EFFECTS OF FARMER-INITIATED MODIFICATIONS OF WATER CONTROL STRUCTURES ON PERFORMANCE OF IRRIGATION SYSTEM: A CASE STUDY OF MKINDO SCHEME, MOROGORO, TANZANIA

BY

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ABSTRACT

A study to assess the effects of farmer-initiated modifications of water control structures on the performance of the irrigation system in Tanzania was carried out at Mkindo farmer managed irrigation scheme (FMIS) in Morogoro region. The scheme had two phases. The changes made on the original water control structures were assessed, the performance of the existing water distribution system, and the effect of the existing water control structures on performance of the irrigation system was evaluated.

The result of the study shows that changes were made by farmers on the original design of already constructed water control structures in the scheme as follows: some of the field canals and the original centrally located field drains were removed by farmers in order to increase irrigable area (bigger utilised land area). Therefore, some farmers were doing field-to-field irrigation method; the main drainage for phase-I has been converted to field irrigation canal by nearby farmers; dimension of existing paddy field earth bunds and secondary canal banks were smaller than original ones; water harvesting from main and secondary canal by farmers outside the scheme exists and no water control gates (wooden stop-logs originally provided) exists at division box openings and at turnout level for the scheme.

Applicable indicators for the performance of FMIS are quantified as follows:-Overall irrigation efficiencies were 6% and 8.3% for phase-I and phase-II of the scheme respectively: Average productivity dropped from 6.6 ton/ha in 1995/96 to 3.1 ton/ha in

1998/99 season. The organisation of Mkindo FMIS was appropriate, however, the scheme was weak in irrigation management as the essential operation and maintenance activities were not carried out effectively. The scheme had canal maintenance problem. There was a corresponding big error in water adequacy of 72% and 68% for both phase-I and phase-II of the scheme respectively arising from improper water control along the main canal and at secondary canal offtake. Both phase-I and phase-II of the scheme were not able to distribute water equitably, reliably as well as maintaining a correct field water depth from tilling to flowering and grain formation stage. This was shown by relatively high error of equity of 18% and 20% for both phases respectively. These figures are far greater than zero, which is the indicator for highest performance.

Therefore, the FMIS in Tanzania may perform better, or be sustainable, if original design of already constructed water control structures are maintained (i.e. not changed) by farmers at operation stage. This emphasises farmer's involvement and empowerment at planning, design and construction stages of the scheme.

DECLARATION

I, JOHN MAGOROMBE MATIKU, do declare to the senate of Sokoine university of agriculture that this dissertation is my original work and that it has never been submitted for a degree in any other university.

Signature: ----------------------

Date: 13-10-2000

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DEDICATION

To my wife Mary C, my son Dickson, and my daughters, Jane, Vaillet and Flora who were patient with me at the time of undertaking this study.

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LIST OF ABBREVIATIONS

ANOVA Analysis of Variance

DIWS Dependability of Irrigation water Supply

FAO Food and Agriculture Organisation of the united nations

FMIS Farmer Managed Irrigation Schemes

GMIS Government Managed Irrigation Schemes

IFAD International Fund for Agriculture development

JICA Japanese International Co-operation Agency

NAEP-II National Agriculture Extension Program-II

NAFCO National Agriculture and Food Corporation

NBC National Bank of Commerce

WUA Water Users Association

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background Information

Tanzania's economy depends mainly on Agriculture (Ministry of Agriculture and Co-operative, 1997). However, due to unreliability of rainfall in climatically marginal areas, promotion of irrigation development in Tanzania has been set up so as to supplement crop water requirements. Therefore, development of extension services on irrigated farming technology for water users is essential to the agricultural development. The essence of agricultural development strategy has been advocated by Ministry of Agriculture and Co-operative (1997) in order to achieve National food security through increasing farmers' productivity and income.

The Government of Tanzania in co-operation with international donor agencies has designed and executed several small-scale farmer-managed irrigation systems (FMIS) aiming at improving irrigation water supplies. The designs were done for new schemes or for existing schemes that needed to be rehabilitated. However, in order to ensure that the set irrigation objectives are met, improvements were necessary in the management of irrigation water supply. To date, 80% of irrigation schemes are farmer-managed while, 20% are managed by the Government (Masija and Kagubila, 1994). Similarly, Ministry of Agriculture and Co-operative (1997) reported FMIS of 125,000 ha out of 150,000 ha (83%) and Government institutions practising irrigated agriculture such as

National Agriculture and Food Corporation (NAFCO) under Paddy and sugar companies, under Sugar Development Corporation of 25,000 ha (17%).

The objectives of irrigation system can be "output", "impact", and management (Manor and Chambonleyron, 1993). The output objectives are associated with functions of irrigation system and measured with reference to maximum utilisation of available resources. The impact objectives are directly related to agricultural productivity of the system. This is indicated by intensity of cultivation, level of production, increased land productions and farmers' income while the management objectives is to ensure the set irrigation objectives and the mentioned two are met. Therefore, the immediate step to effect such improvements at scheme level requires the installation of water control structures, since irrigation performance is the degree to which an irrigation system achieves its objectives. The subject of water control enjoys a wide coverage in irrigation literature. Manzungu (1999) has identified three dimensions of water control. First, it is used to refer to physical control of water flow by means of irrigation technology, with emphasis on different methods of technical control of water. Second, from the irrigation management perspective, water control refers to managerial control of water distribution and related organisational issues. Third, water control refers to political control dealing with how power is wielded over access and utilisation of water. The present study focussed water control from the three 'dimensions' point of view.

Abernethy (1986) has cautioned that proper study to identify areas needing improvements and support should be carried out before any intervention is made. In most developing countries, especially Sub-Saharan Africa, irrigation engineers observe that farmers are suffering from shortage of water mostly because of its unavailability and lack of skills to make it available at the time and place required (Baban, 1995).

According to Mnzavas and Makonta (1994) irrigation development in Tanzania has gone through in three stages. First, the government of Tanzania imposed smallholder irrigation practice. The small-scale farmer-managed/smallholder irrigation schemes are schemes less than 400 ha while large scale farmer- managed schemes are schemes more than 400 ha. The second was the large-scale practice in which only Government was involved in irrigation development. In all these stages, farmers did not participate in their planning, design, and construction. Also, responsibilities of farmers for operation and maintenance of schemes were not clearly defined. Therefore, their chances of adopting modern irrigation technologies were limited. Their irrigation practices remained at traditional level (i.e. modern irrigation technologies were not adopted by farmers in their fields). Although a large amount of funding had been allocated to Government-Managed Irrigation Schemes (GMIS) in Tanzania, their performance remain low (FAO, 1990). Due to poor performance of irrigation schemes, the Government (as the last resort for irrigation development) is currently emphasising development of FMIS as means to attain a sustainable irrigated agriculture (FAO, 1990). The GMIS such as Bugwema, Mbarali, etc. are those in which principal management responsibilities are carried out by government with farmers playing a subsidiary role while FMIS are those in which farmers play the principal role with the government playing a subsidiary role. The GMIS were established to ensure national food security and economic growth while the establishment of FMIS aimed at increasing farmers productivity (Ministry of Agriculture, 1983).

Evaluation of irrigation systems is useful in helping farmers attain greater efficiency in irrigation. Hence, evaluation may lead to better design criteria to suit the farmer's management ability. Inefficiencies in irrigation systems are common particularly in developing countries. Cheong and Lim (1971) found that farmers tend to apply more water per unit area than needed, especially when water supply is abundant. These leads to several problems including low efficiencies, reduced crop yield, water logging and salinity.

It has been realised that lack of farmers participation in planning, design and construction usually results in location of canals and other control structures which do not correspond to farmer's needs (IIMI, 1990). As a result these structures are abandoned or modified by farmers. The changes made by farmers on the original technically designed water control structures sometimes may end up to low water distribution efficiency. Since the changed structures may not perform as planned. The ultimate result of the low efficiency may lead to abandonment of the scheme (IIMI, 1990).

It was reported by Yoder (1995) that the selection of most suitable type of water control structures such as turn out, distribution boxes, etc must take into consideration, among other factors, the operation and maintenance costs of the structure. The chosen design must be flexible to accommodate farmers' requirements, otherwise the farmers will have no alternative but to modify the structures by breaking it (Ford Foundation, 1995). This is due to the fact that farmers do not have the knowledge of operating and maintaining them.

A report by Neupane (1995) states that in order to distribute water from the main canal to the secondary canals or field channels in irrigation systems, farmers often make simple cuts on the side of the canal for water to flow through. They regulate the flow from the main canal by inserting stones or mud from the canal bank into the cut. The continuous flowing stream through the cuts can widen the cross section and result in excess flow at the head reach and diminished the flow at the tail end. The discharge through the cut is difficult to estimate since any irrigator can freely open a cut of any size, causing wastage of a considerable volume of water. This causes scarcity at the tail end, which brings about inequity in irrigation water distribution, and thus conflict among the irrigators.

In irrigated rice in monsoon Asia, Burns (1993) reported that Japan, Korea, Taiwan and to a certain extent China have been relatively successful at making their wet-rice irrigation systems work. While India, Bangladesh, Thailand, Indonesia, Malaysia, the Philippines and others have had tremendous problems in making their systems work as designed. The reasons for this difference in performance, and the question whether it is relevant if a public irrigation system works as the designers intended, are as follows:- In areas with monsoon; rice is planted in the wet season with the assumption that the rainfall is generally adequate. Sporadic wet-season drought generates sporadic demand for irrigation, a demand that cannot always be met. This leads to destruction by farmers of their own irrigation systems in a desperate attempt to extract water from the system and save growing crops. Desert irrigation systems are easier to design and less troublesome to operate because the irrigated area is well defined by the amount of water available, rainfall-dependent standing crops are absent and all farmers are acutely aware of their water allocation and rights. Structuring the monsoon systems to formalise the allocation of sporadic wet-season scarcity, while protecting the civil works from farmer damage, is an unpleasant but necessary task. If this is not done, the rent-seeking activities of system designers, operators and individual farmers will continue to insure that actual system performance bears little resemblance to design intentions (Burns, 1993).

1.2 Purpose and objective of study

The development of the farmer managed irrigation system is currently emphasised in Tanzania. However, no study has been carried out to investigate the factors and conditions that led water users to change the already constructed water control structures the way that seems to suit them. In Tanzania farmers do change original constructed water control structures e.g. at Mkula, Mkindo, etc. This situation has led to poor level of performance of most of FMIS which has led into decline in crop production, deterioration of systems as some times noted in Mkindo and Mkula schemes (FAO, 1987).

In Tanzania, the existing developed systems normally use water control structures such as turnouts, steel gates, stop-logs and others to distribute water among the farmers. These structures are complex to farmers as pertaining to their operation and maintenance and have one distinct disadvantage, that is they need to be regulated every now-and-then. This phenomenon normally brings about conflicts among the irrigators or these structures are modified by irrigators. Ambler (1995) reports that when these conflicts are not attended for, they may result into damages of both irrigation water control structures and property. To solve this problem, it is important to use technical approach that uses simple technology that may be easily understood and practised by water users.

Basing on the above outlined literature, it can be realised that much has been done on the performance of water control structures in water distribution in irrigation system. However, little systematic research has been carried out in this field of assessing the effects of farmer-initiated modifications of water control structures on the performance of the irrigation system in Tanzania.

1.3 Objective of the study

The main objective of this study was to assess the effects of farmer-initiated modifications of water control structures on the performance of the irrigation system. A case study of Mkindo irrigation scheme in Tanzania.

The specific objectives of this study were: -

(i) To assess changes made on the original water control structures in Mkindo irrigation scheme by water users,

(ii) To evaluate the performance of the existing water distribution system,

(iii) To evaluate the effect of the existing water control structures on performance of the irrigation system.

Results of this study would set the stage for seeking appropriate approach for design and construction of future irrigation systems.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction.

This chapter reviews the literature including theories and background of performance of irrigation systems. The background is drawn from irrigation engineering, agriculture and socio-economic disciplines. Therefore it forms the basis for the methodology and analysis of this study.

2.2 Performance of irrigation schemes

There is a general awareness that, farmer-managed irrigation systems (FMIS) in many countries contribute to the production of a significant portion of the subsistence food supply, if irrigation infrastructures were made available (Manor and Chambonleyron, 1993). Governments world-wide have focused their attention on the development of irrigation systems as a means of attaining self-sufficiency in food. However, several approaches have been employed by various agencies in the development of irrigation system. One such technique is the participatory approach in which farmers are fully involved in planning, design and construction of the systems. Lack of farmers' participation results in a host of problems during operation stage. Proposals on design of any farmer managed irrigation scheme should in-fact be presented, discussed and agreed up with farmers. Madeley (1987) cited that aided projects tend to perform badly due to lack of consultation with the beneficiaries.

In the process of transferring irrigation management from the government to farmers, the agencies have to intervene to help farmers conduct irrigation activities in a better way. Martin *et.al.*, (1986) pointed out the need to have basic information before any intervention is undertaken to help farmers. Emphasises was made on the need to know how farmers manage their systems and by that identify the needed intervention. Some of the aspects mentioned are activities that are directly associated with water distribution and organisation of the water users. The need to evaluate water flow parameters such as efficiency, adequacy, equity and dependability were also stressed.

Designers and planners not only tend to assume that the objectives of governments and farmers coincide but also that farming households are homogeneous. The households are presumed to be headed by a male person who is responsible for the livelihood of the other members. It is also supposed that the benefits of irrigation are spread equally within the family and that households will devote all the available labour to irrigated agriculture working in collective manner (Dey *et.al.*, 1990). Based on these assumptions plot sizes are calculated. But many assumptions in the planning and design of irrigation projects have proven to be incorrect. For these reasons, actual plot use often differs from the profit maximisation model usually applied in irrigation planning and design.

2.3 Indicators of irrigation scheme performance

To know the performance of irrigation schemes; schemes are normally evaluated using some of the following indicators (Jensen, 1983; Manor and Chambonleyron, 1993): irrigation efficiencies; water delivery performance; Organisational form; productivity or output of agricultural product.

2.3.1 Irrigation efficiencies

The purpose of irrigation is to replenish the available moisture in the root zone depleted by evapotranspiration. However, in the irrigation process, water losses occur at different levels in irrigation systems (FAO, 1971). Water losses are normally expressed using irrigation efficiencies. These include: Conveyance, distribution and application efficiencies.

Conveyance efficiency

Conveyance efficiency (E_c) is the efficiency of water conveyance in the main canal system from the scheme head works to the main canal outlet or at inlet to block of fields. It is normally calculated as the ratio between water received at inlet to a block of fields and that released (diverted) at the project head works (intake) as shown in equation 1. It is normally affected by the canal length; seepage of the canal bed; lined or unlined; soil type and rate of evaporation. Conveyance efficiencies, in unlined canal ranges from 100% to 70% for areas with effective management and 70% to 0% for area with ineffective management. The conveyance efficiency is normally calculated as: (FAO, 1971).

$$E_c = (Q_d + Q_2)/(Q_c + Q_1) \quad (1)$$

Where: Q_1 = Discharge inflow from other sources (l/s)

Q_2 = Non-irrigation deliveries from conveyance system

Q_c = Discharge diverted from the river (l/s)

Q_d = Discharge delivered to the distribution system

E_c = Conveyance efficiency

Distribution efficiency (E_d)

The field canal distribution efficiency (E_d) is the efficiency of water conveyance in the canals within sectors, blocks or sub-unit. It may be the tertiary unit or the quaternary or even the sub-quaternary unit. It is expressed as the ratio between water received at field inlet and that received at the inlet of the block of fields. The distribution efficiency is calculated as: (FAO, 1971)

$$E_d = (Q_f + Q_3)/Q_d \quad (2)$$

Where: E_d = Distribution efficiency;

Q_f = Discharge furnished to the fields (l/s);

Q_3 = Non-irrigation deliveries from the distributor system;

According to Abdulmumin et al. (1990) distribution efficiency is classified as adequate if it lies within the range of 65% to 100%, sufficient in the range of 55% to 65%, insufficient in the range of 40% to 55%, and poor below 40%.

Application efficiency (E_d)

Application efficiency is defined as the ratio between water directly available to the crop and that received at the field inlet (applied in the field). Field application efficiency is calculated using equation 3 (Bos and Nugteren, 1982) as:

$$E_a = V_f / V_m \tag{3}$$

Where: E_a = Field application efficiency;

V_m = Volume of irrigation water furnished to the fields;

V_f = Volume of water needed for crop evapotranspiration.

The acceptable application efficiency for basin level borders range between 60% to 100% (FAO, 1971).

Overall scheme efficiency

Overall scheme efficiency (**E_p**) is expressed as the product of application efficiency, distribution efficiency, and conveyance efficiency. In surface irrigation systems, the overall irrigation efficiency should not be less than 45% (Abdulmumin *et al.*, 1990).

2.3.2 Water delivery performance

In the context of irrigation systems, the measure to analyse irrigation performance in terms of supplying water adequately, dependably and equitably is important (Oad and Sampath, 1991). Water being a scarce commodity but very important input for crop production should be well managed. For proper monitoring, the amount of water applied into the field should be measured. Such practice will help in judging whether water supply matches the predicted quantities or whether is distributed equally, adequately, and timely among different farmers in an irrigation system. Thampa and Banskota (1991) employed inter-quartile ratio (IQR) as the equity indicator. However, Abernethy (1991) reported that IQR was not a sufficient indicator of water distribution in irrigation canal systems. The IQR assesses the mode of distribution of water between the upstream and the tail end irrigators. However, even the irrigators in the middle are actually affected by the water distribution problem. However, Oad and Sampath (1991) related the measurement of water distribution parameters i.e. equity, adequacy, and dependability at any delivery point using the mean square prediction error theory. This method was observed to be useful in identifying the causes and the levels of low water management performance in the system. The mean square prediction error model is expressed as follows:

$$\frac{\sum_{1}^{x}(Q_{r(x)} - Q_{a(x)})^2}{R} = (MQ_r - MQ_a)^2 + (SQ_r - SQ_a)^2 + 2(1-r)(SQ_r)(SQ_a) \quad (4)$$

Where; MQ_r and MQ_a are arithmetic mean of the required and the actual delivered quantity of water over the region R in an irrigation system respectively.

SQ_r, SQ_a	=	Standard deviation of Q_r and Q_a
$Q_{r(x)}$, $Q_{a(x)}$	=	Required and actual quantity of water to be delivered at any point(x) in an irrigation system.
R	=	Number of points (x) where water is delivered in the system.
'r'	=	correlation coefficient of Qr and Qa and is calculated as follows (Oad and Sampath, 1991):

$$r = \frac{\sum_{1}^{x} \frac{(Q_{r(x)} - MQ_r)(Q_{a(x)} - MQ_a)}{R}}{(sQ_r)(sQ_a)} \quad \text{......................(5)}$$

The term $(MQ_r\text{-}MQ_a)^2$ is an error in water adequacy and is denoted by (Aer). The adequacy of irrigation water supply is a measure of reliability of supply and in turn, a measure of the quality of system operation. As a measure of reliability of supply adequacy is a good indicator of the water delivery system ability to deliver the amount of water required to meet farmers' irrigation water requirement (Sakthivadivel *et al.* ,1992).

