DFID Department For International Development

Smallholder Irrigation: Ways Forward

Guidelines for achieving appropriate scheme design

Volume 2: Summary of Case Studies

F M Chancellor
J M Hide

Report OD 136
August 1997

HR Wallingford

Smallholder Irrigation: Ways Forward

Guidelines for achieving appropriate scheme design

Volume 2: Summary of Case Studies

F M Chancellor
J M Hide

Report OD 136
August 1997

Address and Registered Office: **HR Wallingford Ltd.** Howbery Park, Wallingford, Oxon OX10 8BA
Tel: + 44 (0)1491 835381 Fax: + 44 (0)1491 832233

Registered in England No. 2562099. HR Wallingford is a wholly owned subsidiary of HR Wallingford Group Ltd.

Contract

This report summarises work carried out by the Overseas Development Unit (ODU) of HR Wallingford in collaboration with the Irrigation and Drainage Branch of the Ministry of Agriculture, Livestock Development and Marketing, Government of Kenya, WmrRI, WRC and AGRILEX.

The work was carried out for the Overseas Development Administration (ODA) of the British Government. The ODA Technology Development and Research No. and project details are as below:

Theme	Improve availability of water for sustainable food production and rural development
Theme No.	W5
Project	Minor Irrigation Design
Project No.	R5830

Prepared by Felicity Chancellor (name) . Socio-economist (job title)

Approved by ....

Date 5/8/97

Summary

Smallholder Irrigation: Ways Forward

Guidelines for achieving appropriate scheme design

Volume 2: Summary of Case Studies

F M Chancellor
J M Hide

Report OD 136
August 1997

This report presents summaries of the performance of 13 small schemes in Africa, based on a programme of field investigations carried out with developing country Government Ministries, supported by the UK Overseas Development Administration.

Short summaries of the performance of 10 schemes in Kenya, 2 schemes in Zimbabwe and 1 in Egypt are included, representing schemes ranging in size from 50 to 500 ha spanning a wide range of physical and socio-economic conditions.

Hydraulic and socio-economic investigations were conducted for a minimum period of 1 year on each scheme. In three cases the research extended for three years.

The characteristics and performance of individual schemes are summarized in three matrices at the end of the report. Schemes were ranked for economic performance in Section 4, which includes outline conclusions developed within the comparison volume, Volume l, containing guidelines to scheme identification, design and development.

Contents

Page

Title page *i*
Contract *iii*
Summary *v*
Contents *vii*

1 Introduction 1

2 Methodologies 3
2.1 Hydraulic and physical parameters 3
2.1.4 Analysis procedure 4
2.2 Socio-economic parameters 6
2.2.1 Performance indicators 6
2.2.2 Monitoring procedure 6
2.2.3 Analysis procedure 7
2.2.4 Other information 8

3 Case studies 9
3.1 Exchange Irrigation Scheme, Zimbabwe 9
3.1.1 Location and historic background 9
3.1.2 Scheme characteristics 9
3.1.3 Main findings 12
3.1.4 Design issues 14
3.2 Nyanyadzi Irrigation Scheme, Zimbabwe 15
3.2.1 Location and historic background 15
3.2.2 Scheme characteristics 15
3.2.3 Main findings 17
3.2.4 Design issues 20
3.3 El Hammami Pipeline Irrigation System, Egypt 21
3.3.1 Location and historic background 21
3.3.2 Scheme characteristics 21
3.3.3 Main findings 23
3.3.4 Specific design issues 27
3.4 Gem Rae Irrigation Scheme, Kenya 27
3.4.1 Location and historic background 27
3.4.2 Scheme characteristics 29
3.4.3 Main findings 29
3.4.4 Design issues 35
3.5 Kamleza Irrigation Scheme, Kenya 35
3.5.1 Location and historic background 35
3.5.2 Scheme characteristics 36
3.5.3 Main findings 38
3.5.4 Design issues 42
3.6 Kwa Kyai Irrigation Scheme, Kenya 42
3.6.1 Location and historic background 42
3.6.2 Scheme characteristics 43
3.6.3 Main findings 43
3.6.4 Design issues 49
3.7 Mathina Irrigation Scheme, Kenya 49
3.7.1 Location and historic background 49
3.7.2 Scheme characteristics 49

Contents *continued*

3.7.3 Main findings 51
3.7.4 Design issues 54
3.8 Kangocho Irrigation Furrow, Kenya 55
3.8.1 Location and historic background 55
3.8.2 Scheme characteristics 55
3.8.3 Main findings 57
3.8.4 Specific issues for design 61
3.9 Kiguru Irrigation Scheme, Kenya 61
3.9.1 Location and historic background 61
3.9.2 Scheme characteristics 61
3.9.3 Main findings 63
3.9.4 Design issues 66
3.10 Mutunyi Irrigation Scheme, Kenya 67
3.10.1 Location and historic background 67
3.10.2 Scheme characteristics 67
3.10.3 Main findings 67
3.10.4 Design Issues 73
3.11 Kibirigwi Irrigation Scheme, Kenya 73
3.11.1 Location and background 73
3.11.2 Scheme characteristics 73
3.11.3 Main findings 74
3.11.4 Design issues 79
3.12 New Mataro Irrigation Scheme, Kenya 79
3.12.1 Location and historic background 79
3.12.2 Scheme characteristics 81
3.12.3 Main findings 81
3.12.4 Design issues 84
3.13 Arombo Irrigation Scheme, Kenya 85
3.13.1 Location and historic background 85
3.13.2 Scheme characteristics 85
3.13.3 Main findings 87
3.13.4 Design issues 89

4 Summary of scheme performance 89
4.1 Scheme comparisons 90
4.1.1 Ranking of scheme performances 90
4.2 Discussion of scheme performance 90
4.3 Summary of issues 92

Tables

Table 1.1 Summary of Schemes 2
Table 2.1 Assessment ranges of performance indicators 6
Table 3.1 Gross margins and farm incomes for Exchange, 1989 (Z$) 13
Table 3.2 Irrigation performance indicators for Nyanyadzi 17
Table 3.3 Crop yields for Nyanadzi (kg/ha) 18
Table 3.4 Gross margins and farm incomes for Nyanyadzi (Z$) 19
Table 3.5 Calculated net irrigated income for normal years per block at Nyanyadzi (Z$) 19
Table 3.6 Irrigation performance indicators for El Hammami 23

Contents *continued*

Table 3.7	Farm income for El Hammami (Egyptian pounds)	26
Table 3.8	Irrigation performance indicators for Gem Rae	31
Table 3.9	Unlimited Rice yields for Gem Rae (kg/ha)	33
Table 3.10	Gross margins and farm incomes for Gem Rae (Ksh)	34
Table 3.11	Irrigation performance indicators for Kamleza	38
Table 3.12	Crop yields for Kamleza (kg/ha)	40
Table 3.13	Gross margins and farm incomes for Kamleza (Ksh)	41
Table 3.14	Irrigation performance indictors for Kwa Kyai	46
Table 3.15	Crop yields for Kwa Kyai (kg/ha)	47
Table 3.16	Cross margins and farm incomes for Kwa Kyai (Ksh)	48
Table 3.18	Irrigation performance indicators for Mathina	51
Table 3.19	Crop yields at Mathina (kg/ha)	53
Table 3.20	Irrigated gross margin per ha at Mathina (ksh/ha)	53
Table 3.21	Farm incomes for Mathina (ksh)	54
Table 3.22	Irrigation performance indicators for Kangocho (see also Figure 16)	57
Table 3.23	Crop yields and inputs for Kangocho	59
Table 3.24	Gross margins and farm incomes for Kangocho (Ksh)	60
Table 3.25	Irrigation performance indicators for Kiguru	63
Table 3.26	Crop yields at Kiguru (kg/ha)	65
Table 3.27	Gross margins and farm incomes for Kiguru (Ksh)	66
Table 3.28	Irrigated performance indicators for Mutunyi	69
Table 3.29	Crop yields for Mutunyi (kg/ha)	71
Table 3.30	Gross margins and farm incomes for Mutunyi (Ksh)	72
Table 3.31	Irrigation performance indicators for Kibirigwi	74
Table 3.32	Crop yields for Kibirigwi (kg/ha)	76
Table 3.33	Gross margins and farm incomes for Kibirigwi (Ksh)	78
Table 3.34	Irrigation performance indicators for New Mataro	81
Table 3.35	Crops grown at New Mataro	83
Table 3.36	Crop yields for New Mataro (kg/ha)	83
Table 3.37	Gross margins and farm incomes for New Mataro (Ksh)	84
Table 3.38	Rice yields, costs and revenues for Arombo	88
Table 3.39	Income generation for Arombo (KSh)	88

Figures

Figure 1	Location of Exchange and Nyanyadzi Irrigation Schemes, Zimbabwe	10
Figure 2	Exchange Irrigation Scheme	11
Figure 3	Nyanyadzi Irrigation Scheme	16
Figure 4	Location of El Hammami Irrigation Scheme, Egypt	22
Figure 5	El Hammami Irrigation Scheme	24
Figure 6	Location map of Kenyan irrigation schemes	28
Figure 7	Gem Rae Irrigation Scheme	30
Figure 8	Irrigation performance summary for Gem Rae	32
Figure 9	Schematic diagram of Kamleza Irrigation Scheme	37
Figure 10	Irrigation performance summary for Kamleza	39
Figure 11	Schematic diagram of Kwa Kyai Irrigation Scheme	44
Figure 12	Irrigation performance summary for Kwa Kyai	45
Figure 13	Mathina Irrigation Scheme	50
Figure 14	Irrigation performance summary for Mathina	52
Figure 15	Kangocho Irrigation Scheme	56
Figure 16	Irrigation performance summary for Kangocho	58
Figure 17	Kiguru Irrigation Scheme	62

Contents *continued*

Figure 18 Irrigation performance summary for Kiguru 64
Figure 19 Mutunyi Irrigation Scheme 68
Figure 20 Irrigation performance summary for Mutunyi 70
Figure 21 Kibirigwi Irrigation Scheme 75
Figure 22 Irrigation performance summary for Kibirigwi 77
Figure 23 New Mataro Irrigation Scheme 80
Figure 24 Irrigation performance summary for New Mataro 82
Figure 25 Arombo Irrigation Scheme 86

Matrices
Matrix 1 Scheme characteristics and performance
Matrix 2 Socio-economic parameters and economic performance
Matrix 3 Irrigation system performance indicators

1 Introduction

This volume contains information relating to thirteen smallholder irrigation schemes with each of the case studies looking at physical and socioeconomic factors. Flow monitoring analysis and a more detailed on-scheme efficiency assessment provide an overview of the physical performance while the parallel socio-economic study identified the constraints and opportunities afforded the farmers outside the immediate irrigation environment. It is on these data and observations that the Guidelines contained in Volume 1 are based.

Of the thirteen schemes, two were in Zimbabwe, one in Egypt and ten in Kenya. All the schemes studied can be classed as commercial, although some growing of irrigated subsistence crops is common, and are representative of the types of schemes being developed at the time. Table 1.1 gives a summary description of each scheme and shows the broad range of physical, technical and socio-economic conditions covered by the case studies which are given in Chapter 3.

Most of the studies were conducted in Kenya where Smallholder irrigation accounts for about a third of the total irrigated land. Within that total much of the area irrigated is group-based, gravity-fed horticulture which contributes substantially to the constant flow of fresh vegetables exported from Kenya. The schemes are small (less than 500 hectares), they are all gravity-fed and land holdings within the schemes average less than two hectares.

Assessment of the hydraulic performance of the schemes was carried out in two parts. The first of these was a year-long collection of flow records at strategic locations based on existing structures throughout the site. Thus the irrigation water supplied to various sections of the schemes could be compared to the crop water requirement. This leads to the first two performance indicators: adequacy, the degree to which requirements were met; and efficiency, the degree to which the farmers were able to manage the water and to determine the importance of water losses. By comparing the supply of water to the different locations the equity of supply can be determined. Similarly, by comparing the amounts of water supplied over time, the dependability of the supply can be calculated.

The second part of the study employed rapid-assessment techniques to look at water management within the scheme and to determine where losses occur.

A socio-economic survey was carried out in each scheme consisting of a questionnaire relating to farmer crop choices, costs and revenues, use of labour, water management, participation in the running of the scheme and market strategies. The information was augmented by interviews with key informants and data collected from local institutions. Data are presented on crop choices, agricultural performance, yields and financial returns. The methodologies used for both the technical and socio-economic studies is given in Chapter 2.

Major constraints met by farmers were in marketing, labour availability and water resource reliability. Their ability to distribute water equitably was generally good despite difficult conditions in some cases. Specific issues relating to design, operation and management of each scheme are identified in the case studies.

Table 1.1 Summary of schemes

Scheme	Country	Size	Cropping [1]	Water source	Distrib. method[2]	Applic. method	Manag-ment
Exchange	Zimbabwe	165	Hort+subs 50% cash	Dam/ pumped	Canal	Surface	Agency
Nyanyadzi	Zimbabwe	423	Hort+subs 50% cash	River	Canal	Surface	Agency
El Hammami	Egypt	330	Hort+subs 60% cash	Canal	LP Pipe	Surface	Agency
Gem Rae	Kenya	90	Rice 60% cash	River	Canal	Surface	Farmer
Kamleza	Kenya	314	Hort+subs 60% cash	Spring/ dam	Canal	Surface	Farmer
Kwa Kyai	Kenya	110	Hort+subs 75% cash	River	Canal	Surface	Farmer
Mathina	Kenya	100	Hort+subs 80% cash	River	Canal	Surface	Farmer
Kangocho	Kenya	48	Hort+subs 90% hort	River	Canal	Surface	Farmer
Kiguru	Kenya	60	Hort+subs 65% cash	River	LP Pipe	Sprinkler	Farmer
Mutunyi	Kenya	100	Hort+subs 40% cash	River	Canal	Surface	Farmer
Kibirigwi	Kenya	114	Hort+subs 70% cash	River	HP Pipe	Sprinkler	Agency
Arombo	Kenya	30	Rice 60% cash	Canal	Canal	Surface	Agency/ farmer
New Mataro	Kenya	135	Hort+subs 50% cash	River	Canal	Surface	Farmer

Notes: [1] Hort=horticultural, subs=subsistence
[2] LP Pipe=low pressure pipeline, HP Pipe=high pressure pipeline

In addition to the individual case studies three matrices have been produced allowing comparison between schemes. Matrix 1 gives information on general scheme characteristics and performance, Matrix 2 socio-economic parameters and economic performance data and Matrix 3 irrigation system performance indicators. These are included in Chapter 4 which provides a summary and comparison of scheme performance.

2 Methodologies

2.1 Hydraulic and physical parameters

2.1.1 Performance indicators

Descriptions of the performance of an irrigation scheme have typically focused on the "efficiency" of water use; in simple terms, the volume of water required by the crop divided by the volume supplied at any given level in the system. However, other indicators can be employed to provide further information about how well a system is being used and to identify what the principle constraints to operation of the scheme are. These include the "adequacy" of water supply, the "dependability" of the supply and the "equity" with which the water is distributed among the various parts of the scheme. A prerequisite to making these calculations is the knowledge of how much water was provided to areas of interest within the irrigation network throughout the period of study.

2.1.2 Monitoring procedure

The approach adopted in this project was to utilize wherever possible existing structures to be used for flow measurement. In this way the operation of the scheme is not affected and perhaps more importantly, the farmers should not imagine that the flows have changed because of the study. At each of the schemes sections of the irrigated area were selected for monitoring of water flow. The areas studied fit a "top-middle-tail" pattern so as to provide information about how well the delivery system is able to distribute water.

Gauge-boards were installed at each of the selected structures so that stage-discharge relationships could be developed following calibration (Bos, 1976). Recordings of water level were made twice daily, morning and afternoon, by a member of the farmers' committee who was literate and could speak English. Regular visits by the Agricultural Extension Officer meant that the accuracy of the readings could be checked and also reports on water supply and crop stages could be made.

In addition to the manual readings, ultra-sonic water level recorders were installed at a number of the structures. These were programmed to record data at half-hourly intervals. Using these results, checks could be made on the accuracy of the manual readings. Calculations based on twice-daily readings could also be compared with the total daily flow through the structures measured by the data loggers.

Where appropriate, the times at which offtake gates were opened and shut were also recorded.

Meteorological data providing the basis for calculation of evapotranspiration were obtained from the Kenya Meteorological Department of the Ministry of Transport and Communications. Additionally, daily measurements of rainfall were made using a rain-gauge installed within the scheme area. Potential evapotranspiration was calculated using the Modified Penman method (FAO 24, 1977). Crop water requirements were calculated using agronomic information (FAO 33, 1979) and the evapotranspiration results. Cropping calendars were derived from the socio-economic survey and discussions with farmers and extension workers on the schemes.

2.1.3 Rapid-appraisal programme

During the scheme visits, rapid-appraisal methods were used where possible to provide further information about the operation and management of the schemes. In this way, rough estimates of application and conveyance efficiencies could be determined. Estimates of conveyance efficiencies were made using inflow-outflow methods with discharges measured with flow meters. Application efficiencies were estimated by taking soil samples from the root zone before and after irrigation, measuring moisture content gravimetrically and comparing the amount of water stored in the soil profile with the volume applied by the farmer. The applied volume was measured using Parshall or long-throated flumes. Also, particular problems and limitations were investigated where appropriate.

2.1.4 Analysis procedure

Performance has been analyzed according to the following indicators:

- adequacy of irrigation water supply
- efficiency of irrigation water use
- equity of irrigation supply
- dependability of irrigation supply
- sustainability

The methods described briefly below are based on those discussed in Bird and Gillott (1992) and Molden et al (1990).

<u>Adequacy</u>

To achieve optimum crop yields from irrigated agriculture it is necessary to supply the amount of water required by the crops. This is determined by the area under cultivation, the crop water requirements and any inevitable losses sustained in applying the water to the field.

Two indicators have been calculated:

- Supply - a measure of the extent of under or over-supply
- Adequacy - a measure of the degree to which crop needs were met

The equation used to calculate supply, Sp, to the crop:

$$\boldsymbol{Sp = (e.IWS + PER) / (ET_c)} \qquad . . . (1)$$

where
- e = notional efficiency below given point
- IWS = irrigation water supplied
- PER = potential effective rain
- ET_c = crop evapotranspiration requirement

Sp will equal 1.0 if total water supply equals demand, 0.5 if half the requirement is supplied, 2.0 if twice the required volume is supplied, and so on.

The term *e*, notional efficiency, is a factor allowing for inevitable losses, based on point measurements or target values. For example, the target value for application efficiency in small basins could be taken at 60% in the absence of better information (Bos, 1982). The supply indicator then provides a measure of how much more or less water than the anticipated requirement was actually supplied by the system.

Adequacy, *Ad*, is a modified version of supply.

$$Ad = minimum\ [\ Sp\ ,\ 1\ ] \qquad \text{. . . (2)}$$

In this case, the result is limited to a maximum of 1.0. In so doing, it is assumed that the soil is fully saturated by an irrigation and that any water applied in excess of crop use is lost to the crop. Thus, whilst a scheme may receive twice the required amount of water during the complete season (*Sp*=2.0), the seasonal adequacy may still be below 1.0 if there were periods of shortage.

Efficiency

Conventional measures of efficiency (Bos, 1982) can give misleading results at times of water shortage. Efficiency may appear very high, sometimes in excess of 100%, but crop yields can be adversely affected.

All schemes investigated suffered at times from water shortage. The following procedure was adopted to assess efficiency:-

At times of adequate or excess supply ($Sp \geq 1$):

$$Ef = \left(\frac{1}{Sp}\right) e \qquad \text{. . . (3a)}$$

At times of shortage:

$$Ef = e \qquad \text{. . . (3b)}$$

where Ef = time-averaged overall efficiency
e = notional efficiency

A weighted seasonal overall efficiency was calculated on this basis.

Equity

Equity of supply is concerned with supplying a fair share of water to users throughout the scheme. In these analyses, the goal is to provide each user with a volume of water in proportion to the land holding.

Equity, *Eq*, is essentially the coefficient of variation of the *Ad* values between different locations. Hence,

$$Eq = standard\ deviation\ Ad\ /\ mean\ Ad \qquad \text{. . . (4)}$$

A result of zero indicates perfect equity and a value of 1, say, indicates serious inequality in the distribution. Eq does not have an upper bound. It should be noted that a perfectly equitable distribution will result if all locations receive an adequate supply (with no regard to any over-supply) or if each location receives the same inadequate supply.

Dependability

Farmers are able to make better decisions if they can rely on the availability of water, ie. if the delivery of water is consistent. An irrigation scheme with an adequate supply of water which is not dependable may be less desirable than a scheme with a constant supply of inadequate volumes since farmers can make sensible choices regarding crop choice and planted areas with knowledge of what to expect. Dependability, *Dp,* is taken as the coefficient of variation of Ad for individual locations over different time periods. A result of zero indicates that the supply is always adequate or always the same value.

Sustainability
Sustainability has been measured simply by taking the current irrigated area and comparing it with the design area (expressed as a percentage).

Target ranges for performance indicators
As stated earlier, these indicators have been derived from Molden and Gates' work. The similarity is close enough that they should have similar target ranges as illustrated in Table 2.1.

Table 2.1 Assessment ranges of performance indicators

Indicator	"Good"	"Fair"	"Poor"
Adequacy, Ad	> 0.9	0.8 - 0.9	< 0.8
Equity, Eq	< 0.1	0.1 - 0.25	> 0.25
Dependability, Dp	< 0.1	0.1 - 0.2	> 0.2

Source: Molden and Gates (1990)

Efficiencies should be compared with values for similar schemes.

2.2 Socio-economic parameters

2.2.1 Performance indicators

The most commonly used indicator of economic performance in irrigation schemes is the gross margin per hectare of irrigated area. This information can easily be augmented to indicate which factors of production are effectively used and which are not. It is not a precondition of success that irrigation is of prime importance to each farmer. There are, however, a number of common important factors, such as water, labour and inputs, for which performance can be monitored through use of indicators.

2.2.2 Monitoring procedure

To assess the contribution of irrigation within a farming system, farm income was determined. Incomes and outgoings to the farm household were investigated for the year during which flow monitoring had taken place in the irrigation system.

The aim of the socio-economic studies is to provide baseline data on farm income. Additional information was obtained including:

- constraints on farmers
- perceived problems in the system
- the interrelationships that farmers perceive between irrigated cultivation, other agricultural enterprises and non-farm activities
- response to social and institutional constraints which affect the management of the system and its sustainability.

Success ultimately depends on the farm household's decisions in allocating their productive resources to the irrigated enterprise. It is therefore important to understand the problems and the strategies necessary to overcome them to promote sustainable irrigation development.

The method used was a combination of Rapid Rural Appraisal and Socio-economic questionnaire survey of a random sample of smallholder irrigators. Individual and group interviews were used to augment data collected from the sample surveyed. Information from local off-scheme sources such as markets, hospitals and clinics, extension services and local administration was also used.

Obtaining a sample of smallholder irrigators

In order to handle data easily a sample size of 30 was chosen for all schemes thus enabling results from schemes to be dealt with in a similar manner (Upton 1987). Stratification into head, middle and tail facilitates comparison of economic performance with water supply characteristics obtained from the parallel hydraulic measurement programme.

A sampling frame was obtained for each scheme. The most commonly available is a membership list or a map showing plot boundaries. After categorising members or farms as head, middle and tail, a random sample was chosen for each stratum by placing names or farm plot numbers into a hat and selecting the number required. Sufficient "spares" were included to allow for logistic problems to be overcome.

The socio-economic survey provided quantitative data for the most part although the sections dealing with water management and institutional aspects also obtained qualitative information from the farmers. Data were collected by teams of local enumerators. Questionnaire design, supervision of the survey and analysis were undertaken by HR Wallingford.

The survey obtained information including: personal and household information; labour; irrigated crops; marketing; water management; cultivated dryland; livestock; expenditure and non-farm activities; institutional aspects and health.

2.2.3 Analysis procedure

A data base was established using Dbase. Significant differences in the sub-samples were determined by using Student 't' tests and the 95% confidence limit was used in the following text. Tables give group means and, unless otherwise stated, bracketed figures give standard deviations.

The objective is to gain a general and reasonably accurate picture of present conditions of schemes studied. Emphasis has been on assessment of the financial implications of irrigation for smallholders and review of evidence from existing schemes to link design features with financial success or failure. Cost-benefit analysis has not been undertaken.

The underlying assumption is that farmers will spend on irrigation only when other needs have been met. This assumption enabled the analysis to deal in financial terms for which recall is normally good. Gross margins/hectare produced by this analysis therefore refer only to financial profit and take no account of subsistence.

$$Gross\ margin\ per\ hectare = \frac{(RC_1 - CC_1) + ...(RC_N - CC_N)}{AI}$$

where RC = crop revenue for each crop grown in the year
CC = crop costs
AI = area of the irrigated plot

Gross margins calculated in this way were used to calculate returns per worker and per unit of water used.

$$Returns\ per\ worker = \frac{Gross\ margin\ hectare}{Workers\ per\ ha}$$

Where the number of workers/ha is calculated from labour data on the assumption that one worker works for 240 days/year unless otherwise stated. In some cases the period was shorter as in single cropping rice schemes.

$$Gross\ margin\ per\ m^3 = \frac{Gross\ margin\ per\ ha}{m^3\ per\ ha}$$

Where seasonal water duty per hectare was calculated on a scheme or reach basis.

It must be noted that in economic terms these relationships undervalue irrigation, because no value is assigned to an increase in home-grown food consumption by the household. However, the analysis is conducted in financial terms in order to identify the incentives and constraints to farmers.

For each smallholder, household/farm profits were calculated from recall data for all farm enterprises. In-flows from non-farm activities were added and basic expenditures were subtracted. The remaining amount gives an approximate value for farm surplus or disposable farm income.

$$Net\ farm\ surplus = (RI - CI) + (RL - CL) + (RD - CD) + NFI - EXP$$

Where:
RI Revenue from irrigation
CI Costs for irrigation
RL Revenue from livestock
CL Costs for livestock
RD Revenue from dryland cultivation
CD Costs for dryland cultivation
NFI Non-farm income
EXP Basic Expenditure

The calculation represents an estimate of the potential for investment by irrigating communities. Care must be taken in comparing these figures with those produced from other studies which have used alternative approaches such as calculating the value of production.

2.2.4 Other information

Information from other sources was used to interpret the survey data and to compile case studies. Generally, material was used to enhance understanding of processes and not to amend quantitative information collected in the surveys. Where information was lacking in the survey it was occasionally augmented from alternative sources.

Sources used included:
- local administrative centres
- local extension services
- farmer groups
- farmers committees or individual members

- women's groups
- credit institutions
- schools
- clinics

3 Case studies

3.1 Exchange Irrigation Scheme, Zimbabwe

3.1.1 Location and historic background

Exchange irrigation scheme is in Zhombe Communal area in Midland Province in Zimbabwe (Figure 1). It is more than 100 kilometres from the nearest town of any size and the roads to the scheme are impassable for a number of weeks each year. Climatic conditions are semi-arid; rainfall averages 632 mm/annum. The scheme is at 1200m above mean sea level and frosts can occur. Droughts are common in January.

The scheme is backed by a dam from which water is pumped to a storage reservoir. The irrigated area is located on gently sloping land which drains to the Shangani river in the north. The scheme developed in two phases, the first of which dates from 1973 when 56 ha were developed to provide irrigation as a supplement to farmers who had been settled with 2.5 ha of rain-fed land per household at an earlier date . Each farmer was allocated 0.1 ha of irrigated land. The second phase began in 1985 when the system was rehabilitated and extended to irrigate an area of 165 ha. In the second phase new farmers were allocated plots and existing farmers had the opportunity to acquire more plots.

The objective of the scheme was to raise agricultural incomes so that farmers could generate at least the minimum agricultural wage. The minimum wage at the time was in the region of Z$1000 per annum. It was originally expected that farmers would make high profits from sale of sweet-corn. The scheme directly benefits around 900 farmers who live in surrounding villages where they have dryland farms of approximately 2.5 ha. Most keep cattle and small stock which forage in the adjacent bush.

The scheme was developed and is managed by AGRITEX who in addition to providing water also provide extension services. A farmer management committee which works in partnership with AGRITEX, is responsible for tenant discipline, inputs purchases, marketing, organisation of labour for maintenance and participation in decisions relating to the running of the scheme.

3.1.2 Scheme characteristics

Water is pumped on demand to the scheme. The water is stored in a main night storage dam from which it is released to the scheme on a daily basis via lined channels and two further night storage dams. Layout of the scheme is compact. Fields are uniform in size (0.1ha) and formally arranged in six blocks which are separated by access roads. Blocks vary in area from 20 ha to 30 ha (Figure 2). The tertiary offtake structures consist of hand-operated gates. Water is controlled by the manager and a team of water bailiffs.

All channels are concrete-lined. Excess water from them spills over tail escapes into lower land. Irrigation is scheduled in a fixed, seven day rotation so that each block receives water on a certain day of the week. One day is reserved for scheduling supply to areas under-supplied during the week. Water is applied to

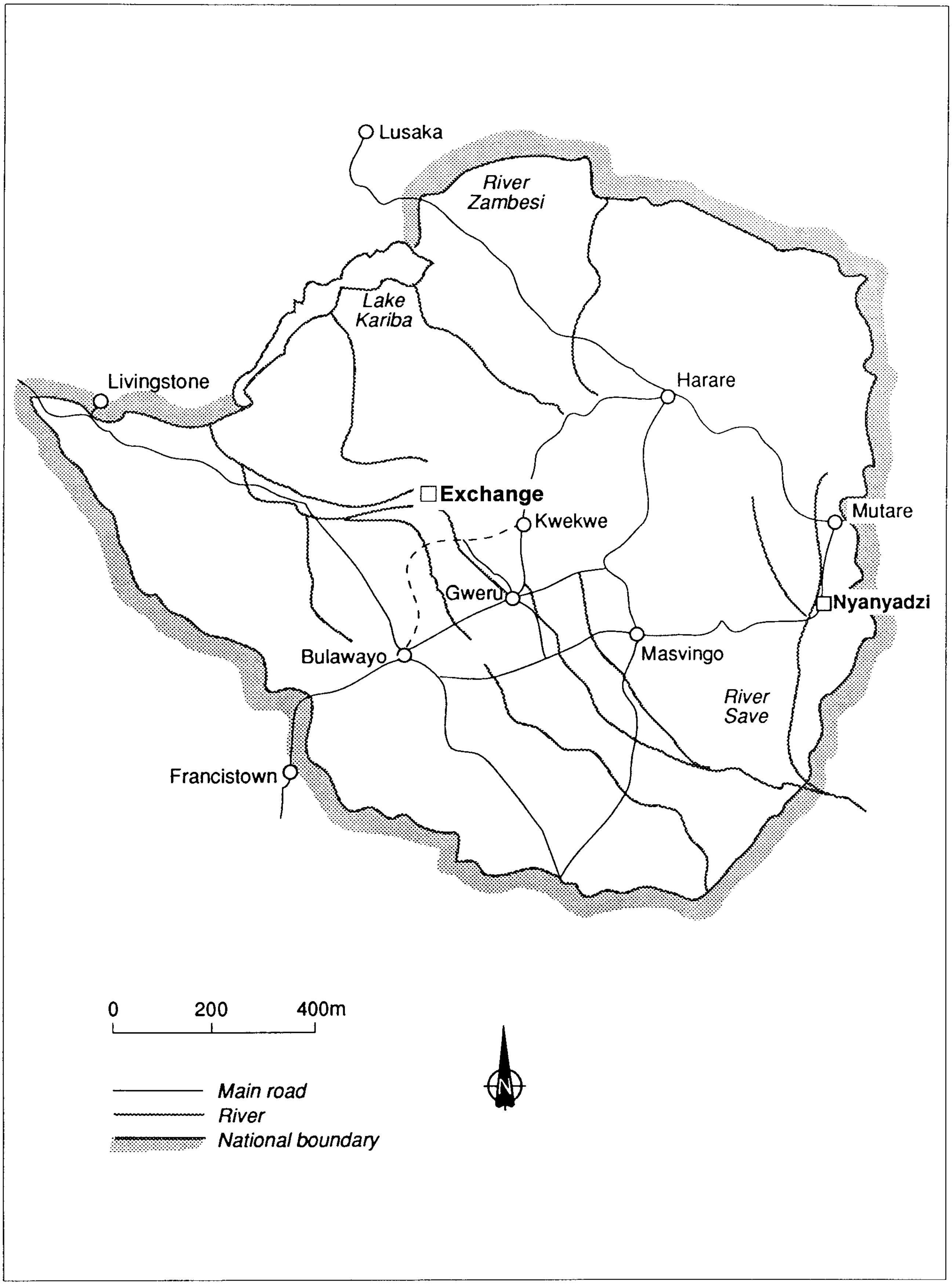

Figure 1 Location of Exchange and Nyanyadzi Irrigation Schemes, Zimbabwe

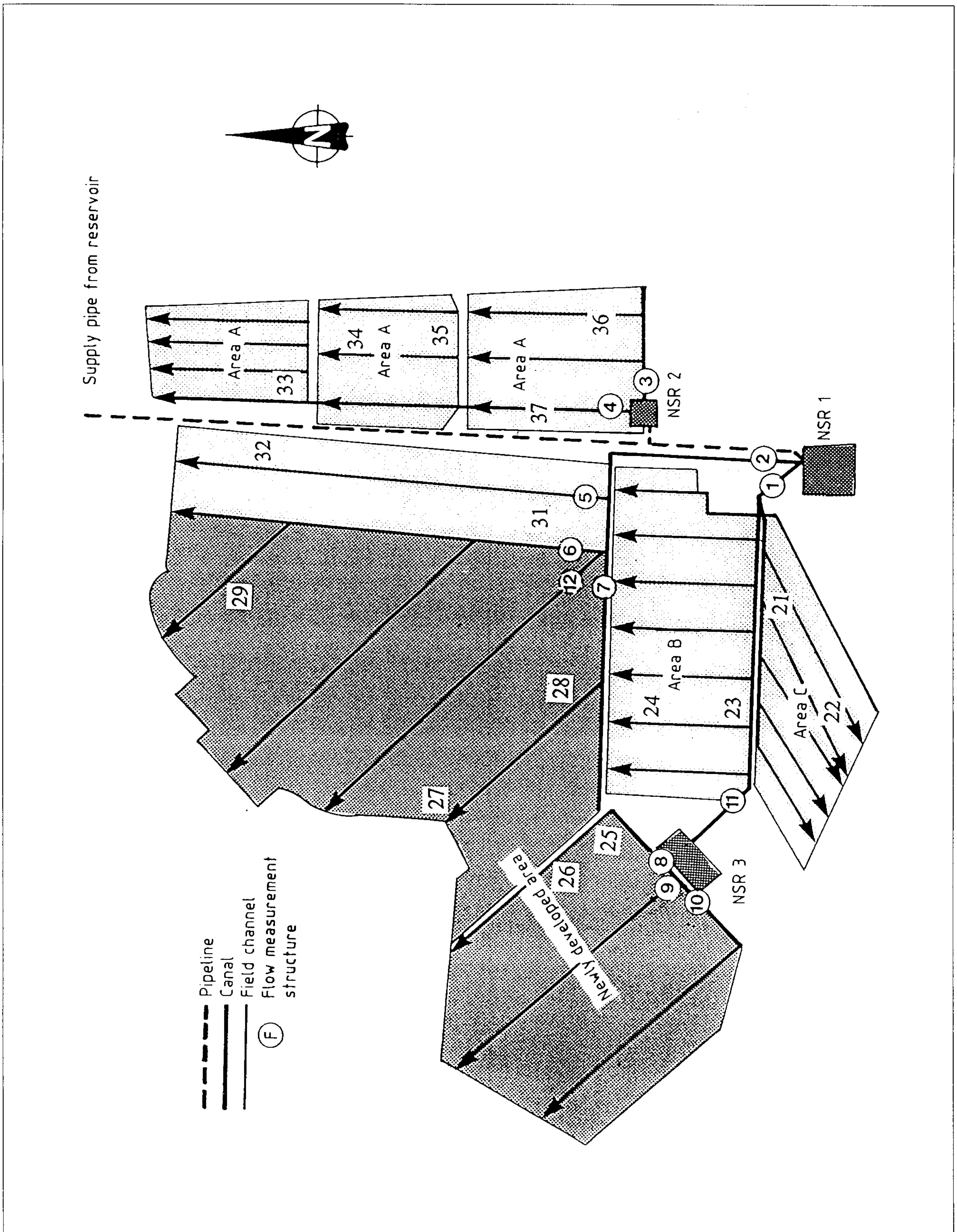

Figure 2 Exchange Irrigation Scheme

the fields by siphon from the tertiary canals in strictly managed rotation. Farmers use communally owned siphon pipes to draw water from the channel using portable checks. Flow along the furrow is cut off once the water flow reaches 75% of the furrow length.

