

**PRICING OF IRRIGATION WATER IN A
FARMERS- MANAGED IRRIGATION SCHEME IN
TANZANIA : A Case Study of Lower Moshi**



BY

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ABSTRACT

A computer program model for pricing irrigation water among beneficiaries, was developed by the use of Turbo Pascal language. The data that was used to test the model was collected from Lower Moshi Farmer-Managed Irrigation System (FMIS) in Northern part of Tanzania as a Case Study area.

The aim was to evaluate the costs involved in the process of allocating irrigation water with the objective of developing a computer program model appropriate for pricing irrigation water in FMIS in Tanzania.

Allam's (1987) mathematical model for allocating irrigation water price which was developed in Egypt, was adopted and adapted for the purpose. The results show that the irrigation water prices obtained differ between different blocks within the same system, and also there is significant difference of irrigation water prices between two systems that exist in Lower Moshi Irrigation System (LMIS) i.e Rau and Mabogini.

By manual calculations, Mabogini irrigation system's water price ranges from 8,276 Tshs/ha to 14,972 Tshs/ha; while for Rau system it ranges from 3,896 Tshs/ha to 13,857 Tshs/ha; with their mean values of 11,940 Tshs/ha and 10,538 Tshs/ha respectively.

The computer program model produced irrigation water prices ranging from 8,479 Tshs/ha to 15,200 Tshs/ha for Mabogini system; while for Rau system they range from 3,913 Tshs/ha to 13,858 Tshs/ha, with their mean values of 12,151 Tshs/ha and 10,414 Tshs/ha respectively. The mean value was adopted as the system irrigation water price in each system.

The farmers' capacity to pay Irrigation Service Fee (ISF) was also assessed and found to be 154,309 Tshs and 194,309 Tshs for tenant and landowner farmers respectively.

The irrigation water pricing computer program model was tested for one cropping season. Therefore, more work is required to test it for the two cropping seasons, and in other FMIS so as to develop universal model. This will make it more universally applicable in Tanzania.

DECLARATION

I, **Lutatina James Mutabuzi**, do hereby 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... 11/7/1999

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DEDICATION

Dedicated to my family.

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ABBREVIATIONS

C/D	Check Drop structure.
CFTC	Commonwealth Fund for Technical co-operation.
CPM	Computer Program Model.
FAO	Food and Agricultural Organisation.
FMIS	Farmer Managed Irrigation Systems.
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit.
ISC	Irrigation Structure Cost.
ISF	Irrigation Service Fees.
JICA	Japanese International Co-operation Agency.
LMIS	Lower Moshi Irrigation Scheme.
MI	Mabogini Intake.
MS	Mabogini System.
NAFCO	National Agriculture and Food Corporation.
O & M	Operation and Maintenance.
OMC	Operation and Maintenance Cost.
P/Flume	Parshall Flume.
PF	Pilot Farm.
PIW	Price of Irrigation Water.

RI	Rau Intake.
RS	Rau System.
SACCAR	Southern Africa Centre for Cooperation in Agricultural Research.
SUA	Sokoine University of Agriculture.
T/O	Turnout structure.
TAC	Total Allocation Cost.
TMM	Turnout and check drop structures in Mabogini main canal.
TMS	Turnout and check drop structures in Mabogini secondary canals.
TPC	Tanganyika Planting Company.
TRM	Turnout and check drop structures in Rau main canal.
TRS	Turnout and check drop structures in Rau secondary canals.
UNDP	United Nations Development Project.
URT	United Republic of Tanzania.
WRC	Water Right Cost.
WUA	Water Users Associations.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Irrigation water is one of the most important input for agricultural productivity in irrigated agriculture. Reliable sources of irrigation water especially in arid and semi arid areas reduce risks and stabilize production levels of individual farms. Irrigation helps to alleviate rural poverty, hunger and malnutrition. On the other hand, irrigation systems need significant amount of resources for operation, maintenance and management for them to be sustainable (Rhodes and Sampath, 1987; Satpathy, 1984; Bryant,1995). Small (1990) and Tiffen (1990) also reached the same conclusion.

Constraints in finance in the public sector severely affect irrigation activities of small-holder farmers as all other public services (Mascarenhas et al.1985). Discussions on institutional constraints generally come down to the recognition of the need to delegate scheme management to water users' associations as much as possible (Speelman,1990; and Mascarenhas et al.1985).

Carruthers (1986) and Gerards (1992) reported that many Governments are turning to the old intractable area of water users' fees and water tariffs.

"Get the prices right" which means get the input prices as well as product prices right is the current slogan in agricultural policy. There is not much enthusiasm in irrigation projects for economic pricing policies, partly because economists and financial analysts can not agree on precisely what this means. Another problem is that any revenue raised from irrigation projects are generally retained by the farmers, without some of it being collected as water cost recovery of the project for operation, maintenance and management (Carruthers,1986; Mcloughlin, 1988).

Due to these drawbacks, performance of most of the irrigation systems in Tanzania is low due to, among other factors, lack of funds for operation, maintenance and management (Carruthers 1985; Gerards 1992). Most of the Government intervened irrigation schemes in Tanzania such as Lower Moshi, Mwamapuli, Majengo and Kitivo just to mention a few, have been handed over to water users.

But the hand over was done without proper and clear guidelines from the executing agency, on how the projects would generate funds for running them (Biomass,1990). Gerards (1992), pointed out that the inability to properly maintain irrigation systems overtime forced the Government of Indonesia to seek cost recovery from water users through introduction of an irrigation service fee. The same was recommended by UNDP/FAO (1993) in Tanzania. Hence, financial constrains coupled with poor performance of Government assisted FMIS in Tanzania, calls for the water users to take the irrigation responsibilities and introduce irrigation service fee as an effective way of attaining successful irrigation farming in the country.

Bhatti and Kijne (1990) have proposed that water trading should be legalised and they observed that farmers who trade water were on average more productive than those who did not.

In Tanzania, the Government in collaboration with international donor agencies commit significant amount of funds for construction of irrigation systems (PPMB,1993), but no funds are allocated for their operation, maintenance and management. Often maintenance efforts continue to be postponed, until a major crisis that can no longer be postponed appears (Biswas, 1990). However, neither the Government nor water users' organisations have formulated guidelines on how the irrigation systems are to be operated and maintained. Moreover, water users associations are either too young and still evolving or absent.

Government subsidies to irrigation projects/schemes are unlikely since one of the Government measures to reduce Government deficit is to remove subsidies on agricultural inputs. Thus, water charges is the major reliable source of revenue and sustainability for the scheme. Previous studies on smallholder irrigation in Tanzania such as Lower Moshi, Bahi. Majengo and Mwamapuli had not paid attention to pricing of irrigation water. Due to lack of a proper system of pricing irrigation water, water charges, in different schemes are implemented on ad-hoc basis, mainly when irrigation water control structure fails. The present study attempts to establish a system of pricing irrigation water in FMIS in Tanzania.

1.2 Objectives of the study

The Study is concern with developing a computer program model appropriate for pricing irrigation water in FMIS in Tanzania and validate the program model using data from Lower Moshi Irrigation Scheme. The specific objectives of this study were:

- (i) To identify and evaluate the required infrastructure (water control structures) to be used in pricing irrigation water in Lower Moshi Irrigation Scheme;
- (ii) To adopt and adapt Allam's mathematical model for allocating irrigation water price among water users in the scheme;
- (iii) To assess farmers' ability to pay for irrigation services in relation to the pricing criteria generated from the model; and
- (iv) To develop a computer program model for allocating irrigation water price among the beneficiaries in the scheme.

1.3 Working definitions

Irrigation is the application of water to farmland in order to increase crop yield or shift to production of a higher valued crop (Bryant,1995; Eckstein,1958).

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Water charges: in literature, is sometimes specified as "irrigation service fees (ISF)", " Water price", or " user charges". In this Study they were used synonymously. "Farmers", "Beneficiaries" or "Groups of farmers" are in this context used to represent "irrigators", " water users", or "water users associations".

1.4 Organisation of the dissertation

The dissertation consists of five chapters. Chapter two reviews some past studies on small holders irrigation schemes in Tanzania as well as studies on pricing of irrigation water in different countries and methods used for allocating irrigation water costs among the different cost elements. Chapter Three describes the materials, methodology employed during data collection, adopted and adapted models; while Chapter Four presents and discusses results of the study. Chapter Five summarizes the major findings, conclusions and recommendations of the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter reviews, previous studies on small holders irrigation schemes in Tanzania and aspects of water pricing as discussed in the subsequent sections.

2.1 Previous studies on irrigation schemes in Tanzania

Many studies on small holder FMIS have been carried out in Tanzania. However, most of these studies dealt with evaluation of performance of irrigation systems, socio-economic analysis of irrigation projects and water management aspects particularly in equity, operation, maintenance, formulation and organisation of WUA(s) and their related problems (Angeir, 1992; Maregesi, 1993; Tarimo, 1994; Riddel, 1989; FAO, 1987).

Orota (1993) carried out a socio-economic and financial analysis of LMIS. In this study, he found that LMIS is economically feasible. Balirwa (1990) studied the economic aspects of large scale irrigation schemes in Tanzania; and explained that they are not economically viable and not sustainable. Although, Orota (1993) explained an economic and financial analysis of FMIS in Tanzania, he did not say anything about WUA and irrigation water pricing.