The second term $(SQr-SQ_a)^2$ is the error due to unequal variation between the required and the actual amount of water delivered in the system and is denoted by(Eer). It measures the equity of water distribution in the system. Abernethy (1991) referred equity as a major feature of FMIS and can be defined as the delivery of a fair share of irrigation water to all irrigators in a fairly and just manner (Gates *et.al.*, 1991). Inequity of water distribution can occur within fields, between users of the same field channel or between the flow issued from the main system to distributaries or to the field channels. Some studies carried in Asia and Africa have shown that variation in water supply may be due to the nature of supply, design faults, poor maintenance of canals and drains, construction faults, lack of farmers participation during irrigation project development and management faults (Spleeman, 1990; Abernethy, 1986 and FAO, 1985, 1989).

The third term $2(1-r)(SQ_r)(SQ_a)$ is the error due to covariance between the actual and required amount of water and is denoted by (Cer). It measures the dependability of irrigation water supply in the system. Dependability of irrigation water supply (DIWS) may be defined as the supply of a fairly uniform quantity of irrigation water and in time throughout the irrigation system. As a performance indicator DIWS reveals the combined effect of reliability and predictability. It describes the arrival of right amount of irrigation water at given place in a given time. Therefore, DIWS is a good measure of a canal physical condition and management capability to implement an irrigation schedule pattern, which is a function of the capacity of the system and organisation procedures (Gates *et. al.* ,1991; Oad and Sampath, 1991 and Molden and Gates, 1990). The total error is equal to the sum of Aer, Eer and Cer and is equal to one. A zero error shows that the system has the highest order of performance.

2.3.3 Organisational form

Organisation of any irrigation system is an important indicator that determines its performance. Here, organisation may be defined as the design of any kind of social arrangements between individuals - regardless of whether they are farmers or government officials- to achieve a goal or a set of goals (Sagardoy, 1986). Any organisation has a form or structure. Whatever the form it must be developed so that each individual has a clear description of the authority, responsibility and accountability necessary for the intended work to proceed (Kerziner, 1992). According to Manor and Chambonleyron (1993), a well organised irrigation project maintain a good linkage between the top and the bottom management; it carries out operation and maintenance of activities effectively; it ensures that irrigation rules are complied with and that conflicts among farmers are well managed.

According to Sagardoy (1986), the qualities of a well organised project include: Water distribution activities, system maintenance, collection of water charges or similar charges, assistance and extension to farmers. Other services would include: Finance, agricultural and infrastructure. Furthermore, Ostrom and Benjamin (1991) described a theoretical framework that consists of predictors of a well functioning irrigation project. These would be the presence of clearly defined irrigation project boundary, fair proportion between benefits received and contribution made by each water user, collective decision making arrangements, accountable monitoring, gradual sanctions against rules violations, governmental recognition of farmers to organise and address different functions.

Abernethy (1991) reported that irrigation schemes, which were rehabilitated by government or donor assistance, farmer's ability to manage the schemes were reduced, thereby creating dependence on the implementing agency. Organisations started by governments were weak especially where they were not properly nurtured towards the independence. Other experience in Equador, where indigenous farmers organisation are common, shows that water management obeys social rules that do not fit with the actual situation, and that, in many cases prevent any evolution of productive systems.

Participation of farmers is seen as the key factor towards successful development in irrigation (FAO, 1986). But participation by itself does not remedy poor irrigation performance. There are other components that must be combined with such as capacity building of farmers and their irrigation association, development of proper altitudes of government irrigation personnel, adoption of appropriate policies by irrigation agency etc. (FAO, 1987). However, participation is the key to attaining sustained performance improvement because government itself cannot handle all tasks of irrigation development. However, it may facilitate the solution of other constraints.

Lack of appropriate methods and policies for motivating and training farmers in effective participation in irrigation development and management poses a basic problem. To this end, effective water users' associations are recommended. The formation of these organisations takes different forms depending on the environment they are to work. In whatever forms, the major functions of any water users' organisation remains the same and these include (FAO, 1985):

- Distribution of water between users
- Maintenance of canal system and related structures
- Fee and fine collections
- Resolving water disputes among farmers
- Involving farmers in decision making process
- Provision of an organised means for extension and farmer training
- Presentation of farmers' views to government agencies and water authorities
- Mobilisation of local resources (cash or kind) to construct, improve or maintain facilities.

In Africa setting three areas have been problematic in farmer management time and time again. These include achieving corporate identification and accountability on a non-kinship basis; managing money; and equipment shared between more than one operator (Speelman, 1990). Unfortunately irrigation schemes require fairly high level of proficiency in all domains. Expatriate staffed scheme management does not necessarily promote development due to lack of government funds and ineffective and top heavy bureaucracy. In due course institutional constraints generally come down to the need to delegate scheme management to water users association as much as possible. With regards to the three problematic domains mentioned water users association should be formed on the basis of traditional forms of co-operation. This is due to the fact that organisation of people involved in irrigation system is not implemented in a social vacuum. Preparatory studies should devote time and energy to finding and assessing what form of organisation will fit in the existing local network, given prevailing traditional forms of co-operation and mutual aid.

Oad and McCornick, (1989) reported that a systematic approach, which can be used to select or formulate methodologies for the study of irrigation system performance, called the reference methodology, was developed by analysing case studies of irrigation sector reviews, project papers and the diagnostic analysis workshops conducted in Kenya, Indonesia, Sri Lanka, India and Nepal. These studies of irrigation systems in developing countries were conducted through USAID's Water Management Synthesis Project. The reference methodology is based on the management concept that performance evaluation must begin with clear understanding of the system goals and objectives. Analyses of the case studies show that a primary goal of irrigation schemes should be to improve farmer welfare through increased agricultural production. The goal of improving farmer welfare can be achieved if schemes are managed according to a specific set of objectives. The research identified key management objectives to be: water control; agricultural productivity; resource conservation; and return on investment. These management objectives must be achieved within the context of effective organisational co-ordination and farmer participation (Oad and McCornick, 1989)

2.3.4 Productivity

Productivity is normally measured as a rate of production per unit area or unit volume of water used. The normal rate for the Kilombero rice variety which is grown at Dakawa Rice Farm 16 km from Mkindo irrigation scheme is 5 ton/ha (Halcrow and TANConsult, 1993). Saouma (1980) reported that the most successful, Mbarali Rice Farm irrigation scheme, has suffered declining yields over the past few years from an average of 7 to 4.5 ton/ha of paddy production. However, evaluation of irrigation system performance based upon crop yield per unit area do not reflect an adequate assessment of performance in water scarce environments; but yield per unit area is a complementary measure and more appropriate in areas where water is not a problem (Batti *et al.*, 1991). However, it has been reported that specific yield (weight of crop produced per unit volume of water issued) is widely used in place of yield per irrigated area (Weller *et al.*, 1989).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Introduction

This chapter describes the study area, the procedures and materials used in data collection and states the methods used in data processing and analysis.

3.2 Location

The study was conducted at Mkindo irrigation scheme, in Morogoro Rural District, Morogoro Region. Mkindo scheme lies North of Morogoro Municipality and is accessible by an all-weather road via Mvomero (80 km) and by dry season a short cut road via Dakawa (65 km). It is located between Latitude 6° 16 'and 6° 18' South, and between Longitude 37° 32' and 37° 36' East. The scheme area lies between Mkindo river in the North and Mgongola river in the South. Its altitude ranges from 345m to 365m above mean sea level (JICA, 1996). It forms a part of the extensive Mkata flood plain, which drains into Wami river and its tributaries (Fig. 3.1).

3.2.1 Description of the study area

Mkindo village irrigation scheme is a small holder irrigation development in Morogoro Rural District, which was started in 1982/83 with financial assistance from the Netherlands Government. The scheme, which covers an area of 40 ha, was then developed as a pilot scheme at the upper reach of Mgongola village scheme. The pilot project is a part of a large Programme to develop Mgongola village scheme (600 ha) for paddy production under gravity irrigation (FAO/UNDP, 1990; JICA, 1996). In this pilot scheme, double cropping a year has been practised under fully irrigated condition. The design and construction of diversion weir, main canal and the system's water control structures were carried out by the donor agency and Tanzania Government staff. Since commissioning of the project in 1985/86, irrigators have made several changes on the constructed water structures aiming at improving water supplies and management at both scheme and farm level without technical advice from experts.

3.2.2 Project layout

There are two rivers related to the Mkindo irrigation scheme. These are: Mkindo and Dizingwi rivers.

Mkindo river is a water source of the existing Mkindo irrigation scheme and is expected to be that for the Mgongola village scheme. It flows east-wards and joins Wami river downstream of Mgongola area. There are no water users other than Mkindo scheme except for domestic and livestock use (JICA, 1996).

The Dizingwi river, which is a tributary of Mkindo river is a perennial river. It always floods the Mkindo scheme in the rainy seasons due to its insufficient carrying capacity and so resulting to drainage problem within the scheme area.

Irrigation water is diverted from the Mkindo river through a main canal structure located 2 km upstream of Mkindo rivers' bridge for the trunk road from Morogoro-Turiani. Irrigation water is then conveyed through a concrete lined main canal passing a very steep slope in the upstream reaches of about 250m long, there-after it is followed by an earth canal. Its length is about 2 km in total, and it feeds secondary canal-1 (Sc1) and secondary canal-2 (Sc2) for Mkindo Phase-I area (19 ha) and secondary canal-.3 (Sc3) for Mkindo Phase-II area (21 ha).

On the way to the phase-II scheme, the Sc3 crosses, Dizingwi river through an inverted siphon structure and through a pipe culvert for the trunk road from Morogoro-Turiani. The Dizingwi river flows east ward along the downstream border of the phase-I fields and joins the Mkindo river. The Dizingwi river serves as the natural drain of Mkindo scheme and Old Dizingwi branch (it was original water course for Dizingwi river) was taking water (64.3l/sec.) into Sc3 as shown in Fig. 3.2. Therefore, it was also a source of irrigation water for phase-II.

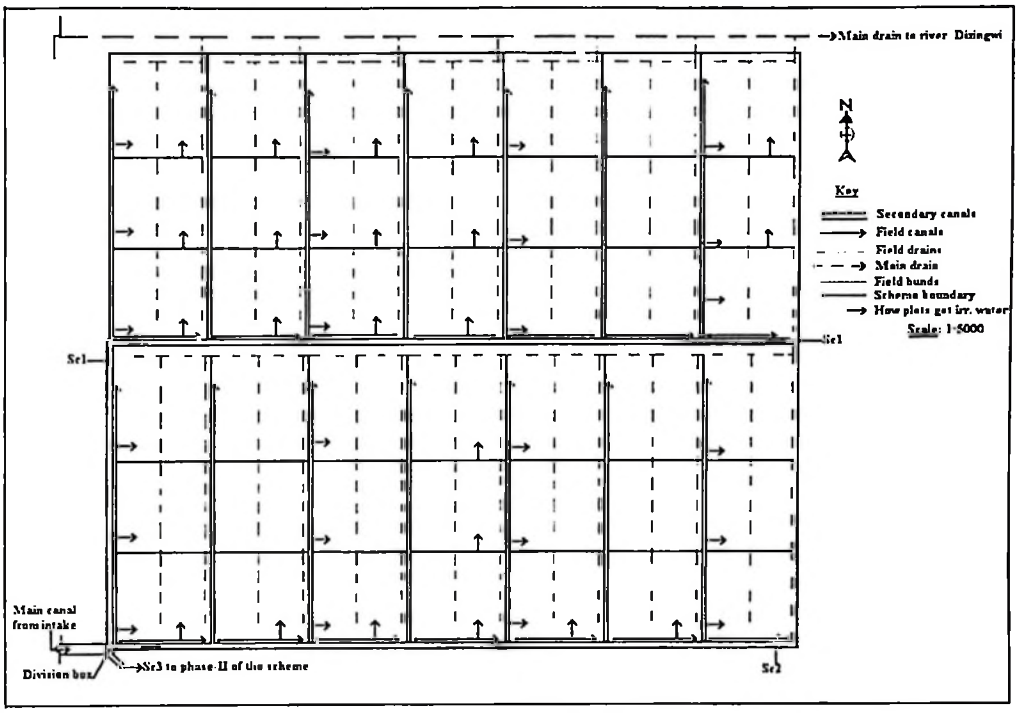

Fig. 3.3 (a): Original layout map of phase-I Mkindo scheme
Source: Morogoro zonal irrigation office

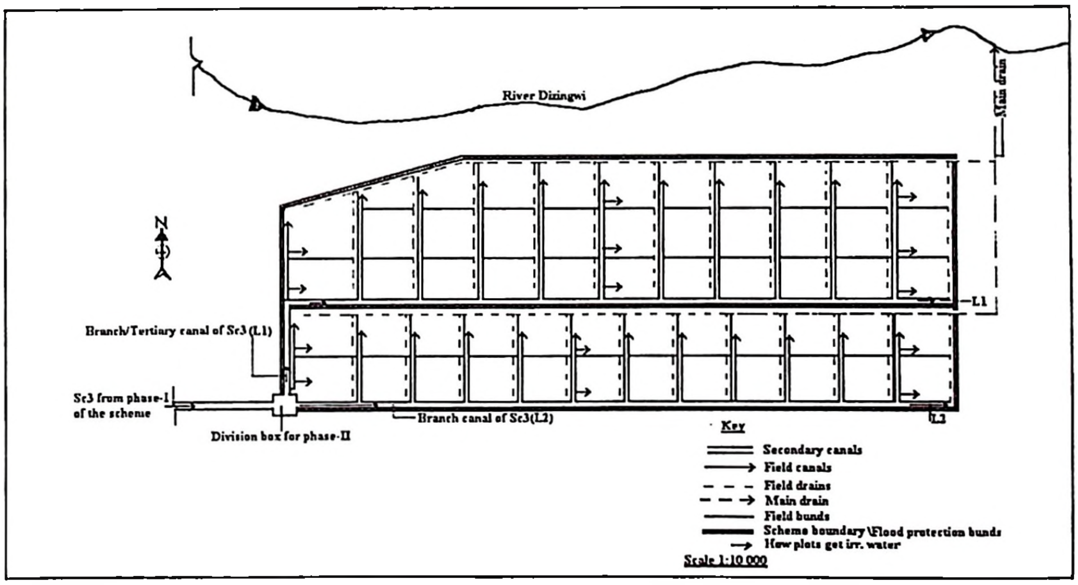

Fig. 3.3 (b): Original layout map of phase-II Mkindo scheme (21 ha)
Source: Morogoro zonal irrigation office

The topography of the scheme area is flat with an overall slope ranging from 0.2% to 0.5% to the east of the scheme (JICA, 1996). It lies at an average altitude of 360 meters above mean sea level.

3.2.4 Climate

The Mkindo scheme experiences three distinct seasons, that is a dry season starting from June to September, short rain season from October to February and a rainy season March to May. The average annual rainfall is 1200 mm. The peak rainy season is in April. The average annual temperature is 24.4°C with a minimum of 15.1°C in July and a maximum of 32.1°C in February. While the mean annual relative humidity is 81.3 percent. It ranges between 72.7 percent in November and 89.4 percent in May. Mean annual sunshine hours 7.0 per day. Annual evaporation rates vary from 3.1 mm/day in May to 6.7 mm/day in February this makes the total annual values to be more than 2160 mm (JICA, 1996).

3.2.5 Hydrology

Estimated monthly mean discharges for twenty years of the Mkindo river shows that, the river has a maximum flow of 11 m^3/sec (March-April) and minimum flow of 1.9 m^3/sec in September (JICA, 1996).

3.2.6 Soils

The soils have relatively high inherent fertility, fine texture (clay to clay loam) and medium soil texture in the deep soil profile. The medium is mainly alluvial having been formed by periodic floods. The drainability of these soils is poor mainly due to high ground water level. Most of the scheme area has pH ranging from 5.6 to 6.9. At present, most of the land is intensively utilised for paddy cultivation (twice per calendar year) under irrigation and rain fed condition. The soils were not saline or Alkaline (JICA, 1996).

3.3 Field measurements

3.3.1 Sampling of farm blocks

The area covered by the first phase had a total of 14 blocks. Given the nature of the layout as shown in Fig. 3.4 each two consecutive blocks covered the entire width of the farm. This resulted into seven lines of blocks covering the entire farm of the phase-I area. The first line was sampled to represent the area located at the head. Alternative lines were sampled after that to the end of the farm blocks. This led to two lines being sampled to represent the middle part of the farm and one line sampled at the end to represent the tail part of the farm. Hence, the sampling of the phase-I farm blocks had a bias towards the head, middle and tail areas of the farm. This kind of sampling led to eight out of fourteen blocks to be sampled for data collection.