This system works well, has achieved high yields and is generally regarded as successful. Shortage of water was not a major issue but waterlogging was a problem. Timely action was being taken on this issue and drains were being installed as this study ended. The reason for the waterlogging appears to be the shallow soil depth overlying rock. A more efficient irrigation system might be considered if it could be economically justified.

Cultivation occurs in two distinct seasons - summer and winter. July/August through to January / February is the main maize-growing season producing sweet-corn by Christmas. Beans and tomatoes are produced between February/March and June.

3.1.3 Main findings

<u>Operation and Management</u>

Water management in the distribution system is overseen by AGRITEX. The cost of providing staff, supervision and materials for maintenance is greater than revenue collected in irrigation service fees. Exchange farmers work closely with AGRITEX staff and co-operation is high on both sides. Equity does not appear to be an issue on this scheme and there is no perceived head/tail problem. The system allows a high degree of control and can accommodate specific requests from farmers where the normal schedule has not worked out. Farmers participated in the plans for rehabilitation in 1985 and in subsequent construction so that commitment to, and understanding of, the system is good.

<u>Agricultural production</u>

All the farmers produce summer maize. Farmers can meet their maize needs from one or two plots and devote the remainder to producing beans for sale. In summer, small areas are devoted to vegetables. In winter, the common crop is beans and a small amount of vegetables. The bean crop is marketed on a group basis. Terms are negotiated with a wholesaler by the treasurer of the farmer committee.

Yields were consistent over the scheme with no significant differences by location, holding size or gender of farmers. Typical yields were: 7000 kg/ha for maize; 1200 kg/ha for summer beans and 1000 kg/ha for winter beans.

Inputs have to be organised in advance for both seasons due to the distance and cost of haulage. This is a constraint for all farmers but is especially difficult for poor farmers who tend to have less irrigated land and less opportunity to create savings.

<u>Income</u>

Income from irrigated farming is the major component of farm income only for those farmers who have more than two irrigated plots. In poor years total agricultural farm income falls sharply due to losses in dryland cultivation and livestock enterprises. Farmers who have only one or two plots sometimes face dire shortages. Farmers of three and four irrigated plots could possibly attain the minimum wage objective in present circumstances, especially if the value of food consumed is taken into account.

Table 3.1 Gross margins and farm incomes for Exchange, 1989 (Z$)

Income (Z$)	SCHEME	0.1 ha farmers	0.5 ha farmers	Women farmers
Irrigated gross margin (Z$/ha)	2360	1990	2815	2040
Irrigated net income (Z$/farm)	472	200	1609	680
Dryland / livestock net Inc. (Z$/farm)	792	296	1042	591
Total agricultural net income (Z$/farm)	1264	496	2651	1271
Other inflows[1] (Z$/farm)	420	420	437	-
Costs[2] (Z$/farm)	850	587	1072	-
NET INCOME PER FARM (Z$/farm)	834	329	2016	-

Source: HR Survey 1989
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Conflicts and complementarities
Dryland and irrigated crop production were managed without major conflict. Dryland maize planting and harvest avoided peak irrigation labour demand. It appears that labour was nonetheless in short supply for planting, weeding and harvesting the irrigated land, particularly for farmers growing both summer and winter beans.

There was a positive relationship between the number of irrigated plots cultivated and dryland income. Manure and fodder are essential elements in the complex relationship.

Sustainability
Irrigation was carried out on approximately 97% of the original design command area. Small areas are lost to waterlogging and salinity. Approximately 87% of total design area was planted in any one season. Land which was not planted was either planned fallow or unplanted as a result of domestic circumstances. It is expected that new drainage will have sustained or even improved yields.

However, if the scheme is to be sustained under farmer management and costs are to be met from local funds then higher financial returns/farm or household will be needed. These might be achieved through the combined effects of increases to yield, use of higher value crops and improved market access.

Poor supply of inputs is a major issue. The farmers attempted to increase their purchasing power by acting as a group, however, the prepayment system worked against the poorer farmers. Farmers showed interest in management, although there was no incentive for them to take added financial responsibility. They had a realistic appreciation of the effort involved in running the scheme. Change from tenancy to ownership might strengthen farmers' interest but the impact would be weak at prevailing income levels.

Environmental issues

The area surrounding the scheme showed some small signs of erosion. The scheme was built on former grazing areas so the development has inevitably increased pressure on land. There was no indication that the change endangered either the farming system or the land. The danger of waterlogging and salinity within the scheme appeared to have been averted before lasting damage occurred.

3.1.4 Design issues

Distribution structures equipped with lift gates were straightforward to operate under the control of project staff. Experience in schemes elsewhere in Zimbabwe suggests that they could be managed by farmers, given suitable instruction. Blocks were compact and distribution canals relatively short. Application efficiency was typical of border strip irrigation under agency management.

Waterlogging, until recently, was a growing problem. Shallow soil overlying rock gives rise to problems under surface layouts in the long term unless adequate drainage is installed. The causes of gradual saturation of the soil profile, in order of importance, were found to be:-

- in-field seepage
- leakage from lined canals
- leakage from night storage dams

Measures to reduce losses where shallow soils are a problem include:

- improved application methods
- good maintenance and timely repair of lined canals
- good maintenance and lining of reservoirs.

Costly pumped water should be used as efficiently as possible.

Marketing and poor availability of inputs limit the success of this irrigation scheme so that the full economic potential of the water is not realised. Farmers exploiting the sweet corn market made almost Z$4,000. Average farmers, constrained by lack of transport and poor roads, made much less. However, they benefited from irrigation and demonstrated their ability to tackle the difficulties arising from their remote situation. They would benefit from access to credit, timely delivery of inputs and improved infrastructure.

Farmers who have only one plot are unlikely to be able to increase production significantly unless access to inputs is improved. Two or three irrigated plots per farm would be needed for sustainability.

Farmers were willing to increase their share of responsibilities but did not wish to manage the scheme. The cost of repair to lined channels and the difficulties involved in acquiring materials are likely to prove more onerous than payment of the irrigation fee.

Farmers paid an operation and maintenance fee of Z$145 per hectare per annum. However, the cost to AGRITEX of running small schemes was over Z$600 per hectare per annum. Sustainable farmer management of this scheme is doubtful unless farmers can make significantly higher profits. A cost effective management strategy to lower costs from the present level is required to encourage farmers to accept farmer management and responsibility after a suitable transition period.

3.2 Nyanyadzi Irrigation Scheme, Zimbabwe

3.2.1 Location and historic background

Nyanyadzi lies at the confluence of the Nyanyadzi and Odzi rivers in Manicaland, Zimbabwe (Figure 1). The surrounding countryside is semi-arid and produces rain fed crops four years out of five. Farmers are almost totally dependant on irrigation to provide for their needs in bad years. The Odzi and Save valleys have a number of irrigation developments and trade is facilitated by the good road from Beitbridge to Mutare.

The scheme was constructed in the 1930's to relieve famine and, at that time, drew water only from the Nyanyadzi river. Irrigation in the 1940's was confined to the area now known as Block C which is nearest to the intake on the Nyanyadzi river. The scheme worked well and was later expanded by extending a canal to conduct water to a lower block of flat land, now known as Block A. A night storage dam was built so that the continuous flow from the canal could be stored for use the following day. The final expansion added two further lower areas, Blocks B and D and incorporated pumped water from the Odzi river, Block A before serving Block B. By 1960 some 300 ha had been allocated and in 1990 the scheme covered 420ha (Figure 3).

The scheme is run by AGRITEX. Considerable technical and social problems affect management of the system. Two main issues addressed in the social economic survey were:

- the size of irrigated plot required to generate a specified minimum income
- the general requirements to be met to enable hand-over of scheme management to farmers and to ensure sustainable farmer management of schemes.

3.2.2 Scheme characteristics

The average holding size is 0.9 ha but there is variation between blocks. Water is taken from the Nyanyadzi river by gravity and from the Odzi river by pumps, which have proved unreliable. The distribution system is partly lined but the main canal bringing water to the night storage dam from the Nyanyadzi river is unlined and is a major source of loss within the scheme. In 1986/7 only one or two of the six pumps at the Odzi functioned and 80% of the total supply came from the Nyanyadzi river. Inability to keep the pumps running was a major constraint. The tendency of farmers above the night storage dam to take water beyond their needs also created problems.

Water is delivered on a rotational basis between blocks and within blocks. The irrigation manager and his team of bailiffs control flows from the night storage dam, Odzi pumps, and canal. Control of flows has been seriously hampered by lack of management information for this complex system. In a bad year, inequity of supply between blocks is dramatic, causing income in disadvantaged blocks to fall to less than a quarter of that obtained elsewhere. Blocks C and A are least affected by shortages.

Main summer crops are maize, cotton, summer vegetables and groundnuts grown in border strips whilst in the winter, beans, wheat, tomatoes and winter vegetables are grown. The cropping pattern varies from block to block to make the best use of the water supply. The farmers on Block C grow tomatoes under contract. Expansion of tomato growing is restricted to areas which have good water supply. Input supply and marketing were channelled through contractors

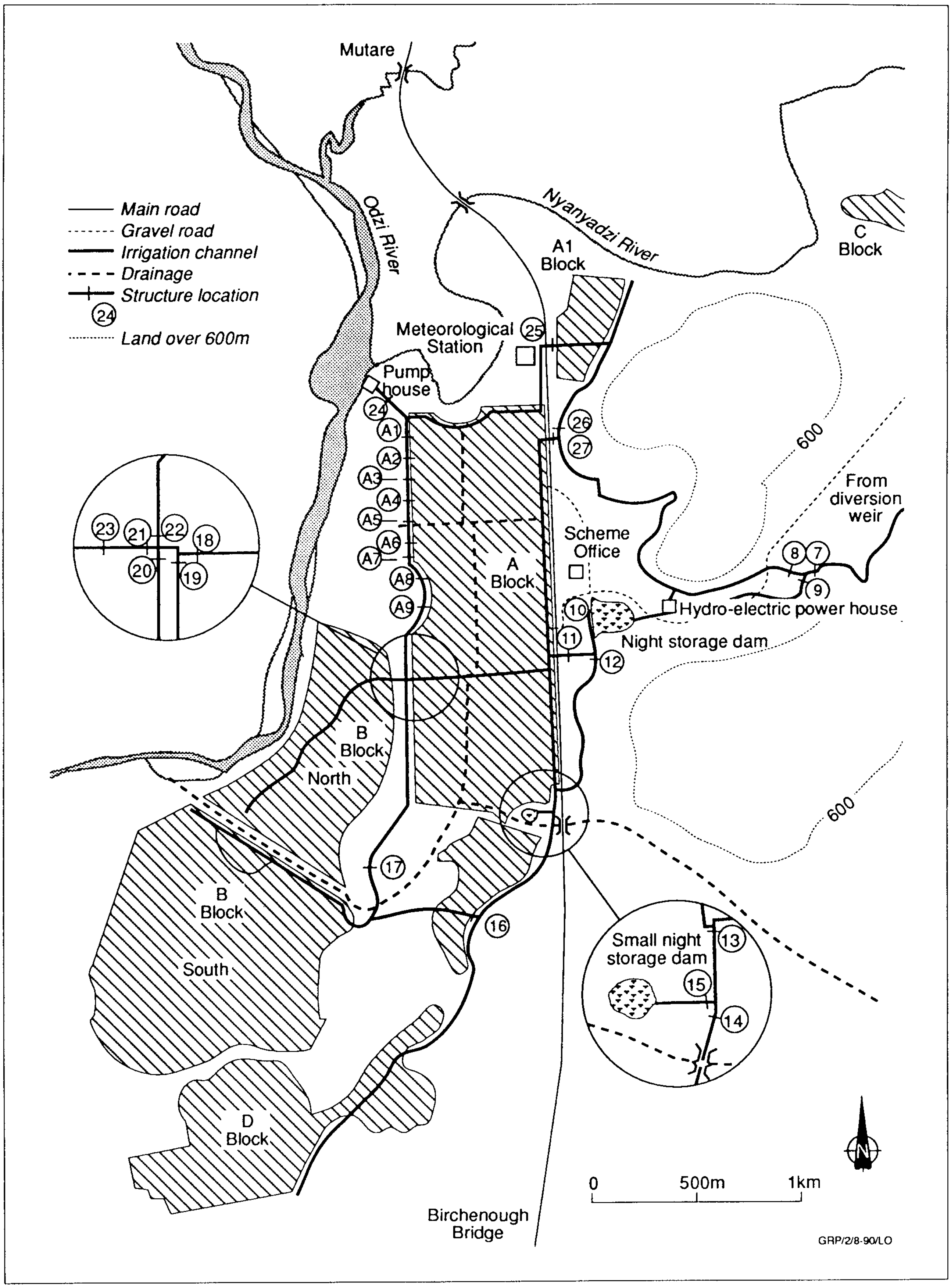

Figure 3 Nyanyadzi Irrigation Scheme

and the scheme co-operative, which now has a limited function. A thriving trade goes on in the roadside market.

The scheme is administered and managed by AGRITEX with assistance from an elected farmer committee. Farmers contributed Z$ 145 per hectare per year, representing approximately one fifth of the cost to AGRITEX of running the scheme. Extension and credit are available to farmers from a number of sources.

3.2.3 Main findings

Operation and management

Nyanyadzi is a complex scheme which is difficult to manage. Problems arise from the following features:

- blocks vary considerably in size, shape and layout. The original development was relatively compact and would have been easy to manage. Subsequent development seriously complicated operations. Deliveries to each block need to be matched with block and channel characteristics. It is difficult to achieve adequate and equitable supply across the scheme without close control, measurement and scheduling.
- the diesel powered pumps were unreliable. Spare parts were difficult to obtain. Low flows in the rivers caused difficulty in abstraction.
- the long unlined main channel (75% of the flow entering the scheme).
- the main supply channel draws sediment from the unregulated head gate causing high maintenance needs in the extended network of channels and night storage dams.
- inequitable water supply and competition for water discourages farmers from cooperating with management and with each other.
- drains are rarely cleared. Flash floods running off adjacent hills sometimes inundate the scheme.

Table 3.2 Irrigation performance indicators for Nyanyadzi

Indicator	SCHEME	Block C	Block A	Block B	Block D
Supply	N/A	N/A	1.89	1.23	1.23
Adequacy	N/A	N/A	N/A	N/A	N/A
Efficiency	40%	N/A	38%	56%	56%
Equity	Poor	Good	Poor	Good	Good
Dependability	Poor	Good	Fair	Poor	Poor
Sustainability	Fair	Good	Fair	Fair	Fair

Agricultural production

In normal years maize, occupied over 80% of the planted area, the remainder was used for cotton. Cropping intensity was usually around 97% in summer but fell a little in winter. In winter, beans, contract tomatoes and wheat were grown. Tomatoes were important on Blocks C and A.

Inputs were available but farmers only applied approximately one third of the rate recommended by AGRITEX. This is partly explained by the fact that income was severely depressed in bad years. In subsequent years working capital is short. In some bad years male workers left the scheme to seek work elsewhere, creating labour shortage in the following season. Households headed by women have a disadvantage especially at land preparation. Unless income is remitted to them regularly they also lack resources for inputs. Thus production was often poor in the year subsequent to a poor year regardless of climatic conditions. Where two poor years occur in sequence the effect is substantially greater.

Yields and marketing
Results shown in Table 3.3 were obtained in a bad year and are typical of one or two years in five.

Table 3.3 Crop yields for Nyanyadzi (kg/ha)

Yield (kg/ha)	SCHEME	Block C	Block A	Block B	Block D
Maize	2400	2780	4120	1640	1200
Cotton	1334				
Beans 1	520	480	480	510	1160
Beans 2	716	581	788	1125	675
Tomatoes[1]	8ha	4ha	2.7ha	0.55ha	0.54ha

[1] Tomato yield was not recorded. The figures refer to total area devoted to tomatoes/block. Average gross margin/ha for tomatoes was Z$1155, and the differences between blocks are significant.

Crops like tomatoes showing the highest gross returns were grown mainly in the blocks with the more secure water supply. The yield of maize was also found to be most strongly related to water supply. Fertiliser use had relatively small effect.

Income
Incomes were relatively even between blocks in good years. However, in bad years variation by block was very large. Table 3.4 shows income composition by block for a bad year. The low incomes in blocks B and D reflect the relatively poor water supply.

Table 3.4 Gross margins and farm incomes for Nyanyadzi (Z$)

Income (Z$)	SCHEME	Block C	Block A	Block B	Block D
Irrigated gross margin (Z$/ha)	282	626	746	-86	11
Irrigated net income (Z$/farm)	254	563	671	-77	10
Dryland / livestock income (Z$/farm)	315	812	459	223	-60
Total agricultural net income (Z$/farm)	569	1375	1130	146	-50
Other inflows[1] (Z$/farm)	107	175	245	1	91
Costs[2] (Z$/farm)	-	-	-	-	-
NET INCOME PER FARM (Z$/farm)	676	1550	1375	147	41

Source: HR Survey 1989
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Only on large plots (1.6 ha.) did irrigated production provide the desired return to labour (minimum of two units of labour per farm). Table 3.5 shows returns for a normal year as calculated from historic data provided by AGRITEX.

Table 3.5 Calculated net irrigated income for normal years per holding by block at Nyanyadzi (Z$)

	SCHEME	Block C	Block A	Block B	Block D
Calculated normal net irrigation income	1862	1957	2030	1600	1620

Conflicts and complementarities

Although the scheme was initially successful in reducing the need for famine relief, expansion of the irrigated area over the years has increased demand so that production can now be only partially successful. Increased poverty is a risk on Blocks B and D where money spent on inputs can be partially or totally lost when water supply is inadequate.

Complementarity exists between irrigated production and livestock production when fodder and manure (secondary products) are used as inputs. The positive effects are observed in larger holdings.

However, there are a number of conflicts present. AGRITEX staff, with limited funds, have problems in supplying reliable irrigation water. Farmers are reluctant to cooperate in maintenance, showing poor discipline and low fee payments. There are also conflicts between farmers due to the competition for water.

Environmental and health issues
Reasonable living standards give positive impact for most farmers although this is not always the case in the disadvantaged blocks. Little additional impact of irrigation on disease was evident in an area where malaria was endemic. The generally free- draining soils showed little evidence of damage from irrigation.

Sustainability
Block C has low operating costs, adequate, dependable supply of water, and established high value marketable output and could sustain itself indefinitely. Nyanyadzi scheme as a whole, however, has problems. In the blocks where income is drastically reduced in bad years sustainability is not assured if bad years occur consecutively. The cost of supplying water reliably to the whole scheme would be high. These costs can only be met if incomes are substantially increased.

It was found that a plot size of 1.25 ha returned the best margins.

- plot size could be adjusted to give a specified level of income corresponding to water supply ie large plots in the tail and smaller plots in the head. This option is inexpensive but difficult and possibly impractical for implement. It would require poor farmers to raise resources to farm larger areas than at present
- water supply might be improved to assure the specified income potential on a given plot size

In order to sustain the scheme and improve performance.

- supply must be improved
- management strategies must be found to overcome design problems

3.2.4 Design issues

Physical
Section 3.2.3 identified problems associated with the piecemeal development of the scheme:

- layout should be compact
- blocks should be comparable in size or provision should be made to match supply to the size and characteristics of different blocks.
- supply channels should be kept short and preferably lined
- discrete areas should be served by a single source.

Subsequent to the investigations, the water supply problem was solved by constructing a new electrically-powered pump system on the Nyanyadzi river. The existing supply channel was abandoned beyond Block C.

Managerial
Farmers must have an incentive to take over a difficult task which could reduce their incomes. Management must be simplified so that farmers can realistically manage the scheme on a small budget. However, it is difficult to supply the individual demands of farmers with an infrastructure designed to serve a supply oriented agricultural system. Alternatively, a main system, managed by an agency could supply a cluster of small farmer managed schemes(former blocks), each with a separate contract and reliable conditions.

3.3 El Hammami Pipeline Irrigation System, Egypt

3.3.1 Location and historic background

Two low pressure pipelines introduced on a pilot basis at Mansouria near Cairo (Figure 4) in the nineteen eighties replaced a traditional open channel network based on the El Hammami canal, which suffered from poor supply and water shortage in the tail regions. The system draws water from the Mansouria main canal. Under traditional supply practice, water in the canal is supplied under a three part, twelve day cycle to head, middle and tail regions. The pipelines, which were constructed under the Egypt Water Use project by USAID and the Water Research Centre, Cairo, were finally commissioned in 1991. In the interim period before the system became operational, farmers became accustomed to irrigating with marginal quality water from a shallow aquifer.

Annual rainfall averaging 30mm falls mostly during a few days in November and December, making virtually no contribution to crop water needs. Daily average maximum temperatures vary from 20^{o}C to 36^{o}C. Annual average evapotranspiration is around 1750 mm.

Mansouria is fairly typical of a peri-urban environment. The nearby city is expanding rapidly, creating a strong impact on farmers' lives. The land must be intensively farmed to produce high returns otherwise it is taken up for other developments, a process which has already started. The city provides a ready market for produce. There is a strong demand for vegetables, and for fodder for animals kept within the city.

3.3.2 Scheme characteristics

The nominal command area of the El Hammami system is about 780 feddans (330 ha). The average landholding size is 1.0 - 1.5 feddans. Soils are fairly uniform, a shallow layer of sandy loam overlying sand.

The basic elements of the two pipelines were designed similarly to simplify O&M. The pumphouses at the head of each line at the Mansouria canal include three pumps with a total nominal capacity of 270 l/sec. The buried pipelines are of asbestos cement serving outlets equipped with alfalfa valves (Figure 5). Each line was intended to serve a few, grouped, outlets. However, farmers refused to cooperate until an outlet was provided for each of the existing tertiary channels and direct outlets. In the case of Line no 1, 33 outlets were constructed in place of the intended eight. The areas served by each outlet differ by more than an order of magnitude, from less than a hectare to nearly 40 hectares. Pumpstand, corner and tailend open tanks are provided on each line to relieve transient operating pressures.

When operation first started, the tertiary canals were all unlined. Later, many of the longer channels were lined, resulting in noticeably better supply to remoter areas and an extended areal coverage. Despite the improvement, the system

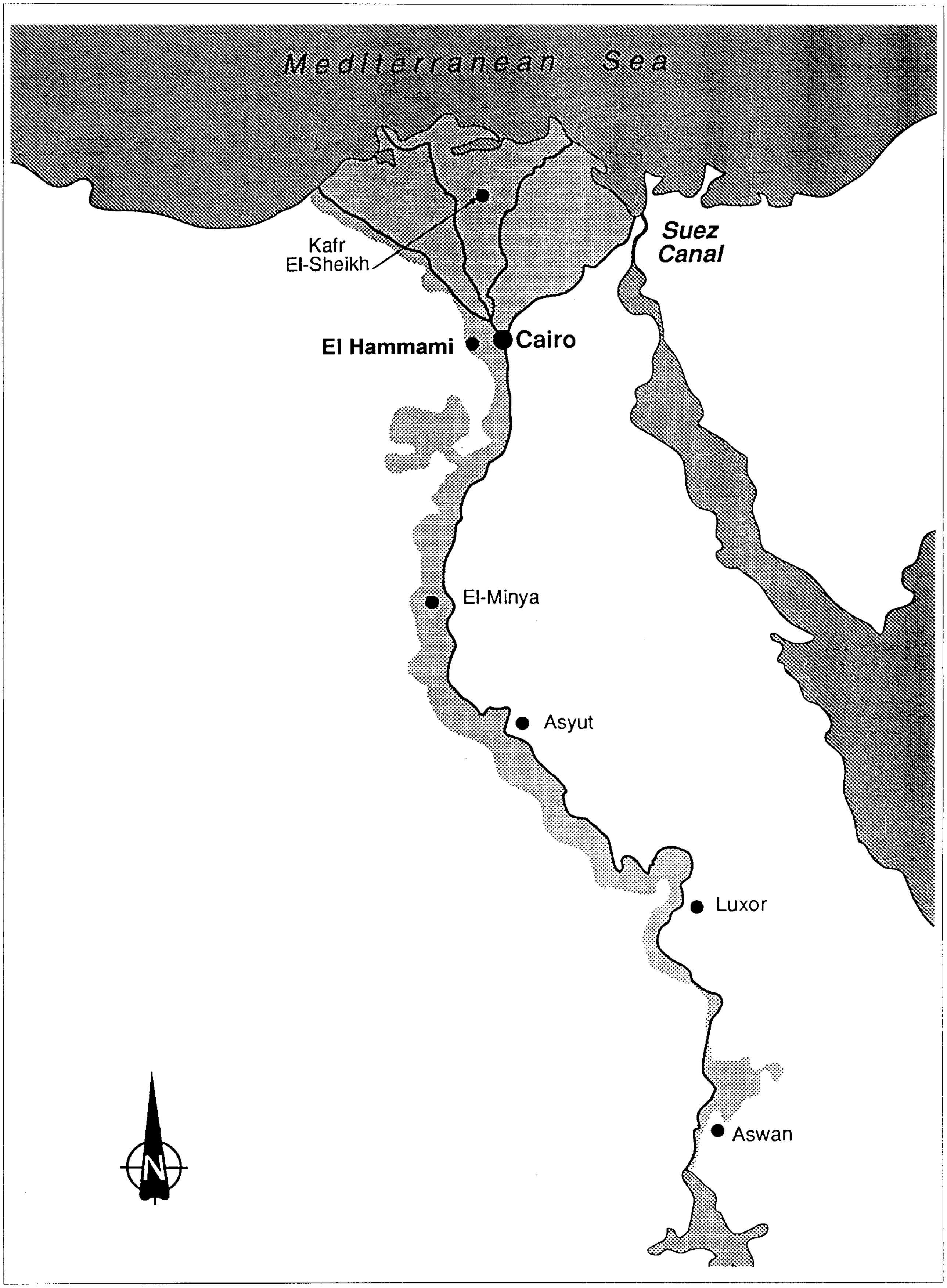

Figure 4 Location of El Hammami Pipline Irrigation Scheme, Egypt

can only serve around 60% of the nominal command area, owing to a number of physical and operational constraints (3.3.3).

3.3.3 Main findings

Operation and maintenance

The system as built is constrained by a number of factors which mean it cannot operate in the relatively straightforward manner intended by the designers.

Pumping capacity and operating hours: only two of the three pumps in each station can be operated simultaneously for any prolonged period owing to limited transformer capacity. The main power supply is cut off once a week for a full day owing to shortage of overall capacity. Budgetary constraints limit the number of hours the pump operators will work to a maximum of around 10 per 24 hour period, rather than 14 as assumed.

Under the prevailing canal supply pattern, the pumping stations at the head of each pipeline can draw water for up to 8 days in each cycle. However, the supply constraints are such that the full command area cannot be served.

The operation of the outlets is under the general control of a linesman, though the task is being gradually delegated to farmers. The system is strongly affected by uncoordinated demand from farmers. It became apparent to all users in the early stages of operation that unregulated outlet operation would reduce line pressure to the point where the system effectively failed. Farmers have learnt from the experience but the system cannot be expected to operate to its full potential unless more formal cooperation between individuals is introduced. Group formation is essential because there are up to 80 individuals on the largest outlet.

Irrigation practice is strongly affected by a high groundwater table. Crops are effectively sub-irrigated. Water lost in transmission and application effectively becomes available for reuse to the plant. Because the moisture-holding capacity of the soil is low, farmers are accustomed to apply excess water which is later drawn upon by plants during the intervals between irrigations. Conventional scheduling based on Penman evapotranspiration factored to allow for losses is not directly appropriate because of the ground water contribution. Reasonable yields were obtained with very modest deliveries from the system. Measures of adequacy cannot be compared directly with other schemes where the water table and tube wells do not contribute to crop needs.

The outlets are too large for efficient water use by a single farmer. It is difficult to equitably split flows of around 50 l/sec without structures. Small basins should be irrigated with flows of 20 l/sec or less.

Table 3.6 Irrigation performance indicators for El Hammami

Indicator	SCHEME	Mesqua serving < 1 ha	Mesqua serving 1 - 2 ha	Mesqua serving 2 - 5 ha	Mesqua serving > 5 ha
Adequacy	0.32	0.51	0.30	0.24	0.24

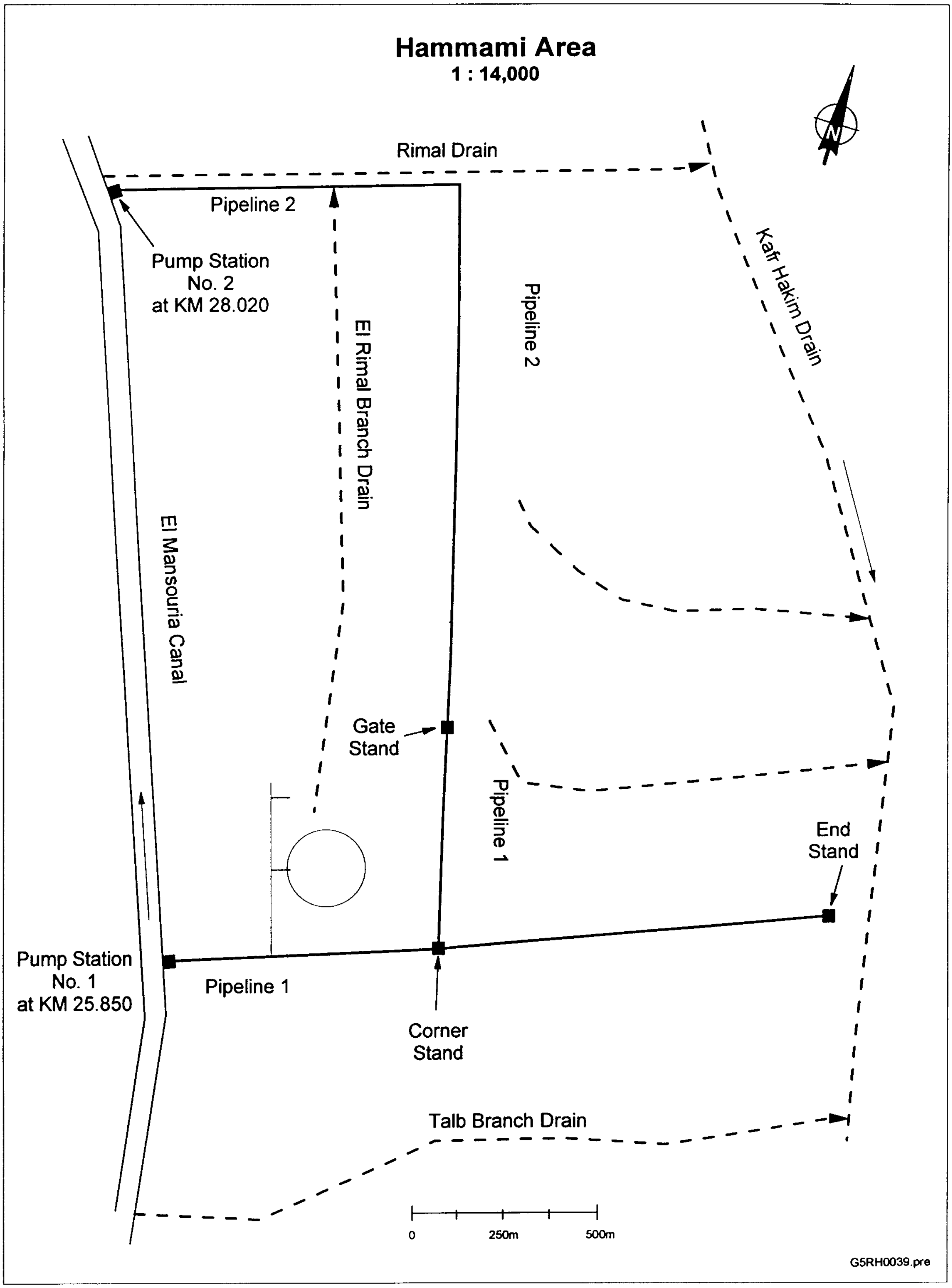

Figure 5 El Hammami Irrigation Scheme

The principal aims of introducing the pipeline were to save water and improve its distribution. Limited pre-construction data indicate that the pipeline did not reduce water use. However, once the tertiary channels had been lined, the equity between the head and tail of the system was much improved over the former open channel system.