The importance of involvement of farmers at various stages of irrigation scheme development has been a concern of many irrigation researchers, planners and managers. Failure of proper organisation and poor turnover preparation of WUA has been found to be one of the problem facing FMIS in Tanzania, hence, poor operation and maintenance of the FMIS (Angier, 1992; FAO, 1987; Adams and Anderson, 1987). Tarimo (1994) studied the influence of technology and management of FMIS in Tanzania and noted the problem of farmers in operating and maintaining irrigation systems. He concluded that the problem is due to failure to involve the intended beneficiaries on the planning, designing and construction of the project from the beginning. This situation has generally led to deterioration of irrigation structures such that farmers fail to repair them (Angeir, 1992; Riddel, 1989; Mkude, 1989).

Another major problem facing most of FMIS in Tanzania is on water management related aspects. According to Maregesi (1993) inequity of water distribution, weak WUA and poor water management at field level contributed much to the decline in crop production in LMIS. He recommended the introduction of ISF as an important factor in order to improve and have good water management at farm level. In his study he suggested formulation of strong organisation of WUA that will be responsible to collect water charges based on amount of water received in the farmer's field rather than being based on farmer's irrigated area. Despite his recommendations, Maregesi (1993) did not consider the problem of lack of measuring instruments in most FMIS in Tanzania.

Due to this problem the suggested method of charging farmers is practically impossible under the actual situation in most FMIS.

CFTC (1978) in their feasibility report of Usangu plains, suggested the need to introduce ISF as the way of making farmers to co-operate and assist in scheme operation and maintenance. However, the report did not explain how the ISF will be estimated and collected.

FAO (1986;1987) studies in Mombo and Majengo irrigation schemes reported that the main reasons for poor operation and maintenance of small holder irrigation schemes in Tanzania are inadequate resources which have been spread too thinly; inadequate financial resources which meant that construction has been done badly and not completed; and very little effective support has been given to farmers to either complete or operate the schemes. In spite of identifying the main reasons for poor operation and maintenance in FMIS; none of studies has attempted to establish a method of estimating and collecting ISF, and how farmers may contribute to operation and maintenance of FMIS. However, a number of studies on different allocation and collection methods of ISF in FMIS have been conducted elsewhere in the world as reviewed in the following sections.

2.2 Studies on irrigation water pricing aspects

Several studies on the water pricing aspects of public irrigation systems have been undertaken in different countries such as Egypt, Indonesia, New Zealand and India just to mention a few.

Bhatia (1991), pointed out that Indian Government collected fees from water users on average less than 10% of the full costs of irrigation services. He went on saying that, Government subsidies ranged from 75% to 99%. This reflects less response to water users, simply because of large Government share to the project. Among the widespread problems encouraged by subsidies are chronic excess demand for water, poor operation and maintenance of completed systems, and inattention to water conservation opportunities (Bhatia,1991; Vaidyanathan,1991).

As efforts to make irrigation more effective and to find new financial resources for irrigation activities proceeded, inevitable policy conflicts have arisen (Vincent, 1990; Eckstein,1958). ISF involves changes of many things such as attitude, procedures, roles, rights and responsibilities of the farmers. And change is often associated with conflicts (Angeles et al,1989; Gerards, 1992). New " rules of the game" in associations for irrigation service fee are to be developed, accepted and instituted. The association should clearly know who will do what, when, where, and how often (Gerards, 1992; Green,1987).

The socio-political aspects of something so penetrating into the water users community (with its often ingrained set of values and traditions) should be kept in mind.

Gerards (1992), working in Indonesia found that farmers in Indonesia who have received water free of charge, and who have seen 3 to 5 rehabilitations of the irrigation systems in a 20 years period, will most likely ask; "why suddenly pay for operation and maintenance?". They may perceive this payment not as a payment for services provided to them, but one for water. And water comes from heaven hence should be available to them as free commodity. This is probably the belief of most water users in Tanzania.

The success in charging farmers will depend on how they recognise the effect of the payments. This was demonstrated by World bank survey (Bos and Walters, 1990) that farmers were frequently reluctant to pay charges when they could not depend on the 'irrigation service'. Moreover, bad operation and maintenance has been a reason for them not to pay realistic charges (Svendsen,1986).

Gopinath and Kalro (1991) observed that sustainability of a project is determined by the attractiveness to the farmers, of the balance of positive and negative effects. Only if farmers can expect a significant betterment due to the project , will they be willing to participate in its operation and maintenance.

Hence, they concluded that farmers can only sustain a project if the costs can be met by the general annual cash supply, leaving them with income increase that provides enough of an incentive for them to participate fully in the project activities. Nor can farmers recognize the effect of their payments when the charging is indirect, e.g through land-tax or through compulsory sale of produce to the Government at a low price than on the free market (Bos and Wolters, 1990).

Six different alternative methods of allocating and pricing irrigation water used in developing countries were compared and ranked on the bases of allocative efficiency in production, equity in the distribution of income, and cost recovery to the provisioning authority (Rhodes and Sampath, 1987). The rankings depend crucially on the relative capital intensities between small and large scale producers.

Rhodes and Sampath (1987) pointed out that the basic objectives of the existing regulatory and pricing systems in developing countries fall into three categories; namely: efficiency, equity and cost recovery objectives.

- (i) The efficiency objective, is concerned with the allocation of available irrigation water among competing users or regions such that it maximizes the total economic returns (however they are measured).
- (ii) The equity objective, is concerned with the improvement of the distribution of income in favour of poorer and smaller farmers; and

- (iii) The cost recovery objective, is to recover the costs of investment, maintenance and operation of irrigation systems.

In order to achieve the combinations of the three objectives mentioned above, Rhodes and Sampath (1987) classified the system that can be used to allocate irrigation water into none pricing and pricing systems.

2.2.1 Non pricing system

The non pricing system was further sub classified by Rhodes and Sampath (1987) into optimal water distribution and proportional water distribution systems. The former system is an ideal system whereby farmers are allocated water without pricing such that the marginal productivity of water across farms is equalized, thus bringing the highest possible production with the given amount of water. This system is impractical due to its regulatory complication, administrative frame work and vast information needed to successfully carry it out (Rhodes and Sampath,1987; Svendsen,1986): In the latter system, water is distributed proportionally among farmers depending on the share of the total irrigated land served by the irrigation system. This system is used widely, either singly or in combination with some form of water pricing. The popular Warabandi system practised in South Asia is a variant of this system (Rhodes and Sampath, 1987; Hussain and Young, 1985).

2.2.2 Pricing system

The pricing system currently used by developing countries was further grouped by Rhodes and Sampath (1987) into two major categories; direct and indirect charges for using irrigation water. Direct charges comprises of two sub-categories; volumetric and acreage pricing systems (Rhodes and Sampath, 1987).

In the volumetric pricing system; the farmer pays for each unit of water used. The system has got practical difficulties, such as high setting up costs (Bowen and Young, 1983; Easter and Welsch, 1983). Small et al. (1986) concluded that it is probably not feasible to collect irrigation service fees based on the volume of water used because of two factors: the inability of most agencies to measure water consumption accurately at the turnout and the administrative costs of collecting fees from the large number of individual farmers usually found in the irrigation systems of developing countries. There does, however, appear to be scope for charging organized groups of farmers served from a common canal. Svendsen (1986) reported a similar conclusion.

In the acreage pricing system; the farmer is required to pay a fixed amount of money on a per acre basis for the irrigated area. This system is easier to administer but has the practical difficulty in terms of difference among entitled water share and received water share in the irrigated land.

These might be caused by physical, logistical and political problems (Small et al. 1986).

Indirect charges also comprise two sub-categories (Rhodes and Sampath,1987; Small,1990 and Tiffen,1990); tax on outputs produced and tax on inputs purchased. In the former system each farmer pays a fixed charge per unit of output produced as payment for the irrigation water he received. The farmers' share of water equals his share of irrigated land in the command area. This system is also easy to administer and less complicated (Small, 1990; Douglass and Lee,1971). Hence, it can be applied even in Tanzania, especially for smallholder development projects which are now emerging rapidly in different parts of the country. In the latter system a farmer pays for the irrigation water he receives indirectly through the higher prices he pays for the inputs purchased from the Government. As with output taxation, the farmer's share in water equals his share in irrigated land in the command areas. This system is also easy to administer (Rhodes and Sampath,1987); but it is not ideal in Tanzania where most of the farmers do not purchase any input from Government or private business sectors. Moreover, the country has got no proper way of collecting taxes and use it for operation and maintenance of the irrigation project under consideration.

2.2.3 Costs allocation for irrigation water

The procedure for dividing total financial cost among the responsible parties is called cost allocation (Allam, 1987; Douglas and Lee, 1971).

Cost allocation requires assignment of total cost among scheme purposes and division of purpose cost among user groups. Each group assigned a cost is called cost centre. Allocation problems have no correct answer (Douglas and Lee, 1971). Any procedure which directly affects the pocket book is always controversial and the fundamentally indeterminate nature of cost allocation intensifies the controversy (Douglas and Lee, 1971). Each party tends to favour the allocation shifting the largest share of the joint costs to others.