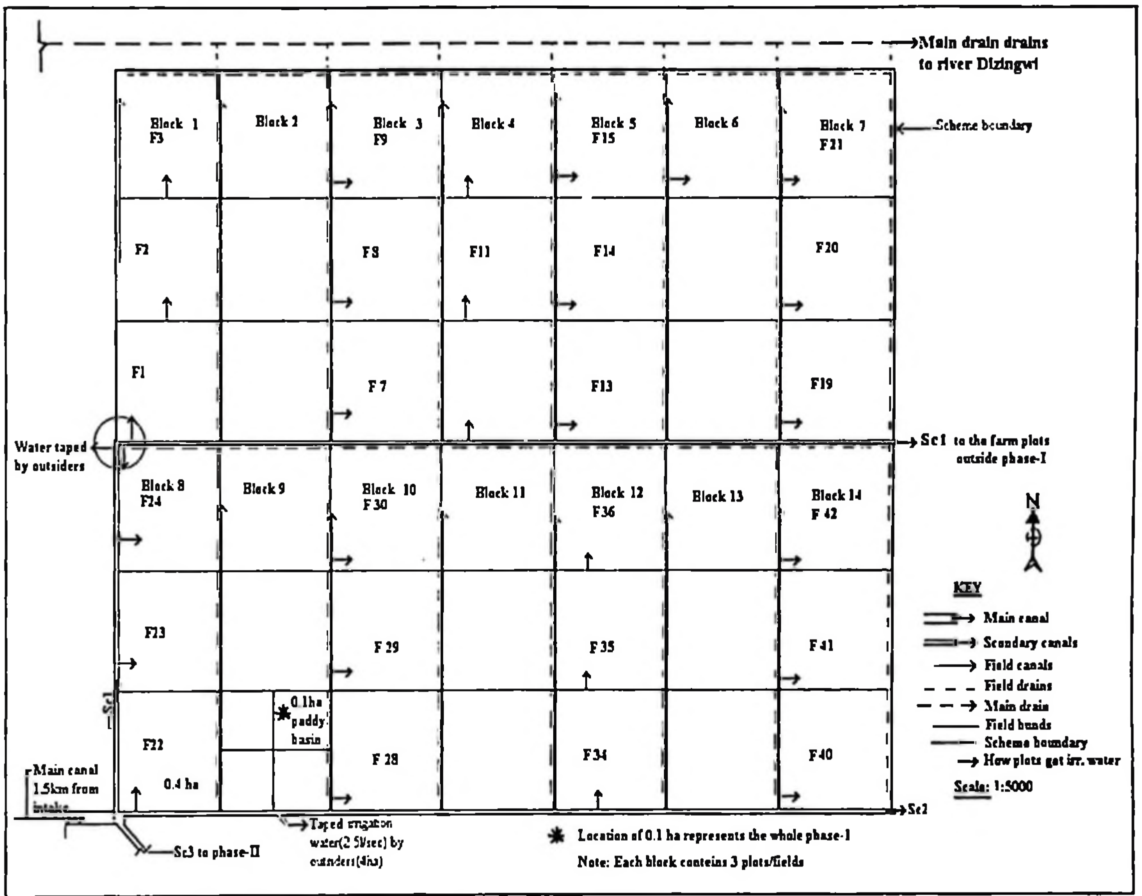

Fig. 3.4: Existing layout map of phase-I Mkindo scheme (19 ha)

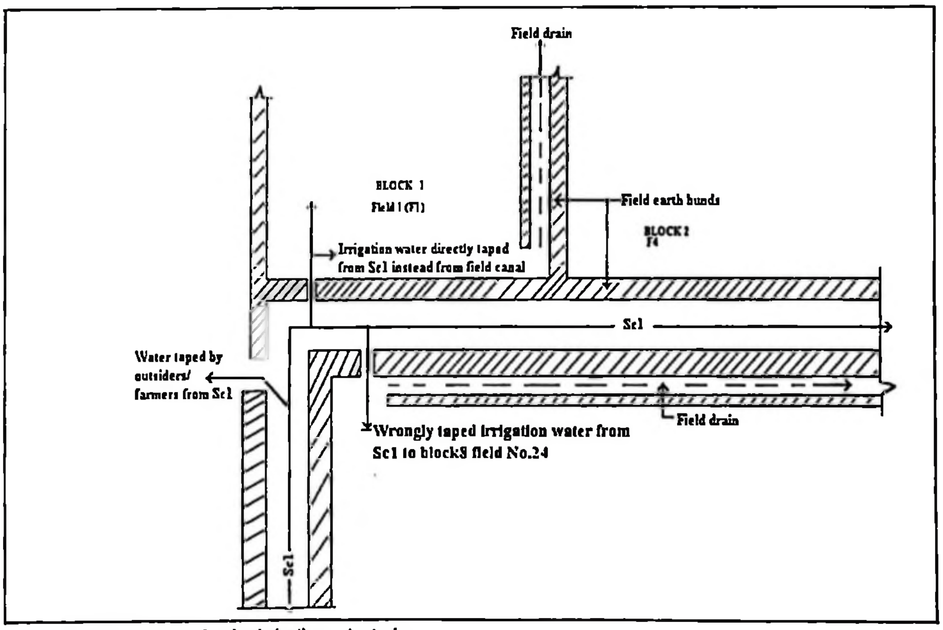

Fig. 3.5: Structure showing irrigation water taping by outsiders from secondary canal-1
(A blown up of the circled area- Fig.3.4)

In the phase-II farm area, there were four blocks. Given the nature of the layout as shown in Fig. 3.6 each block was irrigated by one of four tertiary/branch canals of the Sc3. This resulted into four blocks covering the entire farm of the phase-II area. The first block was sampled to represent part of the scheme irrigated by the tertiary canal one (L1) of the Sc3. Similarly Blocks 2, 3 and 4 were sampled to represent parts of the scheme irrigated by tertiary canals (L2), (L3) and (L4) respectively. Hence, the sampling of the phase-II farm blocks had a bias towards the head, middle and tail areas of the farm. This kind of sampling led to all four blocks to be sampled for data collection.

A total of 36 plots out of 98 plots each belonging to one farmer were sampled in this study taking location into consideration such as head, middle and tail. The number of plots selected per block differed from one block to another depending on the length of watercourse and size of the respective sampled blocks.

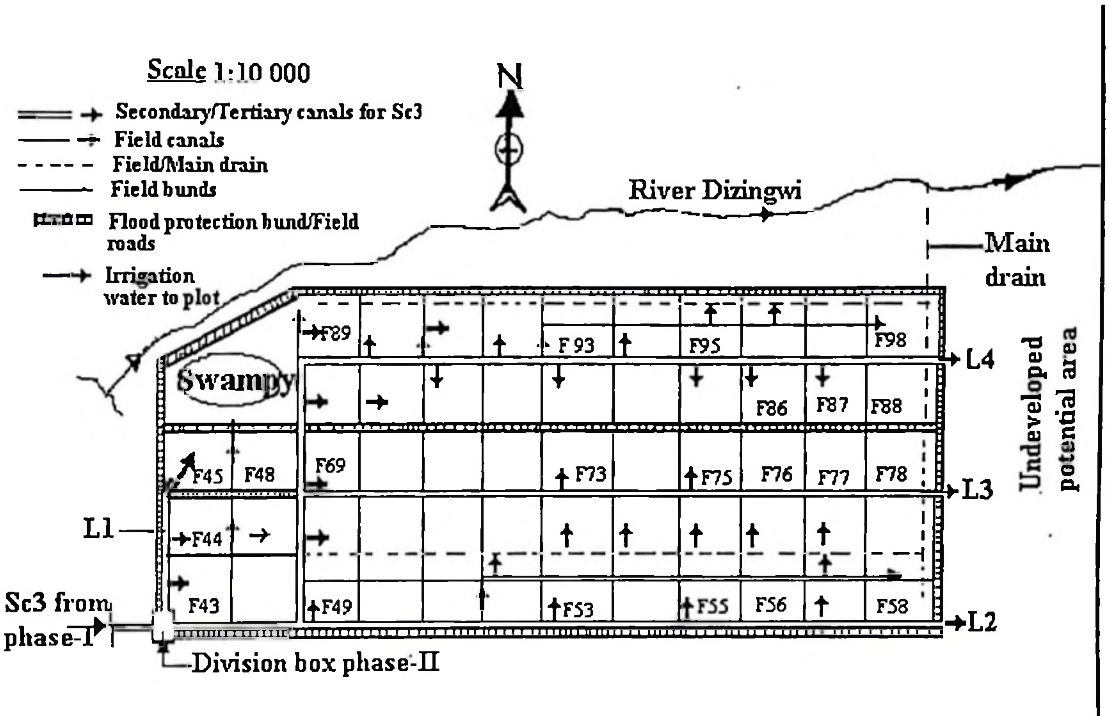

Fig.3.6: Existing layout of phase-II Mkindo irrigation scheme (21 ha)

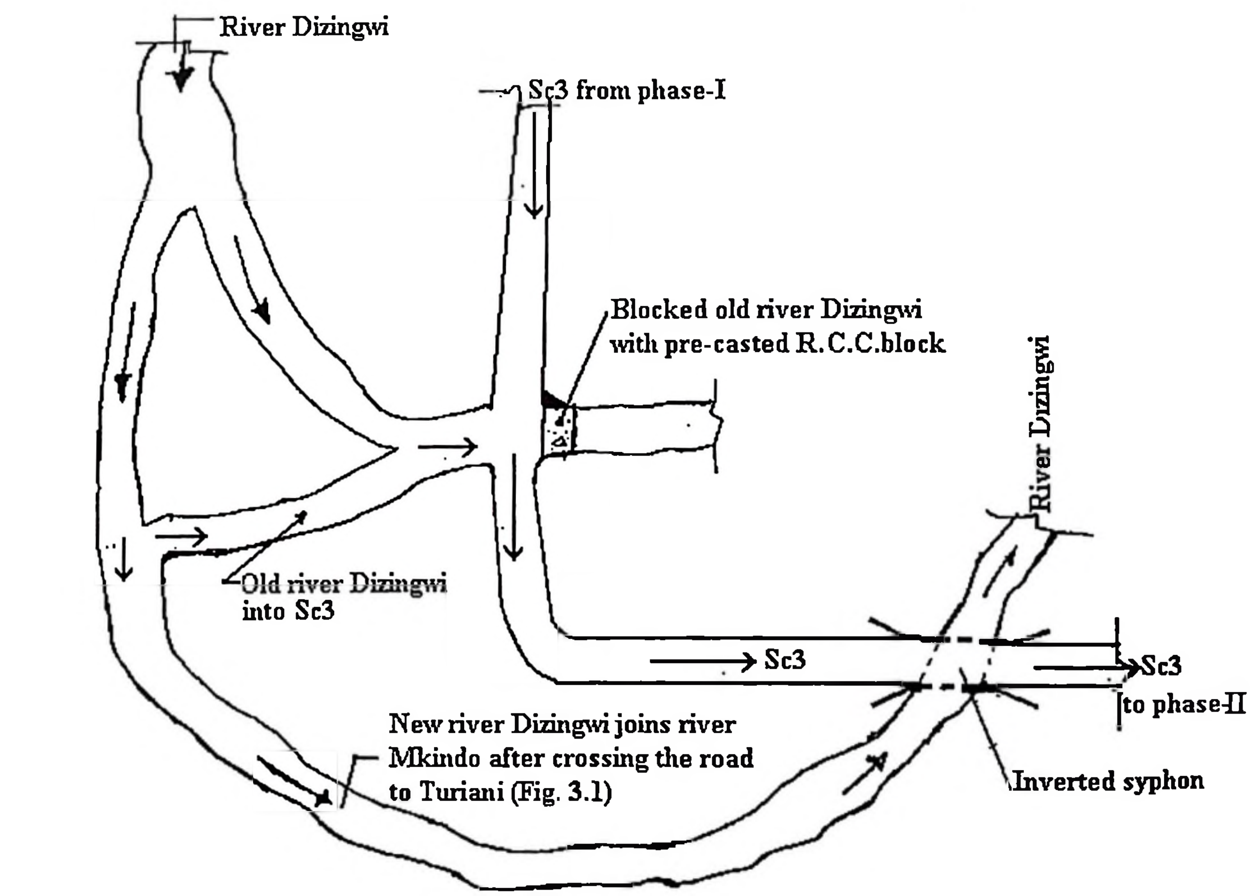

Fig.3.7: Sketch of existing situation of river Dizingwi as part of Sc3 to phase-II

3.3.2 Farmer-initiated changes on water control structures.

In order to identify changes made by water users, farmers were interviewed to indicate where drains and canals were originally located. The original map was used to testify the statement. Benchmarks were identified in the field and their position located in the map. With the help of the bench marks, the centre line for the original canals and drains were established in the whole scheme. Offtakes were measured between the original centre line of the canals and drains in relation to the existing canals and drains. The measurements were used to plot a map on the original layout map of the existing canals and drains.

Similarly changes on dimensions of earth bunds were identified by interviewing, farmers and extension officers to get the original dimensions of the field earth bunds. Measuring tape was used to measure dimensions of the existed bunds and the respective areas of plots. The original maps/drawings were used to testify the statement. With the help of benchmarks and the noted dimensions as shown in Table 3.1, Figs. 3.4, 3.6 and over-lay maps of the original and existing layout for phase-I and II (Figs.3.8 a to d) were obtained.

Table 3.1 Original and existed dimensions of bunds, canals and drains

Type of the structure	Original dimensions (m)		Existed dimensions (m)	
	Base/Bed width	Height	Base width	Height
Field earth bunds	0.6	0.4	0.15 to 0.20	0.15 to 0.20
Bunds for field roads	2 to 3		1 to 1.5	
Flood protection bunds	3		1 to 1.8	
Tertiary/Field canals	**0.3**		**0.12 to 0.18**	
Field drains	**0.3**		**0.12 to 0.20**	

The bolded numbers indicate bed widths.