Table 3.6 indicates the order of the supply to different sized outlets.

The adequacy indicator reflects the fact that the full command area was not served by the system.

There was equitable distribution between channels (measures) serving similar areas. However, on command areas greater than 5 ha, the supply was less good, decreasing to 50% or less of that enjoyed by the smallest areas.

Agricultural production

Principal winter crops are berseem, cabbage and vegetables generally. Vegetables, maize and some sunflower are grown in summer. Some of the area is occupied by permanent tree crops such as dates, citrus fruits and mango.

Vegetables require a comparatively large amount of scarce and costly labour. Berseem (clover) needs less labour. As there is an assured demand, cropping decisions are based on input and output prices.

Vegetables are cultivated almost year round producing one summer harvest and two winter harvests. Berseem, too, is a multi-cropping plant which is cut two to four times a year. Around three quarters of the irrigated area is devoted to vegetables and berseem. This figure has been fairly consistent since 1980, prior to which it was around 60%. In the early eighties, cropping intensity increased dramatically, and although it has not maintained the originally high level it is still well above the 1979 figure.

The changes in 1980 appeared to occur as a result of the move to privately controlled abstraction of irrigation water from the aquifer. Pricing of water (through related diesel costs) was implicit in this change. The impact of the change appeared greater than the later change to use of piped supply, which is provided free of charge.

Inputs

Egyptian farmers are experienced in irrigated farming, thus relationships between nutrients, water and plant performance are well understood. Control of the Nile flood coupled with intensive land use has reduced soil fertility so that fertilizers must be used. The last decade has seen large increases in the cost of fertilizer due to structural adjustment policies.

Farmers have intensified their farming system. Some farmers have increased their nursery activities to supply young plants for sale, in addition to those required for their own land. Seedlings sold at less than six weeks growth represent a potential increase in the cropping intensity of the area. Developments of this sort, have the advantage of utilising small plots, but can only be achieved through increased control of water.

Yields and marketing

Yields were not analyzed in the study but appeared to be typical of the area. Marketing was undertaken individually and locally. There are no access problems in the area.

Income

Incomes were recorded for 1992/3 in order to compare income between benefitting and non-benefitting farmers. There was also an opportunity to compare performance between Pipeline 1, where farmers were assisted in management by Water Research Centre staff and Pipeline 2 where farmers managed the operation of outlets themselves. Findings were not significant and indicated a need for further research. This was in part due to the fast uptake of management ideas from Pipeline 1 by the farmers on Pipeline 2.

Table 3.7 Farm income for El Hammami (Egyptian pounds)

Income (Egypt £)	**Non-benefitting farmers**	**Pipeline users**	**Pipeline 1**	**Pipeline 2**
Net farm income	1668	607	734	433

The higher income achieved by non-benefitting farmers appeared to result from the more intensive use of land.

Health and environmental issues

Irrigation is widespread and for centuries the population has suffered effects of schistosomiasis. Substitution of a pipe for the distribution canal at this site is not likely to on impact the situation in any significant way. However, reduction in the amount of stagnant water, from eliminating seepage, improves health locally, particularly that of children. Accumulation of refuse in the canal is no longer possible which is also likely to be beneficial. If the pipeline results in pulling down the water table and improving the plant root environment then increased yield and generally higher living standards may be achievable.

Conflicts and complementarity

Agriculture and urban economic activities are inter-related. Costs are influenced by wage rates in urban employment. There are also opportunities for urban activities to subsidise agriculture within the family unit. Land values increase as the city expands towards El Hammami, acting as an incentive for urban members to assist agricultural activities until such time as a substantial profit can be made from sale of the land. It is unlikely that all farmers experience the same economic motivation. This sort make generalisation from a small sample dangerous.

Operational difficulties mean that El Hammami is not an ideal pilot study to compare the direct replacement of a canal system by a pipeline. However, it is clear that traditional ways of organizing water may be disrupted by new technology, so that conflicts limit its successful uptake. Design of the pipeline was carried out without consultation with the farmers; subsequent consultation resulted in a compromise design which was both difficult to operate and unsatisfactory for farmers. There appears to have been a conflict between technical innovation and agricultural experience.

3.3.4 Specific design issues

- The need to correctly anticipate the operational pattern of a design becomes especially pressing in pressurized systems were there is no storage to accommodate departures from assumed conditions. Designers need to obtain realistic information on demand patterns and O&M requirements before finalizing designs. Early discussions with farmers are strongly urged.

- Low pressure pipelines were originally developed for on-demand operation by larger landowners where both supply and demand are under control, or influence, of a few individuals. The introduction of such a system to small farming where large numbers of individuals are involved (380 farmers are involved on just one of the pipelines at El Hammami) requires that demands be agreed in advance and executed in practice. Formal scheduling at system level is essential but is insufficient to ensure adequate and equitable supply if water-sharing arrangements are not agreed below the outlet. The consequence of such failure is that disadvantaged farmers either interfere with the system or appeal for additional supplies to management.

- The greater part of losses in a small scheme occur below the outlet. Measures to reduce water-saving should therefore also focus on that level. Physical improvements can include splitting the outlet discharge down to flow rates manageable by a single small farmer by proportional distribution structures; lining channels; encouraging piped distribution. Social measures include the promotion and training of effective water management groups, a policy which is now being followed by GOE.

3.4 Gem Rae Irrigation Scheme, Kenya

3.4.1 Location and historic background

Gem Rae is a rice-growing scheme close to Lake Victoria, about 30 km from Kisumu, Nyanza Province, Kenya, (Figure 6). The water source for the scheme is the River Awach. Topography across the scheme is flat with an average gradient of about 0.5% and prior to irrigation the area was mainly swamp land prone to flooding. The prevailing soils across the scheme are medium to heavy, dark grey or black clays suitable for rice cultivation. The current irrigated area is approximately 90 ha with a total of 270 plots averaging 0.3 ha. There are 230 land-owners. A further 28 ha are occupied by outgrowers on the fringe of the scheme, making use of excess water from Gem Rae and flow in the river downstream of the intake.

Rice cultivation in the area began in 1938 using simple check structures and flood irrigation along the river. However, the meandering nature of the river and erosion meant that by the early 1980's this type of irrigation was impossible. Following a request to the Provincial Irrigation Unit (PIU), rehabilitation of Gem Rae commenced in 1984. The first irrigation was supplied in 1986. Funding for this work was provided by the Kenyan and Dutch governments as part of the Smallholder Irrigation Development Project (SIDP).

Gem Rae is in the Lower Midlands agro-ecological zone classified as "humid/arid". Annual precipitation is 1250 mm with peaks in April and November. The rainfall pattern is unpredictable, however, with monthly maxima typically two or three times the mean. During the study year (1991/92) total rainfall was only 840 mm. Temperatures are fairly constant throughout the year with monthly average maxima ranging from 25°C to 35°C. Reference evapotranspiration varies

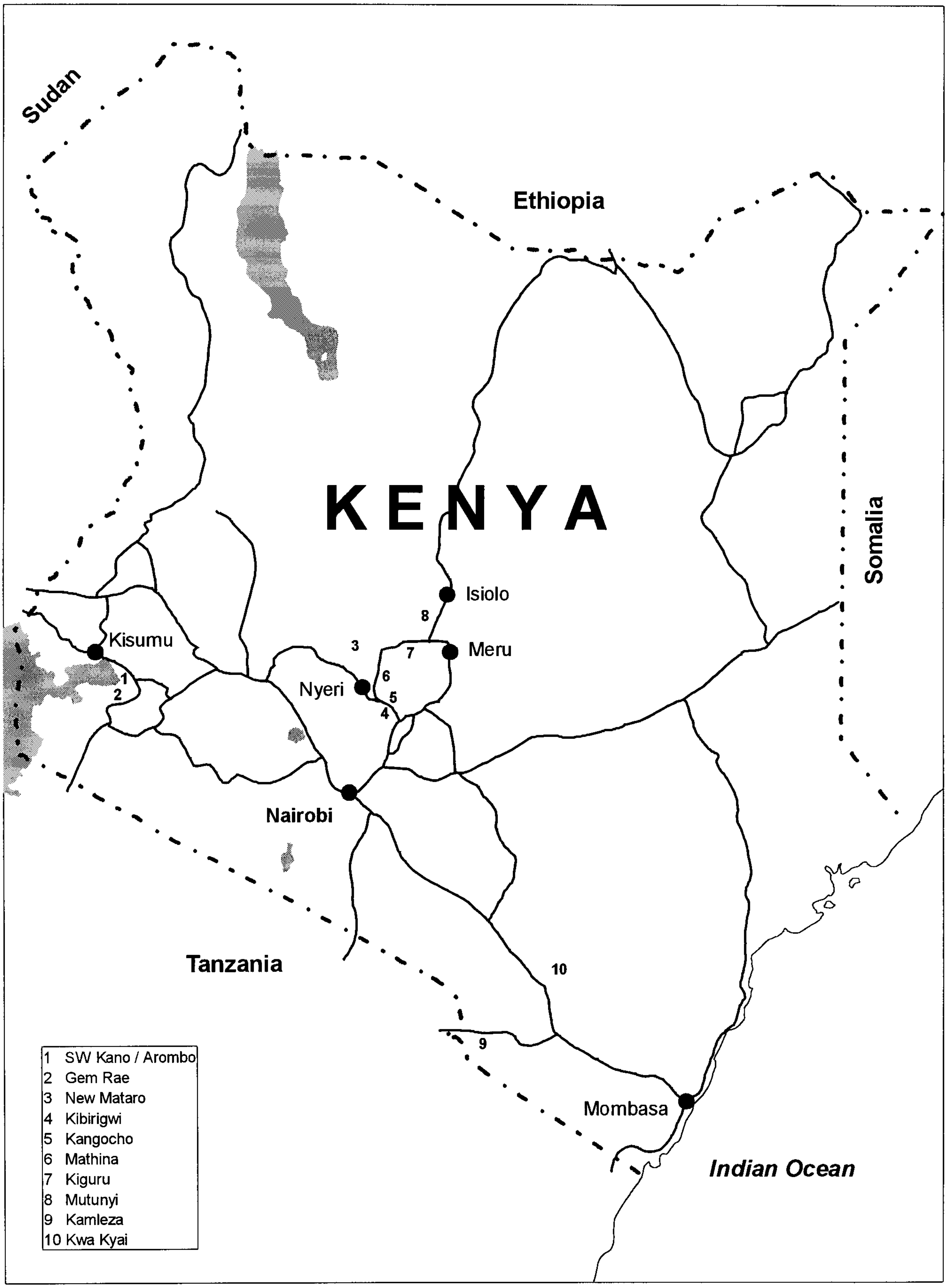

Figure 6 Location map of Kenyan irrigation schemes

from about 4.5 mm/day in November to 6.2 mm/day in March, equating to an annual evapotranspiration of 1800 mm.

Rice is grown exclusively at Gem Rae. One crop is grown per year, land preparation theoretically starting in June. Grain is harvested in December. For the remainder of the year farmers grow maize, the local subsistence crop, and sorghum under rain-fed conditions outside the scheme boundary. Land within the scheme is used for grazing during this period.

3.4.2 Scheme characteristics

The intake to Gem Rae is formed by a gabion weir across the River Awach with a gated culvert leading to the main canal whose total length is 2.4 km. The system consists of the main canal, which also serves the neighbouring scheme, three secondary canals and nine tertiaries (Figure 7). Tertiary canals are spaced at about 200 m intervals along the secondaries and serve between 3 and 15 ha. Flow is continuous to all canals.

Division of water is achieved with eleven proportional division boxes constructed of concrete blocks. No manual control of flow is possible, division is according to relative crest lengths. Basin irrigation is practised, each plot being divided into a number of basins varying in size from about 10 m by 10 m to 50 m by 50 m. Water passes from the tertiary canals and then from plot to plot on a 24 hour basis. Average ponded depth is about 10 cm. Design calculations assumed an average evapotranspiration rate of 6 mm/day, an infield efficiency of 60% and total canal losses of 10%. Thus the design flow was calculated as 1.5 l/s/ha with a maximum of 3 l/s/ha for land preparation.

Operation and management of Gem Rae is carried out wholly by the farmers' committee with advice from the local extension officer. The committee consists of 24 members and meets at the beginning and end of each season. Farmers are divided into groups sharing a common tertiary canal, giving a maximum group size of about 40 farmers. Responsibility for maintenance of the main and secondary canals rests with the whole scheme whilst each group of farmers is responsible for its own tertiary canal.

3.4.3 Main findings

Operation and management

There are problems in the way that the farmers manage the scheme. This is highlighted by the fact that the irrigation season during the study year (1991/92) was six months behind schedule. It appears that this situation has occurred gradually over the seven year period since rehabilitation. The principle reason seems to be lack of organisation and co-ordination amongst the farmers for desilting and maintaining the main canal prior to the irrigation season. There are also a number of exacerbating circumstances. Firstly, organisation of maintenance activities is hindered by involvement of farmers from a neighbouring scheme. Secondly, the farmers at Gem Rae appear to be trapped in a vicious circle. A late start to the irrigation season leads to irrigation during the period when large amounts of sediment are transported in the River Awach. Thus, at the start of the following season there is an even greater amount of sediment to be removed, pushing the season back even later.

Day-to-day operation of the scheme, however, was reasonable (Table 3.8). For the season as a whole, supply to Gem Rae was good . Total supply, including rainfall, exceeded calculated requirements by 34%. When periods of over- and under-supply are accounted for, adequacy was 86%.

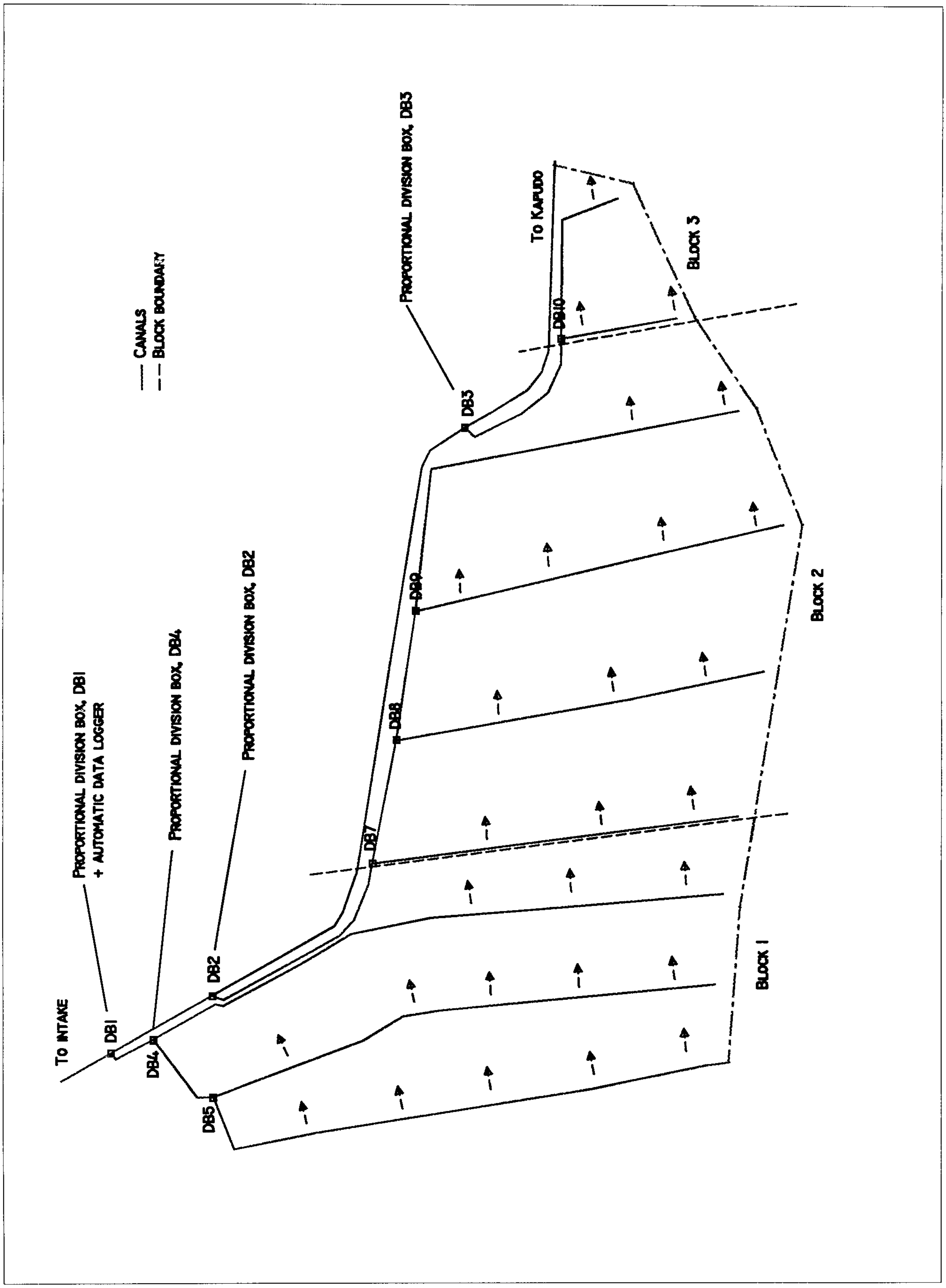

Figure 7 Gem Rae Irrigation Scheme

Table 3.8 Irrigation performance indicators for Gem Rae

Indicator	SCHEME	Head	Middle	Tail
Supply	1.34	0.62	1.55	2.29
Adequacy	0.86	0.60	0.92	0.75
Efficiency	0.49	0.69	0.48	0.44
Equity	0.25 (poor)	-	-	-
Dependability	0.27 (poor)	0.43 (very poor)	0.22 (fair)	0.54 (very poor)
Sustainability	0.95	-	-	-

Source: HR Study 1991/92

The graph of adequacy (Figure 8) shows clearly that there were significant differences between blocks, the tail and middle blocks faring better than the head. Indeed, supply to the head block was below 50% adequate for more than three-quarters of the season. This situation was reversed for the other two blocks (Figure 8). The reaction is not clear being contrary, to what might be expected. The results for the three blocks taken together suggest that the as-constructed weir levels on the offtake structures favoured the lower blocks. Overall efficiency of water use was 49% which compares favourably with other research into rice irrigation. Due to the variation in supply, efficiency varies considerably between blocks. Figure 8 also shows significant variation with time and this is reflected in the dependability scores which can be classed as very poor for the head and tail blocks, poor for the scheme as a whole and fair for the middle block.

Operation could be improved by the appropriate use of the intake gate. At present, there is no attempt to match the volume of water entering Gem Rae with demand.

Agricultural production

The mean application rate of seed was 87 kg/ha compared with a sufficient rate of 45 kg/ha (Acland, 1971). The majority of farmers did not buy rice seed; instead they used seed from last season's harvest. No farmers reported using chemical fertilizers or pesticides although manure was applied at an average rate of 469 kg/ha. Average labour inputs were 550 person-days per hectare. The late start to the rice results in difficulty for farmers in finding labour for irrigated rice when rain-fed maize requires labour at the same time.

Yields and marketing

Yields per hectare are generally very low compared to other figures given in literature for Kenya and have decreased substantially since the late 80's (Table 3.9).

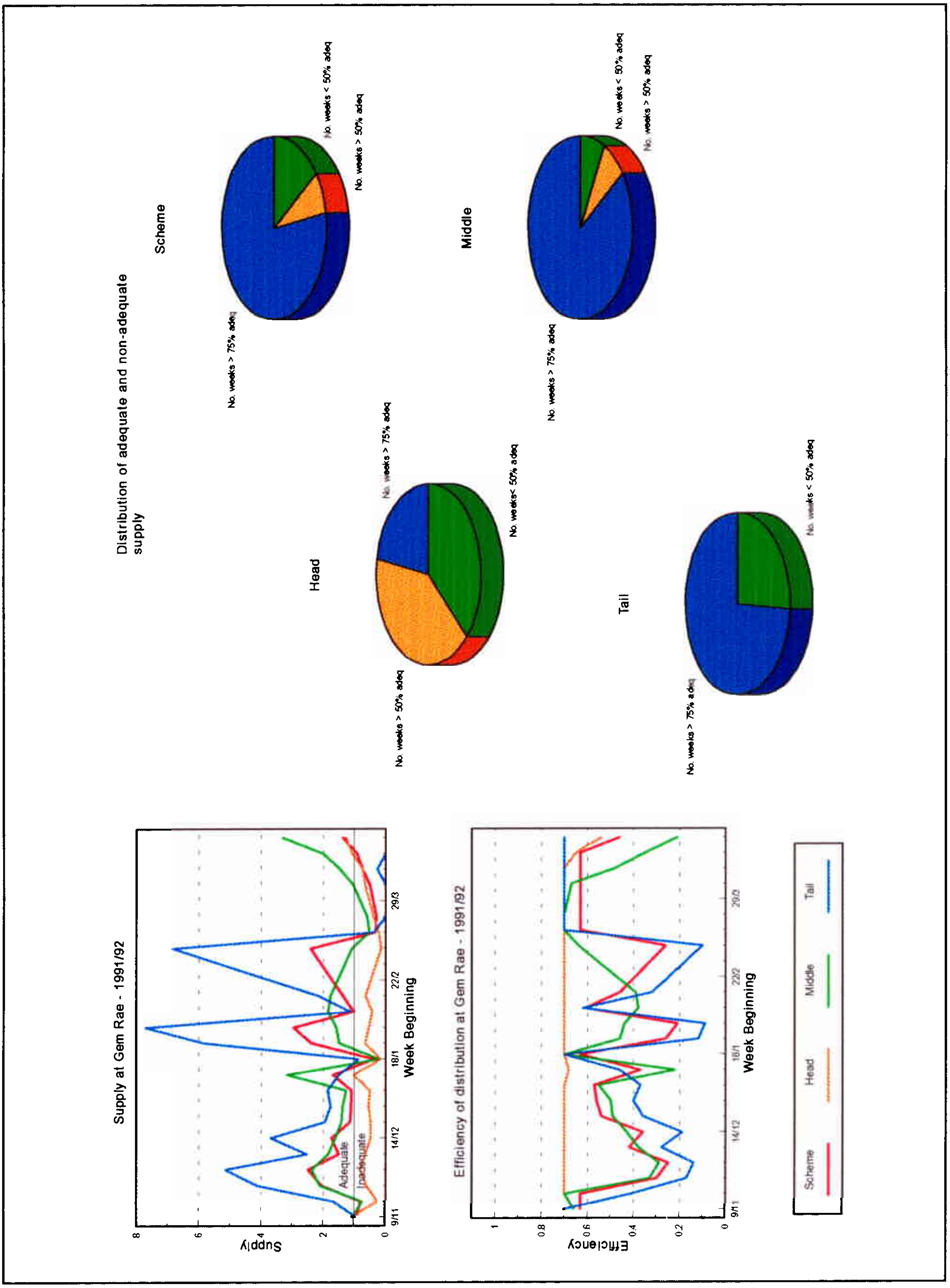

Figure 8 Irrigation performance summary: Gem Rae

Table 3.9 Unmilled Rice yields for Gem Rae (kg/ha)

Yields (kg/ha)	**Mean**	**S.D.**	**Range**
SCHEME	1299	730	330 - 3000
Head	1375	125	1250 - 1500
Middle	1685	927	500 - 3000
FIGURES FROM LITERATURE			
Gem Rae 1989/90 [1]	3600	-	-
Gem Rae 1987/88 [2]	4200	-	-
"controlled flood irrigation" [3]	-	-	3000 - 4000

Source: HR Survey 1991
[1] Source: Hulsebosch (1990)
[2] Source: PIU statistics
[3] Source: Doorenbos and Kassam (1986)

It is not clear why reported yields were so low. Late planting caused an overlap with the rainfed season leading to conflicts in labour allocation; although labour allocations were not significantly different from those found by Hulsebosch in 1989/90. A slight correlation was found between labour input and yield, however. Inadequate water supply may be a contributory factor in the head and tail blocks but does not explain the overall poor yields. Non-use of fertilizers and pesticides probably also contribute and a general decline in soil fertility may partially explain differences between yields in 1990/91 and previous studies. A steep drop in yields was also noted for crops harvested after May 4 probably due to an unusually high rainfall of 100 mm during the previous week damaging the ripening crop. All of these factors and under-reporting may have contributed to the poor results.

Farmers sell rice individually rather than as a group and most sell locally. Average revenue per irrigated area was 6200 KSh/ha. Significant differences in revenue were found against landholding; net benefits per hectare were lower for farmers holding more than 0.8 ha.

Income

Gross margins generated from agricultural activities in the twelve months prior to the survey are reported in Table 3.10.

Table 3.10 Gross margins and Farm incomes for Gem Rae (KSh)

Revenues / costs (KSh)	Mean	S.D.	Range
Irrigated net income	2474	3441	-2400 - 13780
Dryland net income	34	1666	-5360 - 7920
Livestock net income	3681	6243	-8400 - 19900
Food bought	9140	5879	0 - 25920
Equipment costs	700	621	0 - 2030
TOTAL REVENUE(inc. remittances etc.,)	9757	8745	0 - 33800
TOTAL COSTS (inc. necessary expenditure)	13408	8143	2610 - 39884
NET INCOME PER FARM	-3651	10935	-24730 - 25605

Source: HR Survey 1992

The average agricultural gross margin is negative, two-thirds of the farmers apparently make a loss, the purchase of food being the main cause. Net revenues for agricultural activities are generally positive although many farmers sustain a loss on dryland activities, presumably using dryland produce for subsistence needs. When total farm margins are calculated the surprising result is that overall net margin is negative (KSh -1300). Indeed, more than half the farmers made a loss during what has to be termed a "bad" year: a system in which costs are greater than benefits is not sustainable. The low yields will clearly be a cause of inadequate returns.

Conflicts / complementarity

There is a clear division at Gem Rae between the irrigation and rainfed seasons which would normally lead to little conflict of interest. However, the particularly late start to irrigation may have caused some problems with labour. This might also help to explain the delay in carrying out desilting work.

Environmental impacts

Environmental impacts at Gem Rae are low. Indeed, flooding has been alleviated to some degree by the introduction of the canal and drainage network.

Sustainability

During the study year approximately 95% of the scheme area was irrigated. A small area in the head block is not cultivated due to lack of command. The view was also expressed by the farmers' committee chairman that they would like to extend the scheme by a further 35 ha. The adequacy calculations would tend to support the view that there is sufficient water for this proposal.

Problems at Gem Rae appear to make the continued success of the scheme questionable. The loss incurred by the farmers in the study year does not bode well. In particular the level of maintenance, particularly desilting, facing the farmers may lead to a decline in productivity. It is clear that a major obstacle that must be overcome is the organisation and co-operation of the farmers in dealing with the seasonal running of the scheme.

3.4.4 Design issues

The level of maintenance that can be supported by farmers must be carefully considered. At Gem Rae, successive late starts to irrigation have led to ever-increasing amounts of sediment to be removed from the canals. The amount of excavation required clearly causes organisational problems amongst the farmers. In farmer-managed schemes this is a potential source of difficulty. Labour for maintenance must be organized cooperatively.

Intake design should be reconsidered. No provision for exclusion/extraction of sediment is made at the intake to Gem Rae. As a result sediment enters the scheme, adding to the maintenance workload. Naturally, correct operation of any structure would be necessary for successful results. Consideration as to whether the farmers possess the requisite skills and knowledge for this to occur must be made. It is likely that the cost and operation requirements of sediment exclusion structures will preclude this option.

The operation of Gem Rae is successful. Water is delivered and divided across the scheme with little unauthorised intervention from the farmers. Much of this can be attributed to the high standard of workmanship of the division structures. Good construction has paid off in ease of operation.

3.5 Kamleza Irrigation Scheme, Kenya

3.5.1 Location and historic background

Kamleza Irrigation Scheme is in Coast Province, 10 km south of Taveta, close to the Tanzanian border (Figure 6). The elevation is some 1000 m and the scheme falls in the Lower Midlands, an arid agro-ecological zone receiving about 550 mm rain annually. The scheme benefits from good quality water which originates from the Njoro Springs, one of many springs in the area fed from Mt Kilimanjaro.

Temperatures are fairly constant throughout the year with monthly maxima ranging from 26°C in July and August rising to 33°C in March. Reference evapotranspiration, ET_0, varies from about 4.2 mm/day in July to 5.5 mm/day in February/March and October. Annual reference evapotranspiration equates to approximately 1750 mm, an excess of 1200 mm over expected rainfall.

The total scheme area of Kamleza is 314 ha divided into plots of between 0.4 and 2.0 ha serving approximately 200 families. The topography is fairly flat. The Njoro Springs discharge some 2.8 m^3/s of which 0.8 m^3/s passes into the Njoro Kubwa canal. This canal was built in the 1940's primarily to serve the local sisal estate but it supplies several smallholder irrigation schemes including Kamleza. There is some conflict over water rights in the canal. An established right to 70% of the water is claimed by the neighbouring sisal estate and vegetable farm, which is owned by the local MP. The flow of water to Kamleza is managed by the farmers although there is apparently occasional interference by the local landowners. The channel which carries the water to the scheme is about 3 km in length and is maintained by the farmers. Most families also have dryland arable farms and grazing rights for cattle and small stock. The size of dryland farms varies from zero to over 10 ha.

The irrigated area of Kamleza has two main cropping periods in the year: one for maize, planted in March; and the other starting in October for vegetables for market. Extension staff are encouraging experimentation with Asian vegetables. Tree crops such as mango, banana, papaya, citrus fruits and coconuts are grown, as is cotton.

The soils vary across the scheme from medium to heavy, clay/loam . Areas of black "cotton" soils were observed in the tail-end of the scheme. Evidence of soil salinity could be seen in these areas. A harder layer of soil, at a depth of approximately 1 m was encountered, particularly in the north-eastern part of Kamleza.

Periodic inundation causes damage to structures and channels. There is a generalised fear that the scheme risks waterlogging and salinity, something which has occurred in the neighbouring scheme.

Kamleza is farmer-managed and has an annually elected committee of nine people. Groups, based on the offtake channels, assume responsibility for scheduling irrigation times, organising channel maintenance and applying the scheme byelaws.

The scheme is sustainable having remained well cultivated for over 50 years.

3.5.2 Scheme characteristics

The network at Kamleza consists of the main canal running through the centre of the irrigated area with a series of offtake canals serving separate irrigation blocks (Figure 9). A Parshall flume is located on the main canal as it enters the scheme area. There are no control or check structures across the main canal which is maintained well by the farmers. In places, there is evidence of seepage through the canal banks and around the structure headwalls due to the fairly large head difference between the water in the main and offtake canals.

Water is distributed throughout the scheme on a rotational basis according to a schedule devised by the committee. Each block is served by an offtake canal from the main canal, the flow of water is controlled by simple sluice gates set into blockwork headwalls. The degree of opening can be varied by the farmers. In all, there are fifteen offtake canals each serving an area of some 20 ha with approximately thirteen farms per block.

Surface irrigation is practised exclusively within Kamleza although the precise methods employed vary across the scheme. At the head, plots are divided into "fields" measuring up to 50 m by 50 m in which furrows are constructed. Towards the tail of the scheme, small basins measuring from 5 m by 5 m to 20 m by 20 m are used. Small furrows are sometimes used within these basins. Typically farmers have access to the water for a period lasting two to four hours depending on the size of their landholding.

Operation and management of Kamleza is carried out wholly by the farmer's committee. Each block has an elected representative who sits on this committee. Additionally, this person is also the nominated "gate keeper" and has the responsibility for control of their respective gate. The scheme as a whole is responsible for maintenance of the main canal although the sections adjacent to each block are usually cleared and weeded by the farmers in that particular block. The offtake canals are the sole responsibility of the block.

