1977	10.2	10.9	8.9	8.8	9.6	6.4	9.5	12.8	9.5	5.8	5.4	5.4	
1978	6.3	9.4	8.4	7.7	10.8	20.0	16.8	9.4	7.9	-	8.4	-	
MEAN	11.6	11.7	12.7	12.8	14.9	13.4	11.6	10.01	8.0	7.7	7.9	8.1	130.4
SEASONAL INDEX ²	106.7	107.7	116.9	117.8	137.1	123.3	106.7	92.0	73.6	70.8	72.7	74.5	74.5

APPENDIX 13: ONION YIELDS REALISED BY PERKERRA TENANTS
IN 1976. (kg/ha).

(a) JANUARY, FEBRUARY, MARCH AND APRIL.

1292	381	694	571	567
408	1388	462	571	1060
870	721	911 (6)	870	504
952(18)	245	789	1374	1944
3087	232	1714	939	1121
1837	462	721	435	191
421	625(13)	1305	2176	1373(19)
816	122	204	938	1836(20)
1360	775	326	504	
2067	340	1211	627(9)	n = 116
4135	490(4)	272	1129(9)	\bar{x} = 925
1469	408	367	381	S.D.=726
748	109	421	667	
925	843	1265	1686	
1074	599(1)	612	1400	
2462(12)	870	1033	163	
204	584	462	95	
354	204	958	979	
3210(15)	2542	571	1020	
1169	789	435	191	
843	2203(5)	1741	136	
2747(11)	1401	1482	789	
1387	191	1265	544	
2135	762(16)	1197	395	
354(7)	517	299	286	
571	408	41	326	

APPENDIX 13 cont.....

(b) MAY, JUNE, JULY AND AUGUST.

3236	1046 (221)	95	1930	394	
558	1306	2149	4012 (4)	4 678	n = 155
2149	490	284	7126 (4)	2489	\bar{x} = 198
3726	327	1442	1442	5453	S.D= 143
2217	1224	2584	816 (2)	313	
1985	911	1183	667	4161	
1510	435	1197	2299	136	
1414(14)	1904 (22)	1415	3482	3971	
3359	1455 (22)	2231	1904 (1)	2040	
177	1605	3482	2529 (1)	3400	
3414	2380	2625	1863	2325	
3101	694	177(17)	55	6596	
612	1550	938	1047	4352	
2978	1020	585	2013	3999	
326	856	1075	3101	1034	
2148(18)	1238	326	2162	1904	
2271	1972	1632	911	28	
149	2257	612	1782	177	
1087	803	1346	2027	2652	
2638	625	217	4991(5)	245	
2134	761	952	68(5)	2108	
408	1727	1510	1890	1102 (9)	
1999	2802	1183	2122	4474	
4473	4488	1427	160 (16)	3958	
4542	1306	1301	2910(16)	2788	
652	2624	441	2489	3115	
8472(12)	3155 (7)	2788(13)	1415	2029	

APPENDIX 13 cont.....

(b) MAY, JUNE, JULY AND AUGUST.

3236	1046 (21)	95	1930	394	
558	1306	2149	4012 (4)	4 678	n = 155
2149	490	284	7126 (4)	2489	\bar{x} = 1982
3726	327	1442	1442	5453	S.D= 1437
2217	1224	2584	816 (2)	313	
1985	911	1183	667	4161	
1510	435	1197	2299	136	
1414(14)	1904 (22)	1415	3482	3971	
3359	1455 (22)	2231	1904 (1)	2040	
177	1605	3482	2529 (1)	3400	
3414	2380	2625	1863	2325	
3101	694	177(17)	55	6596	
612	1550	938	1047	4352	
2978	1020	585	2013	3999	
326	856	1075	3101	1034	
2148(18)	1238	326	2162	1904	
2271	1972	1632	911	28	
149	2257	612	1782	177	
1087	803	1346	2027	2652	
2638	625	217	4991(5)	245	
2134	761	952	68(5)	2108	
408	1727	1510	1890	1102 (9)	
1999	2802	1183	2122	4474	
4473	4488	1427	160 (16)	3958	
4542	1306	1301	2910(16)	2788	
				3115	

APPENDIX 13 cont.....