Source: Scheme records, 1986

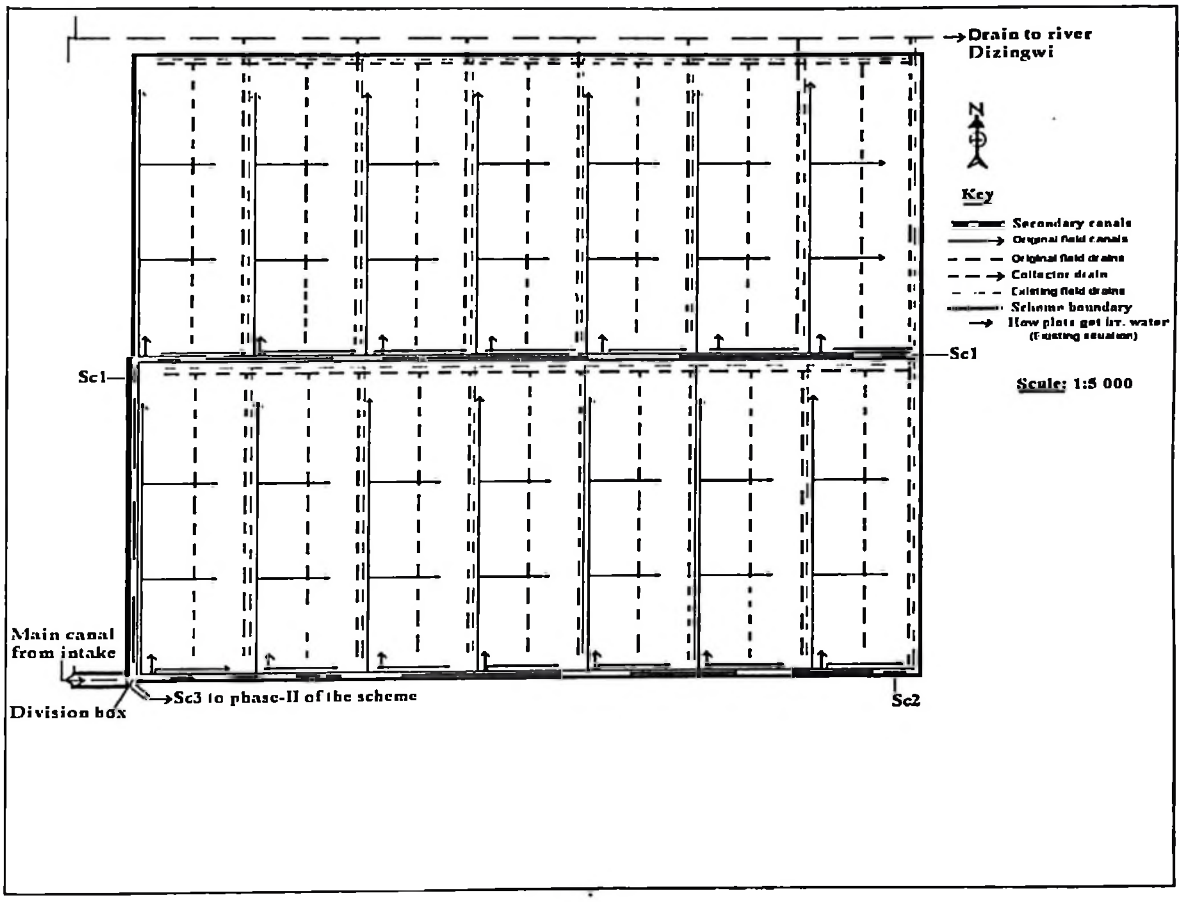

Fig.3.8 (a) Overlay map of the original and existing canals layout for phase-I

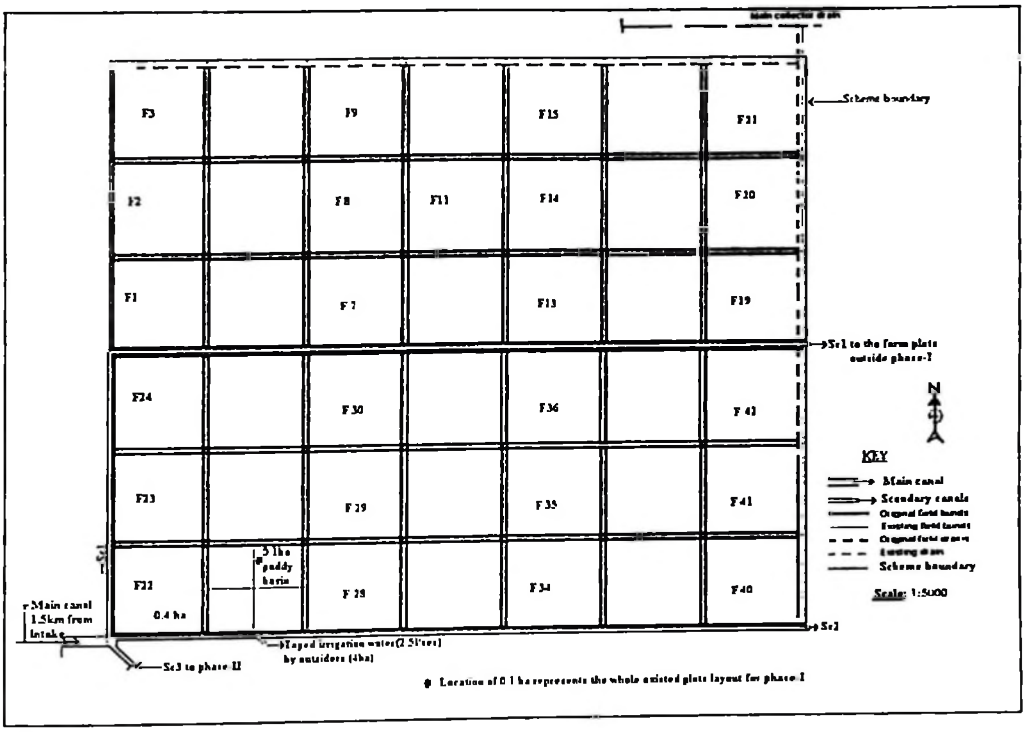

Fig. 3.8 (b): Overlay map original and existing plots layout for phase-I

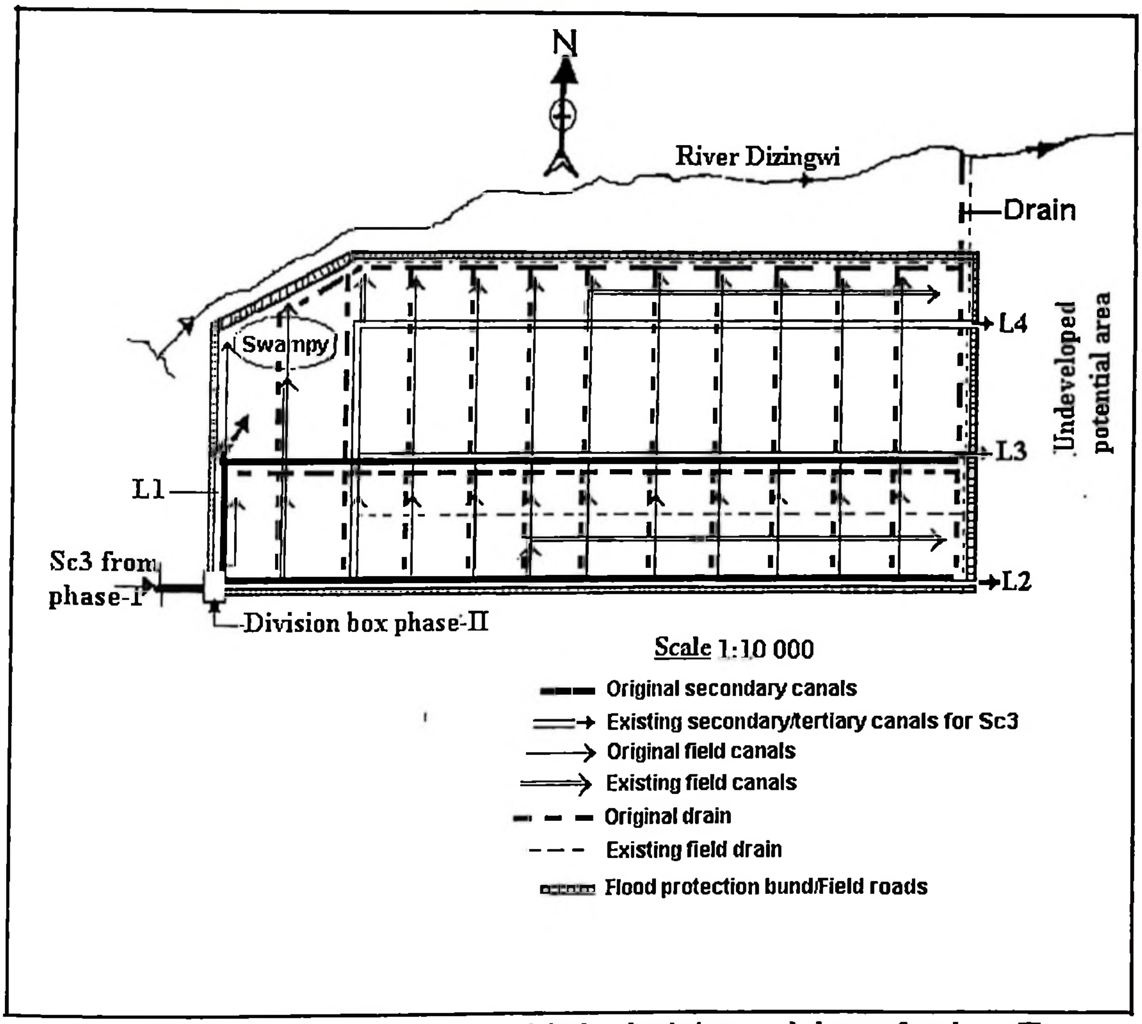

Fig. 3.8(c): Overlay map of the original and existing canals layout for phase-II

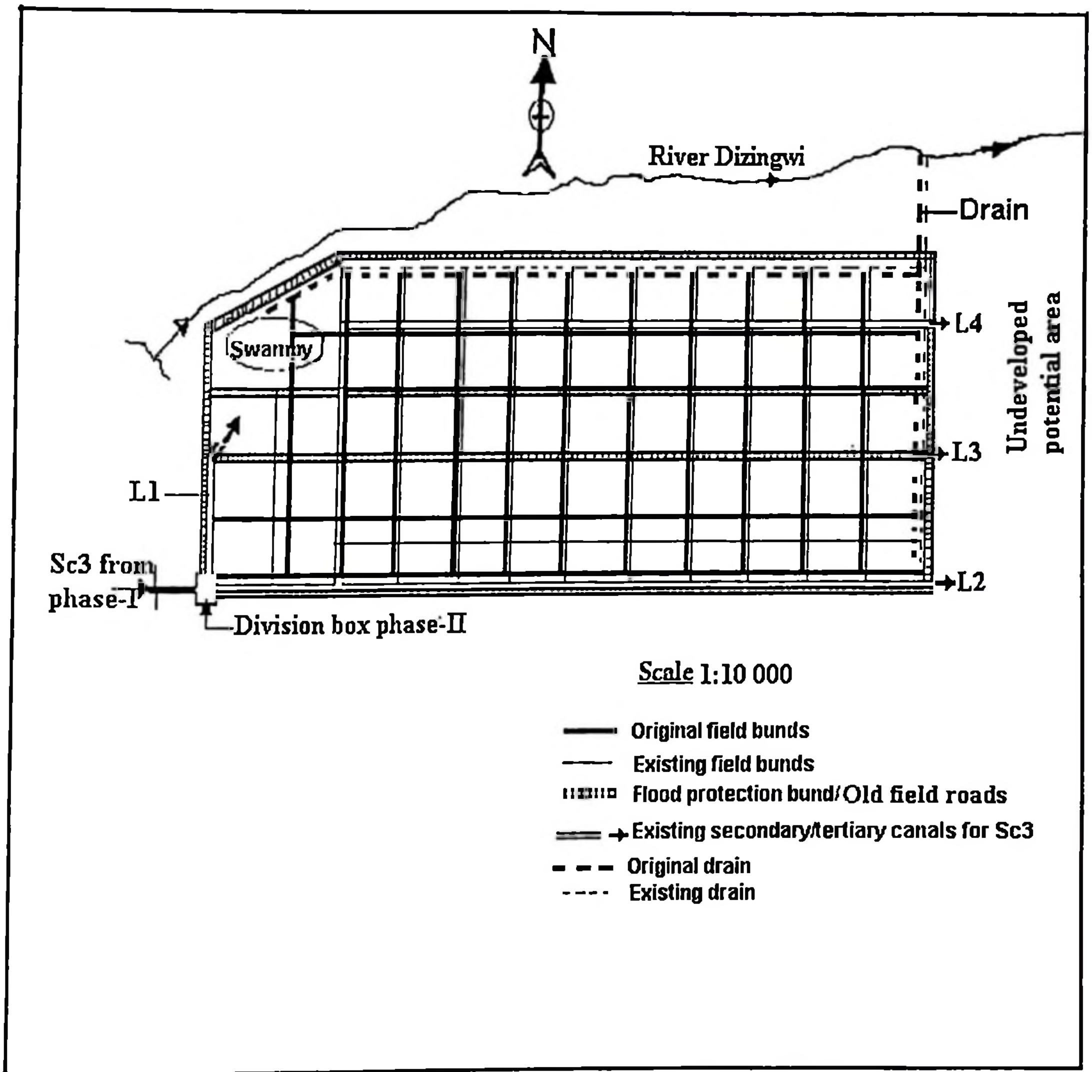

Fig. 3.8(d): Overlay map of the original and existing plots layout for phase-II

Water taping/stealing from main and secondary canals by farmers outside the scheme were identified, from physical observations and from an interview conducted to the farmers and extension officers in the study area. Farmers in the scheme and out growers were interviewed to explain or to give reasons, why the out growers were stealing water from main and secondary canals and its effect if any. The original map was used to affirm the statement (i.e. by comparing the existed situation and the original map). The measurements for sizes of sampled plots and dimensions of all existed water control structures were used to draw Fig 3.4 and Fig 3.5. Also to identify the changes on water control gates at division box openings, farmers were interviewed to indicate how some of water control structures looked like (i.e. Water control gates at division box openings, at turnout level for the scheme, etc.) on the original design and after construction. And also how they were constructed. The original drawings were used to affirm the statement. Changes were identified in the field and their position located in the map.

3.3.3 Field Measurements

The primary data for the study area were collected on daily basis throughout the irrigation season. The data collected included flow rates into the secondary, and tertiary canals, sampled paddy fields, seepage & percolation rates.

Other secondary data that were collected were meteorological data from meteorology station located in Morogoro Municipality. Crop yields, cropped area, cropping pattern, and original layout maps of paddy rice fields of the scheme (Figs. 3.3 (a) and 3.3 (b)) were obtained from Zonal Irrigation Office in Morogoro Municipality. The data were collected using different instruments and technique as explained in Section 3.3.2 and the subsequent section.

3.3.4 Farmers interview

Farmers interview were conducted to sixty four (64) farmers and extension staff in the study area as shown in Appendix 1, 2 & 8. From farmers interview and results of physical observation and physical measurement maps of existing layouts for paddy fields and information on irrigation water management of the scheme were obtained

3.3.5 Flow measurements

Graduated staff were placed at the right side bank in canals to measure water flow rates at the main canal intake and secondary canals. A Wading current meter was used to calibrate the graduated staff. Discharge in field canals was measured by means of Washington H-Flumes. The calibration equations for flow rating curves obtained were used to calculate daily flow rates for main canal, Sc1, Sc2 and Sc3. The equations for flow rating curve of each individual canal (i.e. Main canal, Sc1, Sc2 and Sc3) and data used to plot curves are shown in Appendix 7.

There are several approaches with which the current meter can be used to determine the velocity at verticals. However in this study, the point 0.6 method was used for measurement of velocity water at the verticals in the canal. In this method only one reading was made (single point observation method) at 0.6 of the depth from the surface and the value obtained was taken as the mean velocity of water for the vertical. The reason for using this method is as follows:

The depth of water into the main canal at time of collecting data was less than 3.0m(i.e. in shallow stream), hence the velocity measured at 0.6 depth of flow below the water surface is taken as the average velocity in the vertical (Boyer, 1964).

At the field level (i.e. block inlets and tertiary/ field canal inlets) for sampled blocks of paddy plots, discharge measurement were taken using Washington H-flumes. Check structures were not provided as water control structures at block inlets for secondary canals (Sc1, Sc2 and Sc3) in the scheme. Therefore, when discharge was being measured at block inlets the corresponding secondary canal was blocked tightly.

Discharges into sampled fields were measured by Washington H-flumes. Corresponding areas of the sampled fields were also recorded down from existed layout of the scheme.

Water delivery performance

To assess water delivery performance of the scheme, the total quantity of water delivered in the sampled fields in the scheme was recorded. These data were collected from land preparation to 20 days before harvest on the tertiary canals or sampled field canals of the corresponding secondary canals in the scheme.

3.3.6 Seepage and Percolation equipment

Seepage and Percolation rates were measured using sloping gauge method. The sloping gauge was located in few selected sample paddy plots in each sample block. Daily change in water depth was recorded and used to calculate seepage and percolation losses as suggested by Moya (1990).

3.3.7 Climatic data collected

Daily values of rainfall, temperature, relative humidity, wind speed, evaporation and sunshine hours were obtained from the meteorological station in Morogoro station as shown in Appendix 15. After consultation with the Morogoro meteorological officer in-charge, Morogoro station was chosen as relevant to represent the weather conditions of the study area. A rain gauge and thermometer were installed at the station (Study area) during the research period. The collected data were compared with data from Morogoro meteorological station and no variation was realised.

These data were used in Modified penman equation to estimate the daily ET_0 which was in turn used for estimating crop water requirement (ET_c) as suggested by Doorenbos and Pruitt (1977) as shown in Appendix 3. Ten years daily mean values were used to calculate daily ET_0 from which daily ET_c over the irrigation season was obtained. The daily ET_c values (Appendix 5) were used to calculate Net irrigation requirement (I_n) using general expression (Doorenbos and Pruitt, 1977);

$$I_n = ETc - P_c \tag{7}$$

Where, P_c = Effective rain fall (mm)

Irrigation water supply requirement (seasonal) were calculated as outlined by Doorenbos and Pruitt, (1977);

$$Q = (10*A*I_n)/E \tag{8}$$

Q = Supply requirement (m^3/Irrigation interval)

A = Acreage under a given crop (ha)

E = System Efficiency

3.3.8 Productivity/Crop yield

The 1997/98 season production data of the sampled plots in the scheme were obtained from actual measurements conducted to the 36 farmers of corresponding sampled plots to get their average yield per hectare (i.e. in terms of bags/plot area) as shown in Appendix 6. It was observed that on average one bag of paddy was equal to 70 kgs. The records of production of the previous years (1994-1998) of the scheme were collected from the schemes' extension officer.

3.3.9 Organisation

To assess organisational performance of the scheme, a review on the organisational structure as stipulated in Halcrow and TANConsult (1993) was made. The 64 farmers including WUA leaders and key informers who have lived and worked long enough in Mkindo village were interviewed using a structured questionnaire (Appendix 1& 8). Fig. 3.9 shows the resulting organisational structure of Mkindo FMIS (WUA).

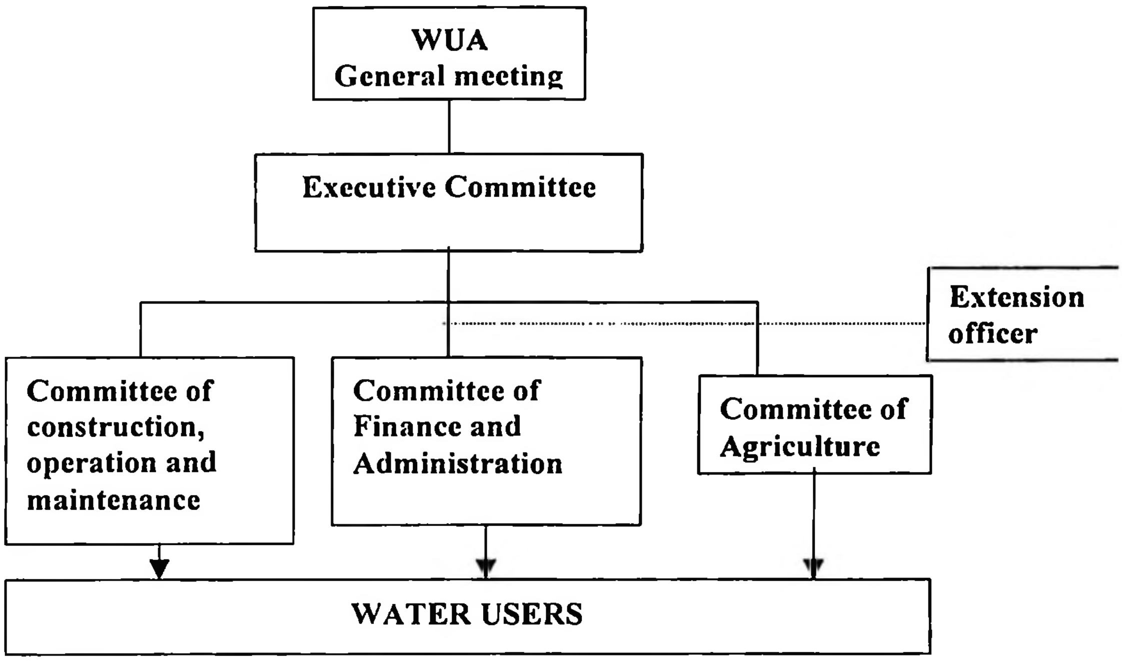

Fig.3.9 Mkindo FMIS (WUA) organisation structure

Source: Mkindo irrigation scheme (1998)

Key —— Line of Authority
........Line of communication

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the result of the study carried out to assess the effects of farmer-initiated modification of water control structures on the performance of farmer- managed irrigation systems using Mkindo scheme as case study. The result includes: changes made on the original water control structures; the performance of existing water distribution system; the effect of the existing water control structures on performance of the irrigation system.

4.2 Observed changes on water control structures

4.2.1 Changes on the field canals and drains

From the results of physical observation and interview conducted to farmers in the study area, it was observed that field drains which were initially centrally located in paddy rice plots were no longer in existence (Fig. 3.3 (a)). The original centrally located field drains were removed by farmers in order to increase irrigable area (increasing land utilisation). As result of irrigable land increase, most of the field irrigation canals and drains have changed their original position. Similarly it was noted that, some field canals were not existing, instead irrigation water was delivered directly to paddy plots by cutting secondary canal banks or drilling holes through lateral canal banks. Farmers having plots adjacent to secondary canals were taping water directly from them to paddy fields as shown in Fig. 3.4. For example all farmers in block –1 and block-8 of phase-1 were getting water directly from the secondary canals as shown in Fig. 3.4. Some farmers from one field canal have absconded in using it and opted for secondary canal and while some do irrigate their plots by breaking the earth bunds of adjacent basin as continuous process (i.e. field-to-field irrigation) as shown in Fig. 3.4. The farmers absconded in using one field canal because their fields were not reached by these canals after being removed/blocked by upstream users. Field-to-field irrigation system is a common traditional innovation in paddy production (Bredero, 1991). The number and size of fields crossed by water flow is based on local experience or guesswork rather than on scientifically supported design. Seepage & percolation and run-off losses inherent in this irrigation method may re-appear somewhere down stream as drainage water or rising ground watertable (Bredero, 1991). The reappearing seepage water is then utilised/used by farmers in irrigating their paddy plots.

Farmers were doing field-to-field irrigation because this method lower on-farm construction costs and increase utilised land area as compared to individual field channel method (Fig. 3.3 (a) and Fig. 3.3 (b)). Field-to-field irrigation method was also easily accepted by farmers because it conforms to their traditional practices (i.e. the number and size of fields crossed by water flow is based on guesswork rather than on scientifically supported design); the method serves as a way of disposing excess water hence act as a drainage system. It serves as an alternative when not all fields can be reached by field canals economically and saving of water management labour. But the time of water availability at a basin at lower end in a cascade is a function of the filling of the preceding basins. As shown in Fig. 3.3(b) and Fig. 3.6 from physical observations, the original layout map for phase-II shows that the secondary canal-3 (Sc3) was designed to branch into two, namely tertiary-1 (L1) and branch-2 (L2) respectively. However, in the existing layout map of phase-II (Fig. 3.6), there are four (4) branches of Sc3, namely L1, L2, L3 and L4. Due to poor land levelling of phase-II scheme, L1 could not irrigate properly the whole expected area (F68 to F98), therefore, farmers had to change to the present system as shown in Fig. 3.6. Similarly as discussed for phase-I and with the same reasons, it was also noted that some farmers in phase-II (Fig. 3.6) were doing field-to-field irrigation (F44 to F47 and F43 to F46, etc). Sizes of the existing paddy basins were not the same as the original ones. The paddy basins were originally planned, designed and constructed for 1 acre (0.4 ha) in size and rectangular shape, but the plots have been divided into smaller rectangular basins (0.1 ha) to simplify land levelling problem (Fig. 3.4), since the plots were not properly levelled during construction stage. Therefore, with paddy basin of 0.4.ha in size the irrigation water was not uniformly distributed within the basin. Hence the reason for resorting to 0.1 ha plot size.

4.2.2 Changes on the main collector drain

It was observed that the main collector drainage was saving a dual purpose both as a field irrigation canal and a drain by nearby farmers, as a result the drainage system of the scheme was not working properly as per original design (Fig. 3.4). Large amount of water in the main collector drain was used by farmers outside the scheme to irrigate an estimated area of more than 10 ha of land. It was observed that this area was not included in the original design although it was potentially good for irrigation. This led to a situation whereby farmers were taping water from main collector drain by cutting its banks or drilling holes through them. However, new main collector drain was not provided downstream of their plots in order to drain excess water from their plots to the natural drain (Dizingwi river). Therefore, excess water taped from the drain caused floods to almost 11 ha of farmer outside the scheme down stream during rainy season. Due to the floods the land was left out of production. Modifications made by farmers on the original design of the drain caused drainage problem downstream, since excess water from plots was left to spread without proper control. As a result some potential area for irrigation was flooded by water.