The essence of cost allocation is the successful resolution of the conflicting interests among these parties (Douglas and Lee, 1971; Young, 1986). They also suggested that even though there is no correct method of cost allocation, the allocation method chosen should avoid costly data and complex computations that have no other use. Complex allocation methods are no more correct than simple ones. Allam (1987) suggested that the methods most commonly used in practice for allocating costs of irrigation water among its users (or uses) are: Facilities and Separable Costs-Remaining Benefits (SCRB) methods.

SCRB method

SCRB method assigns for each use its separable cost and the remaining cost of the project (joint cost) is allocated among the different uses proportionally to the benefits in excess of assigned separable cost. This method is more complicated than the use of facilities method because of the difficulties associated with the estimation of the separable costs of the various services (Allam,1987; Douglas and Lee,1971).

Facilities method

In the Facilities method costs are allocated on the basis of the degree to which each user requires the service of the irrigation system. Allam (1987), also found that the use of Facilities method is superior to the SCRБ method, not only by its practicability but also because of its simplicity, theoretical soundness and economic attractiveness.

Since the SCRБ cost allocation method is complicated in that it requires more information and its evaluation is cumbersome, it will not be an ideal method in Tanzania where flow data collection is a problem due to lack of flow measuring devices and poor ways of data keeping in different Government and local sectors. Therefore, the Facilities method will be used in the development of computer program model for allocation of irrigation water cost among different cost centres.

2.2.4 Service level in irrigation systems

In Tanzania infrastructures in FMIS are lacking. The level of services that can be expected is below the potential service level of a fully technical irrigation system with all facilities in a good working condition. There are then two options (Gerards, 1992):

- (a) Postpone the introduction of irrigation service fee until the time that the system has been fully rehabilitated; or
- (b) Classify the system according to its present condition and associated potential service level, and relate the irrigation service fee level to the system classification.

The latter approach had been adopted in this study as it has the advantage that a start can be made with the introduction of irrigation service fee now, irrespective of a certain degree of the actual condition of the available infrastructure and modify them with time. It is important to determine the concept of service levels, how to establish service levels and how to use service levels in different FMIS in Tanzania.

Finally recognizing the users input is important, as it is also the basis for asking the fee. When users are involved in operation, maintenance and irrigation service fees, the willingness to pay is increased (Gustfson and Reidinger, 1971). This has been supported by Gerards (1992) that water users should pay according to the realised planned services.

He emphasised that, just to ask to pay for the results would not do justice to the equity principle. He went on to say, a farmer harvesting only 20% instead of 40% from his 0.3 hectare plot in the second dry season, will certainly know the difference. Therefore, payment for service will be based on realising the planned 40%. If the realisation drops to 20%, the farmer should not pay, through the use of a fee reduction mechanism.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

The Lower Moshi area lies on the Eastern skirt of Kilimanjaro mountains between 700m and 800m above sea level (Orota,1993). LMIS is located at the far Western part of the Lower Moshi area and is about 3 to 15 kilometres South-East of Moshi town, the capital of Kilimanjaro region (Figure 3.1). The latitude of Lower Moshi is 3°S and longitude 37.5°E. The scheme area consists of a relatively narrow strip of land developed on an alluvial plain along the right bank of the Rau river. The area covers four villages, namely Mabogini, Rau ya kati, Chekereni, and Oria; and bounded by the Rau river on the East, the sugar plantation of the Tanganyika Planting Company (TPC) on the West and North, and by a plantation farm owned by the National Agriculture and Food Corporation (NAFCO) on the South.

The irrigation water distribution system in LMIS consists of two intake weirs (Rau and Mabogini), diversion structures, regulators and canals of various orders.

Two rivers, namely Rau and Njoro are the sources of the irrigation water supply in LMIS. Mabogini system receives irrigation water from Mabogini intake located in Njoro river. It commands a net irrigable area of 955 ha. Mabogini system is subdivided into upper and lower Mabogini.

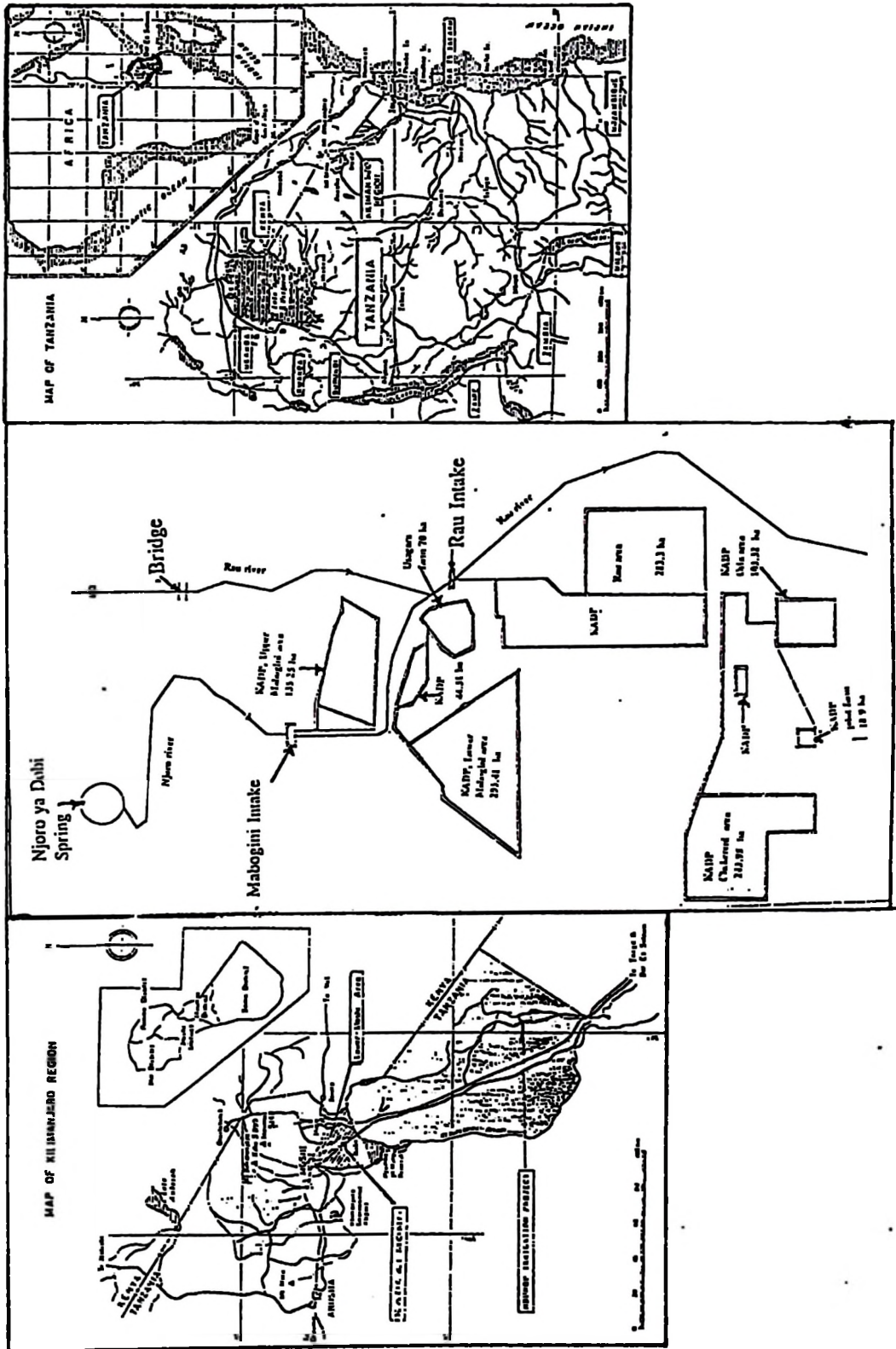


Fig 3.1 Location map of Lower Moshi irrigation scheme.

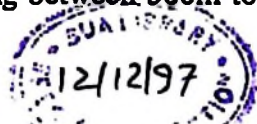
Out of 955 ha, 473 ha are used for paddy production, 412 ha for maize and other upland crops and 70 ha for sugar cane (pilot farm) production.

Rau system receives irrigation water from Rau intake located in Rau river. It commands a net irrigable area of 1345 ha. Out of these, 634 ha are for paddy production, 631 ha for mainly maize, and 80 ha for sugar cane (pilot farm) production. Due to water scarcity, paddy is the only crop grown under irrigation in both systems.

3.1.1 Climatic and Topographic conditions

The climate of the scheme area is characterised by three seasons: a long rain season from March to May, a dry season from June to October and a short rain season from November to February. Annual rainfall averages 590mm of which about 370mm (63%) falls in the long rainy season, 60mm (10%) in the dry season, and 160mm (27%) in the short rainy season (Orota, 1993).

Mean temperature is fairly constant throughout the year being 25°C to slightly above 30°C. The mean daily maximum temperature rises above 30°C in October to April, while the mean daily minimum temperature falls close to 15°C in July and August. Evaporation varies widely from 3mm/day in May to 9mm/day in January, the annual value being more than 2000mm (URT/JICA, 1980). In general LMIS has a gently undulating topography lying between 500m to 1000m above sea level.