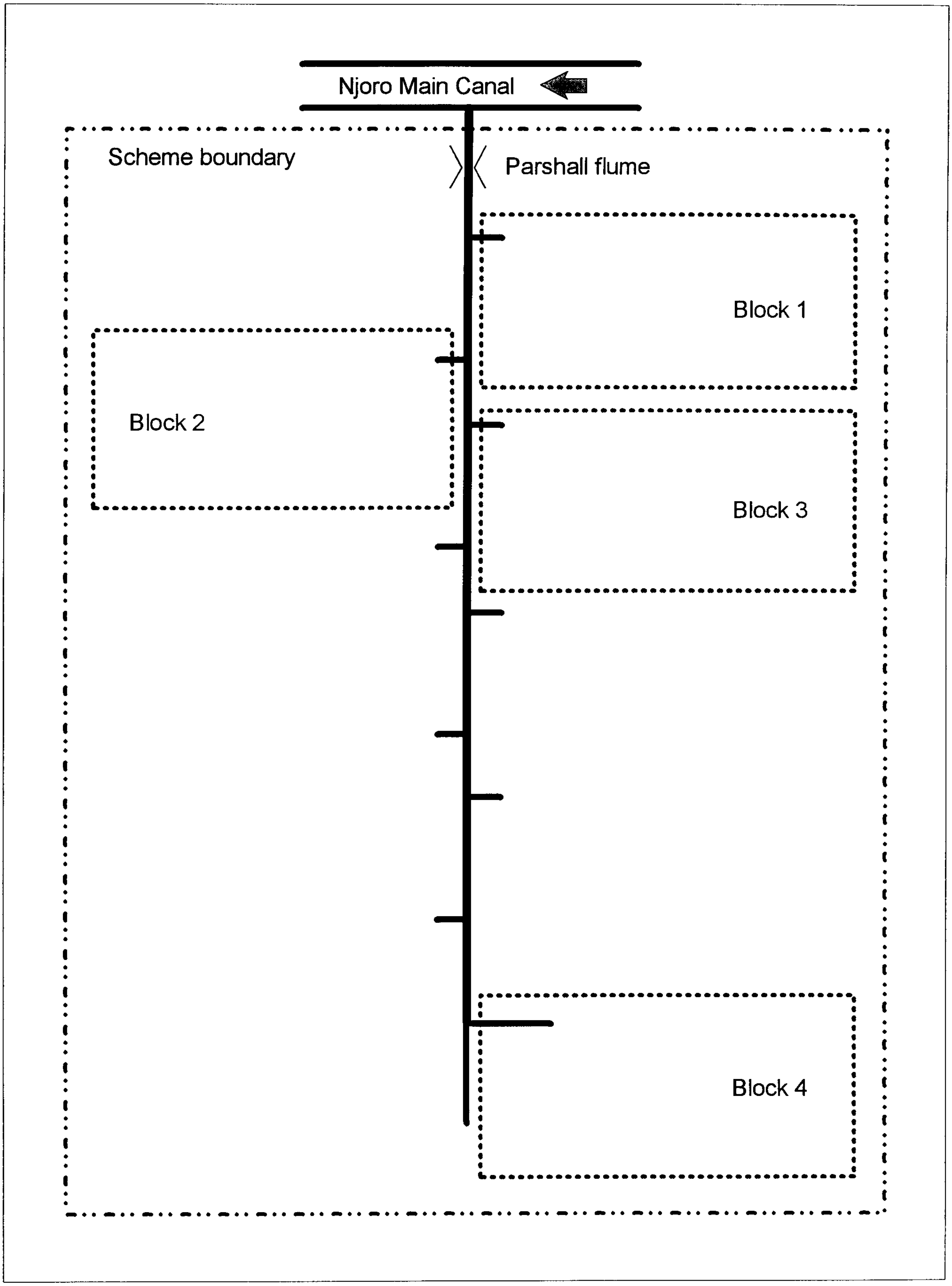

Figure 9 Schematic diagram of Kamleza Irrigation Scheme

3.5.3 *Main findings*

Operation and management

Serious problems of inequity exist at Kamleza and follow a classic "head-tail" pattern. Adequacy to the scheme as a whole is extremely good with supply exceeding requirement by 108% . Even when periods of under-supply are accounted for overall adequacy is 100% (Table 3.11, Figure 10). However, whilst the head block receives 98% excess water with an adequacy of 91% the tail receives just 50% of the required volume. Although overall supply to the middle block is less than to the head, adequacy is higher due to fewer periods of under-supply. Figure 10 clearly shows the extent of under-supply to the tail block with adequacy less than 50% for over half the time. Dependability of supply to the whole scheme is very good but varies considerably across the scheme.

Table 3.11 Irrigation performance indicators for Kamleza

Indicator	SCHEME	Head	Middle	Tail
Supply	2.08	1.98	1.38	0.54
Adequacy	1.00	0.91	0.96	0.50
Dependability	0.04 (very good)	0.26 (poor)	0.13 (good)	0.74 (very poor)
Efficiency	0.29	0.40	0.56	0.58
Equity	0.34 (very poor)	-	-	-
Sustainability	0.80	-	-	-

Source: HR Study 1991/92

The natural result of supplying excess water is a drop in water use efficiency. Thus, total scheme efficiency is only 29% comparing very badly with other small schemes. Efficiency increases through the scheme and approaches 60% (the assumed application efficiency) in the tail block. Application methods varied according to location. At the head, furrows up to 50m long were used with fairly uncontrolled flooding. At the tail, however, small basins were well-prepared and water applied carefully and methodically.

A telling result of the inequity of supply is that substantial portions of the downstream end of Kamleza have fallen out of irrigated production such that only about 80% of the planned area is currently irrigated. Causes for this situation are twofold. Firstly, control of water is poor at the head of the scheme. It is clear that the manual control offtake structures are not being used correctly with an excess of water being applied to the fields. Indeed, irrigation was observed on soil that was at, or very close to, saturation. Secondly, poor co-operation between farmers means that despite the complaints of downstream farmers little appears to change. An effective rotation schedule could alleviate many of the problems with water supply. Despite the presence of a resident extension officer on the scheme, specific irrigation extension appears lacking.

Although farmers expressed general satisfaction with the performance of the committee, improvement was thought most needed in conflict resolution,

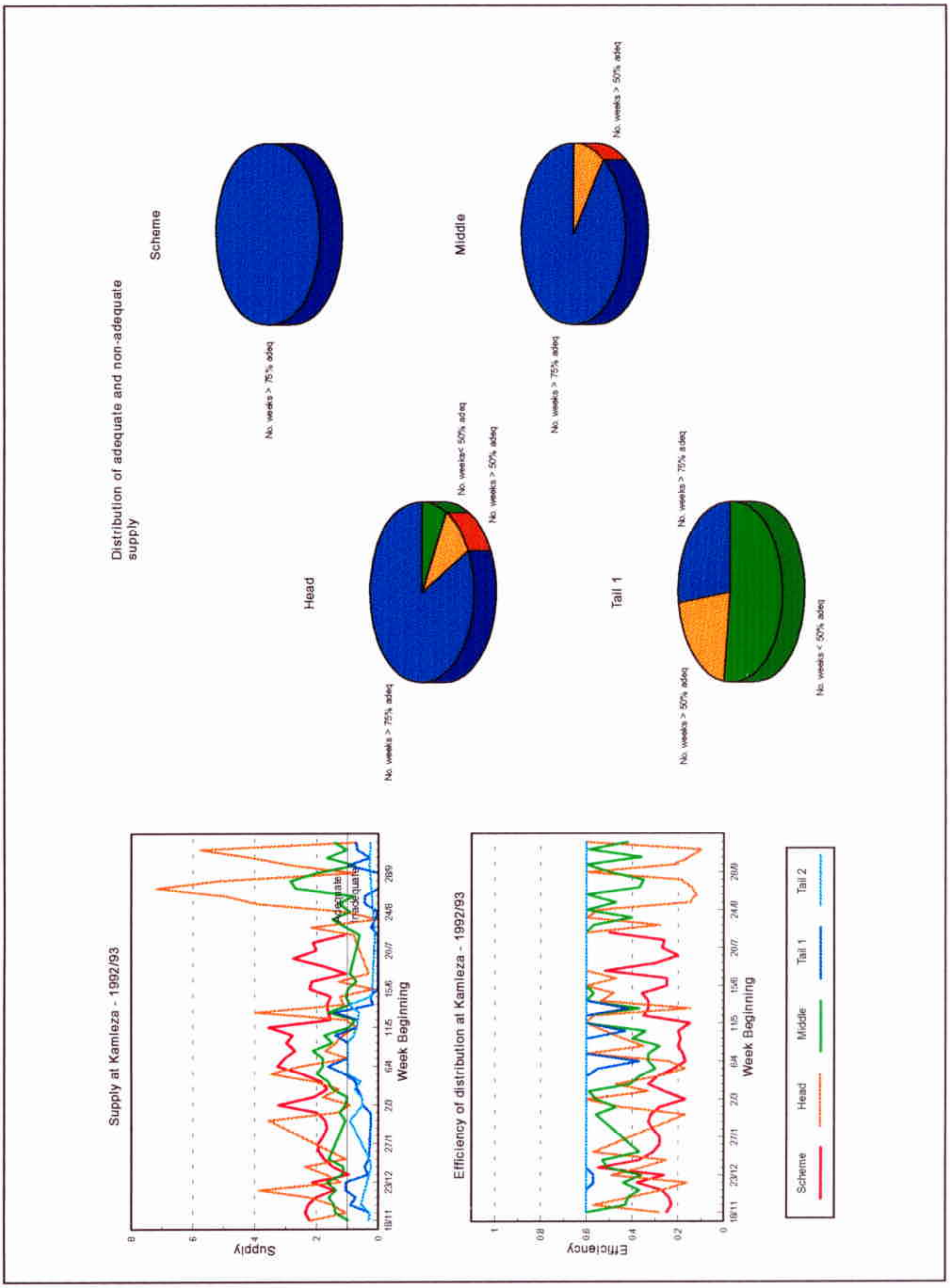

Figure 10 Irrigation performance summary: Kamleza

particularly in the middle reach. Tail-end farmers appeared to be resigned to the lack of water, reducing conflict as they seek alternative strategies.

Maintenance of the channels and structures is very good.

Agricultural production

Crop choice is varied. The most frequently grown crops are maize, beans, cotton, tomatoes and bananas. Annual cropping intensity is about 140%. Farmers appeared to spread risk by growing at least four different irrigated crops. Seed application rates varied widely between 2.6 and 48 kg/ha. Insecticides and fungicides were widely used and represented a major cost for most farmers. The use of chemical fertilizers was minimal, instead manure was used.

Shortage of labour was cited by farmers as a problem, particularly for ploughing and weeding and more so in the tail reach than at the head. On average 3.5 (equivalent) working adults were employed per hectare of irrigated land.

Credit was used by a quarter of the farmers and about 70% would like it to be more easily available. However, only half had any specific ideas about how to use the money and few indicated that they had investigated the costs and benefits of their ideas.

Yields and marketing

Yields at Kamleza were low (Table 3.12) in relation to national averages for irrigated farms and well below FAO figures for irrigated agriculture (FAO 33 Yield Response to Water). The impression gained from the yield results is that production was better in the middle reach for most crops other than beans. However, the conclusion is not significant at the 95% confidence level.

Table 3.12 Crop yields for Kamleza (kg/ha)

Crop yields (kg/ha)		SCHEME	Head	Middle	Tail
MAIZE	Mean	910	770	1210	700
	S.D.	(740)	(390)	(1190)	(230)
COTTON	Mean	1170	890	1380	960
	S.D.	(550)	(620)	(510)	(90)
BEANS	Mean	730	740	710	780
	S.D.	(350)	(370)	(370)	(350)
TOMATOES	Mean	6640	2910	9440	6640
	S.D.	(6690)	(2710)	(8130)	(6690)

Source: HR Survey 1992

It is thought that poor water application, whether in excess or not enough, was a major contributory factor to the depressed yields.

Although there is a clear division between food and cash crops such as maize and cotton, almost all the food crops were regarded as part subsistence and part cash. Crop revenues, which varied widely, depended more on the quantities marketed than variations in price. Apart from Taveta, Kamleza is fairly remote from other markets. Many farmers mentioned that oversupply of produce to the market led to reduced prices. Transport was also cited as a problem, particularly for tail farmers.

Income

Irrigated gross margins at the head of the scheme were low, none in the survey sample exceeding 4000 KSh/ha. Almost 40% of the head reach farmers had negative irrigated gross margins. These low figures are consistent with the low yield obtained and the fact that high value crops such as tomato performed poorly. Higher values were found for farmers lower down the scheme with higher variations in the tail reach (Table 3.13). Total agricultural gross margins are lower in all cases, implying that on average losses are sustained on non-irrigated activities.

Table 3.13 Gross margins and farm incomes for Kamleza (KSh)

Revenues / costs (KSh)		SCHEME	Head	Middle	Tail
Irrigated gross margin (KSh/ha)	Mean S.D.	7000 (11600)	2922 (4801)	9061 (9006)	9894 (19374)
Total agricultural gross margin[1] (KSh/ha)	Mean S.D.	4424 (15735)	348 (5249)	5930 (698)	8236 (30216)
Total agricultural net income (KSh/farm)	Mean S.D.	3520 (14429)	-275 (1570)	6558 (10099)	4125 (26239)
Other inflows[2] (KSh/farm)	Mean S.D.	29182 (124723)	75313 [3] (198315)	1000 (2321)	6100 (11952)
Costs[4] (Ksh/farm)	Mean	-5339	-5506	-4318	-6895
NET INCOME PER FARM (KSh/farm)	Mean S.D.	27363 (197783)	69532 (197738)	3240 (10095)	3330 (29882)

Source: HR Survey 1992

[1] Irrigation, dryland and livestock activities

[2] Other businesses, employment, remittances from family members

[3] This figure includes one single remittance of KSh 600,000 changing the negative net income for the group to a large positive income

[4] Support to relatives, school fees, travel, health, tools

Variability of household income is high at Kamleza and the variation is greatly influenced by remitted incomes.

Conflicts / complementarity

There is no obvious conflict between irrigated agriculture and other activities apart from a slight shortage of labour. The analysis of gross margins has shown that irrigation is the major contributor to farm profits and the partial use of crops for subsistence needs guarantees food security for households at Kamleza.

Environmental impacts
Salinity is a concern at Kamleza. This is caused by over-watering in parts of the scheme, generally inadequate drainage and the presence of a hard soil layer close to the surface restricting deep percolation of excess water. Parts of the neighbouring scheme have ceased production because of salinity problems. Action needs to be taken in order to prevent similar results in sections of Kamleza.

In general, health officials felt that the irrigation scheme had a positive impact on the local health standards because of the contribution to total food availability and the variety of diet and raised living standards in the area. Malaria is prevalent in the area.

Sustainability
In theory, Kamleza should have no difficulty in sustaining agricultural production through irrigation due to generally plentiful supply of water. However, inequitable distribution has caused 15% of the scheme area to cease irrigation due to poor water supply.

Waterlogging and salinity present more serious problems for long-term sustainability. Attention must be focused on improving water application methods to improve equity, and drainage. More detailed investigation should be made to determine the precise effect of the hard soil layer on drainage.

3.5.4 Design issues

Inequity is a primary concern at Kamleza. Allocation and control of water is entirely within the hands of the farmers:

- poor water distribution is reducing irrigation opportunities in the tail reach whilst over-supply has an adverse effect on yields due to waterlogging.

- the offtake structures are gated. It is clear that the farmers' knowledge and skill in managing the irrigation system is not good enough to make the most of the excellent supply. Either simpler proportional structures requiring less control should be installed, or pertinent advice on how to distribute the water better should be provided .

3.6 Kwa Kyai Irrigation Scheme, Kenya

3.6.1 Location and historic background

Kwa Kyai Irrigation Scheme lies within Eastern Province and is situated about 10 km east of Kibwezi town on the Nairobi - Mombassa highway connecting the capital to Kenya's only sea port (Figure 6). Kwa Kyai is on the western edge of the Yatta Plateau where it meets the Chyulu Hills. The elevation is about 1000 m. Water for the scheme is provided from a small dam on a stream flowing from the Chyulu Hills to the Athi River.

The dam was first built in 1952 and was rebuilt in 1968 after flood damage. The original owner gifted it to the local people many years ago. A lined channel of about 1.5 km connects the scheme to the dam. Kwa Kyai includes 110 ha divided into plots averaging 0.5 ha and supports over 220 families. The irrigated area lies on one side of the river valley, where the gradient of the land is steep (up to 4%). Scheme layout is compact.

The surrounding agricultural zone is classed as Lower Midland, semi-arid, with an annual rainfall of approximately 550 mm. During the study year (1991/92) rainfall was 520 mm. Temperatures vary from 25°C in July and August to 33°C in March. Reference evapotranspiration ranges from about 3.6 mm/day in July to 6.2 mm/day in March equating to an annual evapotranspiration of 1730 mm, an excess of 780 mm over expected rainfall.

Cropping is more-or-less continuous throughout nine months of the year and consists of a mix of local and Asian vegetables and small quantities of maize and tree crops. The prevailing soils are reddish sandy loams, very suitable for irrigation. Market access is good and there is a co-operative which markets the produce.

The scheme is farmer-managed and has a nine man elected committee. The committee pays a modest fee of some KSh 400 per annum to the Ministry of Water Development. Farmers pay a contribution of KSh 50 each per annum to the committee towards the fee and the cost of repairs.

3.6.2 Scheme characteristics

A well-constructed and maintained dam provides water for Kwa Kyai. Immediately downstream of the intake is a V-notch weir without a gauge-board. After about 200 m, the main canal passes over the river valley in a number of overhead pipes. From here the canal is lined for 1.5 km and then unlined for a further 1.5 km. There are no control structures along the main canal, which runs along the upper edge of the scheme. A series of ten offtake channels spaced at approximately 200 m intervals serve individual blocks averaging about 11 ha (Figure 11).

Division of water is achieved in a rough-and-ready fashion with no formally designed offtake structures. In effect, orifices have been punched through the canal lining to feed the offtake channels. These openings are of varying areas. Crude stilling basins have been constructed downstream of the offtakes. When water is not required the holes are blocked with bricks, mud and plant material. The flow in the main canal is not supposed to be checked. Lining exists on some of the offtake channels, in places where the velocity is high. However, the quality is often poor with many obvious leaks.

A rotation schedule is used at Kwa Kyai. At any one time, two offtake channels are in operation. The irrigation interval is two weeks. Adherence to the schedule is good although there are occasional disputes from downstream farmers.

Each farmer is allotted an area of one acre (0.4 ha) for irrigated agriculture. Surface application via short furrows and small basins is practised, each farmer having access to the water for a period of up to four hours.

Operation and management of the scheme is the responsibility of the farmers. In addition, each block has an elected representative who is nominally in charge of water sharing within the group. Maintenance of the main canal is carried out on a communal basis and occasionally work groups are organised to remove weeds from the reservoir. Apart from one or two isolated leaks the lined section of the main canal is well-maintained.

3.6.3 Main findings

<u>Operation and management</u>

Kwa Kyai was found to suffer a slight shortage of water during the year of study. Table 3.14 and Figure 12 shows that the total volume of water available was only 87% of requirements. Taking periods of oversupply into account, adequacy was only 81%. Equity is poor at Kwa Kyai, the lower blocks receive poor supply.

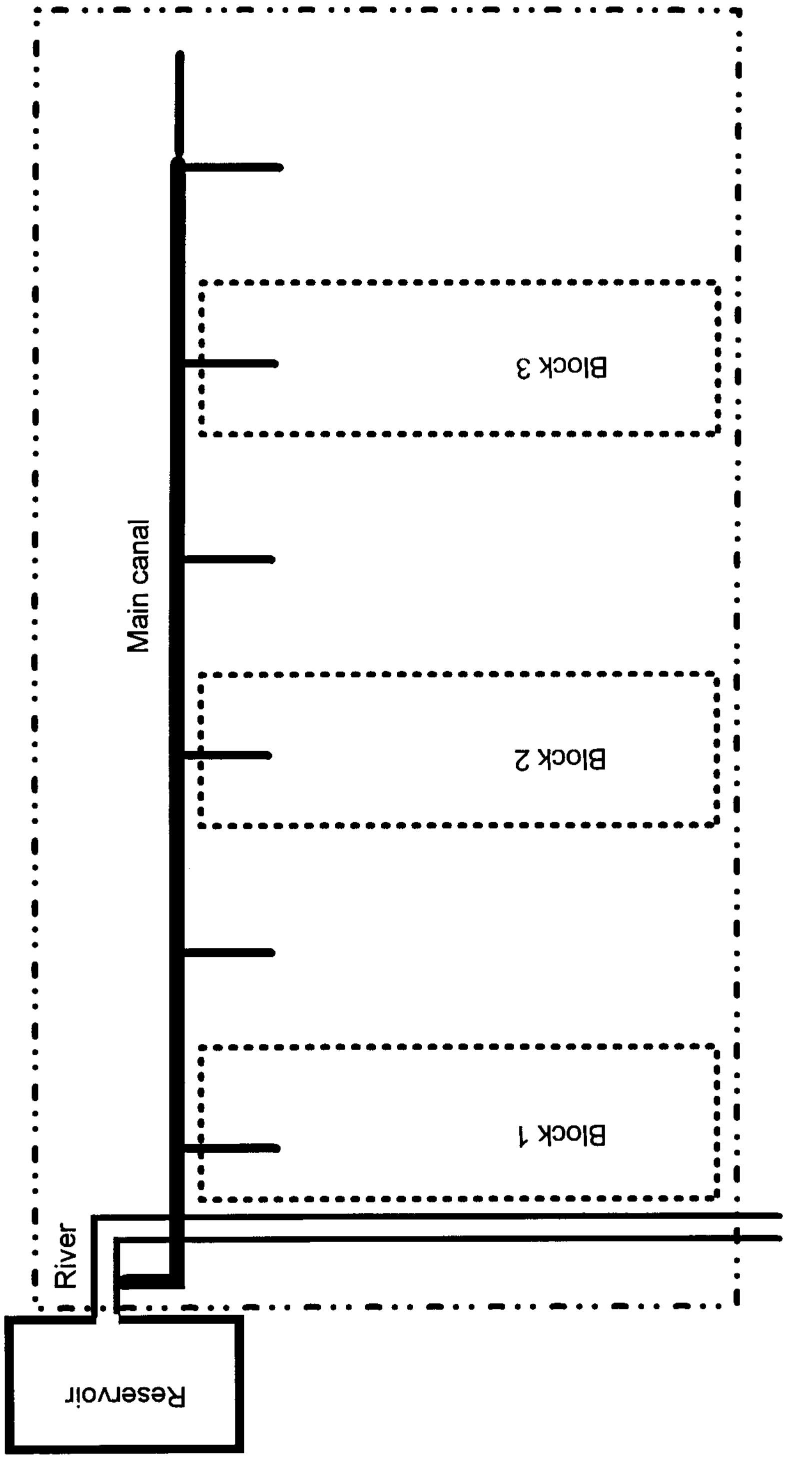

Figure 11 Schematic diagram of Kwa Kyai Irrigation Scheme

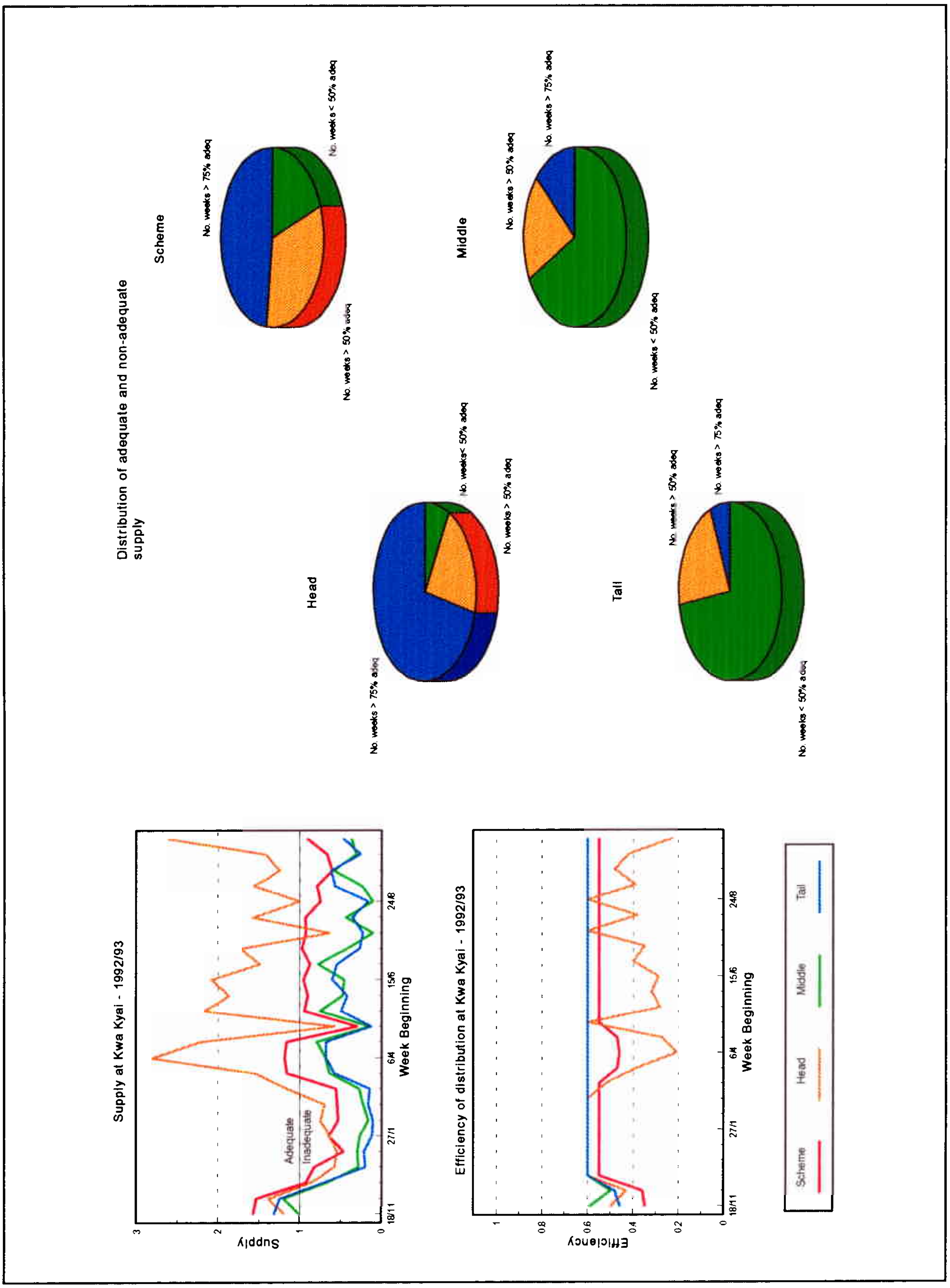

Figure 12 Irrigation performance summary: Kwa Kyai

This is probably due to the nature of the offtake structures whose orifice areas seem to bear little relationship to command areas. The bottom section of the canal is unlined and passes through sandy soil. A large proportion of the flow is lost as seepage. This problem is exacerbated by the use of rotations, under which the canals dry out during the two-week cycle. Extra water is lost as the canal is wetted up.

Table 3.14 Irrigation performance indicators for Kwa Kyai

Indicator	SCHEME	Head	Middle	Tail
Supply	0.87	1.37	0.47	0.45
Adequacy	0.81	0.89	0.46	0.43
Dependability	0.30 (poor)	0.24 (fair)	0.62 (very poor)	0.66 (very poor)
Efficiency	0.52	0.45	0.59	0.59
Equity	0.47 (poor)	-	-	-
Sustainability	0.95	1.00	0.95	0.90

Source: HR Study 1991/92

Agricultural production

Over twenty different crops were grown at Kwa Kyai. Brinjal (aubergine), okra, guar, maize and tomatoes were the most common crops and represented almost 60% of the planted area. Asian vegetables as a whole account for over 40% of the cropped area confirming their important contribution to income. Cropping patterns varied according to location with more subsistence and tree crops grown in the tail reach. No maize was grown in the head reach.

Fertilizers, manure and pesticides were widely used on the scheme. Most farmers used a combination of all three. However, inputs were mainly applied to the Asian vegetables whilst maize, cabbage and cassava received no inputs suggesting that experience has taught farmers which crops respond to fertilizers best.

It seems that labour was not an overall constraint at Kwa Kyai. A quarter of farmers indicated difficulty in finding labour, another quarter that there was no difficulty in obtaining labour whilst the remaining farmers made no comment either way. Over 75% hired labour at one time or other during the year. On a scheme wide basis about KSh 1800 per farm was spent on hired labour. Head reach farms tended to devote more labour to irrigated land than dryland. In the middle and tail reaches the intensity of labour to land falls slightly. Labour may be a constraint for farmers cultivating 0.8 ha and above.

The majority of farmers also had dryland farms, usually near the scheme. Sizes ranged from 0.4 to 6 ha. Maize was always grown and dryland beans were grown 50% of the time. Only about 15% of farmers sold any of the produce from these plots. Few cattle were held but smallstock, sheep and goats, were common (7.6 head per farm).

Credit was used by one farmer in the survey.

Yields and marketing

Yield results from Kwa Kyai were close to the average yields obtained for Kenyan smallholder irrigation obtained in the Profitability Study undertaken by the Ministry of Agriculture, Kenya in 1988 and 1989 (GOK, 1990). The two sets of results are compared for frequently-grown crops (Table 3.15).

Table 3.15 Crop yields for Kwa Kyai (kg/ha)

Crop yield (kg/ha)		SCHEME	Head	Middle	Tail	Profitability Study mean yield [1]
BRINJAL	Mean	16000	17000	20000	8500	16850
	S.D.	(14000)	(12000)	(19000)	(5600)	
OKRA	Mean	6100	7000	5500	4000	5170
	S.D.	(5600)	(7100)	(3500)	(3500)	
GUAR	Mean	7500	9300	5000	-	-
	S.D.	(6000)	(6000)	(3300)		
MAIZE	Mean	2000	-	1600	2300	2530
	S.D.	(1800)		(700)	(2300)	
TOMATOES	Mean	8300	10000	6400	6600	35280
	S.D.	(7800)	(10000)	(4000)	(600)	

Source: HR Survey 1992

[1] Source: Government of Kenya Profitability Study 1990

Only tomato yields are significantly lower in Kwa Kyai than in the Profitability Study. There are no significant trends in the yield figures within the scheme although okra and brinjal give poor yields in the tail reach.

Marketing is highly organised at Kwa Kyai. The farmers have a cooperative which grades and packs produce by weight ready for sale to merchants from the packing station. This undoubtedly strengthens the bargaining power of the farmers.

Income

Revenue was mostly generated by the sale of Asian vegetables through the co-operative which grades produce for sale to wholesalers. Maize, cassava and beans were kept almost exclusively for home consumption. The range of values for irrigated gross margins is wide, meaning that differences are not statistically significant (Table 3.16), but those in the tail of the scheme are well below the levels achieved in the head and middle. Lack of water due to seepage in the unlined section of canal is a major factor. High losses in the offtake and field channels in the tail section where soils have a higher sand content also contribute to lower yields.

Table 3.16 Gross margins and farm incomes for Kwa Kyai (KSh)

Revenues / costs (KSh)		SCHEME	Head	Middle	Tail
Irrigated gross margin per hectare (KSh/ha)	Mean S.D.	48600 (59800)	58400 (65100)	58400 (65300)	19300 (20100)
Irrigated net income (KSh/farm)	Mean S.D.	32000 (51800)	26800 (28000)	54300 (79800)	7400 (8400)
Dryland / livestock net income (KSh/farm)	Mean S.D.	-3980 (5790)	-3110 (5060)	-2870 (3440)	-6640 (7800)
Other inflows[1] (KSh/farm)	Mean	0	0	0	0
Costs[2] (Ksh/farm)	Mean	-7300	-8100	-6900	-7200
NET INCOME PER FARM (KSh/farm)	Mean	20720	15590	44530	-6640

Source: HR Survey 1992
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Two major problems concerned with marketing were identified. One was the fluctuation in price experienced by the co-operative and the other was the fluctuation in the volume of produce sold. Kwa Kyai is distant from both Nairobi and Mombassa so at times of low demand or of glut supply many wholesalers do not call at the scheme. However, farmers are seldom completely unable to sell their produce.

When incomes per farm are compared it is clear that tail reach farmers did not make ends meet in the year 1991/92. Despite high variance within the sample, tail-enders appear to be disadvantaged. If this occurs on an annual basis, irrigation is not sustainable for those farmers. Middle reach farms appear to be most profitable due in the main to their larger landholdings; irrigated gross margins per hectare are similar for the head and middle areas.

<u>Conflicts / complementarity</u>
No problems of conflict between agricultural activities were apparent.

<u>Environmental impacts</u>
Small areas of waterlogging were observed close to the river but are thought not to be due to irrigation. Malaria is endemic across the scheme. Local health officials stated that increased incomes and nutrition brought about by irrigation outweighed any slight increases in the incidence of water-borne diseases.

<u>Sustainability</u>
Overall, about 90% of the scheme design area is still irrigated. However, land has fallen out of irrigated production in the bottom half of the scheme as a result of water shortage.

3.6.4 Design issues

- Specialisation in high value crops enables farmers to achieve high returns to water.

- Group marketing increases the potential for selling and at the same time encourages high production standards

- In sandy soils, well-constructed lining of the main distribution system will help assure supply for lower parts of the system

- An improved design of outlet will improve water distribution across the scheme

3.7 Mathina Irrigation Scheme, Kenya

3.7.1 Location and historic background

Mathina lies 20 km east of Nyeri in Central Province, Kenya (Figure 6). It is on the south west slopes of Mount Kenya at an elevation of approximately 1800 metres. The area is well populated and the scheme is well placed to market fresh produce in Nyeri and nearby Nanyuki.

The intake on the Nairobi river was built before 1965 and irrigation was later developed to supply newly settled farmers after independence. There was formal demarcation of the land in 1980. Rehabilitation of the irrigation scheme took place in 1985 when there were no upstream users of the water in the Nairobi river. Many of the plots which were formally laid out at this time have never been irrigated, as the shareholders to whom they were allocated have not yet taken up their option to farm. All the uncultivated plots are in the middle and lower part of the scheme.

3.7.2 Scheme characteristics

The intake on the Nairobi river is remote from the scheme in a forested area. Water is conducted to the scheme in a lined channel some 2.5 km long (Figure 13). Lining ceases at the first division box. The scheme, of 168 hectares, occupies a flat area which straddles a main route. Each farmer has a holding of approximately 1 hectare or 2.5 acres of which they are allowed to irrigate about one acre, but there is no strict control of the irrigated area. There are 162 scheme members. At present only about 45 hectares are irrigated. Two thirds of this irrigated area is in the head reach.

Farmers in the lower areas have attempted to use pipes to conduct water from the head reach to sprinklers, however, the gradients are too gentle for successful operation. Farmers are very dissatisfied with poor water delivery. Maintenance is consequently poor and damage to structures is commonplace.

Cropping on the irrigated area is more or less continuous. Vegetables for the home market and maize are grown mainly in single stands. Most of the cultivation is done by hand although there are signs of change and technical innovation in the head reach. Marketing is well organised and the scheme is commercially oriented.