4.2.3 Changes on earth bunds and banks

It was observed that dimension of existing paddy field earth bunds and secondary canal banks were smaller than the original ones. The present base width was less than 200 mm and height was less than 150 mm. The original designed height and base width of the paddy bunds were 300 mm and 600 mm respectively, and (2-3m) base width for field roads (Scheme records, 1986) as shown in Table 3.1. Farmers wanted to maximise the present irrigable area (increase land area utilisation) by reducing width of paddy field water control bunds and secondary canal banks. However, the original external boundary of the scheme remained unchanged (personal observation). Bunds are usually built (150-300 mm) high to contain water on the soil surface (irrigation depth 50-200 mm) with a small free board to stop water flowing over the top (James, 1988). In large basin, waves can be a problem in windy conditions. In such cases a large free board will be provided. Bunds vary between (0.6-1.2m) wide at the base and so this provides sufficient thickness of soil to stop leakage. Bunds in paddy field are usually larger than those of other crops. They are 400-500 mm high and 1.5-1.8m at the base. This is because paddy is often grown as single crop on the same land and so more permanent bunds are constructed. However, the existed bunds were thin and had less height thus could not accommodate the applied irrigation water in the paddy fields. Because of the existed conditions, application of fertiliser in the paddy rice basins was not effective. The thin base width did not provide sufficient soil thickness to stop leakage and water flowing over the top due to small free board provided. Leakage and water flowing over the top of the existed water control bunds caused leaching of the fertiliser applied. This was verified statistically (probability of $0.03<0.05$) by having a significant reduction of yield per irrigated area between the present and the original designed area (Appendix 11 and Table 4.1). Data for the analysis are shown in Appendices 9 and 10. The result also show that application efficiency (Ea) was not important factor in determination of yield per irrigated area since the effect was not statistically significant at all levels of significance (Probability value > 0.05) as shown in Appendix 11.

Table 4.1 Original annual mean yields before and after the changes

Year	Yield before the changes (ton/ha)	Year after the changes	Yield after the changes (ton/ha)
1994	5.7	1997	5.9
1995	6.5	1998	3.8
1996	6.6	1999	3.1

Source: Mkindo scheme village extension officer (1998)

4.2.4 Water taping from main canal and secondary canals

It was observed that water taping from main canal and secondary canal by farmers outside the scheme exists as shown in Fig. 3.4, Fig. 3.5 and Plate 4.1-2, due to water/land demand for irrigation. The continuous flowing stream through the cuts made by them may widen the cross section and result in excess flow at the head reach and diminished flow at the tail end as shown in Plate 4.2. The problem was also reported by Neupane (1995) who stated that in order to distribute water from the main canal to the secondary canals or field channels in irrigation systems that they have constructed, farmers often make a simple cut in the side of the canal for water to flow through to their fields. They regulate the flow from the main canal by inserting stones or mud from the canal bank into the cut. The discharge through the cut is difficult to estimate since any irrigator can freely open a cut of any size, causing wastage of a considerable volume of water. This causes scarcity at the tail end of the command area, which brings about inequity in irrigation water distribution, and thus conflict among the irrigators (Appendix 16).

The demand for irrigable area/land and scarcity of irrigation water supply existed because the present irrigation system did not include the area used by farmers outside the scheme during the design /construction stage. Studies by Speelman (1990) show that inequity in water distribution may be due to design faults such as inadequate control and measurement structures and inadequate canal capacity for the area they are supposed to command. Other causes of inequity in water distribution established by FAO (1985) include the failure to carry out essential maintenance leading to clogging of the canals and drains by vegetation and silt, construction faults that render maintenance difficult,

Plate 4.1: Irrigation water taping by farmers outside the scheme from Sc1 (Fig. 3.4 &3.5)

Plate 4.2 Irrigation water taping by farmers outside the scheme from Sc2 (Fig. 3.4)

and management faults. It was observed that the present main canal and its intake was constructed to irrigate 38 hectares of the existing scheme (Phase-I & Phase-II) as shown in Fig. 3.2. Nevertheless, the existing weir structure (Fig. 3.1) was constructed to cover 600 hectares as explained in Section 3.2.1. However, the potential area presently irrigated outside the scheme, was only 22 hectares. Therefore, it may be concluded that study to identify potential irrigable area for the scheme was not properly done before implementation. Moreover availability of financial resource might be one of the hindering factors. Hence farmers opted for original design changes as already explained.

Abernethy (1986) has cautioned that proper study to identify areas needing improvements and support should be carried out before any intervention is made. In most developing countries, especially Sub-Sahara Africa, irrigation engineers observe that farmers are suffering from shortage of water mostly because of its unavailability and lack of skills to make it available at the time and place required (Baban, 1995). From the study (Appendix 2) along with personal observation show that the taping of irrigation water by farmers at the area surrounding/near the scheme caused irrigation water inequity at the tail of the scheme (Phase-II) which also was not levelled properly during construction stage. However, the upper and middle parts of the scheme were getting more water than the tail parts as show in Table 4.2.

Table 4.2 Seasonal planned and actual quantity of water delivered in the sample blocks

Name of the scheme	Block	Designed irrigation water Requirement(mm) at Application efficiency(60%)	Actual Irrigation water applied(mm)
Mkindo phase-I	Upper blocks(B1, B8)	2617.0	1118.3
	Middle blocks(B3, B5, B10, B12)	2617.0	997.2
	Tail blocks(B7, B14)	2617.0	548.45
Mkindo phase-II	Upper(B1& B2)	2617.0	1227.7
	Middle(B3)	2617.0	611.1
	Tail (B4)	2617.0	658.1

Additionally, the existing main and secondary canals were not well maintained for equity in distribution of water in the scheme. Therefore, much water was wasted from canal water taping, unrepaired damaged canals and clogged canals by vegetation and silts. In attempt to compensate the lost water farmers blocked the drains/Old Dizingwi river, which cuts across secondary canal-3 (Sc3) and use Old Dizingwi river water to irrigate Phase-II area as shown in Fig. 3.7. Nevertheless this practice (poor water management) caused a lot of damage to farmers' fields. For example the middle fields: F66, F76, F86 & F96 for Phase-II of the scheme in Fig. 3.6 were flooded by irrigation water (Personal observation). These fields were completely destroyed after they were submerged in water, due to lack of proper field drains. As result fields: F57, F58, F67, F68, F77, F78, F87, F88 and F98 were not farmed at the time of this study for irrigated agriculture because of lack of water (Fig 3.6). Since the tail end of the scheme was poorly levelled therefore, irrigation water supplied at this end was not distributed evenly, leading to irrigation water scarcity to some parts of it. Secondary canals (Sc2 & Sc3) were damaged without repair (Fig. 3.4 & Fig. 3.6) this also contributed to water wastage. These canals maintenance problem usually cause excessive vegetation in canals, obstruction of irrigation water and water losses through evaporation, seepage and percolation. With all mentioned related problems the tail end users don't practice irrigation fully, instead they practice irrigation farming by flooding effect or with inadequate irrigation water.

4.2.5 Changes on water control gates

It was observed that water control gates were not existing at division box openings and at turnout level for the scheme as shown in Fig. 4.1 and Plate 4.3. Also Plate 4.3, Fig 4.1 and Fig. 4.2 shows how some of the water control structures looked like at the design/constructed stage and at the present study. Division box, apart from diverting the flow of the parent canal to another or from a canal to a tertiary canal structure by means of sluice gates or wooden stop-logs, this also served to reduce variation in water depth in the parent canal so that the abstracted discharge would be more- or-less constant for a given gate opening irrespective of the flow in the parent canal (Manzungu, 1999). In the old division box for phase-I farm area as shown in Fig. 4.2, divider wall was provided to control water entering into secondary canals (Sc1, Sc2 and Sc3). Later on farmers thought this wall was the cause of improper distribution of water among the mentioned secondary canals. Then the divider wall was removed by farmers as shown in Fig. 4.1.

However, the removal of divider wall was not a permanent solution for proper and effective distribution of water among the secondary canals in the scheme. Still exists a problem of water distribution in the scheme as discussed in various sections. However, the alternative to a problem would be the provision of proportioning water-division devices to it. It was reported by Mallya (1997) that structures if well designed and properly installed, are able to distribute the irrigation water on proportional basis in FMIS. Also it was reported by Yoder (1995) that the selection of most suitable type of water control structures such as turn out, distribution boxes, etc must take into consideration, among other factors, the operation and maintenance costs of the structure. The chosen design must be flexible to accommodate farmers' requirements; otherwise the farmers will have no alternative but to modify the structures by breaking it (Ford Foundation, 1995). This is due to the fact that our farmers do not have the knowledge of operating and maintaining them.

Plate 4.3: Typical existed layout of division box at phase-I of the scheme

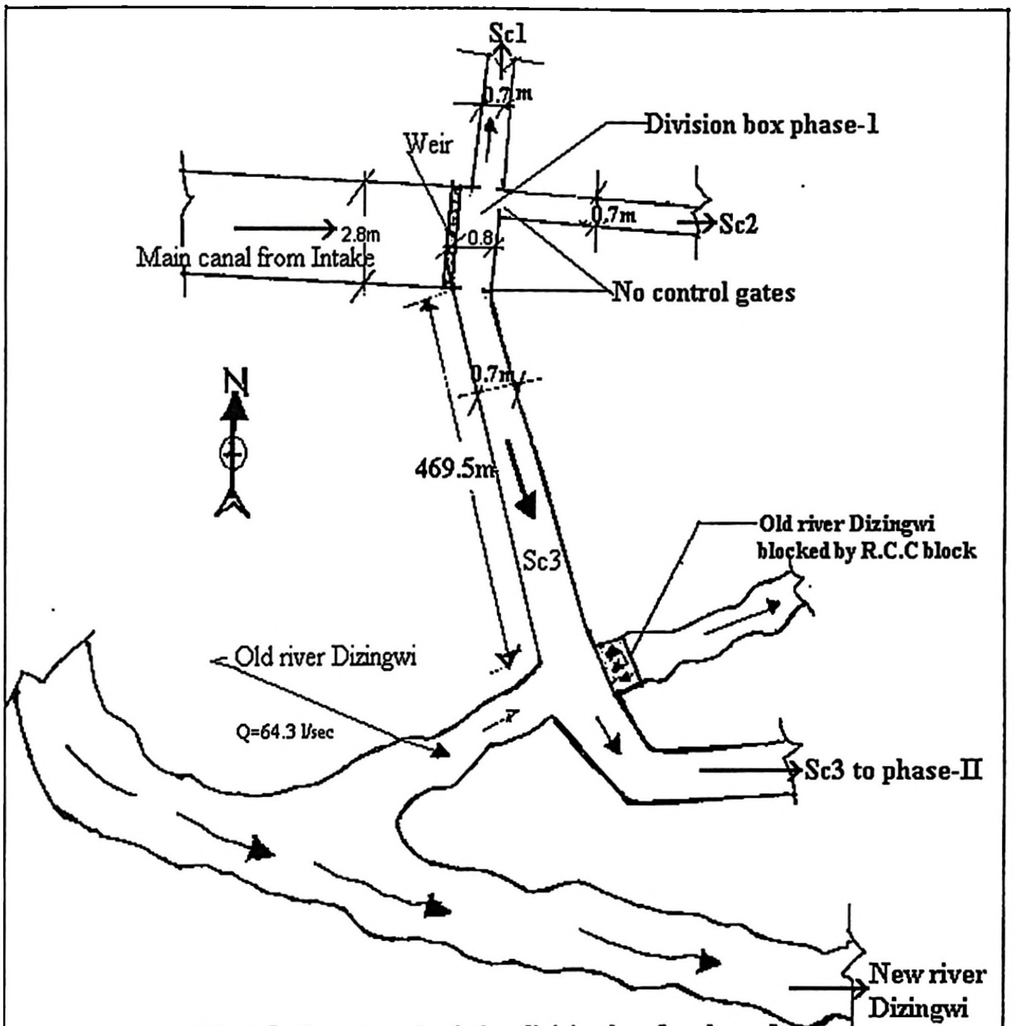

Fig.4.1: Drawing of existing division box for phase-1

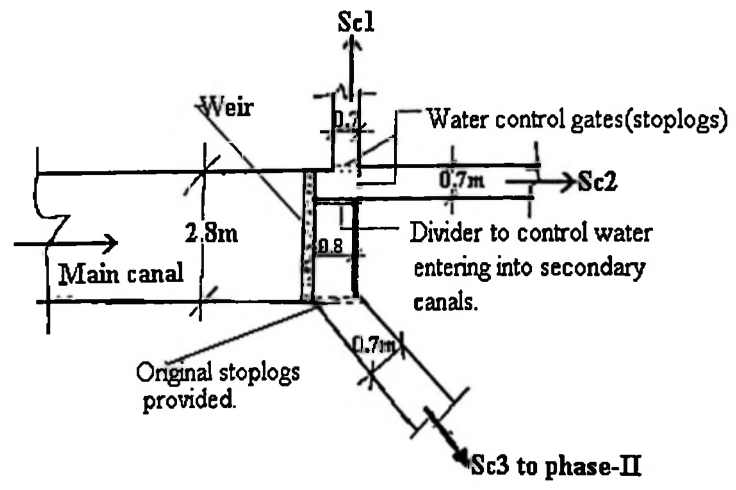

Fig. 4.2 : Drawing of original design division box for phase-I

4.3 Water Management

4.3.1 Irrigation Efficiencies

Results of irrigation efficiencies for both phase-I and phase-II of the scheme are given in Table 4.3. The Conveyance efficiency of the main canal was found to be 65% for the scheme. This was a poor performance as it does not lie within the recommended range of between 80% to 90% (Abdulmumin *et al.*, 1990). This was because of water losses through evaporation, seepage and percolation due to unlined condition of the main canal.

Table 4.3 Irrigation efficiencies (%)

Block		Phase-I	Phase-II	Planned (design)
Application efficiency	Upper	34.3	37.0	60
	Middle	51.7	49.0	60
	Tail	55.0	51.0	60
	Average	47.0	45.66	60
Distribution efficiency	Upper	23	39	85
	Middle	15	23	85
	Tail	22	22	85
	Average	20	28	85
Conveyance		65	65	90
Overall		6.0	8.3	46

The distribution efficiencies of phase-I and II were compared with the planned distribution efficiency and the results are shown in Appendix 12. For both these phases the observed distribution efficiency was found to be lower than the planned efficiency at 5% and 1% levels of significance. The observed distribution efficiency of Phase–I ranged from 15% to 23% with mean 20%, while the distribution efficiency of Phase–II ranged from 22% to 39% with mean 28%. All these figures were less than the planned efficiency, of 85%. as shown in Table 4.3. This poor performance of the two phases was verified by greater absolute T-test statistics than critical T-test values at both levels of significance (i.e. 5.44>4.6).

Table 4.3 shows that the observed application efficiency of both phase-1 and II was lower than the planned efficiency. The Table shows that the observed application efficiency of phase-I and II ranged from 34.3% to 55% with mean 47% and 37% to 51% with mean 45.66 respectively. The observed efficiency was less than the planned application efficiency of 60% but the difference was not statistically significant as shown in Appendix 12. For both phases, the T-test statistics were less than the critical T-values at 1% and 5% levels of significance. It was noted that application efficiency was lower at the upper blocks than in the tail blocks in both phases. This was due to excessive water application at the upper blocks than tail blocks in the scheme. Maregesi (1992) reported similar results for Lower Moshi FMIS.

4.3.2 Water delivery performance

Analysis of water delivery performance by mean square prediction error theory (Oad and Sampath, 1991) is presented in Table 4.4. These result shows that both the phase-I and phase-II of the scheme were not applying water in the fields according to the planned quantities. This is shown by a big water adequacy error of 72% and 68% for phase-I and phase-II of the scheme, respectively.

Table 4.4: Water delivery performance

Type of Error(%)	Phase-I	Phase-II
Adequacy Error(Aer)	72%	68%
Equity error(Eer)	18%	20%
Canal physical/ management error(Cer)	10%	12%
Total error	100%	100%

The amount of water applied in both phase-I and phase-II was generally less than the planned quantities as shown in Table 4.2 and Fig 4.3.

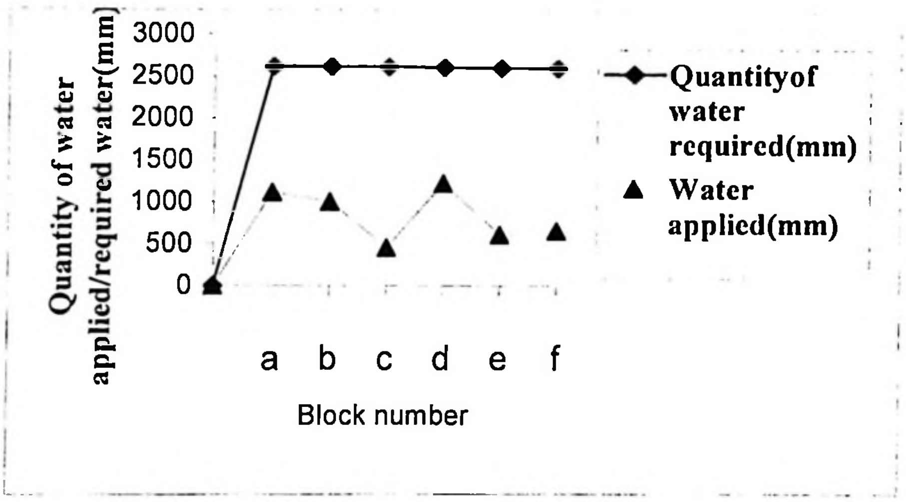

Fig 4.3 Quantity of water applied/required mm/ha,

Key: Phase-I Blocks: a= Upper (B1, B8), b= Middle (B3, B5, B10, B12), c= Tail (B7, B14)

Phase-II Blocks: d= Upper (B1, B2), e= Middle (B3), f= Tail (B4)

This is also shown by the average application efficiencies approaching the planned value of 60% in both phases, as shown in Table 4.3. The inadequacy of water in the scheme is due to (i) improper water control at all secondary canals (Sc1, Sc2 and Sc3) and offtakes as explained in Section 4.2.5 (ii) It was observed that at the time of the present study, some of the sampled blocks received water for 44 days instead of 113 days as planned for the whole irrigation season. For example block 12 and block 14 in phase-I started to receive irrigation water from Sc2 after almost two months, since the starting of irrigation season. This is because the canal systems were not repaired or maintained well before the start of irrigation activities.

(iii) Farmers were not following rotation rules at the level of the tertiary block. According to the system design, water would be discharged at the farm level on seven days irrigation interval in phase-I. It means each block would be taking water for one day a week (Fig 3.4). While in the phase-II farm area, water would be discharged at the farm level on three days irrigation interval. Whereby 3 secondary canals would operate at the same time. However, farmers where irrigating for 24 hours daily. It was continuous irrigation.