(c) SEPTEMBER, OCTOBER, NOVEMBER & DECEMBER

843	1605 (16)	
2910 (14)	1034	n = 50
2380	3686	\bar{x} = 1845
2040	1115	S.D=1199
1224	340	
1863	911	
1033	3399	
1387	571	
3985(12)	1387	
734	1305	
2271(21)	3006	
3903(22)	708	
2040(11)	1469	
1509	1496	
1728 (7)	1700	
2937	693	
3441	1715	
802(17)	1646	
1678	1020	
3210(13)	54	
2353	3196	
6351(4)	326	
395	1809	
1524(1)	2407	
2476	639	

A PPENDIX 14.(a)

LABOUR DEMAND PER HECTARE OF
ONIONS, MANHOURS

TENANT NUMBER	CLEARING CANALS	CROSS - BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING	TOTAL	YIELD Kg ha ⁻¹
1	40	59	237	356	2371	598	3656	8390
2	40	69	316	578	1556	499	3058	6580
3	59	99	316	679	2668	739	4560	4135
4	44	40	198	237	2934	766	4219	2520
5	15	40	311	514	2213	580	3673	5005
6	20	20	395	321	1606	484	2845	7020
7	59	40	435	328	1778	450	3090	8960
8	44	59	534	432	1482	645	3196	6720
9	30	49	889	642	3557	872	6039	2950
10	59	30	346	346	1581	953	3314	6880
11	74	59	198	385	1976	1228	3920	5600
12	59	40	178	514	2668	1460	4918	7550
13	44	59	395	321	7114	1596	9529	10720
14	10	40	667	642	3750	477	5585	6720
15	44	74	356	353	3162	1319	5303	1140
16	30	40	296	642	3557	758	5323	6105
Mean	42	51	379	456	2748	839	4514	6680

SOURCE: Author's Investigation

APPENDIX 14 (b)
LABOUR COST FOR ONIONS,
SHILLINGS PER MANHOUR

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING
1	-	-	1.33	-	-	-
2	0.75	0.96	0.89	0.83	2.00	1.33
3	1.00	0.88	1.35	0.65	1.20	0.75
4	1.33	1.86	0.62	1.50	0.75	0.75
5	3.00	2.00	0.61	0.75	1.42	0.68
6	1.25	4.38	0.61	1.40	2.10	0.65
7	1.00	1.69	0.37	0.85	0.75	0.36
8	1.00	1.45	0.45	1.94	4.67	0.70
9	2.00	1.45	0.24	0.71	1.25	0.90
10	1.25	2.46	0.59	1.18	1.84	0.25
11	1.40	0.41	0.97	1.08	0.81	0.25
12	4.00	1.95	1.56	0.98	0.94	0.34
13	1.00	1.25	0.49	1.80	0.75	0.29
14	2.00	0.59	0.30	0.63	0.87	0.90
15	2.67	1.28	0.68	0.64	0.88	0.34
16	1.00	2.81	0.70	0.60	0.83 ²⁾	0.45
Mean 1	1.50 ¹⁾				1.20 ²⁾	
Mean 2	1.60	1.70	0.70	1.00	1.40	0.60

1) Excluding reading No.12

2) Excluding reading No.8

SOURCE: Author's Investigation

APPENDIX 15 (a)
LA BOUR DEMAND PER HECTARE OF
CHILLIES, MANHOURS

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING	TOTAL M. Hrs	YIELD Kg ha ⁻¹ WET WEIGHT
1	74	54	59	864	2371	2371	5793	7410
2	58	69	79	741	1897	1778	4722	7064
3	59	79	79	716	1186	2371	4490	7410
4	44	40	59	553	1581	2371	4648	6175
5	25	40	133	988	1897	2561	5644	8329
6	49	20	99	618	741	5928	7455	12350
7	99	40	79	277	790	1660	2945	4525
8	74	59	267	556	711	4268	5935	3656
9	69	54	158	1235	1556	2371	5443	6422
10	44	20	40	654	711	1778	3247	10372
11	148	30	99	741	1284	1897	4199	4940
12	99	40	59	988	1739	1778	4703	7904
13	99	59	99	1235	1897	3794	7183	6432
14	15	44	149	1235	3557	1446	6446	9161
15	44	74	59	679	415	5691	6962	9139
16	49	40	89	1112	5691	1927	8759	8398
Mean	72	48	100	824	1752	2749	5536	7480

NOTES:

1. Length of Chilli season = 180 days
2. Period of harvesting = 95 days

SOURCE: Author's Investigation

APPENDIX 15 (b)

LABOUR COSTS FOR CHILLIES,
SHILLINGS PER MANHOUR

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING
1	1.00	1.40	1.20	1.20	1.49	0.16
2	0.75	1.75	0.62	0.83	1.46	0.20
3	1.00	1.38	0.85	1.02	2.27	0.16
4	0.67	0.75	0.55	1.50	0.82	0.13
5	3.00	4.00	0.71	0.75	1.67	0.16
6	1.25	4.38	1.05	1.40	1.40	0.10
7	1.00	1.69	0.56	1.50	0.75	0.14
8	1.00	1.42	0.25	1.89	3.54	0.04
9	0.57	1.33	0.61	0.65	1.44	0.14
10	2.50	3.56	0.89	1.14	2.37	0.29
11	0.60	0.92	0.41	0.92	1.30	0.13
12	1.00	1.62	1.35	0.81	0.99	0.22
13	1.00	1.25	0.75	1.80	1.25	0.08
14	1.00	0.42	0.42	0.50	0.28	0.32
15	2.67	1.40	1.46	0.64	3.75	0.08
16	1.00	2.81	0.50	0.60	0.84	0.22
Mean	1.20	1.90	0.80	1.10	1.60	0.16 (0.20)