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3.2 Materials

Materials, equipments and hydraulic structures used during the field work were either installed during construction or during the research period. Flow measuring devices were installed during construction of the project in different irrigation canals. Parshall flumes were installed at Mabogini and Rau intakes, and other two at the bifurcation of Oria and Chekereni villages. Staff gauges were also installed at each turnout in main, secondary, and tertiary canals. In some parts where the staff gauges were missing or destroyed were replaced during research period. These were used to measure the daily depth of inflow and outflow water to and from the canals.

3.3 Adopted and Adapted mathematical models

The Facilities method was adopted in this Study to modify the model used by Allam (1987) in Nile Valley, Egypt to develop a computer program model that suits Tanzania's conditions, and data collected from LMIS was used to validate it.

3.3.1 Allam's mathematical model

Allam (1987) considered a multipurpose reservoir with a storage capacity S units of water; divided among three major uses: S_D dead storage required for sediment collection, S_F for control, and S_A as an active storage required for meeting water targets of irrigation, navigation, and power generation.

Power requires R_p units of water, irrigation requires R_i of water in excess of power requirements, navigation requires R_N units in excess of power and irrigation requirements and the capital cost of the reservoir is C_K . According to the use of Facilities method, the cost for flood control C_F can be computed as:

$$C_F = C_K \frac{S_F}{S_F + S_A} \quad (1)$$

Similarly, the cost of the other purposes which equals cost of the active storage C_A can be computed as:

$$C_A = C_K \frac{S_A}{S_F + S_A} \quad (2)$$

Allocation of the active storage cost among power, irrigation, and navigation can be performed by two different procedures. The first procedure is as follows:

$$C_j = C_A \frac{R_j}{\sum_j R_j} \quad j = P, I, N \quad (3)$$

Where C_j is the allocated cost for purpose j .

In this procedure no considerations given to the secondary use of water, namely; the secondary use of the power water in irrigation and navigation and of the irrigation water in navigation.

For the second procedure, considered $\alpha_{i,j}$ as the percentage utilization of the water of purpose i for purpose j , the total water requirements for power generation, irrigation and navigation can be computed as:

$$W_j = \sum \alpha_{i,j} R_i \quad j = P, I, \text{ and } N; \quad i = P, I, N \quad (4)$$

Where W_j is the total water requirements of purpose j , and $j = 1$ for $i = j$ ($\alpha_{p,p} = \alpha_{i,i} = \alpha_{N,N} = 1$).

Having determined W_p , W_I , and W_N , then allocation of C_A can be obtained from equation (5) as:

$$C_j = C_A \frac{W_j}{\sum_j W_j} \quad j = P, I, N \quad (5)$$

The main drawback of the second cost allocation procedure is that it gives the secondary use of water the same degree of effectiveness as that of primary use. Allam (1987) used the above procedure to allocate the joint portion of the reservoir operation and maintenance cost among power, irrigation and navigation.

Allocation of the irrigation Structures cost

According to the use of Facilities method, the share of an irrigated area of the cost of serving irrigation structures and of irrigation cost at multipurpose reservoirs can be computed as:

$$IC_j = \sum_{m=1}^{M_j} IC_m \left(\frac{Q_{j,m}}{Q_m} \right) \quad j = 1 \dots N \quad (6)$$

Where:

- IC_j = Share of the area j of the present cost of the irrigation structures and irrigation purpose at the multipurpose reservoirs ;
- N = Number of irrigated areas, $j = 1 \dots, N$;
- M_j = Number of irrigation structures and multipurpose reservoirs which serve area j , $m = 1, \dots, M_j$;
- $Q_{j,m}$ = Annual volume of irrigation water delivered by structure m to area j , including the water conveyance losses through the canal which delivers the water from the structure to the area (m^3/year);
- Q_m = Annual irrigation water delivery of structure, m , (m^3/year) and;
- IC_m = Present cost of irrigation structure m , or of the irrigation at multipurpose reservoir m .

Allocation of the Pump Stations Cost

In a similar procedure, cost of the pump stations can be allocated among the irrigated areas as shown in Equation (7):

$$PC_j = \sum_{k=1}^{K_j} PC_k \frac{Q_{j,k}}{Q_k} \quad j = 1, \dots, N \quad (7)$$

Where:

- PC_j = Share of area j of the present cost of the irrigation pump stations ;
- K_j = Number of irrigation pump stations, which serve area j, $k = 1, \dots, K_j$;
- $Q_{j,k}$ = Annual volume of irrigation water delivered by pump station k to area j including the water conveyance losses through the canal which deliver the water from the pump station to the area ($m^3/year$);
- Q_k = Annual irrigation water delivery of pump station k ($m^3/year$);
and
- PC_k = Present cost of pump station k.

Allocation of the Annual Operation and Maintenance Costs

The operation and maintenance cost of the irrigation structures, irrigation purpose at multipurpose reservoirs, pump stations, and the maintenance cost of the irrigation canals can be distributed among the irrigated areas as follows:

$$OMC_j = \sum_{m=1}^M OMIC_m \left(\frac{Q_{j,m}}{Q_m} \right) + \sum_{k=1}^{K_j} OMPC_k \frac{Q_{j,k}}{Q_k} + \sum_{z=1}^{Z_j} MC_z \left(\frac{Q_{j,z}}{Q_z} \right) \quad (8)$$

Where:

OMC_j = Share of area j of annual operation and maintenance cost of the irrigation network;

$OMIC_m$ = Annual operation and maintenance cost of irrigation structure m, or of the irrigation at multipurpose structure m,;

$OMPC_k$ = Annual operation and maintenance cost of pump station k (Egyptian pounds/year);

MC_z = Annual maintenance cost of the Z^{th} reach of the irrigation canal which transmits the irrigation water from the water source to area j (Egyptian pounds/year);

Z_j = Number of reaches of irrigation canal, ($z = 1, \dots, Z_j$);

Q_z = Annual irrigation water delivery of the Z^{th} reach of the irrigation canal (m^3/year); and

$Q_{j,z}$ = Annual volume of irrigation water delivered to the area j by the Z^{th} reach of the irrigation canal including the conveyance losses (m^3/year).

Annual Irrigation Water Cost

The sum of the two cost terms IC_j and PC_j gives the share of an irrigated area j ($j = 1, \dots, N$) of the present value of irrigation capital (replacement) cost.

Annual value of the cost can be determined as:

$$AC_j = \frac{r(1+r)^{TI}}{(1+r)^{TI} - 1} IC_j + \frac{r(1+r)^{TP}}{(1+r)^{TP} - 1} PC_j \quad (9)$$

Where:

AC_j = Annual irrigation replacement cost at area j ($j = 1, \dots, N$);

r = Rate of discount;

TI = Lifetime horizon of the irrigation structure (years); and

TP = Lifetime horizon of the irrigation pump station (years).

On the other hand, sum of the annual operation, maintenance and replacement costs at an area, gives the total annual irrigation water cost (TAC_j) at this area as:

$$TAC_j = AC_j + OMC_j \quad j = 1, \dots, N. \quad (10)$$

3.3.2 Assumptions

An allocation mathematical model for irrigation water price considered the following assumptions:

- (a) The lifetime of the irrigation water control structures are finite, and original costs are repeatable for shorter lived structures;
- (b) The discount rate remains constant over the lifetime of the irrigation system;
- (c) The operation and maintenance cost remains constant over the lifetime of irrigation system;

- (d) The irrigation structures have zero salvage value; that is the present value of their capital costs equal the present value of the replacement cost;
- (e) There is no replacement (re-excavation) for the irrigation canals;
- (f) Water abstracted at Rau and Mabogini intakes are used for irrigation only; that is other uses such as domestic and industrial uses are neglected, because water used for these purposes are negligible in comparison to water used for irrigation;
- (g) Since the problem of water shortage in LMIS is going to be solved in near future. That is studies are under way to abstract water from Kikuletwa river to the scheme. While, the program is going to be the permanent one. Then the program assumes that both intakes receives water as per water right regulations, but the amount is sufficient for paddy production only. Otherwise the annual water fee will depend on the amount abstracted per day at each intake weir.

3.3.3 Modified mathematical model

The modification involved the removal of parameters such as pumps and reservoirs which are not common in Tanzania because most of FMIS are on-the-river-type of intakes. Parameters which fits Tanzanian conditions were introduced; such as water rights and flow from on-the-river-type of intake.

The water right parameter is important because under irrigation management transfer, water rights become part of the scheme assets (Fairly, 1994). The new model assumes that water flows under gravity to irrigation systems. These parameters were not considered in Allam's model before.

The total irrigation water price (TAC_i) is the sum of costs for water right, irrigation structures and O&M (Allam, 1987). The model has got the following cost elements:

Allocation of the water right cost

Total Water Right Cost (TWRC) is equal to the sum of water right Application Fee Cost (AFC) and water right cost paid by water users per 1,000 m³ of irrigation water paid annually. This was calculated as follows:

$$\text{TWRC} = \text{AFC} + (\alpha * Q)/1000 \quad (11)$$

Where:

TWRC = Total scheme annual water right cost;

AFC = Application fee cost;

Q = Total water required for irrigation, or according to water right regulations (seasonally or annually).

α = Rate paid annually per 1,000 m³ of water received from river;

According to facilities method, the total irrigation water right cost at tertiary block level is given by:

$$WRC_j = (B_j * TWRC)/TB \quad (12)$$

Where:

WRC_j = Block/area j's share of irrigation water right Cost (Tshs);

B_j = Area/Block size j, under consideration (ha);

TB = Total area served by the intake (Annually or seasonally).