Both the phase-I and phase-II had a high error of equity of water distribution of 18% and 20% respectively. The observed error of equity indicates that water was not distributed fairly, the reason being that the scheme was to discharge water along its canal length without fixed check structures. However, the control gates (stopples) provided at construction stage for division boxes were not there at the time of present study. In the scheme, there were no tertiary checks. Instead, soil/mud was used to check the water by damming up the water in order to create necessary head. This contributed to siltation of canals. The essence of check structures was also acknowledged by Manzungu (1999).

In irrigation systems where the plot-to-plot method of water distribution predominates, farmers have to build up the water head at the upper end of the farm to ensure the flow of water, which is often accompanied by excessive percolation. Underbund percolation could cause a further 2-5 fold increase in percolation rate, depending on the size of the field (Guerra *et.al.*, 1998). Underbund percolation results from lateral movement of ponded water into the bunds and then (because of the absence of a semi-impermeable layer under the bunds) vertically down to the water table (Guerra *et.al.*, 1998). Thus we see in relation to the plant requirement (i.e., evapotranspiration) other so called "requirement" or "losses" tend to be large. Since irrigation fees, where they exist, are typically low, farmers are encouraged to use an excessive amount of water. In many systems this exacerbates the "head-tail" problem leading to inequity in the distribution of water.

The management error shown in Table 4.4 between the actual and required amount of irrigation water is 10 % and 12% for phase-I and phase-II respectively. This implies that the supply of irrigation water is not reliable. Probably it was not supplied according to schedule and the poor secondary canals' condition. The low distribution efficiencies of secondary canals shown in Table 4.3 support this result.

4.3.3 Water depth management

Analysis of the observed water depths against the required water depth shown in Appendix 13 generated a T-test statistic of 1.695 and 3.969 as shown in Appendix 14 for the phase-I and phase-II of the scheme, respectively, against a critical T value of 2.571 and 4.032 at 5% and 1% level of significance respectively. This shows that there was no significant difference between the actual and the required water depths in the paddy fields from decade 1 to 9 after transplanting, for both the phase-I and phase-II at

1% level of significance. However, there was a significant difference between the required and the actual water depths in the phase-II of the scheme at 5% level of significance, while in the phase-I there was no significant difference between the required depth and the actual depth at the same level. This shows that water depth in the phase-I was maintained at the recommended values more than in the phase-II because farmers in phase-I were controlling water at the field inlets and at out lets. These farmers were opening the field inlets at the time of irrigating, closing the inlet opening/gates (by mud) after irrigation and draining out water from fields when field drainage was required. While in the phase-II farmers were faced with field drainage problem, since some of the field drains were used as field canals (Fig .3.6).

4.4 Crop Yield

The crop yield per hectare is presented in Table 4.5. Table 4.6 presents past years (same irrigation season) yield for comparison with the study season yield. The results in Table 4.5 for the season shows that yields per hectare are almost low in all blocks compared to past records as shown in Table 4.6. However, Upper blocks (B1, B8, Phase-II: B1 and B2) and Middle blocks (B3, B5, B10, B12 and Phase-II: B3) recorded higher yields relative to downstream most blocks (B7, B14 and Phase-II: B4). The difference in yield per hectare obtained in all sampled block indicates the large differences in technical efficiencies in water utilisation among the sampled farmers. The trend of low yield of paddy for Phase-II blocks and B14 shown in Table 4.5 indicates that the expected trend of water supply for Phase-II blocks and B14 was not achieved. This was partly due to unreliable irrigation water and probably due to the technique or poor farmer practice used to distribute the available water, which could not supply water uniformly to paddy plots for phase-II Blocks and B14. Manzungu (1999) reported that sub-optimal performance in Smallholder irrigation schemes in Zimbabwe is due to:

(a) low productivity as a result of poor farmer practice, insufficient water availability and low crop intensities;

(b) poor sustainability, a result of inappropriate scheme management and inadequate quantity and quality of investment as discussed in Section 4.3.

Table 4.5: Average yield from sampled blocks in 1998/99

Sample block	Yield(ton/ha)
B1	3.5
B3	3.4
B5	5.3
B7	2.3
B8	3.7
B10	3.9
B12	5.4
B14	2.1
Phase-II; B1	2
B2	2
B3	1.8
B4	1.7
Mean	3.1
STDEV.	1.3
VAR.	1.7

Table 4.6 Mean annual paddy rice yield (ton/ha)

YEAR	YIELD(ton/ha)
1994	5.7
1995	6.5
1996	6.6
1997	5.9
1998	3.8
1999	3.1

Source: Mkindo scheme village extension officer (1998)

The late transplanting, inadequacy and inequity of water supply among paddy fields in a block as explained in Section 4.2.4 and agronomy management factors such as inadequate application of fertilizer/manure and improper field bund preparation might have been contributed to the difference in yield observed.

Yield per hectare of the scheme fell from 6.6t/ha in 1996 to 3.1t/ha in 1999 as shown in Table 4.6. The decreasing trend of yield/ha for the scheme may create problems on its sustainability. The poor agricultural performance of the scheme has translated itself into poor financial and economic viability, there by farmers can not maintain well their irrigation facilities as explained in Section 4.5.1

However, this rates of production in 1999 is still low compared the 1987 when the scheme started the production (i.e. 4.5 t/ha), as well as expected rate of paddy rice yield of 7t/ha (Saouma, 1980). It was observed that, change of original water control structures, untimely transplanting (due to late paddy fields preparation), weeding, and application of herbicides and also poor water management and channel maintenance might have contributed to decrease of productivity in the scheme.

4.5 Mkindo Water Users Association (WUA) organisation structure

Mkindo irrigation area has been operated and maintained by a farmers' co-operative registered as "Mkindo Farmers Irrigation Agriculture Marketing primary co-operative Society Ltd.". This co-operative was initially organised by the Phase I farmers in 1984 and the Phase II farmers joined the co-operative in 1986. In April 1997, the co-operative was registered by Ministry of Agriculture and Co-operative. It had 96 members.

Mkindo FMIS has organisation structure for their Association (WUA) as shown in the Fig. 3.9

Mkindo Co-operative Society has an Executive Committee consists of 10 committee members under the General meeting (i.e. Chairman, Vice chairman, Secretary, Treasurer and 6 committee members) .The Executive Committee is further divided into two functional committee

(1) Irrigation water supply Committee consists of 5 members:

- Chairman, Secretary and 3 committee members.
- Water committee is further divided into two more functional sub-committee namely:
- (i) Committee for Construction, Operation and Maintenance.
- (ii) Committee for Agriculture.

(2) Planning, Administration and Finance Committee-3 members:

- Chairman, Treasurer and Secretary.

The Committee members are elected by farmers themselves for a term of 3 years. Farmers are divided into two groups. Namely, Phase-I and Phase-II groups. Phase I group consists of fourteen (14) irrigation blocks and has (2) branch canals, each branch irrigates seven blocks. The Phase II group has three (3) branch canals (Figs. 3.4 & 3.6). For maintenance of irrigation facilities the co-operative has managed the communal work twice a year before every season. At the head–work (Intake) and main canal maintenance was taken by all members of the organisation. Secondary canals were normally cleaned and maintained in communal way by concern organisation members per portion of the canal length covering the particular block of irrigation system (i.e. tertiary block farmers). Similarly tertiary and field canals were cleaned and maintained by members of organisation using the concern canals.

To settle problems in the village related with irrigation activities, water committee liaise with village council

The co-operative punishes absentees according to the following process:

(i) First warning to absentees

(ii) Second fine with TSHS. 500 ($ 0.6) and

(iii) Third the Co-operative stop distribution of water to absentees during one season.

Co-operative commenced collection of irrigation service charge of Tshs.1000 year/acre in 1994/95 season. In August 1997, out of 96 farmers only 85 farmers paid its charge to the Co-operative. In 1997 the Co-operative had a plan to change its mode payment system and rate from "cash" to in kind" amounting to one bag of paddy (70 kg)/year/acre. However, the different funds collected above were not enough to meet maintenance and recurrent costs of irrigation system and hence result on poor maintenance of the system.

Mkindo has a written by-laws prepared on the basis of the standard one for Agricultural co-operatives made by the co-operative office and has no articles for operation and maintenance of irrigation facilities. A punishment rule applied when shirking communal works and evading payment of water charge mentioned earlier should be enacted in the By-laws, otherwise there is no instrument of force in the organisation.

As explained and also shown in Fig. 3.9, WUA has the following duties:

(i) Supervision of farmers at tertiary, block level in timeliness of agricultural operations (including implementation of cropping calendar), irrigation scheduling and maintenance.

(ii) Mobilisation of tertiary block farmers for maintenance of secondary and main system.

(iii) Co-ordination of tertiary block leaders' activities.

(iv) Co-ordination of all committees.

(v) Co-ordination of all maintenance works.

(vi) Collection of members fees.

(vii) To discipline members.

(viii) Plot allocation and reallocation.

(ix) To liaise with village council, primary co-operative, village extension officers and district irrigation officer for irrigation related matters.

This poor performance was not due to poor organisation but probable due to problem of management. According to Bottrall (1981), poor performance at low Hierarchy level is on result of poor performance of top level. The poor performance of the farmer-managed irrigation scheme is associated with the fact that its organisation was started by the Government this result is similar to that reported by Abernethy (1991).

4.5 1 Organisation

The organisational structure of Mkindo farmer- managed scheme was found to be appropriate as in Fig 3.9. A close examination on this structure revealed that all important activities for operation and maintenance of the scheme were taken care of during the project design. Job description for various functionaries had been provided. However, results of physical observation and interview (Appendix 2) conducted among sampled farmers in the farmer-managed scheme (FMS), showed that the scheme had irrigation management problems. Such as poor water management and maintenance of irrigation facilities as explained in Section 4.3, damage of irrigation structures by farmers outside the scheme as discussed in Section 4:2:4 and weak By- laws as explained in Section 4.5

4.5.2 Scheme irrigation water management

The farmers water control within the scheme was not proper. Though water was being controlled at the main canal offtake by the Mkindo FMIS extension officer, and the farmers distributed water among themselves into their fields. However, this function was not properly performed by farmers. Both observation and interview results (Appendix 2) shows that irrigation turns among farmers were not being followed.
According to the system design, water should be discharged at farm level on a seven day irrigation interval in phase-I. This implies that each block would be taking water for one day a week (Fig 3.4). While in the phase-II farm area, water would be discharged at farm level on a three-day irrigation interval in which 3 secondary canals would operate at the same time. However, farmers were irrigating for 24 hours daily. Hence, they were practising a continuous irrigation method.

The system was designed to irrigate under rotation of one block canal per day. This regulation was not complied with. It was observed that the upper and middle part of the scheme were getting more water than it was required (Interview results). In attempt to recover the lost water, phase-II farmers blocked the drains, cut across field canals and were using drainage water to irrigate. As result this practice caused a lot of damage to farmers' fields. For example fields; F66, F76, F86 & F96 were getting more water than was needed as explained in Section 4.2.4. Several water control structures such as division boxes and other structures in irrigation system were damaged with out replacement. Drainage and irrigation canals were inadequately maintained. The canal maintenance problem usually causes excessive vegetation in canals, obstruction of irrigation water and water losses through evaporation, seepage and percolation. There were no credit or loan facilities to meet operational costs. This poor performance was not due to poor organisation structure but probable due to problem of management as discussed in Section 4.3 & 4.5.

A poor performance at low hierarchy level is result of poor performance of top level. The root cause of poor performance in management in the FMIS is the irrigation committee, which is the central managing organ in the FMIS. The poor performance of the farmer-managed irrigation scheme is associated with the fact that its organisation was started by the Government as explained in Section 4.5.1. According to the scheme organisation, the irrigation committee and the field canal representative ought to have advanced training in irrigation management and farm practice, while beneficiaries/farmers ought to have basic training in each aspect. However, observation for the 1998/99 cropping season and interview to farmers revealed that formal training in water management and farming was not a common practice. It was observed that no motivation is made available to those who manage the scheme at different levels for example the tertiary canal representatives and irrigation committee members (i.e. transport and salary).

4.6 Main problems of Mkindo FMIS

4.6.1 Leakage of canal banks

It was observed that most of the canals were leaking through the canal banks causing soil erosion on the outside part as shown in Plate 4.2. This may be attributed to poor maintenance and design of the banks, which has led to a wrong construction causing the leakage. On the other hand, canals were choked with grass. This definitely reduced the flow capacity because the canals were designed and constructed as grassed channels. Overall condition of the canals indicate poor maintenance of the system.

For co-operative activities it self, it has been functioning well and farmers has no dispute among themselves. However, there was some water disputes with the outside farmers who steal water from the upstream part of the main and secondary canals as shown in Plate 4.2. These conflicts were resolved by the village Govt. in 1996/97. The problem was solved by allowing them to take water from the system provided they can follow the irrigation schedule and participation in maintenance of irrigation facilities of the scheme.

4.6.2 Drainage problems:

It was also observed that drainage system of the scheme was not working properly as already discussed. Some field drains have been removed by farmers and a main collector drain has been changed into an irrigation canal by farmers. The Dizingwi river flows eastwards along the downstream border of the phase-I paddy fields and join the

Mkindo river as shown in Fig. 3.2. By design it was supposed to be the main drain of the scheme. The river has insufficient carrying capacity caused by shallow bottom depth of the river and so causes water stagnancy in the downstream area of the phase I paddy fields just before the bridge of the road to Turiani. An old intake weir which exists just down stream of the bridge of the road to Turiani (B127) across the river Dizingwi also aggravates water stagnancy by backwater effect. The old intake weir was constructed before the inception of the scheme. It was constructed before by the Government's intervention to save the same scheme for irrigated agriculture but it failed and so this weir played no role in the overall irrigation system of the scheme.

CHAPTER 5

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the study, the following conclusions are made;

1. In terms of productivity (Yield per unit area/ yield per unit of water), productivity declines in proportion with age of the scheme. This is due to the changes made on already constructed water control structures by farmers in the scheme. Also it could be due to lack of other inputs such as inadequate application of fertiliser/manure, herbicides and improper field bund preparation.
2. Although organisation structure of the scheme is adequate, the scheme faces water management problems. The main problems identified were leakage of canal banks and drainage problems.
3. The conveyance, distribution efficiencies of the main canal and secondary canals for the scheme (i.e. phase-I and phase-II) amounting to 65% and 20%, 28% respectively, are quite low. This means that there are substantial water losses through the main and secondary canals of the scheme. The losses occurring along the canal on its way downstream originated from illegal water harvesting from the main canal and secondary canals by cutting or drilling lateral holes that could not be easily seen along the canal banks. Also because of water losses through evaporation, seepage and percolation due to unlined condition of the main and secondary canals.
4. The average application efficiency in the scheme for phase-I and phase-II amounting to 47% and 45.66% respectively is low compared to the planned value of

60%. These variations in irrigation efficiencies were caused by poor water control at the tertiary block.

5. Farmers in the upper, middle and tail ends of phase-I and phase-II of the scheme were not receiving a fair water distribution. This is shown by relatively high error of equity of 18% and 20 % respectively.
6. From this study, it is concluded that the FMIS in Tanzania may perform better, or be sustainable, if original design of already constructed water control structures are maintained (i.e. not changed) by farmers at operation stage. This emphasises farmer's involvement and empowerment at planning, design and construction stages of the scheme.

5.2 Recommendations

1. Water losses should be reduced through improved water conveyance, distribution and application efficiency. This can be achieved by adopting correct size and proper levelling of irrigated paddy basins.
2. As there were considerable water losses noted along the canals, it is highly recommended to line the main and secondary canals so as to secure this scarce commodity. This will eradicate the illegal taping of water from the canals by upstream users through cutting canal banks or drilling holes through a lateral along the canal banks.
3. It is recommended to use the proportioning water-division devices not only at Mkindo scheme but also in other FMIS on grounds that structures if well designed

and properly installed, are able to distribute the irrigation water on proportional basis.

4. Existing irrigation farmers organisation or water users association (WUA) should be improved, so that the scheme is put under proper irrigation management. A well functioning irrigation association should help in providing education, other services such as water distribution, canal maintenance, credit for agricultural inputs, extension and identification of markets for farmers produce.
5. Presently, those who manage the scheme (leaders) at various levels have no motivation. Availability of motivation to leaders, transport facility for farmer-managed scheme officer who stays 5 km away from the scheme could increase the scheme performance.
6. The average production rate and therefore average income is low for the scheme. An effort should be made to increase the rate of production through the correct use of water and other agricultural inputs, taking into account improvement of drainage system for the scheme.

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7.0 APPENDICES

Appendix 1: Sociological Statistical Programme data analysis for farmers interview

S/NO	Variable name	Description	Codes	Units
1	Colowa	Co-operation in locating water was not effective	1=YES 2=NO	1
2	Cochama	Co-operation in channel maintenance was not effective		
3	Coruco	Contribution to running costs		
4	Deiripe	Determination of irrigation period		
5	Usaewa	Use of sanction against excessive use of water		
6.	Prerifai	Presence of a right for every farmer to irrigate		
7.	Prifalwa	Priority of farmers leaders to receive water		
8.	Maoirr	Maintaining of order of irrigation		
9.	Pracoirr	Practice of complete irrigation		
10.	Prewataf	Presence of water theft among farmers		
11.	Prenirr	Presence of night irrigation		
12.	Recowaco	Resolving of conflicts by water user committee		
13.	Adirric	Adherence to irrigation charges		
14.	Macroc	Maintaining the cropping calendar		
15.	Cofea	Correct fertiliser application		
16(i)	Lap Mech.	Land preparation:- Mechanisation		
16(ii)	LapAni.	- Animal		
16(iii)	LapHump.	-Human power		
17.	Avacrlo	Availability of credit, loan		
18.	Dairrist	Damage of irrigation structures		
19.	Fapdecos	Farmers were fully involved in planning, design and construction of the systems(i.e. location of canals and other water control structures)		
20.	Iwaap.	It was the aided project		
21.	Viulaco	Villagers were used as labourers for construction activities		
22.	Fatriwac.	Farmers in the tails irrigate fully and water control structures function properly		

APPENDIX 1: (continued) Sociological Statistical Programme data analysis for farmers interview

B Co-operation in locating water is not effective

Value Label	Value	Frequency	Percent	Valid Percent	cum Percent
yes	1.0	48	75.0	75.0	75.0
no	2.0	16	25.0	25.0	100.0
		......	....	....	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

C Co-operation in channel maintenance is not effective

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	48	75.0	75.0	75.0
no	2.0	16	25.0	25.0	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

D Contribution to running costs

Value Label	Value	Frequency	Percent	Valid Percent	Cum Perce
yes	1.0	10	15.6	15.6	15.6
no	2.0	54	84.4	84.4	100.0
		------	-------	--------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

E Determination of irrigation period

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	9	14.1	14.1	14.1
no	2.0	55	85.9	85.9	100.0

	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

F Use of sanction against excessive use of water

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	9	14.1	14.1	14.1
no	2.0	55	85.9	85.9	100.0
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

G Presence of a right for every farmer to irrigate

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	56	87.5	87.5	87.5
no	2.0	8	12.5	12.5	100.0
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

H Priority of farmers leaders to receive water

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	54	84.4	84.4	84.4
no	2.0	10	15.6	15.6	100.0
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

I Maintaining of order of irrigation

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent

yes	1.0	7	10.9	10.9	10.9
no	2.0	57	89.1	89.1	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

J Practice of complete irrigation

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	9	14.1	14.1	14.1
no	2.0	55	85.9	85.9	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

K Presence of water theft among farmers

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	13	20.3	20.3	20.3
no	2.0	51	79.7	79.7	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

L Presence of night irrigation

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	55	85.9	85.9	85.9
no	2.0	9	14.1	14.1	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

M Resolving of conflicts by water user committee

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent

yes	1.0	51	79.7	79.7	79.7
no	2.0	13	20.3	20.3	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

N Adherence to irrigation charges

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	10	15.6	15.6	15.6
no	2.0	54	84.4	84.4	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

O Maintaining the cropping calendar

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	3	4.7	4.7	4.7
no	2.0	61	95.3	95.3	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

P Correct fertiliser application

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	7	10.9	10.9	10.9
no	2.0	57	89.1	89.1	100.0
		-------	- -----	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

Q Land preparation:- (i) Mechanisation

Valid Cum

Value Label	Value	Frequency	Percent	Percent	Percent
yes	1.0	55	85.9	85.9	85.9
no	2.0	9	14.1	14.1	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

R Land preparation: - (ii)Animal

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	11	17.2	17.2	17.2
no	2.0	53	82.8	82.8	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

S land preparation:- Human power

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	60	93.8	93.8	93.8
no	2.0	4	6.3	6.3	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

T Availability of credit, loan

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	53	82.8	82.8	82.8
no	2.0	11	17.2	17.2	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

U Damage of irrigation structures

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	57	89.1	89.1	89.1
no	2.0	7	10.9	10.9	100.0
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

V Farmers were fully involved in planning, design and construction of the systems(i.e. location of canals and other water control structures)

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	10	15.6	15.6	15.6
no	2.0	54	84.4	84.4	100.0
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

W It was the aided project

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	54	84.4	84.4	84.4
no	2.0	10	15.6	15.6	100.0
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

X Villagers were used as labourers for construction activities

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	53	82.8	82.8	82.8
no	2.0	11	17.2	17.2	100.0

	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

Y Farmers in the tails irrigate fully and water control structures function properly

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
yes	1.0	14	21.9	21.9	21.9
no	2.0	50	78.1	78.1	100.0
		-------	-------	-------	
	Total	64	100.0	100.0	

Valid cases 64 Missing cases 0

Appendix 2: General results of farmers interview.