The scheme is managed by the farmer committee who are aware of the need to supply more water to the site. The task of managing equitable distribution of water has been made difficult by the weak community in the tail of the system where plots remain unoccupied. Farmers in the tail area who have given up

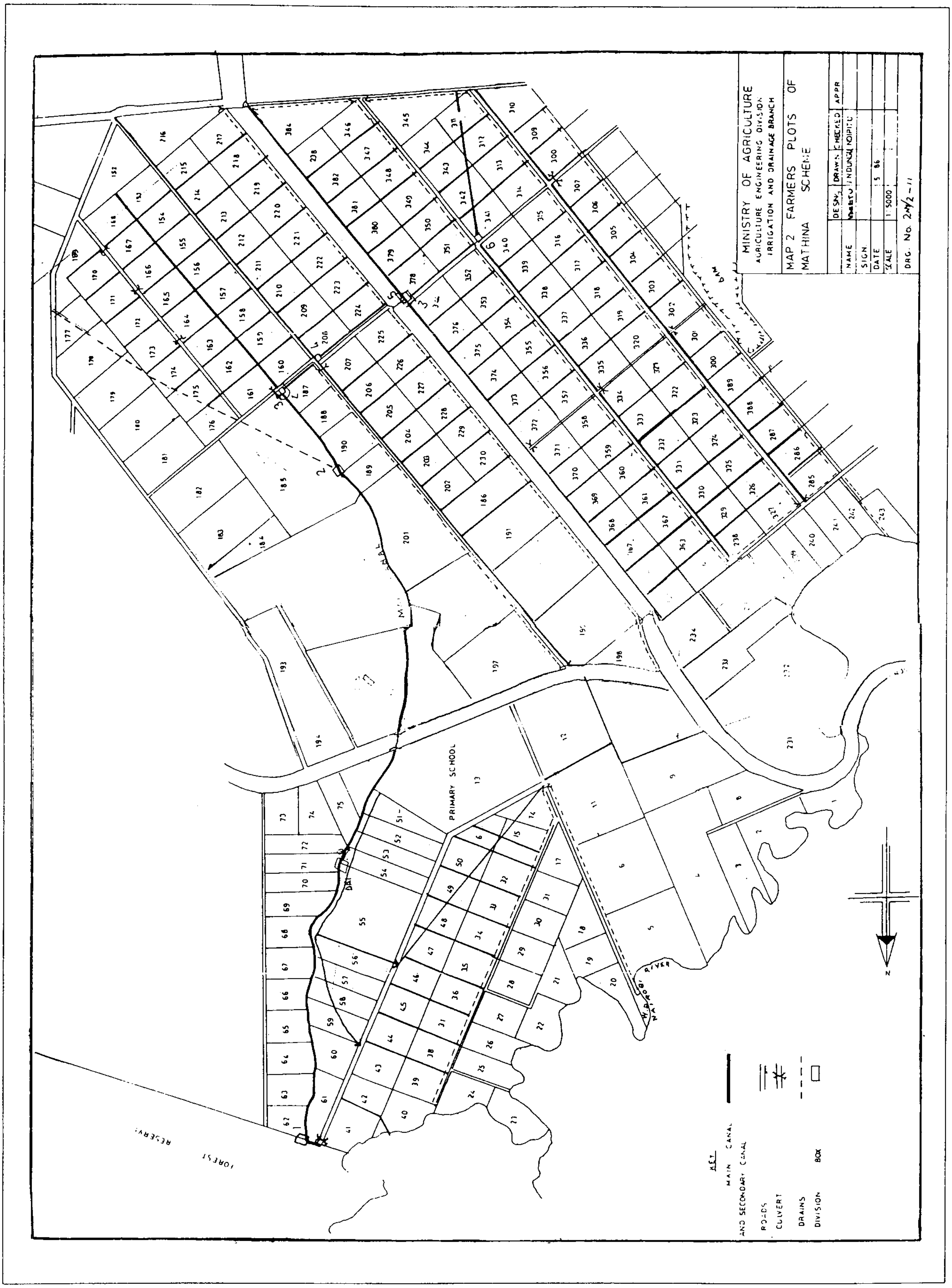

Figure 13 Mathina Irrigation Scheme

irrigation due to inadequate water supply have done so in the last few years, since 1991. Farmers in the head of the system have increased their irrigated area so that average irrigated holding in the head is twice the average in the lower reach. Losses to seepage within the scheme are high. Presently the committee is investigating alternative water sources in the neighbouring river. The plan includes water storage capacity and piped delivery to the scheme. Reliability of supply is essential to further development of vegetable production.

3.7.3 Main findings

Operation and management

As irrigation was not practised in the tail of the scheme, performance was assessed in terms of head and tail only, where the tail of the irrigated area, corresponds to the middle of the original scheme (Table 3.18 and Figure 14).

Table 3.18 Irrigation performance indicators for Mathina

Indicator	SCHEME	Head	Middle	Tail
Supply	1.06	3.29	0.58	0.40
Adequacy	0.77	0.94	0.47	0.37
Dependability	0.37 (poor)	0.17 (fair)	0.73 (very poor)	0.78 (very poor)
Efficiency	0.46	0.28	0.56	0.59
Equity	0.56 (very poor)	-	-	-
Sustainability	0.50	1.00	0.90	0.10

Source: HR Study 1991/92

Agricultural production

Approximately 80% of the irrigated area is devoted to vegetables and the remaining area to maize. Almost all produce is sold, except for 40% of the maize which is retained for subsistence. Fertilizer use is minimal but manure and pesticides are applied. However, yield remains relatively low for most crops except maize and cabbages.

Yields and marketing

Low yields are associated with low inputs. Despite the contribution of non-farm income, input level remains low when good marketing opportunities indicate that expenditure on inputs would be a worthwhile investment. Unreliable water supply may act as a disincentive for input expenditure .

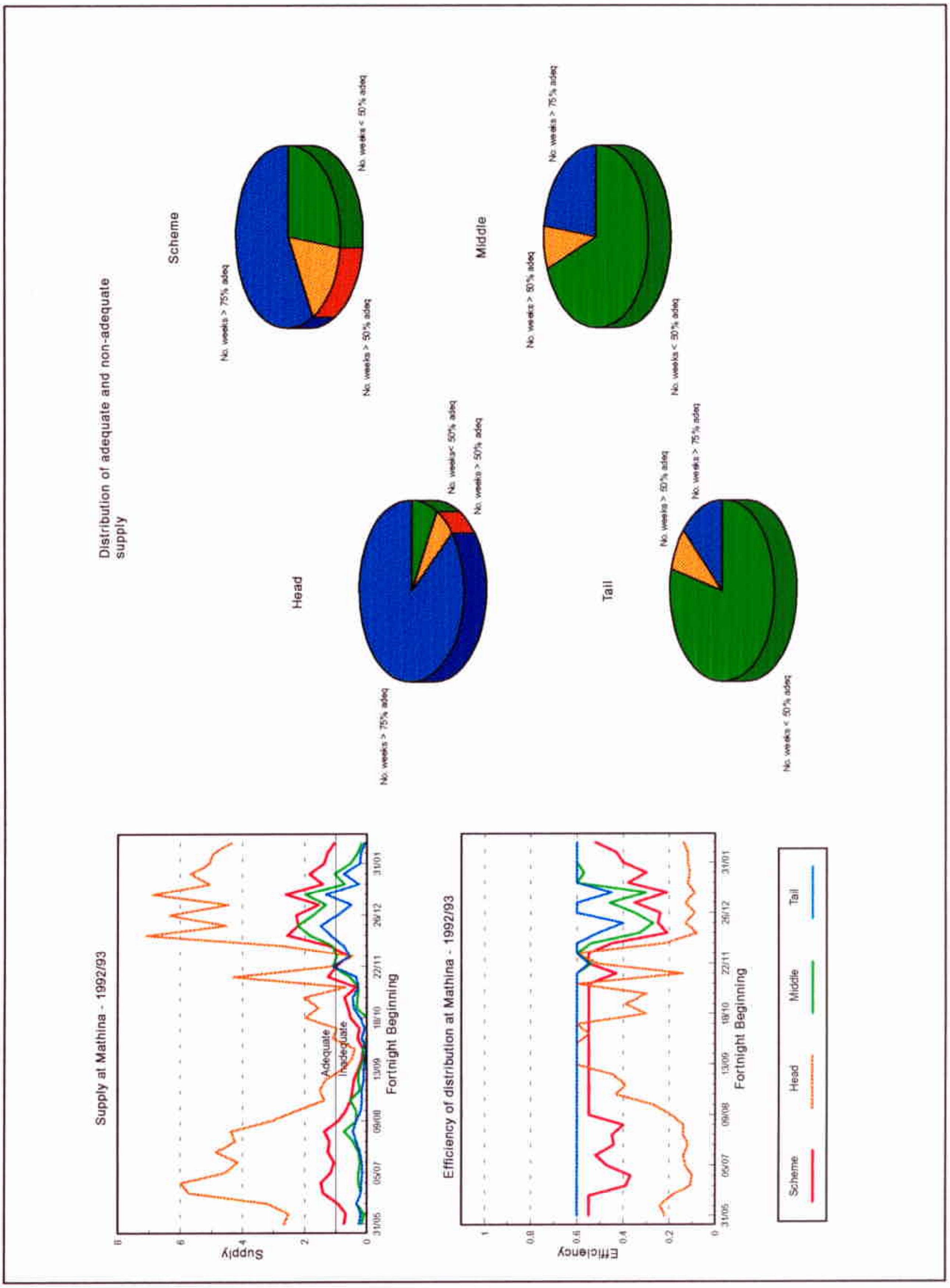

Figure 14 Irrigation performance summary: Mathina

Table 3.19 Crop yields at Mathina (kg/ha)

Yields (kg/ha)	Mathina Yield (Kg/ha)	Profitability Study yields [1]	Percentage of irrigated area
Kales	4000	Low - 7500	13
Tomatoes	7940	Low - 2500-20000	19
Cabbages	11875	Low - 12300	16
Maize	3640	High - 2500+	21

[1] Source: Profitability Study, Government of Kenya, 1990

No significant yield differences emerge between head and tail (Middle). This appears to imply that, on average, farmers in both areas received and made good use of available water. Table 3.20 shows high standard deviation of gross margins in both sections, which implies that individual differences (either in farming skills or access to inputs) are likely to be a greater source of variation than position in the currently irrigated area.

Table 3.20 Irrigated gross margin per ha at Mathina (Ksh/ha)

Irrigated gross margin per ha (KSh/ha)	SCHEME	Head reach	Tail reach (scheme middle)
Mean	23640	26850	18020
SD	(19795)	(22860)	(13955)

Income

Because the farmers at the head each irrigated almost twice the area cultivated by farmers lower down the system, the difference in income from irrigation is greater than the difference in gross margin/ha. However, at Mathina the greatest income source was the non-farm activities of families. Even in the head reach non-farm income was almost double all agricultural income, whereas at the tail the non-farm contribution was seven times the agricultural margin. Thus, farm incomes had only a tenuous relationship with irrigation performance.

Table 3.21 Farm incomes for Mathina (Ksh)

Revenues / costs (KSh)	SCHEME (Irrigators)	Head	Middle	Tail (non-irrigators)
Irrigated net income (KSh/farm)	8,618	10,748	4,892	0
Dryland / livestock income (KSh/farm)		3185	-619	-776
Other inflows[1] (KSh/farm)		22631	36250	3213
Costs[2] (Ksh/farm)		33764	27789	7634
NET INCOME PER FARM (Ksh/farm)	7569	3404	11734	-4927

Source: HR Survey 1992
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Conflicts and complementarities
There appears to be some evidence of complementarity between irrigation and other farm enterprises in the head reach. Livestock and dryland both make profit for head reach farmers. Larger and more profitable irrigated plots may allow complementary activities to proceed more readily than small irrigated plots.

Conflict is not evident between irrigated and rain-fed farming and labour shortage is not an issue. Conflict does arise over water distribution and there is widely held resentment that head reach irrigators use more than their fair share of water.

Health and environmental issues
No major issues were identified.

Sustainability
Prospects are poor for the system as it stands. The present head and middle reaches are probably sustainable as a small scheme.

3.7.4 Design issues

- The area south of the road may be better served under the new proposed development.
- Allocation of plots to absentees leads to management problems associated with non-contiguous irrigated area.
- Well-constructed lining of reaches in sandy soils would improve area coverage.
- At low flows, proportional division boxes become inaccurate and may produce excessively low flows in some channels. Provision of stoplogs would allow rotational delivery to be used in times of shortage.

- Farmer management is difficult if structures do not allow change in operating strategy under conditions of poor supply.

3.8 Kangocho Irrigation Furrow, Kenya

3.8.1 Location and historic background

Kangocho is in Central province 10 km south of Karatina, which is said to be Kenya's largest vegetable market, and 70 km north of Nairobi (Figure 6). Located on the southern slopes of the Mount Kenya uplands, the equatorial climate is moderated by elevation. The terrain is hilly with average elevation of 1800 metres and supports coffee and rain-fed arable farming. Frost is not a risk. Soils in the irrigated area are mainly silt-loam. Rainfall is in the region of 500 mm/annum.

The area is heavily populated and smallholder farming is traditional. There is no lack of farming skills and availability of factors of production is generally good.

The weir on the Ragati river was first built in 1939 to provide irrigation water to assure supply of fresh vegetables to a colonial garrison. Irrigation ceased in 1952, when emergency powers were introduced. Production resumed, in a small way, in 1968. A gradual increase in the number of farmers led to the formation of the Kangocho Furrow Self Help Group in 1979.

In 1984 a concrete weir and intake were constructed and the main channel was lined as far as the division box, with assistance from Danida. Below the division box, channels are unlined. The area irrigated was around 45 ha (Figure 15). The scheme is managed by a farmer committee with advice and assistance from the Provincial Irrigation Unit in Nyeri. Further support is available through the national Agricultural Extension Service based in Karatina but little irrigation expertise is offered by this service.

Each farm consists of around three acres (1.2 ha) of which 0.5 to 1.0 acres is irrigated. Farmers own land individually. The irrigated areas are not contiguous, thus the distribution system is meandering and seepage high. Cropping is continuous for nine to ten months of the year. Maize and tree crops are grown but the bulk of the irrigated land is devoted to vegetable production.

3.8.2 Scheme characteristics

The scheme appears to function less well than could be expected after the improvement works in 1984. The weir on the Ragati river is in need of repair, consequently the level of water at the intake is lower than it should be. The Ragati is subject to damaging floods. Water enters the scheme via a lined channel to the division box. The supply is then apportioned between three blocks, an escape channel returns the flow to the river when irrigation is not required. Water delivered through the unlined channels downstream of the division box is subject to high losses.

The total irrigated area at Kangocho has shrunk from around 45 to 25 ha. A number of farmers who used to irrigate in the tail reach no longer receive water. These farmers devote all their land to rain-fed crops. A small number of farmers in the head reach have extended the area they irrigate. The general impression is that the head reach is successful. However only 50% of the design area now receives water. Even at this reduced level of performance, head to tail inequity is evident. Operation and management is carried out wholly by the farmer committee and is subject to conflicts of interest. The committee consists of nine

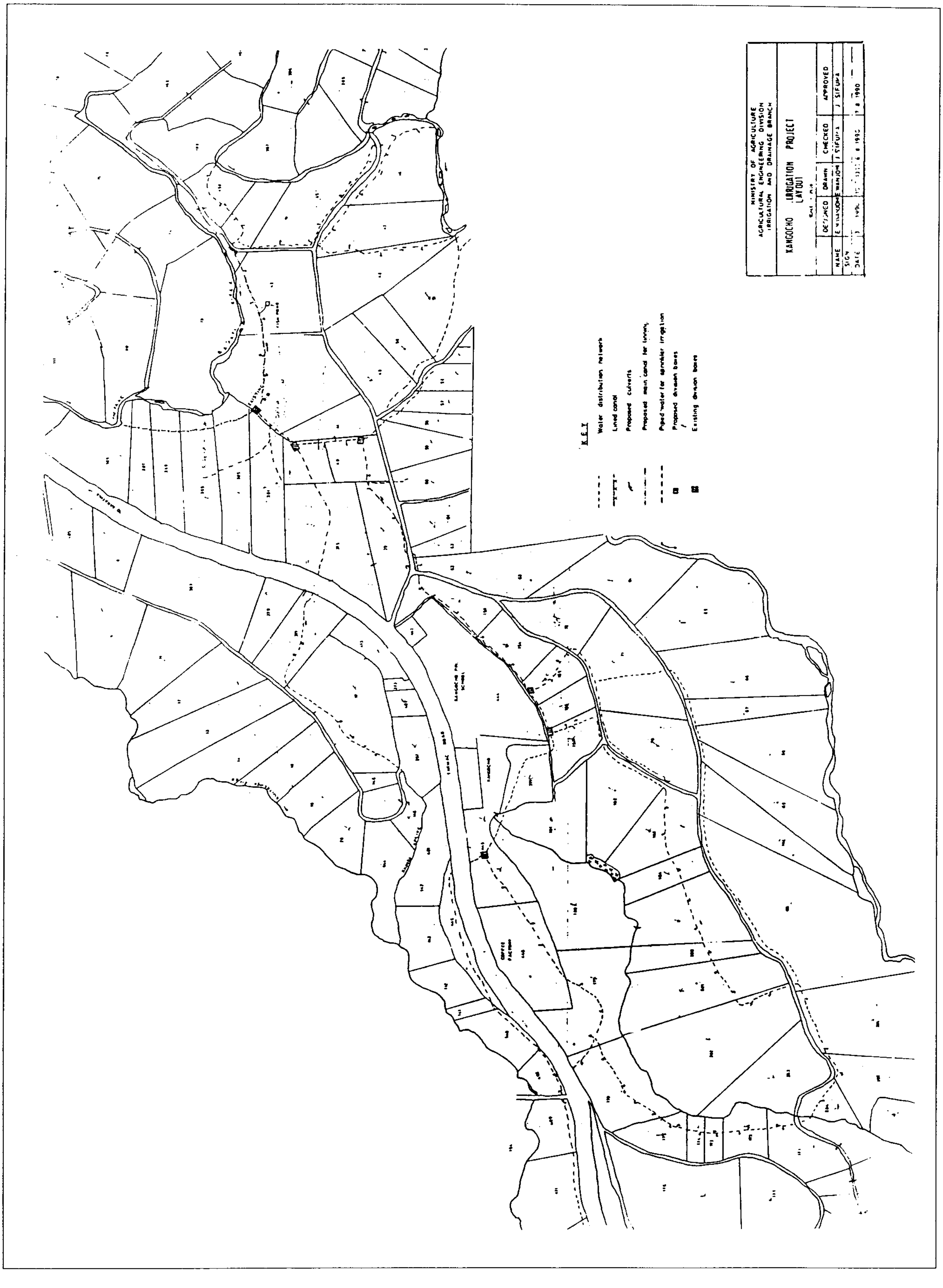

Figure 15 Kangocho Irrigation Scheme

members who are elected every three years. The present chairman has held the position for a long time.

Irrigation water is applied in a variety of ways. Furrows are most common but there are small areas of basin and sprinkler. Sprinklers have been financed and fitted by individuals as a strategy to reduce water loss and labour needs. The investigation of farm income showed that irrigation played a secondary role to rain-fed coffee production.

3.8.3 Main findings

Operation and management

Water available to the scheme has decreased over the decade since improvement in 1984. It is likely that there are several contributory factors leading to this result. The main reason is the lack of maintenance to the weir. However, the committee complains of upstream users who abstract from the Ragati using 5 hp pumps, but it is unlikely that the volumes used are significant.

Kangocho does not impress as a group scheme but rather as a collection of individual irrigators. Participation in group activities was informal despite the committee's efforts. There was evidence of anarchic behaviour by at least one farmer at the head who had blatantly extended his irrigated area. Poor maintenance, damage to the division box and abandonment of irrigation in the tail are indicative of failure of the group to function effectively. This must in part stem from the secondary role of irrigation in generating income.

Table 3.22 Irrigation performance indicators for Kangocho (see also Figure 16)

Indicator	SCHEME	Head	Middle	Tail
Supply	1.05	2.04	1.16	0.00
Adequacy	0.84	1.00	0.85	0.00
Dependability	0.48	0.34	0.50	-
Efficiency	0.73	-	-	-
Equity	0.22	0.00	0.22	-
Sustainability	0.60	0.90	0.90	0.00

Agricultural production

The main source of income in the year of survey was not irrigated vegetables, but rain-fed coffee. Coffee revenues assure farmers' inputs for future coffee and irrigated vegetables (see Dryland net incomes, Table 2.24). All the farmers irrigated kales and most some tomatoes and/or French beans. Other irrigated crops including maize were less frequently grown and only in small areas. Heads of households were predominantly male and were the sole decision-makers. Only two households reported female involvement in farming decisions. Unusually men contributed some 35 % more labour days on this scheme than the women.

Inputs

Inputs are readily available. A number of agricultural suppliers have retail outlets in Karatina and competition for business keeps prices fair. Fertilizer and pesticides are commonly used. Application rates are high in comparison to other

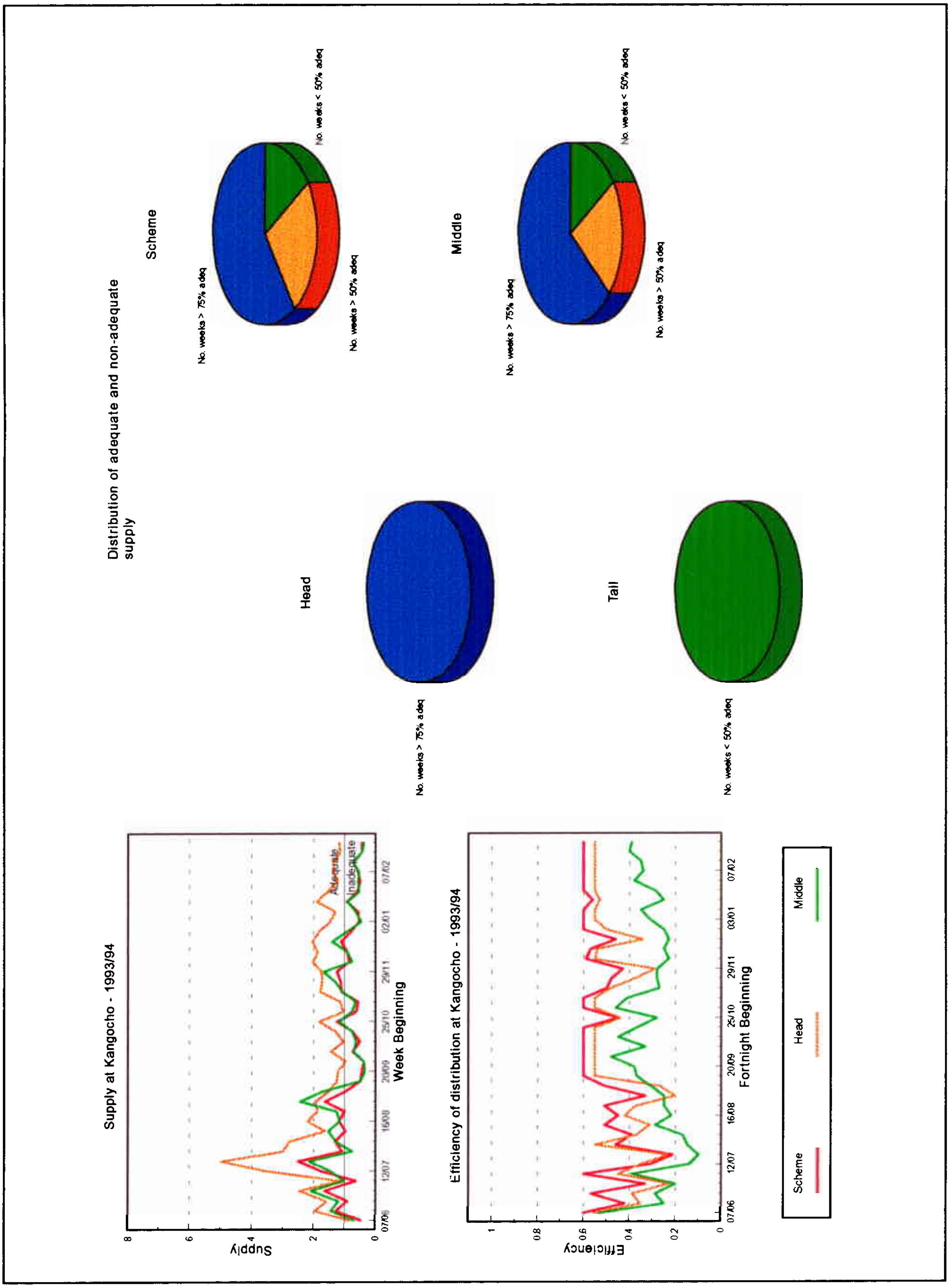

Figure 16 Irrigation performance summary: Kangocho

schemes in this study. Kale and french beans were the main recipients of these inputs.

The sample was divided into three groups on the basis of spending on inputs. The ranges were taken as KSh 0 - 20,000; KSh 20,001 - 40,000 and over KSh 40,000, corresponding to low, medium and high inputs. Irrigated gross margins increased significantly from low to medium input levels but dropped back for the high group. This result indicates that marginal returns to inputs were falling for farmers who spent most per hectare. On other schemes application rates seldom reach this level.

Labour devoted to irrigated land averaged just above 4 full time people per hectare.

Yields and generally
Yields are disappointing at Kangocho, although at the head some very good results are obtained. Marketing poses few problems, the scheme is well situated as it is close to the Karatina market and has good access by a main highway.

Table 3.23 Crop yields and inputs for Kangocho

Crop	Yield (kg/ha)	Fertilizer (kg/ha)	Manure (kg/ha)	Pesticides (litres/ha)
Kale	20000	293	1253	1.8
Tomato	7778	310	129	14.2
French beans	720	620	648	1.8
Maize	1212	79	0	0

Only kales performed in the median range compared to yield standards set in the Government of Kenya 1990 Profitability Study. French bean yield was remarkably poor. This level of result suggests a production constraint. A combination of factors is likely to be responsible including water shortage, labour shortage, poor motivation for farm management and nematode infestation.

Water shortage is a dominant factor in the de facto middle and tail of the scheme. Only the head reach is effectively irrigated

Poor focus on irrigation problems results from the importance of coffee in the area. All farmers earned more from coffee cultivation than from irrigated farming. Labour shortage was identified by most farmers in relation to conflicting demands between coffee and irrigated crops. Provision of labour for maintenance of the scheme is clearly seen as a low priority.

Income

On average dryland cultivation generates three times as much income as irrigated farming. Non-farm income diminishes from head to tail. However, the middle sector shows lowest irrigated margins and lowest overall surplus. Some farmers here may cease irrigating in future.

Table 3.24 Gross margins and farm incomes for Kangocho (KSh)

Revenues / costs (KSh)	SCHEME	Head	Middle	Tail
Irrigated gross margin per hectare (KSh/ha)	67550	227796 (64018)	48914 (15443)	31591 (11744)
Irrigated net income per farm (KSh/farm)	29120 (21200)	57320 (68700)	15626 (7210)	18630 (21260)
Dryland net income per farm (KSh/farm)	93206 (110750)	79383 (52380)	79259 (76180)	108545 (156435)
Livestock net income per farm (KSh/farm)	-1532 (3016)	-360 (640)	-4170 (3180)	-100 (370)
Other inflows[1] (KSh/farm)	5077 (8500)	10250 (12500)	7533 (7400)	1000 (2000)
Costs[2] (KSh/farm)	32600 (22230)	23614 (18540)	57870 (8160)	29500 (19500)
NET INCOME PER FARM (KSh/farm)	93271	120900	47400	98500

Source: HR Survey 1989
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Conflict and complementarity
There is clearly a problem for the farmers in organising labour for both irrigation and coffee growing. However, there is nothing to suggest that any of the farmers who have already ceased to irrigate did so because of labour constraints. All of those farmers claimed that lack of irrigation water was the cause.

Despite the fact that coffee revenues in the year of the survey far outstripped irrigation revenues, farmers are mindful of swings in commodity price and regard irrigation income as relatively secure. Thus farmers in the de facto middle and tail irrigate to stabilize overall income.

Environmental and health issues
More control and management of water would avoid waterlogged areas within the scheme. However, incidence of water-related disease is low so benefit would be minimal. Living standards are good in this area for both irrigators and non-irrigators, and access to facilities is good.

Land use is intensive and little is left fallow. Erosion is not a major problem and some slopes are terraced. The irrigation scheme itself causes no significant hazards

3.8.4 Specific issues for design

- Where a scheme serves as an insurance for beneficiaries who have another major agricultural income source, then their incentive to work as a group to maintain and manage it effectively is poor.

3.9 Kiguru Irrigation Scheme, Kenya

3.9.1 Location and historic background

Kiguru irrigation scheme is set high on the slopes of Mount Kenya in steeply sloping foothills (Figure 6). It is accessed by an earth road from Timau on the main Nanyuki to Meru route. The climate is temperate with a wide diurnal range. Horticultural crops are principally produced on the irrigated parts of the scheme. The surrounding land supports grazing and rain-fed farming, whilst privately-owned farms nearby also produce irrigated horticultural crops. Land for the irrigation scheme was given to the farmers in 1976, of which 60 acres (24 hectares) was irrigated. Nowadays each farm cultivates approximately 3 acres (1.2 ha), of which less than half is irrigated. Water for irrigation is supplied by pipe to locally produced sprinklers.

The scheme appears to be a successful group venture. It is evident that farmers practise good husbandry, have organised farming facilities and enjoy reasonable living standards. There is a settled community (only one scheme member has left since 1980) and young people do not appear to be keen to leave. Facilities such as schools, shops and eating houses are in evidence.

The scheme obtains water from a spring-fed river at a small weir about one kilometre distant from the head of the irrigated area, before being conducted to the fields in pipes (Figure 17).

There are several more recent irrigation developments upstream of Kiguru.

The water permit issued in 1980 allows for a 6" pipe. The pipes, nearly all of which are buried, were installed in 1982, and so far only one has had to be replaced. The intake is overhung by trees which pose a problem due to the debris which needs to be cleared daily. This and other maintenance is organised and implemented by the farmers through the Farmer Committee which has nine elected members including one woman. Members of the committee identified water shortage at the intake as the single biggest constraint to scheme performance.

3.9.2 Scheme characteristics

The scheme is compact. Farmers communicate easily. The range of crops is relatively small, consisting of cabbages, carrots, peas, French beans, onions, potatoes and maize. Maize is treated as a subsistence crop and small amounts of other crops are kept for family consumption. Potatoes and onions are most popular and occupied the greatest part of the planted area.

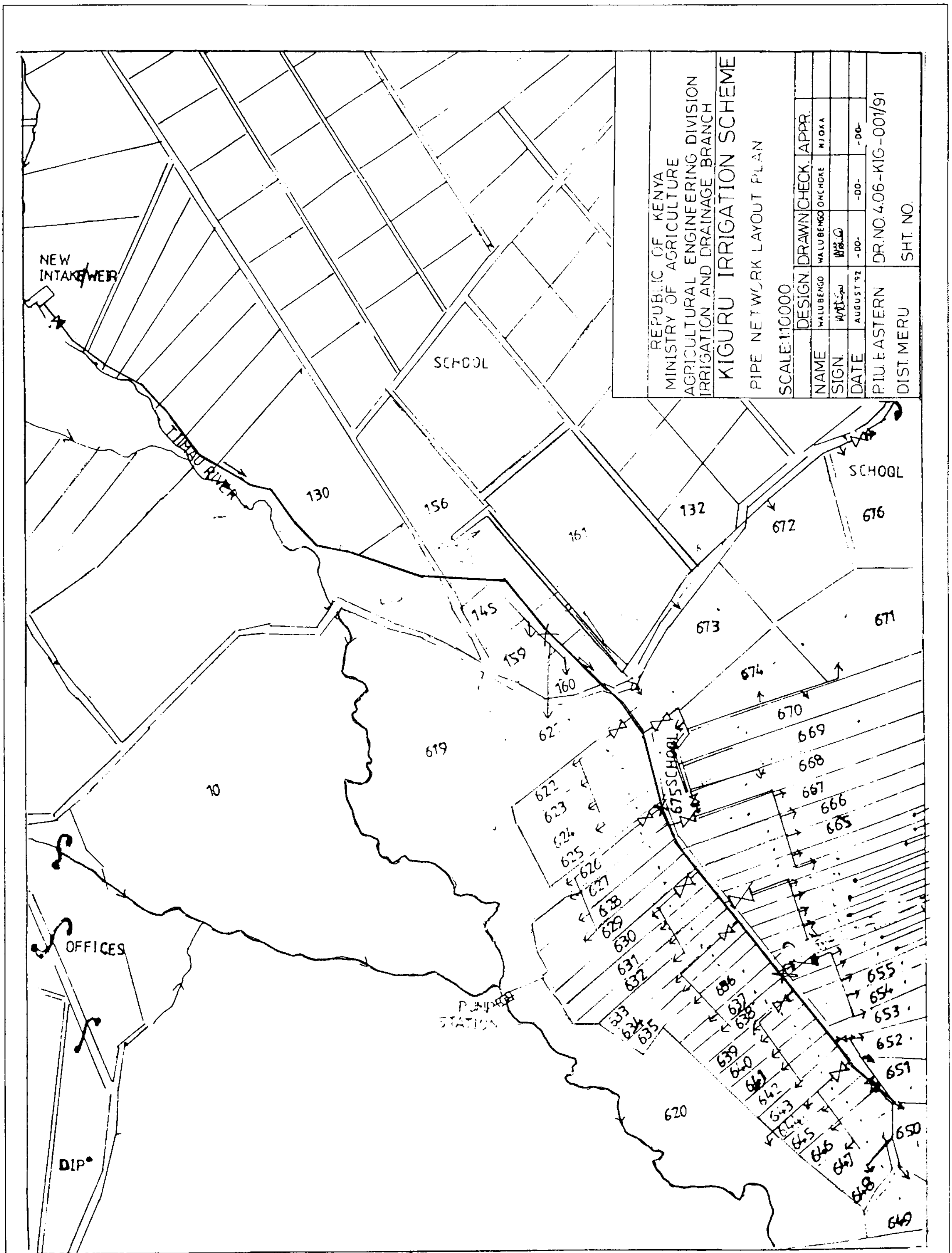

Figure 17 Kiguru Irrigation Scheme

The seasonal cropping intensity is lowest in the middle reach of the scheme at 68%; head and tail achieve 92% and 95% respectively. Both head and tail devote a small portion of planted area to maize, but all planted land in the middle is devoted to cash crops. Horticulture and onions are less popular in the tail. Combined, they account for 15% of the planted area compared to 50% in the head and over 60% in the middle. Potatoes are grown all over the scheme and cover 70% of the tail section.