NOTES: Chilli harvesting charges are KSh-/50 per debe! 6 debes are required to fill a bag which on average weighs 50-65kg depending on the time of the picking season. A debe will therefore be taken as weighing $60 \div 6 = 10\text{Kg}$ (using midpoint of range). The cost Manhr⁻¹ = $\frac{\text{Yield (Kg)} \times \text{-/50}}{10}$ Total Labour (Mhrs)

SOURCE: Author's Investigation

AP PENDIX 16 (a)
LABOUR DE MAND PER HECTARE OF
MAIZE, MANHOURS.

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING	TOTAL M. Hrs.	YIELD BAGS (90Kg) Ha ⁻¹
1	40	54	59	178	395	178	904	10
2	59	40	99	267	227	59	751	10
3	40	40	40	296	316	40	772	12
4	89	30	40	198	158	59	574	20
5	20	20	133	198	474	138	983	25
6	20	20	119	247	124	99	629	15
7	40	40	40	198	158	158	634	20
8	30	59	89	222	415	237	1052	30
9	-	-	-	-	-	-	-	-
10	20	44	69	247	711	173	1264	15
11	25	20	74	395	158	183	855	10
12	59	40	30	148	237	158	672	10
13	-	-	-	-	-	-	-	-
14	10	40	59	247	356	20	732	3
15	30	49	40	247	138	198	702	20
16	40	20	30	198	474	99	861	15
Mean	37	37	66	235	310	128	813	15

- Notes: 1. Length of maize growing season - 90days
2. Period of irrigation - 10 weeks
3. Bags are assumed to be 90 Kg on average.

SOURCE: Author's Investigation

APPENDIX 16 (b)

LABOUR COSTS FOR MAIZE.
SHILLINGS PER MANHOUR.

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING
1	1.00	3.00	0.80	1.50	1.50	1.00
2	0.75	1.88	1.25	0.83	1.25	0.56
3	1.00	2.60	1.50	0.45	1.88	1.30
4	0.67	1.00	1.50	1.50	2.81	0.75
5	3.00	2.50	0.83	1.50	1.56	0.48
6	1.25	4.38	0.75	1.40	1.40	0.75
7	1.00	1.69	1.88	0.75	2.81	0.75
8	1.00	2.08	0.42	1.39	1.19	1.00
9	-	-	-	-	-	-
10	2.50	1.28	0.75	0.92	0.96	0.70
11	0.60	1.12	0.60	0.75	1.88	0.65
12	1.00	1.50	2.50	1.00	3.75	0.75
13	-	-	-	-	-	-
14	1.00	0.49	1.08	0.52	1.62	0.75
15	2.67	1.50	1.56	0.50	2.68	0.70
16	1.00	2.25	1.00	0.30	1.35	0.75
Mean	1.30	1.90	1.20	1.00	1.90	0.80

SOURCE: Author's Investigation

APPENDIX 17 (a)

LABOUR DEMAND PER HECTARE OF
BEANS, MANHOURS.

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING	TOTAL	YIELD BAGS (90Kg) Ha ⁻¹
1	54	54	79	100	395	237	919	15
2	79	40	104	296	277	200	996	15
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
6	20	20	79	124	123	165	531	12
7	20	20	79	99	395	158	771	8
8	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-
11	74	40	148	296	395	237	1190	8
12	59	40	79	198	356	178	910	17
13	59	59	158	247	316	160	999	15
14	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-
Mean	52	39	104	194	322	190	902	13

Notes: 1. Length of growing season = 90 days
2. Period of irrigation = 10 weeks.

SOURCE: Author's Investigation

APPENDIX 17 (b)
LABOUR COSTS FOR BEANS,
SHILLINGS PER MANHOUR.