NO	Variables	Mkindo Phase-I	Mkindo Phase-II
1.	Co-operation in locating water is not effective	YES	YES
2.	Co-operation in channel maintenance is not effective	YES	YES
3.	Contribution to running costs	NO	NO
4.	Determination of irrigation period	NO	NO
5.	Use of sanction against excessive use of water	NO	NO
6.	Presence of a right for every farmer to irrigate	YES	YES
7.	Priority of farmers leaders to receive water	NO	NO
8.	Maintaining of order of irrigation	NO	NO
9.	Practice of complete irrigation	NO	NO
10.	Presence of water theft among farmers	YES	YES

11.	Presence of night irrigation	YES	YES
12.	Resolving of conflicts by water user committee	YES	YES
13.	Adherence to irrigation charges	NO	NO
14.	Maintaining the cropping calendar	NO	NO
15.	Correct fertiliser application	NO	NO
16.	Land preparation:- (i) Mechanisation	YES	YES
	- (ii)Animal	NO	NO
	- (ii)Human power	YES	YES
17.	Availability of credit, loan	YES	YES
18.	Damage of irrigation structures	YES	YES
19.	Farmers were fully involved in planning, design and construction of the systems(i.e. location of canals and other water control structures)	NO	NO
20.	It was the aided project	YES	YES
21.	Villagers were used as labourers for construction activities	YES	YES
22	Farmers in the tails irrigate fully and water control structures function properly	NO	NO

Appendix 3: Crop Water Requirement (ETc)

Year	Date	Mean ETo (mm/day)	Crop coeff. (Kc)	Daily ETc (mm/day)
Aug. 1998	1-Aug	4	1.1	4.4
	2-Aug	4.3	1.1	4.7
	3-Aug	4.4	1.1	4.8
	4-Aug	4	1.1	4.4
	5-Aug	2.9	1.1	3.2
	6-Aug	4.1	1.1	4.5
	7-Aug	4.3	1.1	4.7
	8-Aug	4.4	1.1	4.8
	9-Aug	3.5	1.1	3.9
	10-Aug	4.3	1.1	4.7
	11-Aug	4.7	1.1	5.2
	12-Aug	4.9	1.1	5.4
	13-Aug	5	1.1	5.5
	14-Aug	5	1.1	5.5
	15-Aug	5.1	1.1	5.6
	16-Aug	4.6	1.1	5.1
	17-Aug	3.4	1.1	3.7
	18-Aug	3.7	1.1	4.1
	19-Aug	5.3	1.1	5.8
	20-Aug	5.3	1.1	5.8
	21-Aug	4.7	1.1	5.2
	22-Aug	4.7	1.1	5.2
	23-Aug	5.5	1.1	6.1
	24-Aug	5.3	1.1	5.8
	25-Aug	4.1	1.1	4.5
	26-Aug	5.2	1.1	5.7
	27-Aug	4.3	1.1	4.7
	28-Aug	4.9	1.1	5.4
	29-Aug	4.6	1.1	5.1
	30-Aug	4.8	1.1	5.3
	31-Aug	3.9	1.1	4.3
	1-Sep	4.5	1.1	5.0
	2-Sep	5.3	1.1	5.8
	3-Sep	5.1	1.1	5.6
	4-Sep	4.3	1.1	4.7
	5-Sep	5.6	1.1	6.2
	6-Sep	5.6	1.1	6.2
	7-Sep	5.5	1.1	6.1
	8-Sep	5.2	1.1	5.7
	9-Sep	4.4	1.1	4.8

10-Sep	4.8	1.1	5.3
11-Sep	5	1.1	5.5
12-Sep	5.5	1.1	6.1
13-Sep	4.7	1.1	5.2
14-Sep	5.6	1.1	6.2
15-Sep	4.8	1.1	5.3
16-Sep	4.7	1.1	5.2
17-Sep	5.3	1.1	5.8
18-Sep	5.1	1.1	5.6
19-Sep	5.1	1.1	5.6
20-Sep	4.5	1.1	5.0
21-Sep	4.6	1.1	5.1
22-Sep	4.5	1.1	5.0
23-Sep	4.7	1.1	5.2
24-Sep	5.4	1.1	5.9
25-Sep	4.8	1.1	5.3
26-Sep	6.3	1.1	6.9
27-Sep	5.7	1.15	6.6
28-Sep	4.5	1.15	5.2
29-Sep	5.2	1.15	6.0
30-Sep	5.8	1.15	6.7
1-Oct	6	1.15	6.9
2-Oct	6.4	1.15	7.4
3-Oct	4.6	1.15	5.3
4-Oct	5.9	1.15	6.8
5-Oct	5.9	1.15	6.8
6-Oct	5.2	1.15	6.0
7-Oct	6.2	1.2	7.4
8-Oct	6.3	1.2	7.6
9-Oct	6.2	1.2	7.4
10-Oct	5.6	1.2	6.7
11-Oct	5	1.2	6.0
12-Oct	5.6	1.2	6.7
13-Oct	5.4	1.2	6.5
14-Oct	4.7	1.2	5.6
15-Oct	5.2	1.2	6.2
16-Oct	5	1.2	6.0
17-Oct	4.3	1.25	5.4
18-Oct	4.8	1.25	6.0
19-Oct	4.2	1.25	5.3
20-Oct	2.9	1.25	3.6
21-Oct	5.8	1.25	7.3
22-Oct	5.9	1.25	7.4
23-Oct	5.7	1.25	7.1
24-Oct	6	1.25	7.5
25-Oct	5.2	1.25	6.5
26-Oct	6.2	1.25	7.8
27-Oct	5.9	1.2	7.1

28-Oct	5.8	1.2	7.0
29-Oct	6	1.2	7.2
30-Oct	6	1.2	7.2
31-Oct	6.2	1.2	7.4
1-Nov	6.2	1.2	7.4
2-Nov	6.3	1.2	7.6
3-Nov	5.5	1.2	6.6
4-Nov	5.5	1.2	6.6
5-Nov	6.4	1.2	7.7
6-Nov	6.4	1.1	7.0
7-Nov	7.5	1.1	8.3
8-Nov	4.6	1.1	5.1
9-Nov	5.9	1.1	6.5
10-Nov	5.8	1.1	6.4
11-Nov	4.3	1.1	4.7
12-Nov	6.2	1.1	6.8
13-Nov	5.8	1.1	6.4
14-Nov	6.4	1.1	7.0
15-Nov	5.9	1.1	6.5
16-Nov	6.8	1	6.8
17-Nov	6.4	1	6.4
18-Nov	4.3	1	4.3
19-Nov	6.2	1	6.2
20-Nov	6.7	1	6.7
21-Nov	5.6	1	5.6
22-Nov	5.5	1	5.5
23-Nov	5.3	1	5.3
24-Nov	6.6	1	6.6
25-Nov	6.5	1	6.5
26-Nov	5.1	1	5.1
27-Nov	4.6	1	4.6
28-Nov	6.3	1	6.3
29-Nov	6.4	1	6.4
30-Nov	6.2	1	6.2
1-Dec	8.1	1	8.1
2-Dec	8.1	1	8.1
3-Dec	7.5	1	7.5
4-Dec	7.4	1	7.4
5-Dec	7.5	1	7.5
6-Dec	7.5	1	7.5
7-Dec	7.9	1	7.9
8-Dec	8.1	1	8.1
9-Dec	8.5	1	8.5
10-Dec	8.1	1	8.1
11-Dec	7.5	1	7.5
12-Dec	7.6	1	7.6
13-Dec	7.6	1	7.6
14-Dec	7.4	1	7.4

	15-Dec	6.6	1	6.6
	16-Dec	6.8	1	6.8
	17-Dec	5.1	1	5.1
	18-Dec	6	1	6.0
	19-Dec	7.4	1	7.4
	20-Dec	7.8	1	7.8
	21-Dec	8.3	1	8.3
	22-Dec	8.7	1	8.7
	23-Dec	8.1	1	8.1
	24-Dec	7.8	1	7.8
	25-Dec	8.1	1	8.1
	26-Dec	7.4	1	7.4
	27-Dec	7.6	1	7.6
	28-Dec	7.3	1	7.3
	29-Dec	5.9	1	5.9
	30-Dec	7.6	1	7.6
	31-Dec	7.3	1	7.3
Jan. 1999	1-Jan	7.5	1	7.5
	2-Jan	8.2	1	8.2
	3-Jan	8.2	1	8.2
	4-Jan	7.2	1	7.2

Appendix 4: Mean Seepage (S) & Percolation (P) values (mm/day)

Location	Date	S & P (mm/day)	Mean S & P values (mm/day)
Upper field blocks	1/8/1998	5.0	4.0
	27/9/1998	4.5	
	1/10/1998	4.0	
	16/10/1998	4.0	
	26/10/1998	4.0	
	8/11/1998	3.5	
	15/11/1998	3.5	
	30/11/1998	3.5	
Middle field Blocks	2/8/1998	6.0	5.0
	28/9/1998	5.5	
	2/10/1998	5.5	
	17/10/1998	5.0	
	27/10/1998	5.0	
	9/11/1998	4.5	
	16/11/1998	4.5	
	1/12/1998	4.0	
Tail field blocks	3/8/1998	6.5	6.0
	29/9/1998	6.5	
	3/10/1998	6.5	
	18/10/1998	6.0	

28/10/1998	6.0
10/11/1998	5.5
17/11/1998	5.5
2/12/1998	5.5

Appendix 5: Seasonal irrigation water need for paddy (mm/season)

Variable	mm/day	days	mm	L/sec/ha
Basic irrigation flooding depth (WL)	-	-	100.0	
Crop water requirement (ETcrop)	-	130.0-	846.1	-
Total Mean Percolation & Seepage losses	5.0	130.0	650.0	-
Effective rainfall (Aug.-Jan.)	-	130.0	-25.9	-
Total (Actual crop water needed)	-	-	1570.2	1.38
Irrigation water needed (At 0.6 field application efficiency)	-	-	2617	2.3

Appendix 6: Crop Yield

Sample block	Field Number	Yield per irrigated area(ton/ha)
B1	F1	3.60
	F2	3.50
	F3	3.40
B3	F7	3.60
	F8	3.40
	F9	3.20
B5	F13	5.40
	F14	5.20
	F15	5.30
B7	F19	3.80
	F20	3.70
	F21	3.60
B8	F22	2.40

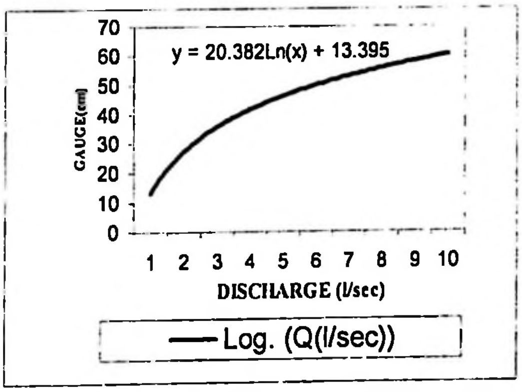
	F23	2.30
	F24	2.20
B10	F28	4.00
	F29	3.90
	F30	3.80
B12	F34	5.50
	F35	5.40
	F36	5.30
B14	F40	2.20
	F41	2.10
	F42	2.00
Phase-II B1	F43	2.10
	F44	2.00
	F45	1.90
B2	F49	2.10
	F53	2.00
	F55	1.90
B3	F69	1.90
	F73	1.80
	F75	1.70
B4	F89	1.80
	F93	1.70
	F95	1.60
Mean		3.1
STDEV.		1.32
Var.		1.74

Source: From farmer's record, which were given in terms of bags/plot area. One bag of paddy was equivalent to 70 KGs.

Appendix 7: The flow rating curves for main canal, Sc1, Sc2 and Sc3

(a) For main canal

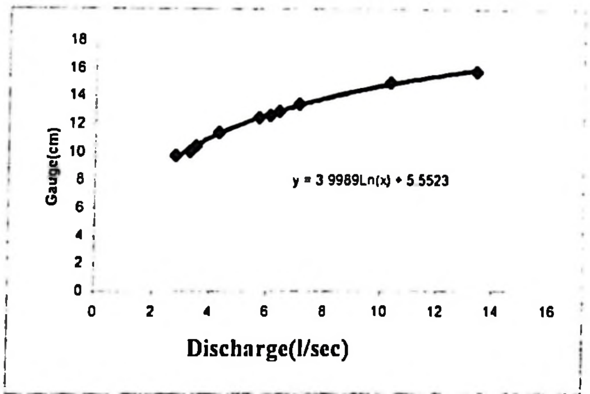
Q(l/sec)	Gauge(cm)
15	7
26.9	10.5
34	11
41.3	11.5
46	12
50	12.5
52.6	13
56	13.5
58	14
62	14.5



(a)MAIN CANAL INTAKE FLOW RATING CURVE

(b) for Sc1

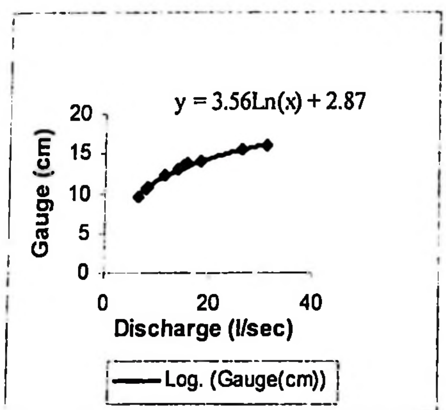
Q(l/sec)	Gauge(cm)
2.79	9.8
3.3	10.1
3.5	10.5
4.3	11.5
5.7	12.5
6.1	12.7
6.4	13
7.1	13.5
10.3	15
13.4	15.8



(b) flow rating curve for Sc1

(c) for Sc2

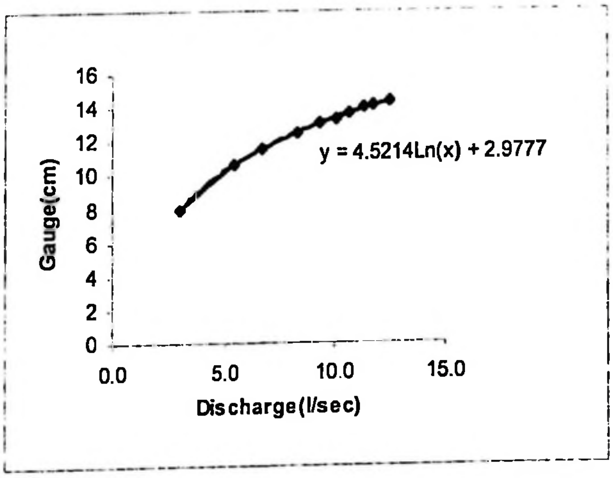
Q(l/sec)	Gauge(cm)
6.4	9.6
8	10.5
8.2	10.9
11.7	12.3
14.2	13.2
15.3	13.5
16	13.8
18.4	14
26.3	15.5
31	16



(c) flow rating curve for Sc2

(d) for Sc3

Q(l/sec)	Gauge(cm)
3.0	8
5.4	10.6
6.7	11.6
8.3	12.5
9.3	13.1
10.1	13.3
10.6	13.7
11.3	14
11.7	14.1
12.5	14.4



(d) Flow rating curve for Sc3

Appendix 8: Key Probes for Diagnostic Analysis of the Study Area

1. When did the scheme start and how?

2. What has been the influence of population growth (population changes) on water use, land tenure etc.?

3. Who have been the key decision makers on the scheme operation?

4. What are the nature, extent and effects of upstream, middle and downstream deprivation?

5. Which farmers do not irrigate fully, when, and why?

6. What do farmers, especially in the tails, know about what water they will receive and when it will come?

7. Could some farmers do as well or better with less water?

8. How and by whom are water allocations, scheduling and delivery decisions made and implemented?

9. How does individual farmer liaise and interact with water committee members?

10. What incentives do the water committee members have to manage badly or well?

11. What happens at night?

12. What does the water committee know and not know, and how accurately, about water movement and delivery, crops, cropped areas, and crop stages on the system?