The greater part of production is sold after grading on site.

3.9.3 Main findings

Operation and maintenance

Normally irrigation water is available on demand; rotation of turns is required when water is short. Sprinkler application frees farmers from the relative inefficiencies of basin and furrow irrigation, although involves operational problems in windy conditions. Farmers are nominally supposed to irrigate a one acre plot and are restricted to using just two sprinklers simultaneously.

Overall, the proposed system has required little maintenance, but one or two replacements have been needed recently.

Overall supply to Kiguru was found to be good, with an excess over the year of 29% (Table 3.25 and Figure 18). Adequacy was also fair, 84% of requirements being met overall. However, the middle and tail blocks had an adequate and dependable supply whilst the head appeared to suffer a shortage (adequacy was just 53% of requirements). Field observations did not suggest such differences in supply so it is considered that measurement errors in the head reach may explain the result.

Table 3.25 Irrigation performance indicators for Kiguru

Indicator	SCHEME	Head	Middle	Tail
Supply	1.29	0.73	2.05	1.20
Adequacy	0.84	0.53	0.99	0.82
Dependability	0.26 (fair)	0.68 (poor)	0.04 (good)	0.24 (fair)
Efficiency	0.59	0.70	0.46	0.67
Equity	0.23 (fair)	-	-	-
Sustainability	1.00	1.00	1.00	1.00

Agricultural production

Unfortunately no national data were available for comparison of yields for potatoes and peas with yields on other Kenyan schemes. Yield data for cabbages and onions were not comprehensive, as harvesting was only partially completed. Undoubtedly the figures tend to be low for this reason.

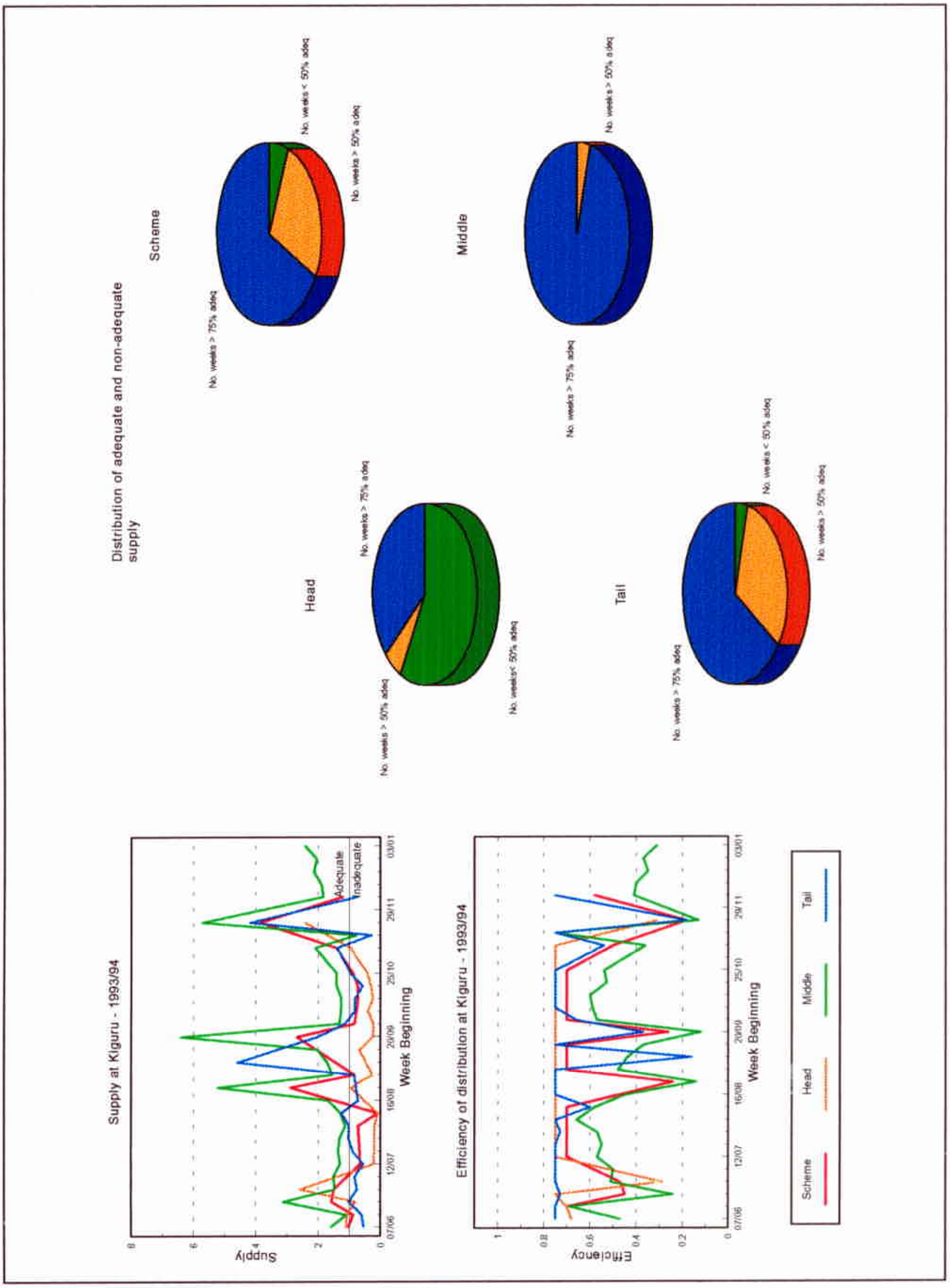

Figure 18 Irrigation performance summary: Kiguru

Table 3.26 Crop yields at Kiguru (Kg/ha)

Yield (kg/ha)	SCHEME	Profitability Study yields [1]
Onions	7220	low - 10000
Potatoes	9018	no data
Cabbages	31717	medium - 32000
Snow peas (mangetout)	10102	no data

[1] Source: Profitability Study, Government of Kenya, 1990

<u>Inputs</u>
Hand cultivation is still common. However, some farmers own items such as a plough, a pick-up, a hand-cart or an ox-cart. Hoses and sprinklers are basic to the system. Generally, farmers spent some KSh 600 annually on repair, and a further KSh 860 on hiring equipment.

Fertiliser and manure were commonly used at rates only slightly below recommended levels; potatoes received by far the heaviest fertilizer applications. Slightly lower applications, with varying proportions of expensive chemical fertilizer and home produced manure, were given to onion, cabbage and mangetout. Maize received low inputs. Protective spraying of crops was common practice.

There was no general shortage of labour but weeding and harvesting were identified as critical activities. 3 or 4 workers worked each hectare of irrigated land.

Farmers at this scheme tended to be elderly; crop choice may have been determined by the numbers of active workers.

<u>Income</u>
Income from irrigated agriculture is the main contribution to household income in Kiguru. Production and marketing strategies were successful and incomes were good. A "niche" market in mangetout was complemented by good demand for potatoes and onions. It was clear that farmers put considerable effort into marketing, running their own grading and packaging unit on the scheme. This undoubtedly has an impact on income and on stabilising prices. Farmers had benefitted from the advice of a neighbouring businessman at an early stage.

The lower returns of the tailend appears to reflect crop choice. There is no clear indication that the choice resulted from water shortage. On the other hand, the apparently poor supply figures in the head did not result in poor revenues. Incomes in the three reaches of this scheme did not appear to be clearly linked to water supply measurements.

Other incomes were less important, but the losses made in rain-fed farming in the tail reduced incomes in this part of the scheme.

Table 3.27 Gross margins and farm incomes for Kiguru (Ksh)

Revenues / costs (KSh)	SCHEME	Head	Middle	Tail
Irrigated gross margin/ha (KSh/ha)	67490	100320	58130	53411
Irrigated net income (KSh/farm)	50554	54476	58263	36640
Dryland / livestock income (Ksh/farm)	4822	500	17150	-4055
Other inflows[1] (KSh/farm)	4860	12500	0	3817
Costs[2] (KSh/farm)	28811	37487	25534	25756
NET INCOME PER FARM (Ksh/farm)	30831	29999	49879	10637

Source: HR Survey 1989
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Environmental and health issues
Environmental degradation is not evident in or around this irrigation scheme. High altitude, cool conditions and good quality water provide a generally healthy environment. Sprinkler distribution and the topography encourage quick drainage. There was no evidence to suggest water-borne disease. Domestic water is supplied to 60% of the homes with a major positive health impact.

Farmers were unanimous that the quality of diet was improved by irrigated farming and that child health was improved as a result. Nine households had no loss of work time due to illness in the year of the survey and, on average, only 8 days/household were lost in the year.

Community issues
It was felt strongly that the water right must be protected.

Only 7% of farmers in the sample used credit despite the relatively high expenditures for inputs. This is thought to result from the sustained and regular income from irrigation.

3.9.4 Design issues

- The sprinkler system has reduced labour demand for water application and for maintenance, allowing high value crops with heavy labour demand to be cultivated.

- The water source is reliable, providing good quality water. The water right must be protected to sustain the system.

- Support in cultivation and marketing has enabled and encouraged innovative expansion such as the grading facility.

- Overall efficiency of the scheme was some 59% under reasonably adequate supply. This is a good result given the low cost, locally made equipment, and is a substantial improvement in water use efficiency over typical open channel systems.

- Where topography and water source allow this type of low pressure delivery system, the advantages in water and labour savings have enabled farmers to develop sustainable systems

3.10 Mutunyi Irrigation Scheme, Kenya

3.10.1 Location and historic background

Mutunyi is a mixed irrigation scheme growing subsistence and cash crops. It lies 16 km south of Isiolo, Meru District, Eastern Province, Kenya (Figure 6) in gently undulating country, at an elevation of some 1500 metres on the lower northern slope of the Mount Kenya massif. The scheme itself is a relatively flat area, of around 420 hectares west of the Isiolo road, reached by a rough road of 1.5 km which crosses the Rogoso river below the scheme. Water is diverted to the scheme at a concrete weir and off-take in the adjacent forest. The scheme is reasonably placed to market fresh produce in Isiolo to the north, and in the more distant town of Meru. The surrounding land is dry and windy and temperatures are high. Rainfed crops only succeed in very good years. The privately owned farm which existed at the site was split in 1975 to give former farm labourers land; the remainder is still privately run.

The scheme began with 119 homesteads. There were no initial costs to the farmers as irrigation was already in place, but the intake at Amanji Springs is poorly built and requires frequent repair. Irrigation has been unsatisfactory for some time and various attempts have been made to improve the situation.

3.10.2 Scheme characteristics

There are now 244 plots of varying size, layout is informal and channels are unlined. Water is distributed by four channels, two of which are over 2.5 kilometres in length (Figure 19). Division of water to the channels is achieved informally. There is said to be difficulty in organising labour to maintain channels and conduct water. The scheme is organised into eight blocks, each of which has a committee and a chairman. The block committee makes a rota and apportions tasks to both men and women members. A flexible rotational water use system has been developed which obliges farmers to conduct water from the last point of use to their own plot.

Block committees are subordinate to the scheme committee, which has nine members who are elected every two years. Block committee members remain in office so long as the group is satisfied with their work, and when this is no longer the case, a new chairman is elected for the block. Maintenance is organised by farmers with advice from the Provincial Irrigation Unit (PIU).

3.10.3 Main findings

Operation and management

Operation and maintenance of this scheme are made difficult both by the layout and the stony soil. The four unlined distributary channels were never formally designed and were poorly constructed. As a result, they suffer from high seepage losses and demand frequent maintenance.

A flexible water schedule has been developed for each channel and is overseen by an appointed person. Farmers who have a crop at risk due to lack of water may apply to obtain water out of turn. If this is granted then it is the farmer's obligation to conduct water to his field and inform other users.

Figure 19   Mutunyi Irrigation Scheme

Owing to the irregular and extended nature of the canal network, it is not particularly meaningful to consider the scheme in terms of head, middle and tail regions. Instead, water supply to three of the eight blocks spread across the scheme was deduced. Block 1 appears particularly ill-favoured in terms of layout, though not in the location relative to the source of supply. The unfavourable water supply figures in Table 3.28 and Figure 20 appear to support this conclusion.

The scheme is very water-short, only 41% of requirements is supplied. However, despite the informal nature of the distribution system, water is reasonably fairly distributed over the scheme. The poorly-maintained intake canal loses up to a third of its discharge before reaching the scheme area.

Table 3.28 Irrigated performance indicators for Mutunyi

Indicator	SCHEME	Block 1	Block 2	Block 3
Supply	0.41	0.37	0.59	0.75
Adequacy	0.41	0.37	0.55	0.67
Dependability	(very poor)	-	-	-
Efficiency	0.45	0.60	0.60	0.57
Equity	(fair)	-	-	-
Sustainability	0.90	0.90	0.90	0.90

Agricultural production

The scheme committee ranked constraints to irrigated production in the scheme as: poor availability of water; poor availability of fertilizer and chemicals; and lack of farming skills. The main crops are maize, beans, onions, tomatoes and kales. Planted area per farm decreases from head to tail of the system in response to available water. Labour is plentiful and there are few competing agricultural activities. The scheme committee appeared to be active in controlling activities.

Inputs

The stratification of the scheme for the purposes of the socio-economic survey did not correspond exactly with the water measurement locations. However, broad cross comparisons could be made. Expenditure on inputs is generally low ranging only up to KSh 10000 per hectare. There is a strong correlation therefore between inputs and gross margins. Part of the reason for low investment in fertilizer and pesticide may lie in the logistical problems of delivery to the farms and part in the relatively high risk attached to water delivery. Expenditure on inputs in the middle of the scheme tended to be higher than in the head. If the head has been water-short for a number of years this would be the expected response as spending on inputs in these circumstances would be low.

Yields and marketing

Yields are low, in line with the level of investment in inputs and the low reliability of the water delivery system.(Table 3.29).

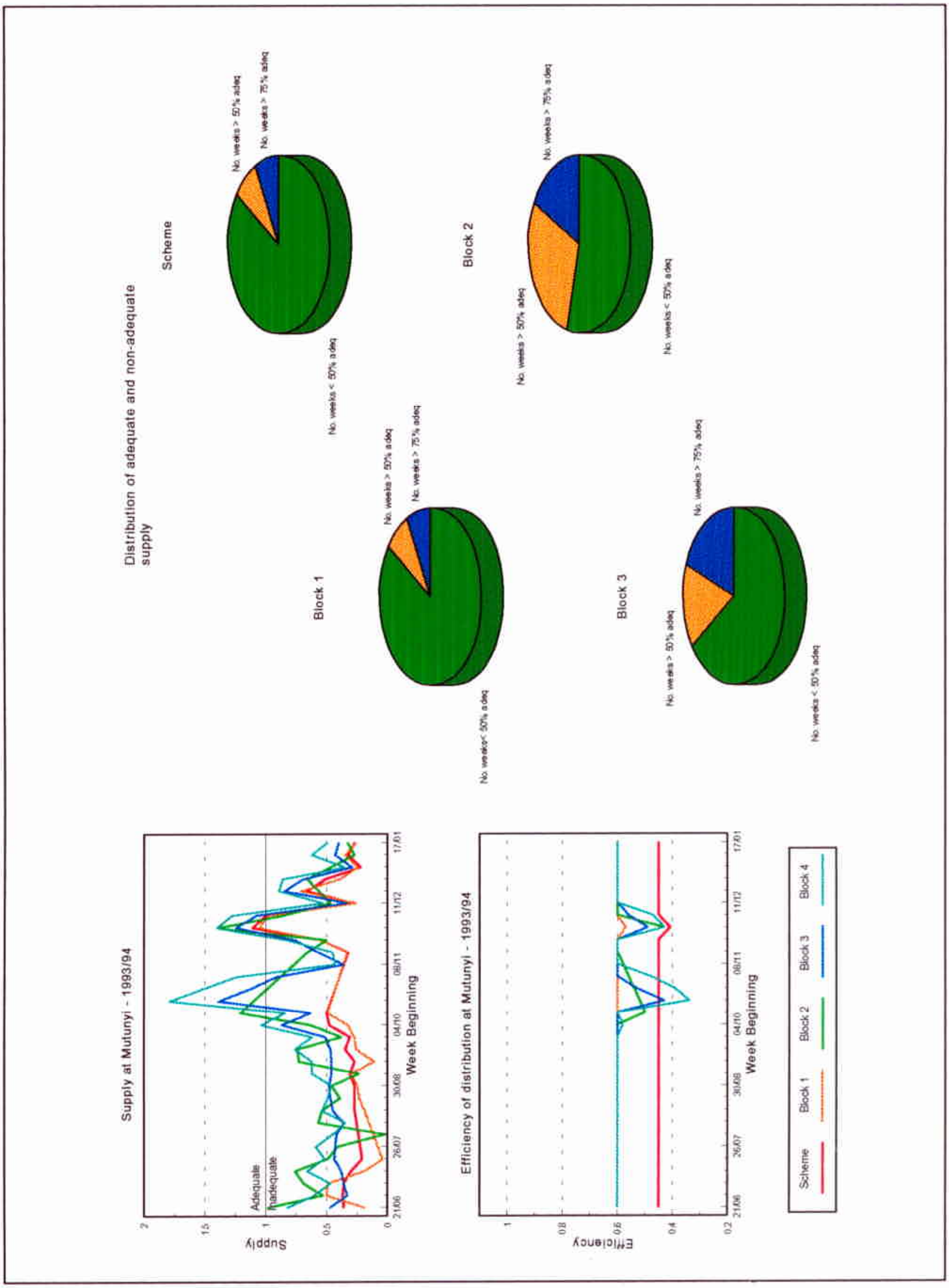

Figure 20 Irrigation performance summary: Mutunyi

Table 3.29 Crop yields for Mutunyi (kg/ha)

Yield (kg/ha)	SCHEME	Head	Middle	Tail
Maize	1055	1128	1264	772
Beans	8063	7880	4500	11810
Onions	4978	4122	6484	4333
Tomatoes	10713	4593	21170	6375
Kales	7983	1680	14286	-

Farmers in the middle of the scheme generally achieved better yields than others. It is noted that tomato yield is sensitive to both water supply and input levels. Average expenditures on inputs for tomatoes were 5800 Ksh/ha, 9900 Ksh/ha, 7100 Ksh/ha for head, middle and tail regions respectively.

Marketing was not the major problem that might be expected in this remote location. Strategies used to overcome marketing difficulties extended from marketing on the nearby road, to hiring lorries to transport produce to markets in Nairobi, Naivasha, Nanyuki and even Mombasa. The wide variety of marketing strategies produced a wide range of prices for the produce and resulted in returns which appear to be high for the yields reported.

Income

Gross margins generated by farms for the year prior to the survey are detailed in Table 3.30. Also included are additions to income from non-farm activities and expenditures on essentials, leaving net farm surplus.

Income from irrigation is less than 50% of total income, except in the middle of the scheme. Non-farm income is important as other agricultural activities are limited. Low income from irrigation in the head reach is consistent with the supply and adequacy indicators.

Table 3.30 Gross margins and farm incomes for Mutunyi (KSh)

Revenues / costs (KSh)	SCHEME	Head	Middle	Tail
Irrigated gross margin per hectare (Ksh/ha)	52030 (26400)	34410 (22000)	61760 (73450)	53000 (64800)
Irrigated net income (Ksh/farm)	31220 (17300)	24770 (15610)	42000 (52990)	22120 (26710)
Dryland net income (Ksh/farm)	1225 (4900)	157 (1005)	172 (1410)	3877 (8400)
Livestock net income (Ksh/farm)	1480 (9390)	1841 (8670)	1470 (11860)	1010 (3490)
Other inflows[1] (Ksh/farm)	27852 (71200)	38482 (104300)	18296 (19300)	23988 (22480)
Costs[2] (Ksh/farm)	21764 (22630)	22208 (30050)	23051 11040)	19704 (20180)
NET INCOME PER FARM (Ksh/farm)	40013	42988	38887	31291

Source: HR Survey 1989
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

More than half the available rainfed area is used for grazing. Rainfed land is close to the scheme and in many cases is within the scheme boundaries. Rainfed holdings are relatively even in size.

Livestock numbers are larger than on other smallholder schemes surveyed in this study. This perhaps reflects the traditional activities of the locality and the interests of the ethnic groups represented.

Cultivated rainfed land was devoted to maize and beans and a very minor area to potatoes. There was no particular trend from head to tail, the greatest proportion of cultivated land falling in the middle section.

Ownership of agricultural equipment was typically limited to hand tools although two respondents had motor vehicles. Money for investment in tools appears short and lack of returns limit investment. Costs relating to equipment purchase and repair in a year were also low.

Conflicts and financial
By far the greatest contribution comes from other activities which include paid employment. There is a school which employs a number of teachers and there are government posts as well as agricultural jobs. In fact the head region appears to have more income from non-agricultural activities than from agricultural ones.

A decline in net income from head to tail is apparent. Successful irrigation for a number of years has enabled farm families to stabilise income and diversify so that irrigation is no longer the mainstay of the family.

Health issues
Impact on diet and general standard of nutrition has been positive. Respondents were unanimous in asserting that benefits outweighed risks. Malaria is, however, present and absence from work through illness averaged 19 days/family/annum.

Environmental issues
Situated on the edge of a wildlife reserve, agricultural activity attracts herbivores when arid conditions outside the scheme offer little alternative. There is as yet no sign that this poses a major problem but problems could arise in future if fences fail.

Degradation of surrounding land is not yet severe and fuel-wood appears to be readily available. Facilities such as schools, shops and eating houses indicate that the community is expanding.

3.10.4 Design Issues

A lot of water is lost in this scheme. The main reasons for this are:

- non-contiguous nature of the scheme
- rocky terrain and sandy soils
- poorly designed and constructed channels

The scheme is notable for the apparent success of the rotation system which has been developed in response to the difficulty of sharing water without proportional division structures. This is a more effective form of distribution than proportional division when water is so short. However channel improvements would pay for themselves in terms of better output for available water.

3.11 Kibirigwi Irrigation Scheme, Kenya

3.11.1 Location and background

Kibirigwi scheme is in Kirinyaga district of Central Province in Kenya (Figure 6). The scheme straddles the main Sagana - Nyeri road for some three kilometres, about 7 km south of Karatina town.

Kibirigwi scheme was constructed in the late seventies for sprinkler irrigation tapping the Ragati river to irrigate during the dry months so that year-round production could be achieved. It was designed to be run by a management agency operating and maintaining the system, providing extension to the farmers and marketing the horticultural produce.

The surrounding countryside is well populated. Rain-fed farming of coffee and food staples is the main occupation in the area. The condition of its infrastructure is adequate and the scheme benefits from being on a main road.

3.11.2 Scheme characteristics

Kibirigwi draws water from the Ragati river using a concrete weir upstream of the scheme. A 12" pipe takes water to the settling tanks from where it is distributed through laterals to the in-field hydrants (Figure 21). Each hydrant supplies a maximum of three farmers. Each farmer has a maximum of 1 acre or 0.4 ha. of irrigated land and up to 4 acres of dryland.

The system irrigates an area of 114 ha in total. The irrigated areas are divided into six blocks, corresponding to the laterals, each of which serves approximately 50 farmers. Irrigated areas are not contiguous and layout of pipework was determined by existing farm boundaries. There are 280 farmers in all.

The system is operated by the Ministry of Agriculture, and was designed to allow watering on demand. Rotation of watering has become necessary for part of the time when shortage is anticipated. Water is rotated between head, middle and tail areas on a two day schedule, the remaining day is used to satisfy scheme-wide demand.

Kibirigwi has extensive on-site facilities with office accommodation for Ministry of Agriculture (MOA) staff, for extension workers and artisan workshops for repair of pipework and machinery. There are also facilities for meetings, for grading and storing produce and for cultivation of demonstration plots.

Kibirigwi initially specialised in production of vegetables, some of which were grown on contract for processors. French beans, cucumbers and tomatoes are popular on this scheme. However, marketing has been a source of difficulty. Considerable bad feeling and distrust between farmers and the agency has resulted. The farmers also face problems from both plant disease and water shortage.

The farmers elect a committee of nine members consisting of representatives from each block plus chairperson, treasurer and secretary. Although women form at least half of the work force, no women are committee members. The committee assists management in matters of policy, fee collection and maintenance. Hand-over of management from MOA to the farmer committee is under discussion. A cooperative group, KIFCOS began in 1994 with a small membership and shareholders initiated a seed bank. It is hoped that their activities can expand to bulk purchase of fertilizer, which would enable farmers to take advantage of substantial discounts.

3.11.3 Main findings

<u>Operation and management</u>

Adequacy of supply at Kibirigwi is good (Table 3.31 and Figure 22). The design provided for extra water use to ensure flexibility. There was no evidence of severe water shortage, overall supply was adequate for 50 weeks of the year. However, supply varied dependent on location. In-field water pressure was less good on higher lands at the head. Table 3.31 shows the favoured supply at the tail.

Table 3.31 Irrigation performance indicators for Kibirigwi

Indicator	Scheme	Head	Middle	Tail
Supply	1.63	0.87	1.36	2.95
Adequacy	0.97	0.74	0.88	0.99
Dependability	0.08 (good)	0.36 (poor)	0.22 (fair)	0.03 (very good)
Efficiency	0.56	0.74	0.62	0.40
Equity	0.16 (good)	-	-	-
Sustainability	1.00	1.00	1.00	1.00

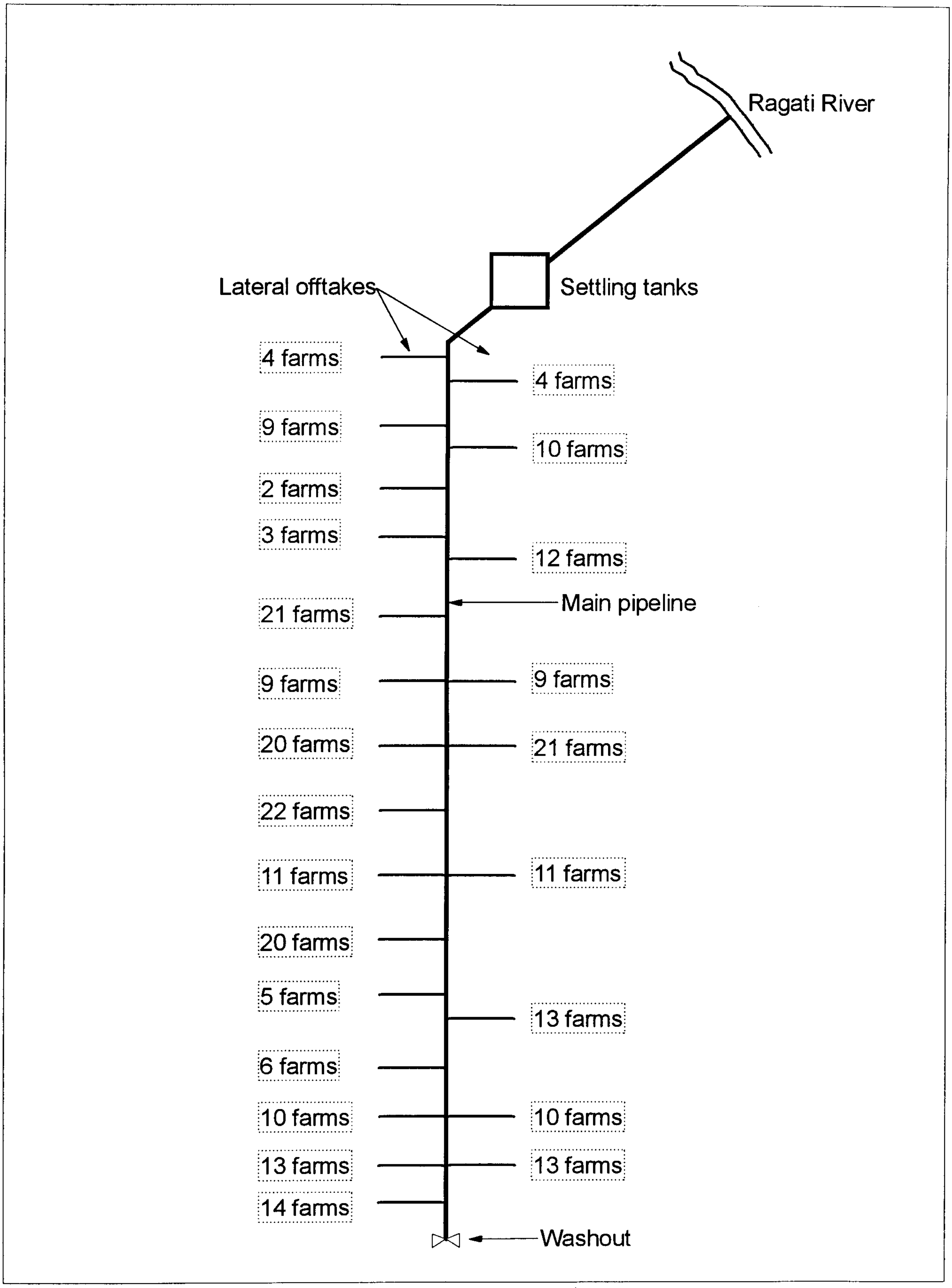

Figure 21 Kibirigwi Irrigation Scheme

Farmers take water at will during their irrigation turn. Each farmer has two sprinklers although some are believed to operate four. The recent change to cropping sweet potato, which uses a lot of land, may mean some farmers attempted to water greater areas, although not necessarily using more water. Women used relatively small areas of land for French beans but use water more intensively. Water demand for French beans peaks during January, February and March and again in September and October. Women at the head and middle of the scheme complain of water shortage. Operation and maintenance of the scheme is undertaken by the agency. Farmers contribute labour, especially for emergency repairs.

Agricultural production

Until the recent conflict between farmers and agency over marketing produce, the farmers grew a range of horticultural crops which were graded and marketed on-site. The consequent distrust meant that farmers cultivated sweet potatoes in the survey year, in place of vegetables . Kibirigwi is evidently a busy scheme, virtually all land appears to be in use. In the year of investigation less than 40% of the irrigated area was devoted to horticultural crops. Women were the main growers of horticultural crops, particularly French beans, and many used input loans arranged through their women's groups. Maize and sweet potato occupied almost half the planted area. The chairman explained that the margin on sweet potato was favourable and few inputs were required so that farmers were able to grow the crop without credit. It was also attractive because of relatively steady demand and easy marketing. Sweet potato was mostly grown by men. Findings of the 1995 survey are, therefore, atypical of the past performance of this scheme.

Yields and marketing

French beans, returned good yields (Table 3.32). Maize and beans, which are usually regarded as subsistence crops, yielded poorly. Other vegetable crop yields were poor except onion and sweet potato. Tomatoes are particularly prone to disease and produced poor yield.

Table 3.32 Crop yields for Kibirigwi (kg/ha)

Crop	Percentage of planted area	Average yield (kg/ha)
Sweet potatoes	24	6500
Maize	25	2200
Beans	12	8400
French beans	11	940
Kales	5	2000
Onions	4	14300

Inputs

On average, farmers spent KSh 11,500 per irrigated hectare on purchasing inputs. For the average plot that involved a layout of some KSh 7000. Higher levels were associated with inputs for French beans. It is expected that inputs will be higher in years when horticultural produce occupies a greater proportion of the irrigated area.

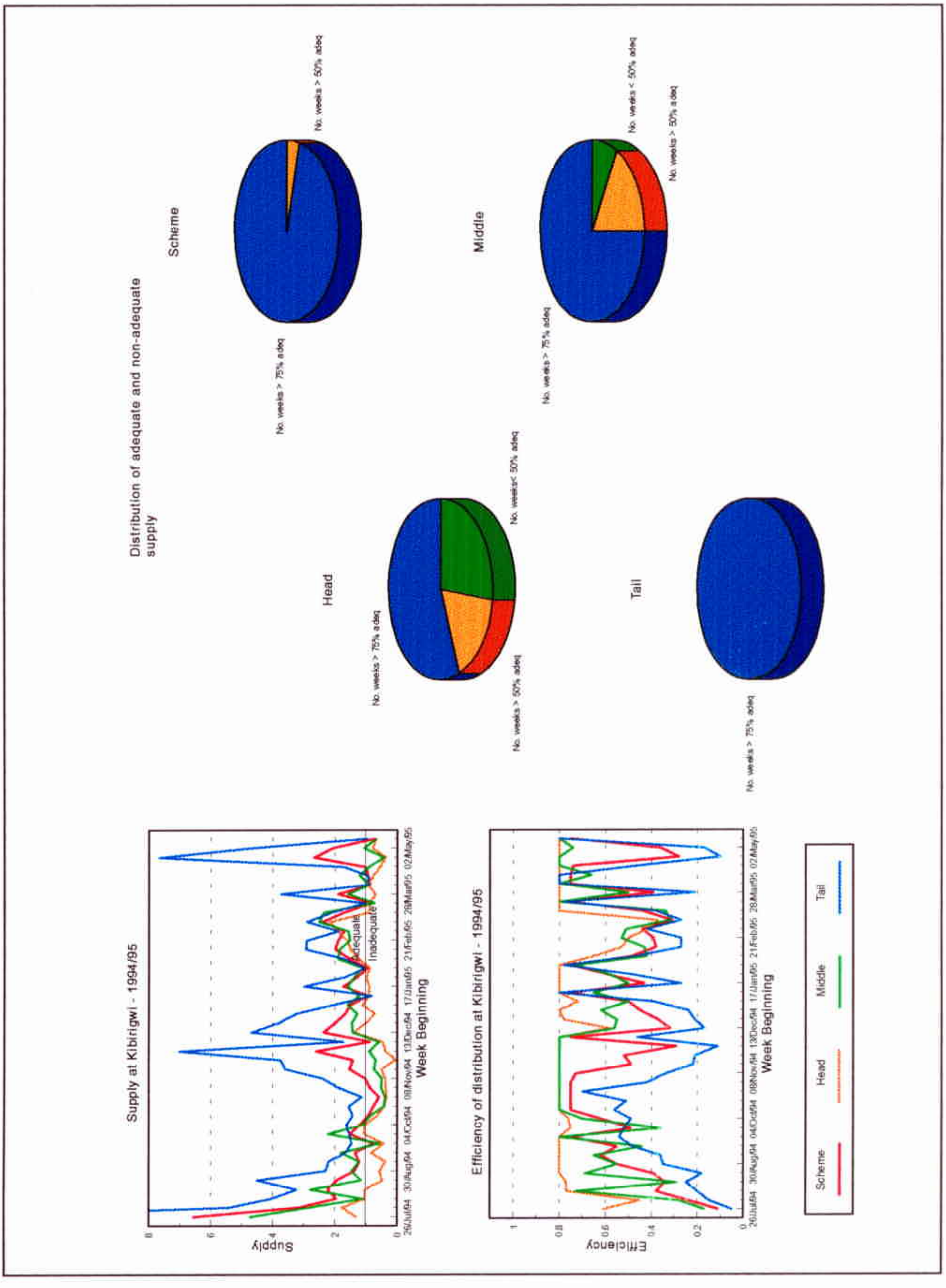

Figure 22 Irrigation performance summary: Kibirigwi

Income
It must be emphasised that present conditions are atypical. It is noticeable that expenditure level is high relative to income (Table 3.33) and this probably indicates a lag between lower income and reduction in spending. Kibirigwi is unlikely to continue a strategy which results in overall loss.