Allocation of the cost of irrigation structures

According to facilities method (Allam,1987), the share of an irrigated area of the cost of serving irrigation structures and of irrigation cost can be computed as:

$$ISC_j = \sum_{m=1}^{M_j} ISC_m \left(\frac{Q_{j,m}}{Q_m} \right) \quad j = 1 \dots N \quad (13)$$

$$Q_{j,m} = IR_j + \sum_z^{z_{j,m}} WL_z^j \quad m = 1 \dots M_j \quad (14)$$

$$WL_z^j = \frac{IR_j * L_j}{\sum_j IR_j * L_j} * WL_z \quad j = 1 \dots J \quad (15)$$

Where:

- ISC_j = Share of the area j of the present cost of the irrigation structures (Tshs);
- N = Number of irrigated areas; $j = 1, \dots, N$;
- M_j = Number of irrigation structures which serve area j , $m = 1, \dots, M_j$;
- $Q_{j,m}$ = Annual volume of irrigation water delivered by structure m , to area j , including the water conveyance losses through the canal which delivers the water from the structure to the area (m^3/year);
- Q_m = Annual irrigation water delivery of structure m , (m^3/year);
- ISC_m = Present cost of irrigation structure m , or of the irrigation at river m , (Tshs);
- WL_z = Seasonal Water losses in canal Z (m^3);
- IR_j = Seasonal irrigation water requirement of area j (m^3);
- L_j = Length of the canal reach which transmits the water to area j (km); and J is number of areas irrigated with canal Z ;
- $Z_{j,m}$ = Number of reaches of the irrigation canal from structure m to area j ; and
- W_z^j = Share of area j of the water losses of the canal reach Z .

By using Equation (14), the values of $Q_{j,m}$ for the 18 and 25 irrigated tertiary blocks at the 18 and 25 irrigation structures of the Mabogini and Rau systems were determined.

This equation along with Equation (13) were used to allocate the share of each irrigated area of irrigation structures as shown in Table 4.7 and Table 4.9 for Mabogini and Rau system respectively.

Allocation of the operation and maintenance cost

The operation and maintenance cost of the irrigation structures, and the maintenance cost of the irrigation canals can be distributed among the irrigated areas as follows (Allam, 1987):

$$OMC_j = \sum_{m=1}^M OMIC_m \left(\frac{Q_{j,m}}{Q_m} \right) + \sum_{z=1}^{Z_j} MC_z \left(\frac{Q_{j,z}}{Q_z} \right) \quad (16)$$

Where:

- OMC_j = Share of area j of annual/seasonal O&M cost of the irrigation network (Tshs);
- $OMIC_m$ = Annual/seasonal operation and maintenance cost of irrigation structure m, or of the irrigation at multipurpose structure m, (Tshs);
- MC_z = Annual/seasonal maintenance cost of the Z^{th} reach of the irrigation canal which transmits the irrigation water from the water source to area j (Tshs);
- Z_j = Number of reaches of irrigation canal ($z = 1, \dots, Z_j$);

- Q_z = Annual/seasonal irrigation water delivery of the Z^{th} reach of the irrigation canal (m^3/year); and
- $Q_{j,z}$ = Annual/seasonal volume of irrigation water delivered to the area j by the Z^{th} reach of the irrigation canal including the conveyance losses (m^3/year).

The O&M costs were not found for each individual irrigation structures, however according to Allam (1985); most studies revealed that maintenance cost of irrigation structures including maintenance cost of the irrigation canals was found to be equal to 2.9% of present capital cost of irrigation structures. On the other hand no maintenance cost is assigned to the irrigation canals since it was already included in the cost of irrigation structures. Therefore, Equation (16) above reduced to:

$$OMC_j = \sum_{m=1}^{M_j} OMIC_m \left(\frac{Q_{j,m}}{Q_m} \right) \quad (17)$$

Annual irrigation water cost

The cost term ISC_j give the share of an irrigated area j ($j=1, \dots, N$) of the present value of irrigation capital (replacement) cost. An annual value of cost can be determined as follows (Douglas and Lee, 1971):

$$AC_j = CRF * ISC_j \quad j = 1...N \quad (18)$$

$$CRF = \frac{r(1 + r)^T}{(1 + r)^T - 1} \quad (19)$$

Where:

CRF = Cost recovery factor;

AC_j = Annual/seasonal irrigation replacement cost at area j
(Tshs/year);

r = Discount rate;

T = Lifetime horizon of the irrigation structure (years).

The cost recovery factor indicates the amount of money one can withdraw in equal amounts at the end of each of T years if one shilling is initially deposited at rate of r percent interest.

In general, the sum of the annual/seasonal operation and maintenance, water right and replacement costs at an area gives the total annual/seasonal irrigation water cost (TAC_j) at cost centre j as follows:

$$TAC_j = AC_j + OMC_j + WRC_j \quad (20)$$

Price of irrigation water

The irrigation water price per hectare (Unit irrigation water price) was given by dividing the total annual/seasonal share of irrigation water cost (TAC_j) to total block area served by the responsible system.

$$PIW_j = \frac{TAC_j}{AS_j} \quad (21)$$

Where;

PIW_j = Seasonal/annual price of irrigation water per hectare in block j (Tshs/ha);and

AS_j = Total served area in block j.

3.4 Development of computer program model

The computer program model was developed by using Turbo Pascal language (Duntermann,1990; Delannoy,1989; Palmer,1991). The program is based on the modified mathematical model as explained in the previous section.

The program model takes into account all assumptions given in section 3.3.2. The subroutine and main body of the program are presented in Appendix 5. It requires the input data collected from the site, such as tertiary block name, area size (ha), daily mean water supplied (l/s), area serving structures, structures lifetime horizon, structures installation year, seasonal or annual water delivery by each structure, structures installation cost, canal losses (m³), water right and canal length to each tertiary block. In order to compile and run the program successfully the user must be familiar with file components, constant factors and data files used in the program as described in sections 3.4.2, 3.4.3 and 3.4.4.

3.4.1 Description of computer program flow chart

The flow chart of the computer program model developed is presented in Figure 3.2, while Table 3.1 describes how the computer program model works.

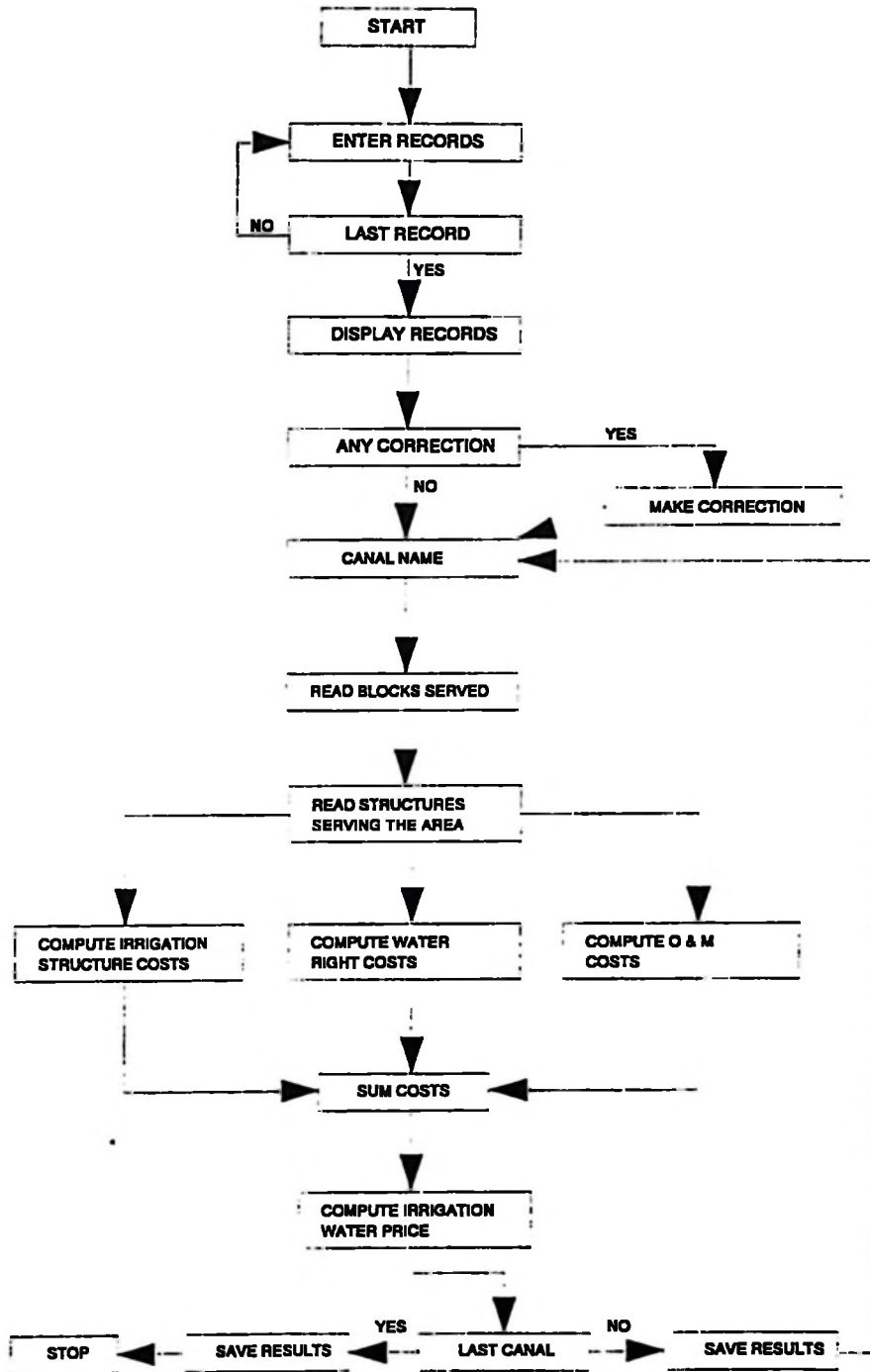


Figure 3.1 Flow chart of the computer program.