13. What happens when and where water is scarce?

14. What is the control capacity of the system; how much is used?

15. How much water is available?

16. How could farmers gain more from the way the system is managed?

17. How the existing structures were constructed?

Appendix 9: Variation of observed area from original design area

Field No.	Observed area(m^2) (O)	Original design area(m^2) (E)	Area change (O-E)	Yield per irrigated area(ton/ha)	Application Efficiency (%)
F1	4264.09	3969	295.1	3.60	34.3
F2	4264	3969	295.0	3.50	34.3
F3	4265	3969	296.0	3.40	34.3
F7	4121.64	3969	152.6	3.60	51.1
F8	4057.69	3969	88.7	3.40	50.2
F9	4225	3969	256.0	3.20	49.5
F13	4212.01	3969	243.0	5.40	48.4
F14	4070.44	3969	101.4	5.20	51.7.
F15	4251.04	3969	282.0	5.30	51.0
F19	4254	3969	285.0	3.80	55.0
F20	4238	3969	269.0	3.70	54.5
F21	4258	3969	289.0	3.60	54.7
F22	4096	3969	127.0	2.40	34.3
F23	4252.04	3969	283.0	2.30	34.3
F24	4265	3969	296.0	2.20	34.3
F28	4264	3969	295.0	4.00	51.3
F29	4096	3969	127.0	3.90	51.7
F30	4265	3969	296.0	3.80	51.6
F34	4212	3969	243.0	5.50	51.7
F35	4096	3969	127.0	5.40	51.4
F36	4121	3969	152.0	5.30	51.5
F40	4258	3969	289.0	2.20	55.0
F41	4256	3969	287.0	2.10	54.3
F42	4263	3969	294.0	2.00	53.8
F43	4239	3969	270.0	2.10	37.0
F44	4251	3969	282.0	2.00	47.7
F45	4253.1	3969	284.1	1.90	51.0
F49	4265	3969	296.0	2.10	37.0
F53	4256	3969	287.0	2.00	49.0
F55	4253.5	3969	284.5	1.90	48.7
F69	4256.2	3969	287.2	1.90	37.0
F73	4057.69	3969	88.7	1.80	49.2
F75	4250	3969	281.0	1.70	49.0
F89	4265	3969	296.0	1.80	37.0
F93	4254	3969	285.0	1.70	49.0
F95	4265	3969	296.0	1.60	48.9

Appendix 10: ANOVA Table of regression of yield per hectare by Area change and Application efficiency (Ea) for data in Appendix 9

ANOVA

Source	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	2	8.80	4.40	2.98	0.06
Residual	33	48.77	1.48		
Total	35	57.57			

Appendix 11: Regression results of Yield/ha per original design area change and application efficiency

	Coefficients	Standard Error	t-Statistic	P-value
Intercept	4.09	1.07	3.8	0.001
Change in original area(O-E)	-0.01	0.002	-2.21	
Application efficiency (Ea)	0.01	0.01	0.84	0.41

From Appendix 11, Y= 4.09-0.01 (O-E) +0.01 Ea
Where: Y= Yield per irrigated area (ton/ha)
(O-E)= Change in original design area (m2)
Ea = Application efficiency.
Note the definition refers to data in Appendix 9

Appendix 12: T-test results (Irrigation efficiencies)

Efficiency	t-test	Phase-I/Planned	Phase-II/Planned
Distribution	Test statistic T	-5.44	-5.44
efficiency	Critical T at 5% level of significance	2.78	2.78
	Critical T at 1% level of significance	4.60	4.60
Application	Test statistic T	-2.02	-3.28
Efficiency	Critical T at 5% level of significance	4.30	4.30
	Critical T at 1% level of significance	9.92	9.92

Appendix 13: Water depth management

Decade after transplanting	Block	Required Depth (cm)	Actual depth (cm) Phase-I	Phase-II
			(Mean values) cm	
1 to 6	Upper blocks	5.0	5.5	3.5
	Middle blocks	5.0	3.5	3.0
	Tail blocks	5.0	2.0	2.5
7 to 9	Upper blocks	10.0	10.5	9.0
	Middle blocks	10.0	9.5	7.0
	Tail blocks	10.0	5.0	4.5

Appendix 14: T-test results (Water depth management)

Degree of freedom (df)=10.		Phase-I actual depth against required	Phase-II against required
Decade			
1 to 9	Test statistics T	1.695	3.969
	Critical T at 5% Level of significance	2.571	2.571
	Critical T at 1% Level of significance	4.032	4.032

Appendix 15: Meteological data at Morogoro station for Mkindo FMIS (August1998-Jan. 1999 season)

Month	day	Max. Temp. °C	Min. Temp. °C	Relative Humidity (%)	Wind speed (ml/day)
August	1	28.8	15.5	40	51.3
August	2	29	16.4	47	70.83
August	3	28.8	17.6	46	61.55
August	4	28	15.5	48	65.99
August	5	28	18	58	47.17
August	6	28.8	16.8	43	64.79
August	7	28.6	16	45	59.38
August	8	29.2	16.5	42	57.74
August	9	27	16.6	52	53.09
August	10	29	18.2	45	62.66
August	11	29.3	18	45	74.49
August	12	29.3	16.8	41	72.49
August	13	29.4	17.3	36	69.54
August	14	29.8	15.6	40	62.78
August	15	31.1	14.8	41	57.84
August	16	30.5	17.2	44	71.86
August	17	28.5	16.7	48	49.13
August	18	27.8	18.4	55	42.89
August	19	30.2	17.6	31	89.61
August	20	30.5	17.7	40	88.71
August	21	29.8	17.6	43	66.93
August	22	29.2	16	42	76.88
August	23	30.3	15	43	80.59
August	24	30.4	16.7	50	92.05
August	25	30	16.9	49	72.17
August	26	30	15.1	43	86.88
August	27	28.8	18.8	52	59.32
August	28	30.2	16.4	45	87.93
August	29	29.8	20.2	45	65.71
August	30	29.9	19.7	44	68.67
August	31	29.7	19.6	45	57.09
September	1	30.5	18.4	47	83.1
September	2	30.8	18.3	46	77.62
September	3	30.8	18.9	42	87.38
September	4	30.2	20.1	45	66.72
September	5	31.2	18.2	56	110.74
September	6	30.9	17.7	37	102.61
September	7	30.7	16.1	45	122.67
September	8	29.1	17.2	51	118.58
September	9	28.8	17.1	44	66.84
September	10	30.2	16.1	42	69.81
September	11	31.6	19.6	45	68.86
September	12	30.8	20.6	46	85.32
September	13	29.7	20	44	78.65
September	14	30.8	18.1	38	109.27

September	15	30.8	19.6	45	68.32
September	16	30.3	19.2	40	70.85
September	17	30.6	17.2	44	103.77
September	18	30	18.6	44	96.16
September	19	30.5	16.6	42	85.2
September	20	29.5	18	49	80.07
September	21	30.1	19.3	49	79.08
September	22	30.3	17.7	43	77.34
September	23	30	15.9	45	74.07
September	24	30.8	18	39	108.11
September	25	29.7	17.6	44	97.43
September	26	32.8	19.8	36	99.88
September	27	31	19	48	97.74
September	28	30.3	17.7	49	99.01
September	29	30.6	17.5	43	91.22
September	30	31.7	16.6	37	92.99
October	1	32.3	15.8	32	89.46
October	2	32.2	16	41	93.89
October	3	29.9	17.6	48	84.55
October	4	31.5	17.3	37	84.04
October	5	31	17	38	87.66
October	6	30.7	16.2	43	83.07
October	7	32.2	15.2	29	94.32
October	8	32.6	17	32	87.45
October	9	32.4	17.9	38	97.86
October	10	32.2	20.3	38	96.98
October	11	32.4	18.3	45	82.72
October	12	31.5	19.2	42	86.68
October	13	31.3	17	42	93.31
October	14	30.2	17.1	52	75.24
October	15	31.3	17.8	45	76.31
October	16	30.8	17.8	42	69.48
October	17	31.2	17.2	85	94.6
October	18	31.4	17.4	46	88.89
October	19	29.1	17.4	50	81.4
October	20	27.5	20.2	35	26.41
October	21	31.8	20.6	46	77.4
October	22	30.9	18.6	46	96.66
October	23	31.1	18.3	40	86.6
October	24	32.2	17	38	87.29
October	25	31.7	18.5	38	87.33
October	26	31.8	18.6	33	80.42
October	27	32	17.4	38	76.16
October	28	33	18.2	37	83.47
October	29	32.4	18.8	40	81.61
October	30	32.7	19.1	38	130.22
October	31	33	16.9	33	88.28
November	1	33.7	18.3	37	82.8
November	2	32.5	18.4	38	106.9
November	3	33.1	18.2	39	110.8
November	4	32.7	18	53	78.8
November	5	33.1	18.7	40	104.7

November	6	33.7	19.2	56	135.8
November	7	33.2	19.4	42	184.3
November	8	33.2	20.6	40	91..6
November	9	31.5	19	42	81.6
November	10	31.7	19.2	41	132.9
November	11	31.3	19.6	48	69.7
November	12	32.7	20.6	42	111.2
November	13	32.2	20.5	38	85.8
November	14	33.5	18.1	36	98.3
November	15	32.7	17.4	40	82.9
November	16	33.5	17.9	34	104.9
November	17	33	18.5	35	94.5
November	18	31	19.3	49	78.3
November	19	33.7	19.2	32	108.5
November	20	33.5	19.5	24	112.3
November	21	32.7	19.7	41	82.3
November	22	33.1	19.4	44	61.5
November	23	33.2	21.6	60	73.5
November	24	31.7	20.6	52	199.4
November	25	30	21.5	56	232
November	26	30.7	22.3	61	203.3
November	27	29.3	20.9	69	125.7
November	28	33	18.9	42	115
November	29	33	20.8	46	133.9
November	30	33.1	22	44	164.6
December	1	33.6	20.1	44	241.2
December	2	32.4	22.8	48	246.3
December	3	33.5	22.2	54	206.8
December	4	34	22.7	39	200.3
December	5	33.4	23	50	185.1
December	6	33.9	21.2	40	191.8
December	7	33.8	22.7	38	209.3
December	8	33.8	22.5	34	227.3
December	9	34	23.2	38	231.8
December	10	34.1	23.5	37	239.5
December	11	34	23.1	40	201.2
December	12	34.6	21	37	167.8
December	13	34.5	20	35	200.7
December	14	34.2	21.8	36	181.8
December	15	34	21.1	38	173.8
December	16	33.7	22.1	41	152.3
December	17	34.8	20.4	35	-
December	18	34.7	-	41	125.8
December	19	35	20.2	36	144.9
December	20	35.1	21.6	32	176.5
December	21	36.2	22.4	26	219.9
December	22	36	23.5	32	243.3
December	23	34.9	24.2	34	248.3
December	24	34.5	23.2	32	229.6
December	25	34.8	23.5	34	230.6
December	26	34	22.5	40	192.7
December	27	34	22.3	40	222.8

December	28	34.5	23	36	188.3
December	29	33	22.4	44	181.9
December	30	35.1	22.6	37	192.2
December	31	35.1	24.1	37	192.8
January	1	36.2	24.2	40	161.5
January	2	36.6	24.1	37	209.8
January	3	35.5	24.4	36	222.7
January	4	35	24.4	38	213.6

Appendix 15: (Continued)

Month	day	Sunshine (Hrs/day)	Radiation (MJ/m^2)	Evaporation (mm/day)	Rainfall (mm/day)
August	1	7.9	14.95	4	0
August	2	6.9	15.7	4	0
August	3	7.3	17.38	4	0
August	4	6.9	14.76	3.5	0
August	5	2.9	8.7	3	0
August	6	5.4	14.86	4	0
August	7	7.6	16.44	4	0
August	8	8.3	17.56	3.5	0
August	9	2.7	12.15	3	0
August	10	5.2	15.51	3.4	1
August	11	6.4	17.56	2.4	0.9
August	12	6	19.15	6.5	0.4
August	13	10.1	20.36	5.5	0
August	14	9.8	20.36	5.5	0
August	15	10.6	19.52	5.5	0
August	16	9.1	18.03	5.5	0
August	17	3.6	11.5	3	0
August	18	3.7	11.4	2.7	2.5
August	19	10.5	20.17	6	1.7
August	20	9.4	21.11	5.5	0
August	21	6.9	16.83	4.8	0.8
August	22	8	17.29	4.5	0
August	23	10.2	20.64	6	0
August	24	10.1	20.81	5	0
August	25	6.8	13.55	6.5	0
August	26	9.7	19.33	5	0
August	27	7.7	15.7	4.3	1
August	28	6.2	17.46	6	0.8
August	29	6.4	16.62	4.3	0
August	30	4.6	17.46	4.5	1.8
August	31	3.9	12.71	3	0
September	1	4.4	14.78	4.5	0
September	2	8.7	19.88	5.5	0
September	3	8.9	17.54	6	0

September	4	4.4	14.24	3.5	0
September	5	10.3	19.42	6	0
September	6	8.4	19.8	5.5	0
September	7	7.6	18.67	5.5	0
September	8	6.2	18.04	6	0
September	9	6.5	15.86	4	0
September	10	7.9	17.66	5.5	0
September	11	6.3	17.75	4.8	0
September	12	8	19.8	5.8	5.8
September	13	7.3	15.78	5	1.8
September	14	9	19.26	6.5	0
September	15	6.4	16.45	4	0
September	16	6.4	16.16	5	0
September	17	8.6	17.75	4.5	0
September	18	8.6	17.66	5.5	0
September	19	7.3	17.83	5.5	0
September	20	5.4	15.49	4	0
September	21	5.3	15.24	4.5	0
September	22	4.2	14.48	5	0
September	23	6.2	16.24	5	0
September	24	6.9	17.66	5.5	0
September	25	4.2	15.86	5.5	0
September	26	9.4	22.52	6	0
September	27	8.5	19.88	7	0
September	28	2.7	13.73	4.5	0
September	29	7.2	17.83	6	0
September	30	8.6	20.64	7	0
October	1	10.6	22.4	6.5	0
October	2	10.9	23.44	7	0
October	3	6.2	15.4	5.5	0
October	4	10.8	21.93	7	0
October	5	10	21.85	7	0
October	6	9.5	18.04	6.5	0
October	7	10.8	23.15	8	0
October	8	10.4	23.44	7.5	0
October	9	10.2	21.85	7.5	0
October	10	9.6	18.59	7	0
October	11	9.8	16.32	5.5	0
October	12	8.6	19.34	6	0
October	13	8.2	18.38	6	0
October	14	5.8	16.07	5.5	0
October	15	9.2	17.83	6	0
October	16	8.2	17.37	5.5	0
October	17	10.4	17.54	6.5	0.6
October	18	7	15.49	6	7.6
October	19	4.6	13.44	3.6	0
October	20	0.5	8.24	1.1	0
October	21	8.9	20.64	6	0
October	22	8.9	20.93	6	0
October	23	9.1	20.43	7	0
October	24	9.6	21.64	7	0
October	25	9.4	16.83	5.5	0

October	26	11.1	23.44	6	0
October	27	10.8	21.48	7	0
October	28	8.7	20.26	7	0
October	29	9.8	21.77	6.5	0
October	30	8.5	18.67	6	0
October	31	10.7	22.32	6.5	0
November	1	8.5	21.86	7.5	0
November	2	9.7	21.48	6.5	0
November	3	7.9	17	7.5	0
November	4	8.8	19.13	6	0
November	5	10.7	21.94	7.5	0
November	6	7.5	20.43	6	3.5
November	7	10.2	23.07	8	0
November	8	6	18.38	6.5	0
November	9	9.9	21.19	6.5	0
November	10	10	17.84	7.5	0
November	11	3.5	13.36	5	0
November	12	9.7	20.73	7	0
November	13	9.5	19.89	7	0
November	14	9.2	22.4	6.5	0
November	15	8.7	20.64	8	0
November	16	10.7	23.99	7.5	0.4
November	17	10.7	23.15	8	0
November	18	4.1	12.89	3.4	0
November	19	10.9	20.43	9	0
November	20	10.6	23.61	7.5	0
November	21	8	19.05	6.5	0
November	22	7.9	19.43	4.5	0
November	23	5.9	17.75	6.6	0
November	24	8.6	19.59	6.5	2.1
November	25	7.1	19.51	7.5	1
November	26	4.3	14.11	5.3	TR
November	27	4.5	15.24	3.6	1.3
November	28	8.9	21.1	7.5	1.6
November	29	8.9	20.56	5.5	0
November	30	10.5	17.75	7.5	0
December	1	10.5	23.16	8.5	0
December	2	11.1	24	10.5	0
December	3	9.9	22.41	8	0
December	4	10.5	21.57	9	0
December	5	10.4	22.97	7.5	0
December	6	10.8	22.23	9	0
December	7	10.5	23.45	9	0
December	8	10.7	23.53	9.5	0
December	9	11.2	24.91	10.5	0
December	10	10.9	22.86	10	0
December	11	9.9	21.77	10.5	0
December	12	10.8	23.53	10	0
December	13	10.1	22.23	9	0
December	14	10.6	22.23	8.5	0
December	15	9.9	18.97	9	0
December	16	9.1	21.02	7.5	0

December	17	10.8	21.02	-	0
December	18	9.1	20.56	7.5	0
December	19	10.9	23.91	8.5	0
December	20	11.2	23.82	11	0
December	21	11.4	23.7	11	0
December	22	10.9	24.58	11.5	0
December	23	11	22.23	9.5	0
December	24	11.1	21.77	10	0
December	25	10.7	22.97	13	0
December	26	9.5	21.57	9	0
December	27	10.9	21.4	10	0
December	28	7.7	21.4	9	0
December	29	7.4	15.58	6.5	2
December	30	10.3	22.02	8.5	0
December	31	7.2	20.56	8.5	0
January	1	10.2	22.23	8.5	0
January	2	9.6	23.15	9	0
January	3	10.8	23.15	10.5	0
January	4	9.2	18.97	11	0

Appendix 16: Mean flow data values in field blocks (l/sec)

Location	Date	(l/sec)	Mean values (l/sec)
Upper field blocks	1/8/1998	6.0	6.5
	27/9/1998	8.25	
	1/10/1998	7.25	
	16/10/1998	8.0	
	26/10/1998	7.25	
	8/11/1998	5.5	
	15/11/1998	5.0	
	30/11/1998	5.25	
Middle field Blocks	2/8/1998	5.0	5.5
	28/9/1998	5.25	
	2/10/1998	6.5	
	17/10/1998	7.0	
	27/10/1998	6.9	
	9/11/1998	6.25	
	16/11/1998	3.8	
	1/12/1998	3.5	
Tail field blocks	3/8/1998	3.0	3.5
	29/9/1998	4.25	
	3/10/1998	4.5	
	18/10/1998	4.75	
	28/10/1998	3.5	
	10/11/1998	3.25	
	17/11/1998	2.75	
	2/12/1998	2.25	

Appendix 17: The start and end dates of all sampled irrigation blocks

Location (Irrigation blocks)	Start date	End date
Phase-I: B1	1/8/1998	22/11/1998
B8	1/8/1998	22/11/1998
B3	1/8/1998	22/11/1998
B5	2/8/1998	23/11/1998
B10	2/8/1998	23/11/1998
B12	2/10/1998	15/11/1998
B7	3/8/1998	24/11/1998
B14	3/10/1998	16/11/1998
Phase-II: B1	1/8/1998	22/11/1998
B2	1/8/1998	22/11/1998
B3	2/8/1998	1/12/1998
B4	3/8/1998	2/12/1998