TENANT NUMBER	CLEARING CANALS	CROSS-BUNDING	PLANTING	IRRIGATING	WEEDING	HARVESTING
1	-	-	3.00	-	-	-
2	0.75	0.94	1.25	0.83	2.50	1.25
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	1.25	4.38	1.09	1.40	2.80	0.75
7	1.00	1.69	0.94	1.50	0.75	0.75
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	0.60	0.61	0.54	1.08	0.81	0.75
12	1.00	1.38	0.86	0.69	0.51	0.75
13	0.67	1.25	0.94	1.80	0.70	1.00
14	-	-	-	-	-	-
15	-	-	-	-	-	-
16	-	-	-	-	-	-
Mean	0.90	1.70	1.20	1.20	1.30	0.90

SOURCE: Author's Investigation

APPENDIX 18 (a)

EXPLANATION OF SYMBOLS USED IN THE PROBLEM MATRIX

"LP PROBLEM MATRIX PERKERRA 2" (TABLE 6.1)

COLUMNS

CONS	=	Constraint type as indicated on the rows			
PON	=	Onion producing activity			
PCH	=	Chillies producing activity			
PMA	=	Maize producing activity			
PBE	=	Beans producing activity			
PKE	=	Kenaf producing activity			
PRH	=	Roselle hemp producing activity			
SON	=	Onion selling activity			
SCH	=	Chillies selling activity			
SMA	=	A maize selling activity			
SBE	=	A bean selling activity			
SKE	=	A kenaf selling activity			
SRH	=	A roselle hemp selling activity			
LJA	=	A labour hiring activity for month of January			
LFE	=	-----	ditto	-----	February
LMA	=	-----	ditto	-----	March
LAP	=	-----	ditto	-----	April
LMY	=	-----	ditto	-----	May
LJU	=	-----	ditto	-----	June
LJY	=	-----	ditto	-----	July
LAU	=	-----	ditto	-----	August
LSE	=	-----	ditto	-----	September
LOC	=	-----	ditto	-----	October
LNO	=	-----	ditto	-----	November
LDE	=	-----	ditto	-----	December

ROWS

UNIT	=	The unit of each activity explained in the columns above			
C	=	Objective function			
R01	=	A land restraint in hectares			
R02	=	A labour restraint (manhours) for January			
R03	=	-----	ditto	-----	February
R04	=	-----	ditto	-----	March
R05	=	-----	ditto	-----	April
R06	=	-----	ditto	-----	May
R07	=	-----	ditto	-----	June
R08	=	-----	ditto	-----	July
R09	=	-----	ditto	-----	August
R10	=	-----	ditto	-----	September
R11	=	-----	ditto	-----	October
R12	=	-----	ditto	-----	November
R13	=	-----	ditto	-----	December
R14	=	Operating capital restraint in shillings			
R15	=	An onion transfer row. The transfer unit is one kg.			
R16	=	A chillies transfer row. The transfer unit is one kg.			
R17	=	A maize transfer row. The transfer unit is one 90-kg. bag.			
R18	=	A beans transfer row. The transfer unit is one 90-kg. bag.			
R19	=	A kenaf transfer row. The transfer unit is one kg.			
R20	=	A roselle hemp transfer row. The transfer unit is one kg.			

APPENDIX 18 (b)

EXPLANATION OF SYMBOLS USED IN THE MATRIX DEPICTED

AS TABLE 6.8 MODEL 5)

ROWS

OBJI	=	Objective Function
LAJAN-LADEC	=	Land. There are 12 land activities for January to December.
WOJAN-WODEC	=	Labour. There are 12 labour activities for January to December
CRJAN-CRDEC	=	Credit. There are 12 credit activities for January to December.
WAJAN-WADEC	=	Water. There are 12 water activities for January to December.
TAONS	=	Transfer row for onions.
TACHI	=	Transfer row for chillies.
TAKEN	=	Transfer row for kenaf
TAHEN	=	Transfer for for roselle hemp.
TAMAI	=	Transfer row for maize.
TABEA	=	Transfer row for beans.

COLUMNS

ON01- ON12	=	12 Onion activities
CH01- CH12	=	12 Chillies activities
KE01- KE12	=	12 Kenaf activities
HE01- HE12	=	12 Hemp activities
MA01- MA12	=	12 Maize activities
BE01- BE12	=	12 Bean activities
SELON	=	A selling activity for onions
SELCH	=	A selling activity for chillies
SELKE	=	A selling activity for Kenaf
SELHE	=	A selling activity for roselle hemp
SELMA	=	A selling activity for maize.
SELBE	=	A selling activity for beans
HLJA-HLDE	=	A labour hiring activity. There are 12 labour hiring activities for January to December.
TRJA-TRDE	=	12 capital transfer columns for January to December.
BUCA	=	A capital borrowing activity
RHSI	=	Name of the Right Hand Side i.e. resource restraints.
ROW TYPE	=	The nature of the constraint

In addition to this it should be noted that land units are hectares, labour units are man-hours, credit has the unit shillings and water is measured in cubic metres.