Table 3.1: Description of the Computer program flow chart

KEY WORD(S)	ACTIVE SUBROUTINE OR PROCEDURE	REMARKS
START	ProgramStart	Program is initialised
ENTER RECORDS/ LAST RECORDS	Create DataFile and Structure_Cost.	All input data are stored in the input file.
DISPLAY RECORDS	Read_Data1 and Read_data2	All input data are displayed on the screen.
ANY CORRECTION/ MAKE CORRECTION	Correction and Correction2	For correction of your input data if any.
CANAL NAME	Share_Cost	Canal to be evaluated
READ BLOCKS SERVED	Share_Cost	Computer reads all tertiary blocks served by the canal from the input file.
READ STRUCTURES SERVING THE BLOCKS	Share_Cost	Computer reads all structures serving the tertiary blocks on that canal.
COMPUTE IRRIGATION STRUCTURE COST	Share_cost	Computer starts to process the data and it determines ISC.
COMPUTE WATER RIGHT COST	Share Cost and Water_RightCost	Computer calculates the Water right cost for each tertiary block.
COMPUTE O&M COST	Share_Cost	Computer calculates O&M cost for each tertiary block.
SUM COSTS	Share_Costs and Summation	Computer Calculates total tertiary block share.
COMPUTE IRRIGATION WATER PRICE	Share_cost, Summation and Price_IrrWater	Unit water price is calculated for each tertiary block.
LAST CANAL	Repetition	Computer asks the user if he wants to evaluate another canal.
SAVE RESULTS	Repetition and MeanValue	Computer computes system mean unity irrigation water price and saves all output in output file.
STOP	End_Program	Computer ends computations and it tells the user to see results in the output file.

3.4.2 File components

The component number in the file means the number of rows in the file as they are arranged in the file during data entry. The function file size provides the number of components in the file. The first component has the number zero, and the last component has the number $n - 1$; where n is the total number of components or rows in the file. The model allows several components to be altered and not oblige the user to retype data that does not need to be altered. The user must be sure of the arrangement of components in the input file, otherwise wrong entry of the component number leads to wrong irrigation water price. Therefore each component must be assigned in the correct manner and sequentially at the correct cost centre. For simplicity structures were divided into three main categories, intake, major structures and minor structures. Intake weir is the headwork which serves the whole system. Major structures are turnouts, check drops and their accessories diverting or regulating water from or within the main canal to secondary canals and minor structures are turnouts, check drops and their accessories diverting or regulating water from the secondary canals to respective tertiary blocks.

3.4.3 Constant factors

The Program assumes three constant factors which are subject to change in case the user wants to change them so as to fulfil his/her needs.

These factors are:

- (i) Sample = 100; If the user wants to consider more than 100 tertiary blocks or cost centres, he must change this value to the appropriate value.
- (ii) Factor = 439.2; This factor takes care of the amount of irrigation water required in one season and units conversion.

Season here refers to the number of days taken by the crop from sowing to harvesting period. This case study was dealing with paddy of variety IR54 which takes 122 days to mature. The factor should be changed if other types of varieties with different maturity time are considered. The factor was obtained as follows:

$$SWR = \frac{N Q_u T (A)^2}{I_n} = \frac{N Q T (A)}{I_n} \quad (22)$$

Equation (22) can be simplified further to Equation (23).

$$SWR = \frac{122 * 3600 * 10^{-3} Q_u T (A)^2}{I_n} = \frac{C * Q T (A)}{I_n} \quad (23)$$

Where:

- N = Number of days in a season;
- Q_u = Water duty (l/s/ha);
- Q = Daily mean water supplied(l/s);
- T = Irrigation duration (hrs/ha);
- I_n = Irrigation frequency (days);
- A = Tertiary block size (ha); and
- C = Constant = 439.2.

- (iii) **Fact = 0.33425**; This factor is equal to 122 days divided by number of days in a year. For annual irrigation water price the factor **Fact** must be set to be equal to one.

3.4.4 Data files

The program works with two kinds of data files which can be accessed by the computer. Sequential files for input data and random access file for output data. Input data file receives data entered through the key board and store them for later use in the determination of irrigation water price.

Procedure number one up to procedure number four as listed in the main body of the program in Appendix 5 are for data input starting with areas to be evaluated followed by the definitions of irrigation structures.

Output data file is the file where the results can be found. The file shows how much share each cost centre should contribute in terms of Operation and Maintenance Costs (OMC), Water Right Costs (WRC), Irrigation Service Costs (ISC), and the last column indicates the price of irrigation water per hectare per cost centre (Tertiary unit block prices). The mean value of irrigation water to be charged from any farmer in the system is also found in the file. This file is the text file which can be printed if needed for further use.

3.5 Data used

Data on the following parameters were collected for validating the price allocation model:

- Irrigation water requirements of the cultivated land.
- Installation dates, proposed lifetimes, costs, operation rules, and discharge capacities of headwork.
- Installation dates, proposed lifetimes, costs and operation rules of the other irrigation structures.
- Water losses in irrigation canals, and maintenance cost of these canals.
- The discount rate.
- Water right regulations.
- Discharges in the main canal(s), secondaries and tertiaries.
- Total area served by irrigation water.
- Total yield and area per block.
- Canal reach (length) from the intake to each tertiary block in the system.

The primary or secondary data on the above parameters were collected over the period of one cropping season (October to February) of paddy crop. Since the aim was to collect data under the system's ordinary conditions, it was not appropriate to introduce any new structures that would further distort head relationships in the canals and over outlets. The measuring system was therefore based on water level observations at existing irrigation structures.

These are quite numerous, and they have a uniform geometry. Common calibration tables were adopted for all identical structures. These data were collected/or estimated as described in subsequent sections.

3.5.1 Determination of seasonal irrigation water requirements

Tertiary canal outlet flows were recorded from staff gauges installed in tertiary canals. The rating tables which were already developed by the executing agency, were used to convert recorded water depth into discharge. The seasonal irrigation water supply of the irrigated land in Mabogini and Rau systems were determined by using Equation (23).

The seasonal water delivery of each structure was obtained by direct addition of all irrigation water requirements of the areas or tertiary blocks served by the structure, plus the losses in their respective canals.

3.5.2 Determination of water losses in the main and secondary canals

A farmer cannot irrigate without losing water between the farm head gate and the crop field by seepage, surface runoff, or evapotranspiration from ditches and weeds. Losses apart of other factors contribute to increase of water charges. The data on water losses in different irrigation canals were estimated using the inflow-outflow method. The following steps were followed:

- (i) Parshall flumes installed in main and secondary canals were used to measure inflow and outflow of the canals;
- (ii) The water diverted at the intake H_1 from Rau and Njoro rivers to Rau and Mabogini intakes were measured respectively;
- (iii) The water depth at main canal(s) off take points H_2 , secondary canals off takes (H_3) up to tertiaries were also measured. Then by the use of already developed corresponding rating tables, the readings were converted to water discharge ;
- (iv) The determination of total losses in each canal was obtained by calculating the difference between inflow and outflow water for each canal reach.

3.5.3 Yields of paddy in LMIS

Paddy yield data was collected by sampling farm plots along the water supply canals with a bias of head, middle and tail locations. During selection of locations for sampling, the following were taken into account:

- (a) For each tertiary block in Mabogini and Rau system, three major sample plots were considered. One major sample plot from upstream, the second sample plot from the middle and the last sample from tail end of the tertiary canal;

- (b) For each major sample plot, three minor samples were taken from two square meters area each and sampled at one end, middle and other end of the plot under consideration.

The samples were weighed and recorded. The records included plot number, sample weight and sample field moisture content. The actual weight was calculated at standard moisture content of 14% and then, the mean production per hectare in both Mabogini and Rau systems were computed.

3.5.4 The irrigated lands in LMIS

Total irrigable area in LMIS was determined in each system by adding the acreage of each plot in each tertiary block. The size of most plots are standard, 0.3ha (30m x 100m); while others are more or less to standard, their dimensions were determined by direct measuring using a tape measure.

The net paddy irrigated area in LMIS according to design was of the order of 1,100 ha during wet season and 800 ha during dry season. In total 1,900 ha of paddy per year were supposed to be cultivated, but due to severe shortage of water only 588 ha of paddy had been cultivated per year from 1988 on wards. The irrigation water is served by the two intake weirs, numerous irrigation canals, 38 and 52 turnouts, 17 and 32 check drops for Mabogini and Rau system respectively. A schematic presentation for the irrigation distribution systems and the irrigated areas for both systems are shown in Figure 3.3 and Figure 3.4 respectively.