Irrigation is the greatest single generator of income even in present circumstances. If the marketing dilemma is resolved then, even with endemic price fluctuation, net irrigated income will rise. Low margins in dryland farming and negative livestock income are testimony to the fact that irrigated margins subsidised other agricultural activities in past years.

Table 3.33 Gross margins and farm incomes for Kibirigwi (KSh)

Revenues / costs (KSh)	SCHEME	Head	Middle	Tail
Irrigated gross margin (KSh/ha)	28750	14000	27500	47500
Irrigated net income (KSh/farm)	11500	5600	11000	19000
Dryland net income (KSh/farm)	1850	2800	2400	50
Livestock net income (KSh/farm)	-2450	-3800	-3800	1000
Other inflows[1] (KSh/farm)	10200	18400	7500	4700
Costs[2] (KSh/farm)	27500	26300	26300	31100
NET INCOME PER FARM (KSh/farm)	-6400	-3300	-9200	-6350

Source: HR Survey 1989
[1] Other businesses, employment, remittances from family members
[2] Support to relatives, school fees, travel, health, tools

Environmental impacts
Positive social impact is achieved through the general rise in income and employment. Negative impact on the water source is probably low, as the volume abstracted from the river is relatively small. Excess water is returned to the river. There is no evidence of either erosion or waterlogging.

Conflict/ complementarity
Conflict with other agricultural enterprises was not apparent at Kibirigwi. Complementarity between livestock and irrigation is being encouraged with the "Zero grazing units" promoted by the Government (SISDO). Milk production from stall fed cattle will generate income for women who may have limited access to land but who can use crop residues and plant fodder crops as land boundaries. SISDO loans capital in the form of a cow. Repayment from milk and calf sales is possible.

Sustainability
The irrigation infrastructure has been supported since inception by stocks of replacement pipe and repair materials. As the system ages it is likely that repair will become more frequent and at the same time more expensive. It is possible that the scheme will henceforward involve higher repair costs. There is no

reason why higher costs should not be met if marketing is developed successfully and horticultural demand remains stable.

Water supply from the Ragati river is assured. Equity in terms of water supply is good, a positive precondition for cooperation between farmers. Indeed conflict with present management may have had the effect of further uniting farmers. Prospects for sustainability appear good.

3.11.4 Design issues

Sustainability and development hinge on marketing and maintenance.

Overall system efficiency at 56% is better than open channel systems. Farmers are competent in the use of sprinkler equipment and operate the system without problems.

If marketing is to be done through an agency:

- financial transparency is essential
- market knowledge is needed
- institutional arrangements must ensure the agency is answerable to the farmers

Present initiatives in input credit and "zero grazing" by SISDO fulfill the dual function of improving access to credit and dealing with gender imbalance in access to resources.

3.12 New Mataro Irrigation Scheme, Kenya

3.12.1 Location and historic background

New Mataro Irrigation Scheme is located in the Kenyan Highlands, almost on the equator at an altitude of 1950 m, west of Mount Kenya and in Laikipia District (Figure 6). The towns of Nyeri and Nanyuki are about 50 and 60 km distant respectively, although only half of this distance is paved. Average annual rainfall amounts to approximately 700 mm, whilst total annual reference evapotranspiration is about 1750 mm. The surrounding area is classified as semi-arid with a low potential for rain-fed agriculture, and as such the prevailing land use is for cattle ranching.

The upper part of the valley in which the scheme lies is narrow, with a gently undulating relief with slopes of up to 2%. Downstream, the scheme is about 1 km wide and the slopes decrease. The soils consist of clay-loams and clays with areas of black cotton soils in the lower areas. According to a survey carried out in 1986 the soils are moderately fertile. Water for irrigation is drawn from the Ngobit river which originates from the Aberdare mountain range. Flow is perennial but exhibits wide seasonal variations.

New Mataro scheme is actually composed of two distinct parts termed Gatawakwa and New Mataro. Gatawakwa occupies part of a former privately-owned settler farm bought in 1977 and divided between 27 farmers most of whom also owned land close to Nyeri. New Mataro however was obtained in 1976 by wives of the farmworkers of the settler. They sub-divided the area into 132 plots consisting of about 1 ha of irrigated land and 2.5 ha of grazing land. A basic irrigation network had been implemented previously but rehabilitation and improvement started in 1983 with a diversion weir constructed across the river, realignment of part of the main canal and construction of twelve division boxes.

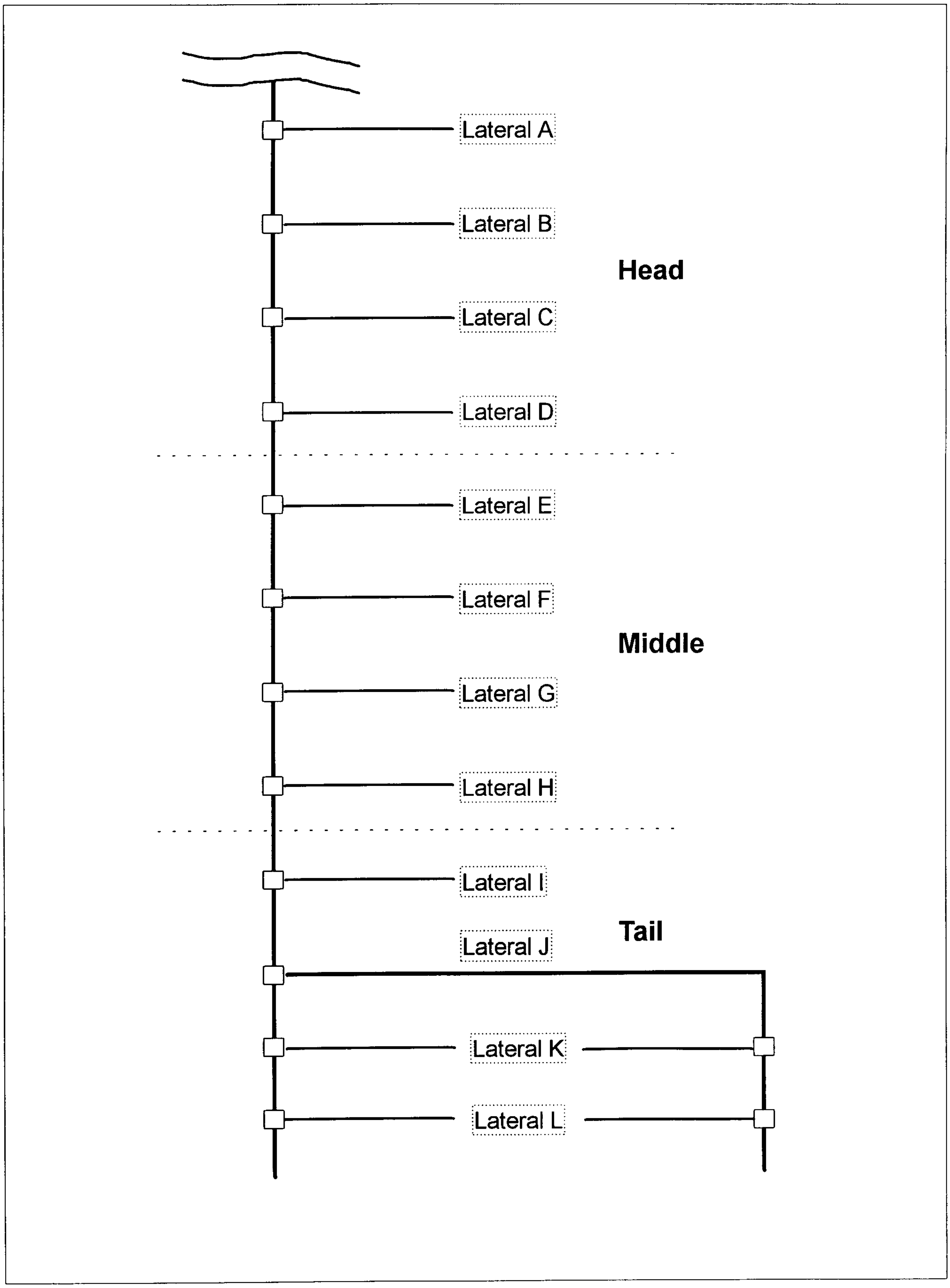

Figure 23 New Mataro Irrigation Scheme

The farmers were responsible for excavating the lateral canals and shaping the main canal. Funding was provided by the European Community.

3.12.2 Scheme characteristics

The intake to New Mataro is well-constructed including a weir across the river and a gated culvert to the main canal, which has a total length of 4.15 km. Along its length are 12 concrete division boxes that control the flow of water using proportional weirs (Figure 23). These were found to be in good condition with little sign of tampering. Also along the main canal are two road-bridges, a sideweir to convey excess water back to the river and a number of drop structures. The overall condition of the canal is good and it appears to be fairly well-maintained along its length.

3.12.3 Main findings

Operation and management

Adequacy of supply at New Mataro is fairly good at 86% overall, water being shared equitably between blocks (Table 3.34 and Figure 24). Inequity was observed, however, along laterals; some farmers had stopped irrigating due to lack of water. Lateral lengths were too long for the low flow rates. To counter this, some farmers had resorted to siphoning water directly from the main canals. Problems also exist in organising rotas for water sharing. Farmers choose not to understand that irrigation times should be divided if land allocations are divided. Maintenance of main channels is good and the presence of a resident extension officer has helped to raise the general level of scheme management.

Table 3.34 Irrigation performance indicators for New Mataro

Indicator	SCHEME	Head	Middle	Tail
Supply	1.12	1.57	1.07	1.02
Adequacy	0.86	0.86	0.80	0.85
Dependability	0.25 (poor)	0.34 (poor)	0.35 (poor)	0.26 (poor)
Efficiency	0.46	0.41	0.50	0.53
Equity	0.17 (fair)	-	-	-
Sustainability	1.00	-	-	-

Agricultural production

The irrigated area is split almost evenly between production of subsistence crops such as maize and beans, and vegetable crops such as tomato and onion for sale to merchants. Considerable extension effort goes into this scheme and includes close attention to disease control and to marketing. The extension officer is resident at the scheme and organises a variety of group activities in addition to visits and demonstrations. Parallel developments such as rainwater harvesting are encouraged to improve facilities generally and to free womens' time for productive tasks. Female labour is often crucial to development of intensive horticultural production.

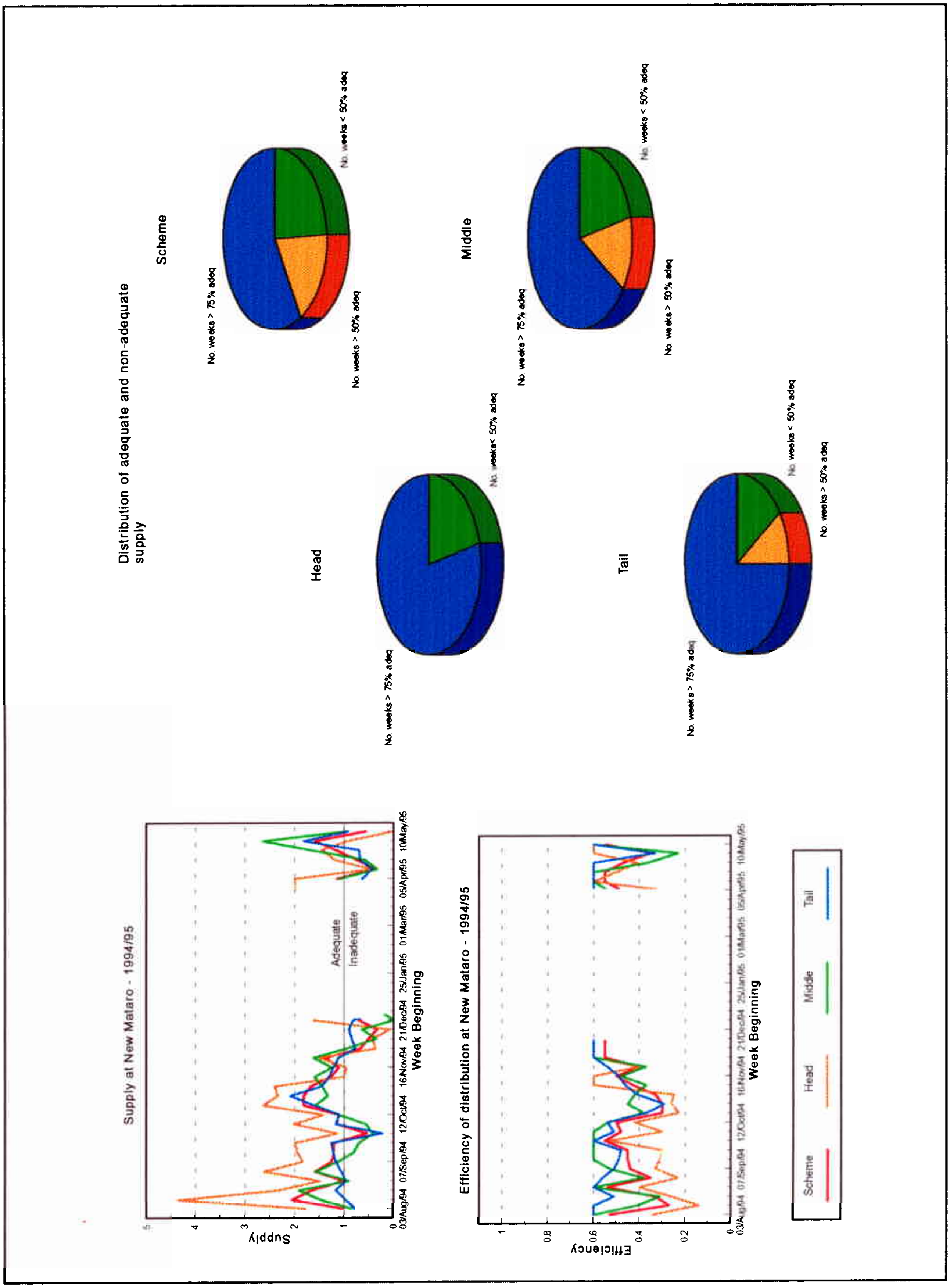

Figure 24 Irrigation performance summary: New Mataro

Table 3.35 Crops grown at New Mataro

CROP	Maize	Beans	Onions	Tomato	Potato	Cabbage	Other
% of planted area	40%	18%	16%	14%	7%	4%	1%

Yields and marketing
Table 3.36 demonstrates that substantial differences in crop yield can occur despite fairly even supply of water to the irrigated area.

Table 3.36 Crop yields for New Mataro (kg/ha)

Crop yields (kg/ha)	**SCHEME**	**Head**	**Middle**	**Tail**
Onions	9361	4836	12348	12700
Tomatoes	10229	2420	19116	11131
Maize	2439	2297	2684	2342
French beans	635	619	694	605

Low yield in the head of the scheme was largely due to distribution problems. Farmers in the end of laterals have poor supply and were often water-short. Some of the area also suffers flood problems, which can be disastrous for the horticultural crop. Post-flood humidity favours the spread of disease, also reducing yield. Yield in the middle and tail was significantly greater for the horticultural crops but subsistence crops performed evenly over the scheme.

Marketing took place both on and off the scheme. Middlemen bought from the farm gate, striking bargains with individual farmers, although farmers say that the prices offered are now more or less consistent, whereas previously price had varied greatly from farmer to farmer. Most farmers felt that the prices were low and undoubtedly this was a penalty for the distance that had to be travelled. It was possible for farmers to hire pick-ups to drive produce to Nairobi or elsewhere. The cost, and the length of absence from labour-short farms presumably was the reason why it was not common practice. Weekly auctions had been suggested as a method of increasing farmers' bargaining power.

Labour
On irrigated land generally there were approximately four workers to each hectare. Less labour is devoted to irrigation on farms where rain-fed land is cultivated. The study revealed a difference of 25%. The gender balance was almost even. The sample contained 15% of female-headed households, which is low for rural Kenya. Women had almost exclusive responsibility for food crops and more than 50% had responsibility for some or all of the cash crop too. About 20% took responsibility for allocation of water.

Income
Income from irrigation was dependent on crop choice, yield and price and the proportion of production which the farmer could sell. Poor agricultural performance in horticultural crops produced poor income in the head reach. As

well as suffering poor yield, some farmers in the head were unable to irrigate the full area.

Table 3.37 Gross margins and farm incomes for New Mataro (KSh)

Revenues / costs (KSh)	SCHEME	Head	Middle	Tail
Irrigated gross margin (KSh/ha)	19100	10330	23500	26830
Irrigated net income (KSh/farm)	12450	6200	14100	16100
Dryland net income (KSh/farm)	1500	180	5170	-175
Livestock net income (KSh/farm)	4100	960	7450	4250
Other inflows[1] (KSh/farm)	19300	6940	16560	32970
Costs[2] (KSh/farm)	26500	17000	32250	30540
NET INCOME PER FARM (KSh/farm)	10800	-2720	11030	22605

Source: HR Survey 1995
[1] Other businesses, employment, remittances from family members
[2] Food and fuel plus support to relatives, school fees, travel, health, tools etc.,

Other income sources at this scheme are important. Families in the head were unfortunate in receiving less income from this source in addition to their low agricultural incomes.

Conflicts / complementarity
The major cause of low income from rainfed land in the head of the scheme is probably the small proportion of crops sold. It is less clear why farmers in the middle perform better on approximately the same areas of rainfed land as those in the tail, given equivalence in water supply. Labour demand for rainfed farms reduces the amount of labour devoted to irrigation.

Environmental impacts
There were no significant environmental impacts of irrigation; however, flooding of the scheme is a persistent problem and difficult to control, given the 'flushing' nature of the river. It has been aimed to exclude wildlife from the scheme using a solar powered electric fence, but this is only partially effective.

Sustainability
There is sufficient water to supply the scheme. The good organisational foundations currently being laid will improve sustainability, particularly if distribution problems in the head reach can be addressed to produce an effective and acceptable schedule for each lateral.

3.12.4 Design issues
Long laterals make scheduling water between farmers difficult. When the flow rates are small, most of the water is lost in seepage. The use of small diameter PVC piping to convey water from the main canal to lower areas remote from its alignment was an effective and attractive solution which could have application elsewhere.

3.13 Arombo Irrigation Scheme, Kenya

3.13.1 Location and historic background

Arombo is a small rice-growing scheme in the Kano plains on the eastern shores of Lake Victoria (Figure 6). The scheme is close to the town of Ahero where a good range of facilities is available. The plain is very flat and slopes gently towards the lake. The scheme is one of a cluster supplied with irrigation water by South West Kano Irrigation Project which is managed by SISO (Smallholder Irrigation Support Organisation). There are three clusters and a total of 21 schemes. Farmers pay an annual maintenance fee to SISO, which covers the costs of maintenance of the main canal intake, main canal and cluster offtakes. Construction of the South West Kano Irrigation Project began in 1991 and irrigation water delivery began in 1993.

Water is abstracted from the Nyando river and distributed to schemes where farmers share the water between their irrigation plots. Arombo scheme now has an assured water supply where previously farmers irrigated using water from the Nyatini drain from the nearby National Irrigation Board scheme. Rice cultivation is well established in the area, agribusinesses cater for rice growers' needs and marketing networks function effectively.

Annual rainfall is in the region of 1200 mm with rain occurring mainly in April and November, although the timing is erratic and drought and flood are common. Soils are heavy dark clays suited to rice cultivation, with depths in the range of 90 cm - 120 cm.

The area is well populated. Social organisation favours multiple marriage so family size tends to be large. There is no shortage of hired labour although the nearby town possibly increases the cost of casual labour for farmers.

3.13.2 Scheme characteristics

Arombo scheme consists of 54.4 acres or 22 hectares. The irrigated fields are contiguous and farmers live in homesteads outside the irrigated area. There are some 70 farmers, most of whom also cultivate rain-fed land to produce maize, sorghum, bananas and cotton. Livestock is included in the farming system. Rice is grown in one season, as a cash crop, although a small proportion is used by the farm families. The scheme is relatively new and conflict arises between the farmer committee and SISO on a number of matters including land registration, fee collection and availability of tractors for land preparation. There are other issues which seem to arise from general conflict and mistrust.

Water for irrigation is delivered to the scheme from the main canal via the cluster canal. Water flows to the scheme over a duck-billed weir and distribution is controlled by division boxes. The scheme functions in three blocks (Figure 25). Managing water within the system is difficult due to the small gradient.

The scheme committee consists of 12 elected members and is responsible for distribution within the scheme. Each block is represented on the committee. Main responsibilities are maintenance of the channels and drains within the scheme and collection of the maintenance fee and payment of dues to SISO. The schemes of the clusters are represented on the board of SISO; there are three board members to represent the interests of all the schemes.

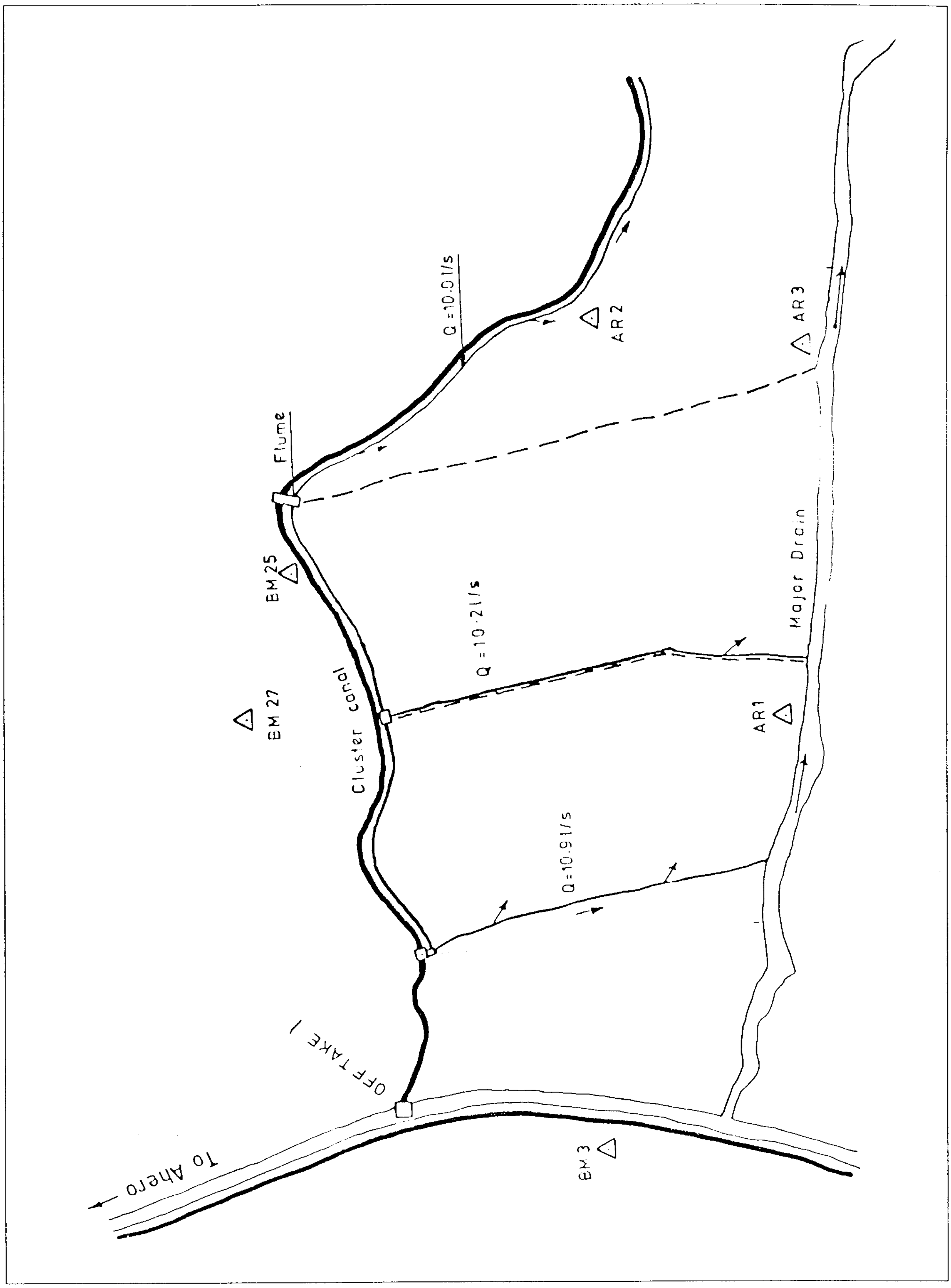

Figure 25 Arombo Irrigation Scheme

3.13.3 Main findings

Operation and management

Delivery of water to the scheme is managed by SISO. So far, the only delay in delivery has resulted from the farmers' failure to pay dues to SISO. It is management policy to withhold delivery until payment is made. Delay in planting is generally held to result in reduced yield so farmers have an incentive to pay fees on time.

Water delivery at Arombo appeared good with an adequate supply and no evidence of serious inequity. Arombo is a new scheme and as such is expected to show equitable distribution. Complaint about the volume and reliability of water delivery was minimal. The available hydraulic data were inadequate to conduct an analysis of supply.

Yield appeared to be slightly higher in the middle reach of the scheme but differences were not statistically significant. Regression analysis implied that yield was more sensitive to differences in inputs than to differences in location, which supports the view that all areas receive an adequate supply of irrigation water.

Agricultural production

Arombo grows one irrigated rice crop per year. All the irrigable land was in use. Cost of inputs and hired labour was approximately KSh 2000 per farm. The maintenance fee to SISO was KSh 3500 per hectare so the average farmer paid a fee of around KSh 1200. Although the current rice price was quoted as KSh 12 per kg. some farmers obtained less, the average price from the survey was KSh 11 per kg. In general farmers bought seed and applied fertilizer, but those who did not achieved significantly lower yield, averaging less than 2.5 t/ha. Opportunities exist for farmers to obtain credit for inputs. Care International operates in the area and channels credit mainly through women's groups. Women are major participants in field tasks.

Most of the rain-fed crops are produced for home consumption. Maize, sorghum and millet take up most land. Cotton and sugar cane are grown for cash but on small areas. Most households have some livestock but numbers are small, the average farm keeping 4 - 6 cattle, 6- 8 small stock and a dozen or so chickens.

Yields and marketing

The overall average yield of rice reported was 4.6 t/ha, in line with the estimate of 18 bags/acre given by the farmers committee. It was, however, less than the 7 t/ha that SISO estimated from their observation of the harvest. This yield is equivalent to 27 bags per acre. It appears from the original proposals that yield of 16 bags/acre was common prior to development. Farmers assert yield prior to 1993 was higher, around 20 bags/acre. An increase of two bags/farm at current prices does little more than cover average farm maintenance fee. The issue of true yield has become a major source of conflict. Standard deviation of the reported yield from the mean value (in brackets below figures in row one of Table 3.38) suggest that yield was only moderately variable. The correlation between inputs and yield was strong and supports the view that the data are genuine.

Table 3.38 Rice yields, costs and revenues for Arombo

	SCHEME	Head	Middle	Tail
Rice yield (kg/ha)	4630 (2740)	3735 (1562)	6090 (3460)	4110 (2125)
Revenue (KSh/ha)	41300	42300	48690	30850
Production costs (KSh/ha)	6345	4444	8840	5612
Irrigated gross margin (KSh/ha)	34955	37856	39850	25382
Maintenance fee (KSh/ha)	3500	3500	3500	3500
NET INCOME (KSh/ha)	31455	34356	36350	21880

Gross margins in the tail were reduced by a combination of factors; cost per ha was higher than in the head and the percentage of the crop sold was lower. Yield in the tail is slightly better than in the head so that it is unlikely that water shortage exists.

Marketing of rice is done through individual sales and through wholesalers. Although the price varied through the season, the price at any given time appeared to be within the range of eight percent either side of the average. Markets were stable and predictable. Wholesale buyers visited the scheme, thus marketing costs were borne by the traders.

If indeed yield has only increased by 12% (from 16 bags to 18 bags) then farmers are little better off after paying fees and those achieving a less-than-average yield may have less cash left than previously.

Table 3.39 Income generation for Arombo (KSh)

Revenues / Costs (KSh)		**SCHEME**
Irrigated net income	(KSh/farm)	8375
Dryland net income	(KSh/farm)	7800
Livestock net income	(KSh/farm)	4710
Employment	(KSh/farm)	15580
Business	(KSh/farm)	4260
Other	(KSh/farm)	610
Costs [1]	(KSh/farm)	31460
NET INCOME PER FARM	(KSh)	9875

Source: HR Survey 1989

[1] Support to relatives, school fees, travel, health, tools

Conflict / complementarity
Conflict of interest between dryland or rain-fed crops and the rice crop was reported by 60% of the farmers. The two problem periods are January/ February when rice is harvested and July/August when maize is harvested. Some difficulty may arise from the fact that conditions on neighbouring schemes are different from those on Arombo where irrigation was already in progress with water from the Nyatini drain. Farmers at Arombo may feel that the cost of the new water supply is high relative to the advantage brought.

Environmental impacts
As the scheme has only been in operation for two seasons, environmental impacts are not yet apparent.

Sustainability
The management of SISO is disappointed that farmers at Arombo are not more willing to pay their fees. The system will be unsustainable if conflict continues and SISO refuse to supply water. An effort must be made to resolve the problem so that farmers and SISO can work together.

3.13.4 Design issues

- Irrigation infrastructure must add significantly to production and income otherwise farmers will be reluctant to pay repayments or service fees.

- When designing cluster irrigation programmes, socio economic differences between participating groups must be considered when fixing fees.

- Management and farmers need to develop a more flexible relationship in order to ensure sustainability. Farmers now deprived of Nyatini drain water and not yet achieving higher yields need a reliable supply of water.

4 Summary of scheme performance

Three matrices have been prepared giving general scheme information and performance data for all thirteen of the schemes studied and allow comparisons between schemes to be made:

- Matrix 1: Scheme characteristics and performance
- Matrix 2: Socio-economic parameters and economic performance
- Matrix 3: Irrigation system performance indicators.

Data for the ten Kenyan schemes were collected over a four year period. To enable true comparisons of economic performance to be made, incomes and costs have been reduced to a standard study year, 1992/93. This was carried out on the basis of national inflation rates but may not give a true representation of inflation as felt by the farming communities. Furthermore, values have also been converted to US$, again 1992/93, using the average exchange rate for that year, for use in comparing between countries.

4.1 Scheme comparisons

4.1.1 Ranking of scheme performances

When ranked according to irrigated net incomes per ha, schemes fall into three distinct groups:

• Group 1:	Kwa Kyai	$1765
	Kangocho	$1330
	Kiguru	$1260
	Mutunyi	$1025
	Nyanyadzi	$995
	Exchange	$945
• Group 2:	Arombo	$470
	Mathina	$465
	Kibirigwi	$400
• Group 3:	New Mataro	$222
	Gem Rae	$130

There appears to be very little correlation between irrigated net incomes and other individual factors, such as adequacy of supply, distance to market or availability of labour, implying that the interaction of these determinants for scheme success is extremely complex. It is noted that the schemes that had higher incomes from irrigation tended to concentrate more on irrigation as the main source of income for households.

4.2 Discussion of scheme performance

Whilst information has been provided in the individual case studies and matrices it is useful to summarise why certain schemes performed better than expected and why others were below expectations.

Note: currencies refer to 1992/93 KSh where appropriate, and to 1992/93 US$

<u>Exchange</u>

Adequate water supplies at Exchange ensured good yields. Because most farmers have access to small areas and marketing does not favour high value crops, farm income from irrigation is low but still represents a major contribution to total farm income ($945 per ha). Water supply, pumping and O&M costs were paid by Government. Exchange is judged to be successful through equitable water distribution and effective participation. Agency-farmer relations on this scheme are good.

<u>Nyanyadzi</u>

Nyanyadzi is complex to manage and equitable distribution was not achieved. However, the farmers have developed strategies to ameliorate these effects and achieve good returns from irrigation in good years, $995 per ha on average. The scheme is agency-managed; farmer representation is poor, as is fee collection.

<u>El Hammami</u>

Distribution of water at "secondary" level has been transferred from open channels to low-pressure pipes and has transformed El Hammami from a poorly-performing scheme into one that is comparable to others in the area. This has not been achieved without considerable conflict, which could have been avoided had farmer participation been encouraged and considered prior to design. Water deliveries were notably poor where groups included more than twenty persons.

Gem Rae
Adequacy of supply at Gem Rae was good (86% overall) although this was not divided equitably. Rice yields were very poor. Irrigated incomes were the lowest of all the Kenyan schemes at just KSh 3535 per ha ($130 per ha), although for just one cropping season. Large quantities of sediment in the canal system from the previous year meant a delay to the start of the irrigation season due to poor farmer cooperation in maintenance work and conflicts between irrigated and dryland farming interests.

Kamleza
Farmers at Kamleza achieved poor incomes from irrigation of around KSh 7000 per ha ($255 per ha) despite having an abundant water supply. Division of water using variable offtakes led to serious inequity of water distribution. Yields were depressed in the head of the scheme due to waterlogging, exacerbated by a high water table, and in the tail by inadequate water. Farm households received substantial amounts of money from remittances from other sources.