For each irrigated area, size, location, seasonal irrigation water requirements and the area serving irrigation structures were determined and recorded as elaborated in the previous sections.

3.5.5 Irrigation structures

Four main types of irrigation structures were considered; these were diverting, regulating, conveying and measuring irrigation structures. Data on their installation dates, proposed lifetimes, costs, operation rules of the irrigation structures were collected from the LMIS office.

3.5.6 The discount rate

The purpose of discounting is to measure different flows of income and expenditure in terms of their present value so that they can be compared (Gittinger, 1982). For financial analysis, the discount rate is usually the opportunity cost of capital to the farm or firm for which the analysis is being done. This will often be the rate at which a private enterprise is able to borrow money.

In investment decisions like irrigation, consideration of opportunity cost of capital and the social time preference rate is necessary in arriving at an appropriate discount rate (Little and Mirrlees, 1974; Schreiner, 1989).

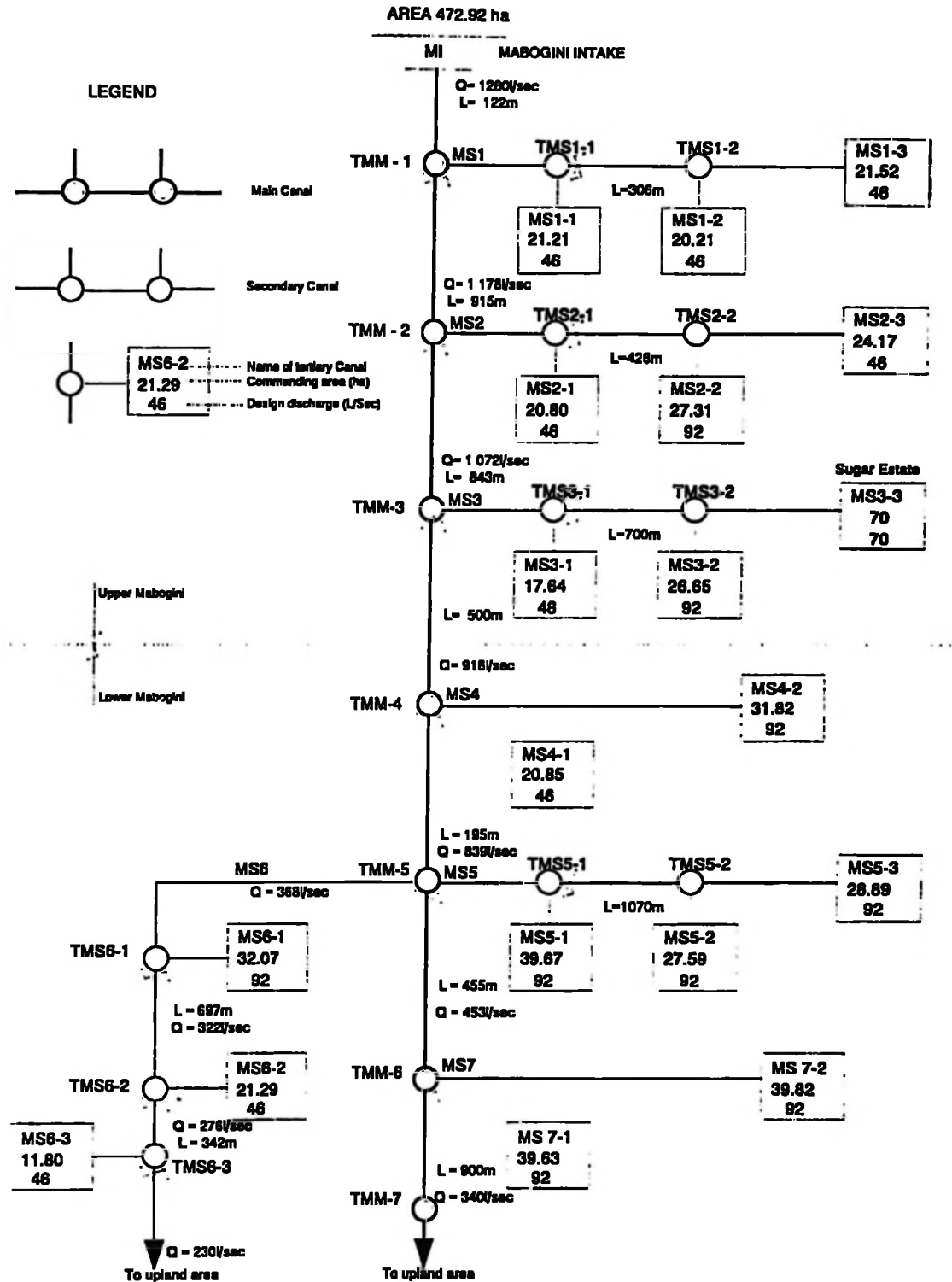


Figure 3.3: A schematic presentation of the irrigation distribution in the Mabogini system.

However, estimating a discount rate to reflect opportunity cost of capital and the rate of social time preference in developing countries is fraught with difficulty. Dasgupta et al. (1972) and Mishau (1975) outline the problems as:

- (i) The existence of various imperfections in the market place e.g. different rates of interest rate are paid to lenders and thus there is a problem of choosing which one to apply.
- (ii) The existence of capital rationing such that the rate arrived at can not be the true rate of interest.
- (iii) The rate of social time preference can be treated as a value judgement. The Government judge the relative weight to be accorded aggregate-consumption benefits and costs at different times. The National plan is used to estimate per capita consumption which is used in turn to estimate the social discount rate.

Gittinger (1982) suggested a discount rates of 10% to 15% in real terms common to be used typically in project appraisal in most developing countries. Bank lending rates to agricultural projects in Tanzania lies between 18% and 25% (Balirwa 1990; Orot, 1993). Whilst the willingness to make long-term investments in the study area suggests low discounting of the future, the value of capital and the need to consume in the short-run can not be set lightly aside. Orot (1993) used a discount rate of 18% in financial analysis of LMIS. On balance, a rate of 20% per annum was adopted in this study.

3.5.7 Determination of farmers' capacity to pay ISF

In estimating the ability for the farmers to pay, the following assumptions were made:

- (i) The average family holding is one hectare of paddy (3 plots) per year at an average of one plot per season;
- (ii) URT/JICA (1980), estimated the annual home consumption of paddy per family to be equal to 9,600 Tshs per year equivalent to 800 Tshs/month. The present study converted the value into present value to cope with current prices based on 20% compounded interest rate. Hence the present value has been found to be Tshs 177,489 per year or 59,325 Tshs per season.

The farmers capacity to pay ISF was determined through the following steps:

- (i) Total seasonal mean yield of paddy was calculated by multiplication of the unit mean paddy yield by the 0.3 ha (Plot size).
- (ii) Dehusking cost and selling price were collected from paddy milling plant department, and found to be 14 Tshs/kg and 300 Tshs/kg respectively. Through farmers experience (Ngodoki,G. Personal communication, 1996) out of 1 kg of paddy one third is husks and two third is clean rice.

- (iii) The clean rice was then calculated by multiplying (i) by two thirds.
- (iv) The gross income was calculated by multiplying (iii) by 300 Tshs/kg.
- (v) The farmers costs were collected from LMIS office and are as presented in Table 4.14 in chapter 4. The capacity to pay ISF per season per family was calculated by taking gross income less production costs and family home consumption.

3.5.8 Water right regulation for LMIS

The scheme water right regulations was collected from LMIS office and Ministry of water; and they are well discussed in Chapter Four.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Irrigation duration and irrigation frequency

The irrigation duration recorded from different plots selected at random is presented in Appendix 1. These data were used to establish the scheme irrigation duration. For Mabogini system the irrigation duration was found to be 2 hours per 6 plots of 0.3 ha each, which is equivalent to an irrigation duration of 1.11 hours per hectare. In Rau system, the irrigation duration was found to be 2 hours for 4 plots of the same size irrigated together, which is equivalent to irrigation duration of 1.67 hours per hectare.

The irrigation frequency in Mabogini and Rau systems was found to be 3 days in upper Mabogini and 5 days in lower Mabogini and Rau system. The irrigation frequency reported by the project management staff was 3 days in Mabogini system and 5 days in Rau system. These values together with the irrigation durations were used in the determination of seasonal water requirements in each tertiary block.

4.2 Hydromodule

Table 4.1 presents the hydromodule for paddy for Rau and Mabogini systems in LMIS. The hydromodule of each system was calculated from the daily means of water supplied (l/s) presented in Appendix 2.1 and Appendix 2.2 for Mabogini and Rau system respectively.

The mean hydromodule for each system was determined to be 3.87 (l/s/ha) and 4.54 (l/s/ha) in Rau and Mabogini system respectively, which is still within the range of 3.5 to 4.5 l/s/ha reported by the project executing office in LMIS. These hydromodules were later used to establish daily and seasonal irrigation water requirement in each tertiary block as indicated in Table 4.2 and Table 4.3 for Mabogini and Rau systems respectively. The area serving structures for each tertiary block were also identified and are shown in the last column of these tables.