Kwa Kyai
Incomes from irrigation at Kwa Kyai were the highest of the schemes studied in Kenya at KSh 48600 per ha ($1765 per ha). Water supply was 81% of requirements but did not show much variation throughout the year. Specialisation in Asian vegetables for export and marketing through a farmer-cooperative helped achieve this success. Farmers at the tail were disadvantaged by poor water supplies due to high seepage losses along the unlined section of the main canal.

Mathina
Problems at Mathina centred on poor equity of water supply; farmers at the tail received little or no water. However, farmers at the head of the scheme performed well. Average irrigated income was KSh 12765 per ha ($465 per ha) putting Kamleza in the middle-earning group of schemes. Canal maintenance in the lower sections was poor, structures were interfered with and tail-farmers were under-represented on the committee.

Kangocho
Observations at Kangocho indicated that there were severe inequity problems, the tail of the scheme has not received water for a number of years, and that water supply is inadequate due to the intake weir that has collapsed. However, returns to irrigation are high at KSh 36480 per ha ($1330 per ha). Net farm incomes are the highest of all schemes, $1840, because of the profitability of the major crop, coffee. Availability of cash for inputs and labour, and proximity to markets mean that those farmers that practise irrigation generally do very well.

Kiguru
The simple, low-pressure piped sprinkler system at Kiguru served farmers very well. Past experience of working on a settler farm, observation of the neighbouring commercial farm and suitable climate have led farmers to specialise in a number of profitable horticultural crops. Produce is graded at site and sold through the farmer cooperative. As a result irrigated incomes were good, at KSh 36445 per ha ($1260 per ha). Locally manufactured butterfly sprinklers are cheap and reliable.

Mutunyi

Mutunyi is deceptive. Irrigation infrastructure is poorly constructed with a meandering and informal canal layout and lack of proper division structures. Up to a third of all water is lost through seepage in the intake canal. Overall adequacy of supply is less than 50%. However, irrigated incomes are among the highest at KSh 28095 per ha ($1025 per ha). Good farmer organisation, as shown by the successful rotation schedule, and mobilisation of the available human resource appears to have overcome these problems. Other businesses and employment provided households with additional income.

Kibirigwi

Despite having an advanced, high-pressure sprinkler system, adequate water supply and ideal location, returns at Kibirigwi during the study year were disappointing; KSh 11025 per ha ($400 per ha). Indeed, overall farm surplus was negative (KSh -2460, $ -90). Farmers were recovering from a failed marketing venture between farmers, scheme management and commercial private traders caused by a lack of transparency in transactions. Low value crops were cultivated.

Arombo

Irrigated incomes at Arombo were good, KSh 12905 per ha ($470 per ha), considering that rice is grown for just one season. Water is supplied via the SW Kano Project. Farmers were required to pay a maintenance fee, collection of which had been poor. Farmers at Arombo previously used an erratic supply of drainage water from the upstream NIB rice scheme and were reluctant to pay for water. Households received substantial incomes from other employment.

New Mataro

Irrigation performance at New Mataro with irrigated net income of KSh 7321 per ha ($222 per ha) was low. Seepage losses in long tertiary canals and disputes between farmers over irrigation times appeared to negate the fairly adequate and equitable supply. Marketing was difficult because of remoteness and lack of an all-weather road.

4.3 Summary of issues

Sustainability

- Under a technical criterion for sustainability, that the area irrigated on established schemes should be at least 90% of the nominal area, ten of 13 schemes were sustainable. Excluding five schemes supported by Governments, five out of eight Kenyan farmer-managed schemes were sustainable. However, there was evidence that irrigation on a reduced area would continue on the remaining three schemes, despite the fact that the infrastructure was long past its design lifetime. On a minority of schemes, farmers' income from agriculture did not fully cover the true economic costs yet they continued to farm. In the better schemes, farmers were successfully marketing their produce to the European Community via intermediaries.

- The success and long-term sustainability of new irrigation schemes can be improved if farming communities, including cultivators and their families, are involved in their identification and planning. Formal processes to encourage such interaction have been introduced in Kenya and Zimbabwe. Farmers wishing to develop a scheme are encouraged to approach the Government for technical review and assistance, if found feasible. In return for technical assistance, farmers must present clear plans setting out the way they will operate and manage the proposed scheme. Essential elements are investment by farmers and definition of the responsibilities of farmers and government in the form of a formal contract.

- Almost all schemes suffered water shortages more frequently than the accepted design figure of once in five years. It is clear that catchment planning is now essential in many countries where exploitation of the water resource for new developments increasingly jeopardizes the viability of existing ones. Farmers are skilled in adjusting cropped area to expected supply but the area actually cropped frequently fell short of the nominal area.

- In most cases, farmers possessed both small irrigated plots and dryland holdings. Their choice of crops and their farm income generally reflected the relative security of their water supply. Economic returns were generally highest at the head of the schemes and lowest at the tail. Scarcity of labour, caused by immigration of men and competing demands on the time of the predominantly female labour force, was a serious constraint to improved returns. Yields tended to be below national averages.

- System maintenance is not well carried out on the farmer-managed schemes. Shortage of labour and the demands of other community activities can delay irrigations and reduce output. Despite severe constraints on funding, central management tends to manage maintenance better.

- Ready access to credit is important to farmers, particularly women, to maximise returns from land.

<u>Technical Aspects</u>

- The engineer has an essential role to play in ensuring that land and water are suited to more intensive development. If water supply falls below 70% of the need for optimal crop production, yield falls off very rapidly and destructive disputes over water break out. Above that level of security, and providing there are no major conflicts amongst farmers, the technical performance of small schemes in a wide variety of circumstance appears very similar. Variation in economic performance between individual schemes growing similar crops was influenced by the experience of the farmers, the location of the scheme relative to market, and the availability and cost of inputs and farm labour.

- The designer also has prime responsibility for ensuring that the land is suitable for intensive irrigated development and that adverse environmental effects such as waterlogging, disease and downstream pollution are minimized. Design must also be sufficiently flexible to allow for changes in the assumed cropping pattern. Small schemes are increasingly required to operate with very limited financial and technical support from governments. The designer must therefore assume operation and maintenance by relatively untrained farmers. Landholding sizes, traditional agricultural practices, shortage of labour and limitations on the available irrigating hours all intimately affect design. Social factors should govern the sizing of blocks, canals, irrigation streams, water distribution and/or storage arrangements.

- Proportional division structures appear to be robust, easily understood by farmers and as efficient as more complex regulating structures. They can be unsuitable where systems suffer heavy sediment ingress or where water is short, because rotations cannot easily be introduced. Some inequity in water use across a surface irrigation scheme appears inevitable. Systems which are simple to operate offer the best chance for farmers to reach practical compromises in water use distribution.

- An investigation of the functioning of a low pressure pipeline in small farming demonstrated that technologies which can be highly successful in developed countries may need to be fundamentally rethought, adapted and tested before being introduced to small farmers. Water management becomes a fundamentally different operation when supply must be rotated between large numbers of small farmers accustomed to traditional methods, rather than one or two large farmers. Cooperation between individuals begins to break down when the farmer groups become too large. An upper limit of 15 - 18 farmers is recommended.

- At times when the supply was sufficient for the area cropped, overall efficiency on farmer-managed surface irrigation schemes was found to be 40-45%. The figure is comparable with the performance of small, centrally managed schemes which carry heavy management overheads. It is higher than achieved by many large schemes, which may operate at 30-40% efficiency or less.

- The output of the better schemes is sufficient to allow farmers to tackle water shortages by introducing low pressure, locally-made sprinkler systems. The water use performance of the equipment is substantially better than surface irrigation, though not up to the standards of commercial farming. The systems are robust, can be maintained by farmers and represent a successful strategy for small schemes growing higher value crops.

<u>Institutions and policies</u>

- Clear national policies defining the role of smallholder irrigation within a holistic development policy are needed. The policy should establish:

- rights to water and the proportion of the resource to be allocated to smallholder production

- that developments should only be undertaken when financial viability has been established and risks have been fully assessed

- funding and cost recovery for schemes that have been eligible for grants or assistance under other government policy objectives

- basic objectives for institutions, incorporating principles of participation, gender-balance, needs for minority and disadvantaged groups

- government responsibility for the provision of support services including specialised irrigation extension, infrastructure and enforcement of marketing standards (such as acceptable contractual agreements) and standardised credit agreements.

- Governments need to show commitment to continuing training of staff and farmers to improve the dynamics of development. Focus on ways of improving the productive performance of the irrigation sector needs to be improved.

- Designers and farmers need to interact throughout the scheme identification and definition process to produce designs which are easy to operate and maintain, affordable by small farmers and minimise adverse environmental impacts.

5 Bibliography

Acland, J.D. 1971
East African Crops
FAO/Longmans, ISBN 0-582-6031-3

Bembridge, T, 1991
Farmer Characteristics, Innovativeness and Cotton Production at Makatini Irrigation Scheme, Kwa Zulu. Development Southern Africa 8 (1): 61-77

Bird, J.D.A. and Gillott P.W.K. 1992
A Quantitative Review of Adequacy and Equity Indicators for Irrigation System Distribution, Conference proceedings, Leuven 1992

Brown, E P and Nooter K R, 1992
Successful small-scale irrigation in the Sahel
World Bank Technical Paper No 171, Washington

Bentum, Robert van and Smout, Ian K, 1994
Buried Pipelines for Surface Irrigation, Intermediate Technology Publications Limited, ISBN 1-85339-187-5, Wageningen

Booher, L J, 1974
Surface Irrigation, FAO Agricultural Development Paper No. 95, FAO Land and Water Development Series No. 3, FAO, Rome

Bos, M G and Nugteren J, 1982
On Irrigation Efficiencies, ILRI Publication 19, International Institute for Land Reclamation and Improvement, ISBN 90-70260-875

Carney, J A, 1988
Struggle over crop rights and labour within contract farming households in a Gambian irrigated rice project, Journal of Peasant Studies, 15 (3)

Dey, J, 1990
Gender issues in irrigation project design in sub-Saharan Africa. Contribution to design for sustainable farmer managed irrigation schemes in sub-Saharan Africa, Wageningen Agricultural University.

Diemer, G and Huibers, F P, 1991
Farmer Managed Irrigation in the Senegal River Valley: Implications for the Current Design Method. WARDA Water Management Project, Wageningen Agricultural University, Department of Soil and Water Conservation.

Doorenbos, J. and Kassam, A. H. 1986
Yield Response to water , FAO Irrigation and Drainage Paper 33, Rome

FAO, Rome
1995 Irrigation and Drainage Paper 53, Environmental Impact Assessment of Irrigation and Drainage Projects
1989 Richard Carter (ed), NGO Casebook on Small Scale Irrigation In Africa
1989 Irrigation and Drainage Paper 45, Guidelines for Designing and Evaluating Surface Irrigation Systems
1986 Irrigation and Drainage Paper 33, Yield response to water

1977 Irrigation and Drainage Paper 24, Crop water Requirements
1974 Irrigation and Drainage Paper 25, Effective Rainfall

Government of Kenya
1986 Scheme identification and evaluation
1992 Loan scheme for group based Smallholder Irrigated Horticultural Production in Kenya
1990 Profitability of Smallholder Irrigation in Kenya (1 and 2)
1986 Scheme Identification and Evaluation - section 2

Hansen, V E, et al, 1979
Irrigation Principles and Practices, John Wiley and Sons

Hooff, I van, 1990
Irrigation planning for women: The planning process of Jahaly Pacharr in the Gambia, contribution to design for sustainable farmer managed irrigation schemes in sub-Saharan Africa, Wageningen Agricultural University.

HR Wallingford, Wallingford UK
Socio-economic parameters in designing small irrigation schemes for small scale farmers: Case studies

1990	Nyanyadzi	OD/114-117
1991	Exchange	OD/121
1992	Kamlesa	ITM/35
1992	KwaKyai	ITM/36
1993	Gem Rae	ITM/41
1993	El Hammami	OD/TN 66
1994	Kangocho	ITM/45
1995	Mathina	ITM/47
1995	Mutunyi	ITM/50
1996	Kiguru	ITM/51

HR Wallingford, Wallingford UK
1992 DASCE (Design Analysis for Canal Sediment Extractors) Software User Manual
1992 DORC (Design of Regime Canals) Software User Manual
1992 DOSSBAS (Design of Sluiced Settling Basins) Software User Manual
1993 The ICID Environmental Checklist, ISBN 1-898485-01-1
1993 Vortex Vane Sediment Excluder : Field Verification of Design Procedure. OD 126
1993 Design Manual for Canal Sediment Extractors
1994 MIDAS (Modular Irrigation Design Aid Software) User Manual
1995 ENCHECK (Environmental Impact Assessment Software) User Manual

Hulsebosch, J. 1990
Wachamos Mchele: A labour inputs Study in a Small-Scale rice scheme in Kenya,
Department of Tropical Agriculture, Wageningen Agricultural University , The Netherlands

ICID, 1996
Checklist to Assist Preparation of Small-Scale Irrigation in Sub-Saharan Africa, International Commission on Irrigation and Drainage.

Ingle-Smith, David and Stopp, Peter, 1978
The River Basin: An Introduction to the Study of Hydrology, Cambridge University Press, ISBN 0-521-29307-3

Jensen, M E, 1983
Design and Operation of Farm Irrigation Systems, American Society of Agricultural Engineers

Kay, Melvyn, 1993
Surface Irrigation: Systems and Practice, Cranfield Press

Kay, M, 1983
Sprinkler Irrigation : Equipment and Practice. Batsford Academic and Educational Ltd. ISBN 0 7134 1229 1

Laar, A van de, 1994
Working Paper Series No. 169, Irrigation, Evaluation, Performance measurement and Trade-offs Between Production, Efficiency, and Equity in Irrigation Investment Strategies. Institute of Social Studies UK, Management of Common Pool Resources Project, Discussion Note 14

Lange, Marna de, 1994
Small Scale Irrigation in South Africa, Murray Biesenbach and Badenhorst Inc., South Africa Water Research Commission (WRC), Pretoria, South Africa

Molden D. J. and Gates T. K. 1990
Performance measures for Evaluation of Irrigation-Water-Delivery Systems, ASCE Journal of Irrigation and Drainage Engineering, November 1990

Moris, J and Thom, D J, 1985
An Overview of African Irrigation, USAID, Water Management Syntheseis Project II, Report 37

Rihal, S, 1994
Performance Evaluation in Small Scale Irrigation Schemes in Kenya. ENGEES, Strasbourg, France.

Rousseau J G and Bembridge, T, 1993
Aspects of the Impact of Imposed Technology in the Neavee Irrigation scheme in Transkei, Development Southern Africa 10 (4) : 535-547

Rouxel, J-M, 1995
Socio-economic Parameters in Assessing the Performance of Small Scale Irrigation Schemes in Kenya, ENGEES, Strasbourg, France.

Seckler, D (ed), 1993
Agricultural Transformation in Africa. Winrock International. ISBN 0-933595-77-8

Smallholder Irrigation Development Project, SIDP, Ministry of Agriculture, Government of Kenya
1986 Manual for Scheme Identification and Evaluation
1986 Manual for Scheme Design
1986 Manual for Design of Structures

1989 Smallholder Irrigation Manual (Ministry of Agriculture, the Netherlands)
1990 Atlas of Irrigation
1990 Evaluation of Small Scale Irrigation Development Project

Publications available from the Irrigation and Drainage Branch of the Ministry of Agriculture, Livestock development and Marketing, PO Box 30028, Nairobi, Kenya

Simon, A L, 1981
Practical Hydraulics. John Wiley and Sons. ISBN 0 471 05381 3

Smallholder Irrigation Support and development Organisation (SISDO) 1993
Financial Assistance to Farmers for Smallholder Irrigation Development. SISDO, PO Box 76622, Nairobi, Kenya

Smedema, L K and Rycroft, D W 1983
Land Drainage : Planing and Design of Agricultural Drainage Systems. Batsford Academic and Educational Ltd. ISBN 0 7134 3500 3

Stern, Peter, 1980
Small Scale Irrigation, Intermediate Technology Publications Ltd, ISBN 0-903031-64-7

Ubels, J and Horst, L, 1994
Towards interactive Irrigation Design, Agricultural University of Wageningen, Nieuwe Kanal, Wageningen, Netherlands

Upton M 1987
African Farm Management
Cambridge University Press, ISBN 0-532-32842-X

United Sattes Bureau of Reclamation (USBR)
1965 Earth Manual
1974 Design of Small Canal Structures
1974 Design of Small Dams

United States Department of the Interior, Bureau of Reclamation.

Withers, Bruce and Vipond, Stanley, 1980
Irrigation Design and Practice,
Batsford Academic and Educational Limited

Matrices

Summary matrix 1: Scheme characteristics and performance

	Exchange	Nyanyadzi	Hamammi	Gem Rae	Kamleza	Kwa Kyai	Mathina	Kangocho	Kiguru	Mutunyi	Kibirigwi	Arombo	New Mataro
General													
Scheme size (ha)	165	423	330	90	314	110	100	48	60	100	114	30	135
Number of famers	850	430	650	230	200	226	300	100	60	220	272	66	190
No. farmers / block	100	100	10	90	15	22	50	20	-	70	11	20	15
Average farm size (ha)	0.2	0.9	0.5	0.3	1	0.4	0.25	0.5	1	0.5	0.4	0.3	0.4
Contiguous irrigation	No	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes
Land tenure	Tenants	Tenants	Owned	Owned	Owned	Owned	Owned	Owned	Owned	Owned	Owned	Owned	Owned
Settlement / consolidation	Yes	No	No	Yes	Yes	Yes	Yes/No	No	Yes	No	No	Yes	Yes
Construction / rehab funding	GoZ	GoZ	USAid / GoE	GoK	GoK	GoK	GoK	GoK	GoK / farmers	-	GTZ / GoK	Farmers	EU / GoK
Farmers / km main canal													
Farmers / km distributary canal													
Climate	Semi-arid	Semi-arid	Arid	Semi-humid	Semi-arid	Arid	Trans.	Sub-humid	Trans.	Arid	Sub-humid	Semi-humid	Semi-arid
Soil type	Sand/loam	Mixed	Sandy	Clay	Mixed	Sand/loam	Mixed	Mixed	Mixed	Sandy	Mixed	Clay	Sand/loam
Topography	Flat	Flat	Flat	Flat	Flat	Steep	Flat	Steep	Steep	Flat	Flat	Flat	Mixed
Water source	Dam	River	Canal	River	Spring/dam	River	River	River	River	River	River	Canal	River
Percentage cash crop	50		60	60	60	75	80	90	65	40	70	60	50 ?
Accessibility to market	Very poor	Very good	Very good	Good	Poor	Poor	Fair	Good	Fair	Very poor	Good	Good	Very poor
All-weather access	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
Irrigation infrastructure													
Gravity / pump fed	Pumped	Gravity	Pumped	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity	Gravity
Distribution method	Canal	Canal	Piped	Canal	Canal	Canal	Canal	Canal	Piped	Canal	Piped	Canal	Canal
Rotation / continuous supply	Rotation	Rotation	Rotation	Continuous	Rotation	Rotation	Continuous	Rotation	On-demand	Continuous	On-demand	Continuous	Continuous
Application method	Surface	Surface	Surface	Surface	Surface	Surface	Mixed	Mixed	Sprinkler	Surface	Sprinkler	Surface	Surface
Basin / furrow application	Furrow	Furrow	Furrow-basins	Basin	Mixed	Furrow-basins	Mixed	Mixed	-	Mixed	-	Basin	Mixed
Lined canals	Lined	Mixed	Lined	Unlined	Unlined	Mixed	Mixed	Unlined	-	Unlined	-	Unlined	Unlined
Proportional division	No	No	No	Yes	No	No	Yes	No	No	Yes	No	Yes	Yes
O & M													
Agency / farmer managed	Agency	Agency	Agency	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Agency	Farmer	Farmer
Maintenance performance	Good	Fair	Fair	Poor	Good	Good	Poor	Poor	Good	Fair	Good	-	Good
Extension availability	Very good	Fair	Poor	Poor	Poor	Good	Poor	Very poor	Good	Fair	Good	Good	Very good
Effective participation	Very good	Good	Very poor	Poor	Fair	Good	Good	Very poor	Very good	Good	Good	Fair	Very good
Percentage work by women	33	None	None										
Percentage women on committee	50	0	0	0	0			0	11	20	0		
Finance													
Credit use (note 1)							15	23	7	18	12	47	0
Importance of irrigation (note 2)	28	38		30	17	(Note 4) 100	33	23	85	51	55	21	20
Limitations													
Soil	Some	None	Some	None	Some	None	None	None	None	None	None	None	None
Water supply	None	Severe	Some	None	None	None	Severe	Some	Some	Some	None	None	None
Diminishing water supply	None	Some	None	None	None	None	Severe	Some	Some	None	None	None	None
Infrastructure design	None	Some	Some	None	None	Some	None	Some	None	Severe	None	None	Some
Maintenance	Some	Some	Some	Some	None	None	Some	Severe	None	Severe	None	None	None
Operation	None	None	Some	Some	Severe	Some	Severe	Severe	None	None	None	None	None
Drainage	Severe	Some	Some	Some	Severe	None	None	None	None	None	None	None	None
Marketing	Some	None	None	None	Some	Severe	Some	None	Some	Severe	Severe	None	Severe
Labour	None	Some	Some	Some	Some	Some	None	Some	None	None	None	None	None
Performance indicators													
Sustainability (note 3)	100	80	60	95	75	100	50	50	100	100	100	100	100
Adequacy of supply	Good	Poor	-	Good	Good	Fair	Fair	Fair	Fair	Poor	Good	Good	Good
Equity of distribution - main system	Good	Poor	-	Fair	Poor	Poor	Very poor	Very poor	Fair	Fair	Good	-	Fair
Scheme efficiency (%)	62	40	-	49	29	52	46	48	59	45	56	-	46
Irrigated net income per farm	472	1676	1073	2474	5609	32000	8618	29120	50554	31220	11500	10100	11460
Irrigated net income per ha	2360	1862	2044	3534	7000	48600	23640	67550	67490	52030	28750	33656	19100
Irrigated net income per ha (1992/93 KSh)	-	-	-	3535	7000	48600	12765	36480	36445	28095	11025	12905	7350
Irrigated net income per worker	621	564	-	785	2000	11854	7164	16083	18747	9817	8214	6010	4548
Irrigated net income per m3 water	0.04	-	-	0.14	0.18	1.69	0.39	1.25	0.84	1.14	0.3	-	0.47
	Exchange	Nyanyadzi	Hamami	Gem Rae	Kamleza	Kwa Kyai	Mathina	Kangocho	Kiguru	Mutunyi	Kibirigwi	Arombo	New Mataro

Notes:
1. Percentage of farmers making credit repayments
2. Percentage of farm income from irrigation
3. Percentage of design area currently irrigated
4. Irrigated income supported losses in dryland and livestock

Summary matrix 2: Socio-economic parameters and economic performance

	Exchange	Nyanyadzi	Hamammi	Gem Rae	Kamleza	Kwa Kyai	Mathina	Kangocho	Kiguru	Mutunyi	Kibirigwi	Arombo	New Mataro
Labour													
Household size	8.5	9	-	5	7.3	8.2	5.1	6.5	6.8	7.4	5.3	5.6	6
Workers per irrigated ha	3.8	3.3	-	4.5	3.5	4.1	3.3	4.2	3.6	5.3	3.5	5.6	4.2
Percentage female work	80	46	-			56	53	38	36	50	52	63	53
Percent literate	65	80	-		77		59	80	54	68	78	75	86
Irrigated area per person	0.02	0.10	-	0.14	0.11	0.08	0.08	0.06	0.10	0.08	0.11	0.05	0.10
Irrigated crops													
Average area irrigated per farm	0.2	0.9	0.5	0.7	0.8	0.68	0.4	0.38	0.7	0.6	0.6	0.3	0.6
Average number of crops cultivated	2	3	5	1	5	6	5	5	6	6	5	1	5
Percentage cash crops	100		95	100	54	75	75	85	80	37	70	100	60
Percentage sold	100		95		85	80	80	100	95	87	94	69	87
Percentage farms using credit			-				15	23	7	18	12	47	0
Input costs			1185				5905	6150	13676	4729	4826	1406	4688
Revenues / costs	2.5	4.2	1.7		1.7	7.2	2.3	5.2	4.2	6.7	5.1	5.6	4.8
Extension visits per year	6		-			10	2	2	4	3	3	3	22
Markets													
Access	Poor	Good	Good	Good	Poor	Good	Good	Excellent	Good	Fair	Good	Good	Poor
Cost	High	Low	Low	Low	Low	High	Low	Low	Low	High	Low	Low	-
Price / average Kenya price			-	Average	Below	Fluctuates	Below	Above	Above	Above		Average	-
Specific issues	Low profits	Contracts Variability	High costs		Price fluctuations	Crop disease Lack of credit Powerful market	Price fluctuations	Crop disease	Co-op Grading shed	Remoteness	Agency / market	Labour shortage	Wholesalers
Management													
Principal actor	Agency assisted	Agency	Agency	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer	Farmer / agency	Agency	Farmer
Farmer participation	High	Poor	Poor	Poor		High	Adequate	Fair	Fair	Fair	0.35	1	0.43
Committee gender balance (f:m)	50 : 50	0 : 100	0 : 100	0 : 100	0 : 100			0 : 100	11 : 89	20 : 80	0 : 100		
Performance of committee	Good	Poor	Poor			Good	Poor	Poor	Good	Good	Poor	Fair	Good
Specific issues	Marketing Inputs Drainage	Inequity Maintenance	Mistrust	Sediment Maintenance	Water control Drainage Equity	Inequity Construction Marketing	Inequity High losses Shortage	Inequity Maintenance	Water short	System losses Maintenance	Agency	Agency conflict	Long laterals
Conflicts													
Environmental	Drainage	-	Drainage	Degradation	Flooding / salt	Drainage	Drainage	Flooding	Erosion	-	-	-	Flooding
Agricultural	Low value crops	-	-	Low yields	Failure to plant	Prices	-	Water control	-	Water shortage	Low value crops	-	-
Resource	-	Water short	-	-	Water	-	Water availability	Water	Water rights	-	-	-	-
Social	-	-	-	-	-	-	Inequity	-	-	-	Agency conflict	Agency conflict	-
Irrigated net income													
Per farm (local currency)	472	1676	1073	2474	5609	32000	8618	29120	50554	31220	11500	10100	11460
Per farm (1992/93 KSh)	-	-	-	2475	5610	32000	4650	15740	27330	16880	4420	3880	4408
Per farm (1992/93 US$)	189	671		91	204	1162	169	574	945	616	160	141	134
Per ha (local currency)	2360	1862	2044	3534	7000	48600	23640	67550	67490	52030	28750	33666	19100
Per ha (1992/93 KSh)	-	-	-	3535	7000	48600	12765	36480	36445	28095	11025	12905	7321
Per ha (1992/93 US$)	945	995	-	130	255	1765	465	1330	1260	1025	400	470	222
Per worker (local currency)	621	564	-	785	2000	11854	7164	16083	18747	9817	8214	6012	4548
Per worker (1992/93 KSh)	-	-	-	785	2000	11854	3870	10390	10120	5300	3150	2300	1749
Per m3 water (1992/93 KSh)	0.04		-	0.14	0.18	1.69	0.39	1.25	0.84	1.14	0.3	-	0.47
Farm income													
Cultivated dryland net income	460	115	-	34	-2089	-3980	948	93206	6301	1225	1850	7798	1500
Livestock net income	332	200	-	3681			-322	-1532	-2073	1480	-2450	4712	4100
Total agricultural income	1264	1991	-	6189	3520	28020	9244	120794	54782	33925	10900	22610	17060
Non-agricultural income													
Employment income			-	120				0	960	16522	2968	15580	7000
Business income			-	850		0	11260	3833	3733	10632	6128	4260	5300
Other remittances	420	107	-	1203	29182		5468	1244	167	698	1104	611	7000
Total farm income	1684	2098	-	8362	32702	28020	25972	125871	59642	61777	21100	43061	36360
Household costs	850		-	9840	5339	7300	20528	32600	28811	21764	27500	31463	26500
Net farm surplus (local currency)	834	2098	-	-1478	27363	20720	5444	93271	30831	40013	-6400	11598	9860
Net farm surplus (1992/93 KSh)	-	-	-	-1479	27368	20720	2937	50415	16668	21634	-2460	4455	3792
Net farm surplus (1992/93 US$)	-	-	-	-54	999	756	107	1840	608	790	-90	163	138
% income from irrigation	28	80	-	30	17	100	33	23	85	51	55	23	32
	Exchange	Nyanyadzi	Hamami	Gem Rae	Kamleza	Kwa Kyai	Mathina	Kangocho	Kiguru	Mutunyi	Kibirigwi	Arombo	New Mataro

Summary matrix 3: Irrigation system performance indicators

	Exchange	Nyanyadzi	Hamammi	Gem Rae	Kamleza	Kwa Kyai	Mathina	Kangocho	Kiguru	Mutunyi	Kibirigwi	Arombo	New Mataro	
Scheme characteristics														***Scheme characteristics***
Water source	Dam	River	Canal	River	Spring	Spring / dam	River	River	River	Spring	River	Canal	River	Water source
Application method	Surface	Surface	Surface	Ponded basin	Surface	Basin	Surface	Basin/sprinkler	Sprinkler	Surface	Sprinkler	Ponded basin	Surface	Application method
Distribution method	Canal	Canal	Pipe	Canal	Canal	Canal	Canal	Canal	Pipe	Canal	Pipe	Canal	Canal	Distribution method
Crop water requirement (mm)			1600	1290	998	1685	1675	1495	2365	2510	1590		1610	Crop water requirement (mm)
Rainfall (mm)	632		0	310	357	520	450	630	800	550	1120		815	Rainfall (mm)
Potential rainfall contribution			0	0.24	0.36	0.31	0.27	0.42	0.34	0.22	0.70		0.51	Potential rainfall contribution
Depth of irrigation water supplied (mm)			550	1729	2076	1466	1776	1570	3051	1029	2592		1803	Depth of irrigation water supplied (mm)
Supply														***Supply***
Scheme		1.45	0.32	1.34	2.08	0.87	1.06	1.05	1.29	0.41	1.63	Good	1.12	Scheme
Head		1.89	-	0.62	1.98	1.37	3.29	2.04	0.73	0.37	0.87	"	1.57	Head
Middle		1.23	-	1.55	1.38	0.47	0.58	1.16	2.05	0.59	1.36	"	1.07	Middle
Tail		1.23	-	2.29	0.54	0.45	0.40	0.00	1.20	0.75	2.95	"	1.02	Tail
Adequacy														***Adequacy***
Scheme		-	0.32	0.86	1.00	0.81	0.77	0.84	0.84	0.41	0.97	Good	0.86	Scheme
Head		-	-	0.60	0.91	0.89	0.94	1.00	0.53	0.37	0.74	"	0.86	Head
Middle		-	-	0.92	0.96	0.46	0.47	0.85	0.99	0.55	0.88	"	0.80	Middle
Tail		-	-	0.75	0.50	0.43	0.37	0.00	0.82	0.67	0.99	"	0.85	Tail
weeks with > 75% adequate supply		-	-	21	52	25	30	31	35	4	50	-	36	weeks with > 75% adequate supply
weeks with > 50% adequate supply		-	-	2	0	17	8	13	14	4	2	-	11	weeks with > 50% adequate supply
weeks with < 50% adequate supply		-	-	4	0	10	14	8	3	44	0	-	5	weeks with < 50% adequate supply
Dependability		Poor	Fair	Fair	Good	Fair	Poor	Fair	Fair	Poor	Good	Good	Fair	Dependability
Equity of distribution		Poor	Good	Fair	Very poor	Poor	Very poor	Very poor	Fair	Fair	Good	Good	Fair	Equity of distribution
Efficiency														***Efficiency***
Scheme		0.40	0.40	0.49	0.29	0.52	0.46	0.48	0.59	0.45	0.56	-	0.46	Scheme
Head block		0.38	-	0.69	0.40	0.45	0.28	0.34	0.70	0.60	0.74	-	0.41	Head block
Middle block		0.38	-	0.48	0.56	0.59	0.56	0.50	0.46	0.60	0.62	-	0.50	Middle block
Tail block		0.56	-	0.44	0.58	0.59	0.59	-	0.67	0.57	0.40	-	0.53	Tail block
Measured application efficiency		-	0.50	-	0.52	0.57	0.59	0.59	0.74	0.59	-	-	-	Measured application efficiency
Measured conveyance efficiency		-	0.92	-	-	-	-	-	-	0.65	-	-	0.90	Measured conveyance efficiency
Sustainability														***Sustainability***
Scheme		0.90	1.00	1.00	0.80	0.95	0.50	0.60	1.00	0.90	1.00	1.00	1.00	Scheme
Head		-	-	1.00	1.00	1.00	1.00	0.90	1.00	0.90	1.00	1.00	1.00	Head
Middle		-	-	1.00	1.00	1.00	0.90	0.90	1.00	0.90	1.00	1.00	1.00	Middle
Tail		-	-	1.00	0.60	0.70	0.10	0.00	1.00	0.90	1.00	1.00	1.00	Tail
Economic performance														***Economic performance***
Irrigated net income per farm	472	1676	1073	2474	5609	32000	8618	29120	50554	31220	11500	10100	11460	Irrigated net income per farm
Irrigated net income per ha	2360	1862	2044	3534	7000	48600	23640	67550	67490	52030	28750	33656	19100	Irrigated net income per ha
Irrigated net income per ha (1992/93 KSh)	-	-	-	3535	7000	48600	12765	36480	36445	28095	11025	12905	7350	Irrigated net income per ha (1992/93 KSh)
Irrigated net income per m3 water	0.04	-	-	0.14	0.18	1.69	0.39	1.25	0.84	1.14	0.30	-	0.47	Irrigated net income per m3 water
Total farm income	1684	2098	-	8362	32702	28020	25972	125871	59642	61777	21100	43061	36360	Total farm income
% income from irrigation	28	80	-	30	17	100	33	23	85	51	55	23	32	% income from irrigation
	Exchange	Nyanyadzi	Hamami	Gem Rae	Kamleza	Kwa Kyai	Mathina	Kangocho	Kiguru	Mutunyi	Kibirigwi	Arombo	New Mataro	