Table 4.1: Mean Hydromodule for paddy in LMIS.

Block	Size(ha)	Daily mean water	Hydromodule
		supplied(l/s)	(l/s/ha)
RS1-1	15.18	80.80	5.32
RS3-2	23.81	90.20	3.79
RS4-1	34.78	121.90	3.50
RS8-2	37.25	106.50	2.86

Mean Hydromodule for Rau system lies between

$$2.21 \leq \mu \leq 5.52$$

MS2-1	20.80	85.20	4.10
MS3-1	17.64	50.70	2.87
MS5-1	39.67	203.20	5.12
MS6-3	11.80	71.60	6.07

Mean Hydromodule in Mabogini system lies between

$$2.35 \leq \mu \leq 6.73$$

Source: Appendix 2.1 and Appendix 2.2

Table 4.2: The irrigated areas in Mabogini system.

Area Name	Size (ha)	Daily mean irrigation	Seasonal mean irrigation	Area Serving Structures
		water supplied(l/s)	water requirement (m ³)	
MS1-1	21.2	96.43	333168	MI, TMM-1, TMS1-1
MS1-2	20.2	91.75	301639	MI, TMM-1, TMS1-2
MS1-3	21.5	97.70	342010	MI, TMM-1, TMS1-2
MS2-1	20.8	94.43	319508	MI, TMM-2, TMS2-1
MS2-2	27.3	123.99	550805	MI, TMM-2, TMS2-2
MS2-3	24.1	109.73	431427	MI, TMM-2, TMS2-2
MS3-1	17.6	80.09	229801	MI, TMM-3, TMS3-1
MS3-2	26.6	120.99	524504	MI, TMM-3, TMS3-2
MS4-1	20.8	94.66	192627	MI, TMM-4
MS4-2	31.8	144.46	448648	MI, TMM-4
MS5-1	39.6	180.10	697317	MI, TMM-5, TMS5-1
MS5-2	27.5	125.26	337294	MI, TMM-5, TMS5-2
MS5-3	28.8	131.16	369829	MI, TMM-5, TMS5-2
MS6-1	32.0	145.60	455726	MI, TMM-5, TMS6-1
MS6-2	21.2	96.66	200843	MI, TMM-5, TMS6-2
MS6-3	11.8	53.57	61698	MI, TMM-5, TMS6-3
MS7-1	39.6	179.92	695911	MI, TMM-6
MS7-2	39.8	180.78	702600	MI, TMM-6
Total	472.	2147.28	7195355	

Source: Own data (1995).

Table 4.3 : The irrigated areas in Rau system.

1	2	3	4	5
Area name	Area size(ha)	Daily mean water supplied(l/s)	Seasonal water requirements $m^3 \times 10^4$	Area serving structures
RS1-1	15.18	58.75	13.06	RI, TRM-1
RS1-2	28.82	111.53	47.06	RI, TRM-1, TRS1-1
RS1-3	28.45	110.10	45.86	RI, TRM-1, TRS1-2
RS1-4	25.56	98.92	37.01	RI, TRM-1, TRS1-3
RS1-5	22.35	86.49	28.30	RI, TRM-1, TRS1-4
RS1-6	22.43	86.80	28.50	RI, TRM-1, TRS1-5
RS1-7	22.55	87.27	28.81	RI, TRM-1, TRS1-6
RS1-8	11.52	44.58	7.52	RI, TRM-1, TRS1-7
RS1-9	10.95	42.38	6.79	RI, TRM-1, TRS1-8
RS3-1	20.28	78.48	23.30	RI, TRM-3, TRS3-1
RS3-2	23.81	92.14	32.12	RI, TRM-3, TRS3-2
RS3-3	28.93	111.96	47.42	RI, TRM-3, TRS3-3
RS3-4	26.31	101.82	39.22	RI, TRM-3, TRS3-4
RS4-1	34.78	134.60	68.53	RI, TRM-4, TRS4-2
RS4-2	13.54	52.40	10.39	RI, TRM-4, TRS4-3
RS4-3	41.11	159.10	95.75	RI, TRM-4, TRS4-4
RS4-4	29.8	115.33	50.31	RI, TRM-4, TRS4-5
RS4-5	22.27	86.18	28.10	RI, TRM-4, TRS4-5, TRS4-6
RS4-6	18.8	72.76	20.02	RI, TRM-4, TRS4-5, TRS4-6
RS4-7	22.06	85.37	27.57	RI, TRM-4, TRS4-5, TRS4-7
RS4-8	18.75	72.56	19.92	RI, TRM-4, TRS4-5, TRS4-7
RS4-9	42.34	163.86	101.57	RI, TRM-4, TRS4-9
RS8-2	37.25	144.16	78.61	RI, TRM-4, TRS8-1
RS8-3	33.41	129.30	63.24	RI, TRM-4, TRS8-3
RS8-4	32.66	126.39	60.43	RI, TRM-4, TRS8-4
Total	633.91	2453.23	1009.43	

Source: Own data (1995).

4.3 Water right regulations for LMIS

The average annual water supply of the Njoro river is approximately $3.77 \times 10^7 \text{ m}^3$, and for Rau river is approximately $3.04 \times 10^7 \text{ m}^3$. Of this amount, LMIS is allocated $2.54 \times 10^7 \text{ m}^3$ for Mabogini intake and $3.53 \times 10^8 \text{ m}^3$ for Rau intake. This is according to the 1991 water right No.4807 and No.4808.

Mabogini intake weir located in Njoro river was entitled to abstract 804 l/s of water (69,465,600 l/day) by furrow from Njoro spring for irrigation of 500 ha of paddy, 400 ha of maize, and 70 ha of Usagara farm. Since most of the water in the Njoro river come from springs, the river discharge is relatively stable throughout the year, being in the range of $1.06 \text{ m}^3/\text{sec}$ in January to $1.33 \text{ m}^3/\text{sec}$ in July (NIPPON KOEI, 1985).

Rau intake weir located in Rau river was entitled to abstract 1,135 l/s of water (98,064,000 l/day) from Rau river for irrigation of 634 ha of paddy and 655 ha of maize. The discharges of the Rau river fluctuate greatly from season to season, being affected by patterns of rainfall distribution and severe deforestation on Kilimanjaro mountains.

The discharges of the Rau river estimated at the site just upstream of the confluence with the Njoro river range from $0.19 \text{ m}^3/\text{sec}$ in December to $1.74 \text{ m}^3/\text{sec}$ in April (NIPPON KOEI, 1985).

For Rau system the entitled water right is greater than the estimated average flow discharge of the River, thus less dependable.

Figure 4.1 and Figure 4.2 present the relationship between water right and actual water obtained from Njoro and Rau river respectively. Since the water right regulation was based on crop water requirement, then it is obvious that the actual water received by the project is not enough to irrigate the intended acreage. Hence, due to serious shortage of water (Figure 4.1 and Figure 4.2), only 473 ha of paddy in Mabogini system and 634 ha of paddy in Rau system are irrigated under random rotational basis at an average of 99.64 ha and 96.27 ha of paddy per season for Mabogini and Rau systems respectively. Upland crops (i.e maize) are not irrigated at all.

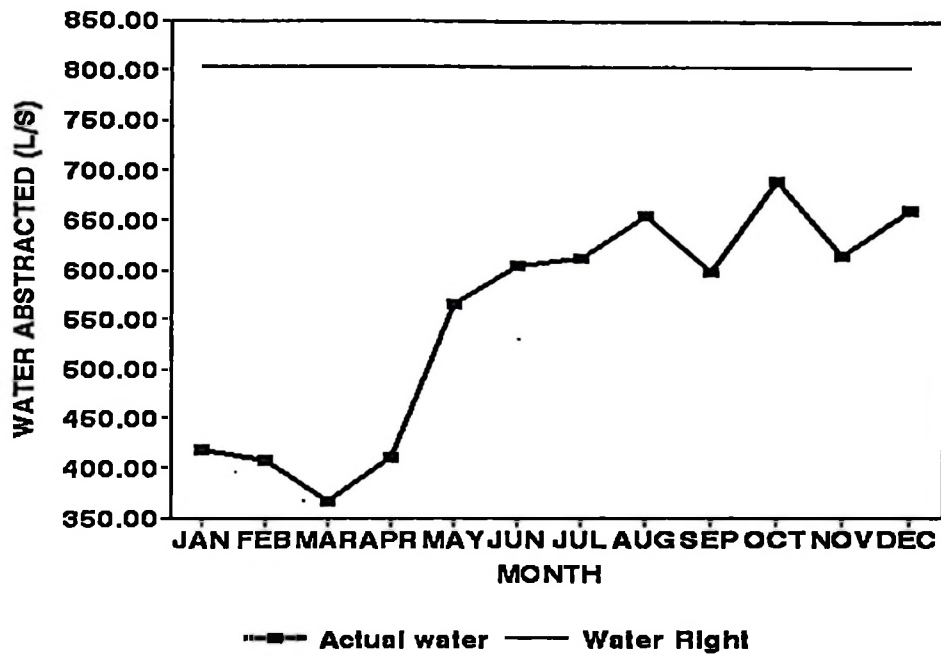


Fig 4.1: Relationship between water right and actual water obtained from Njoro River, 1995.

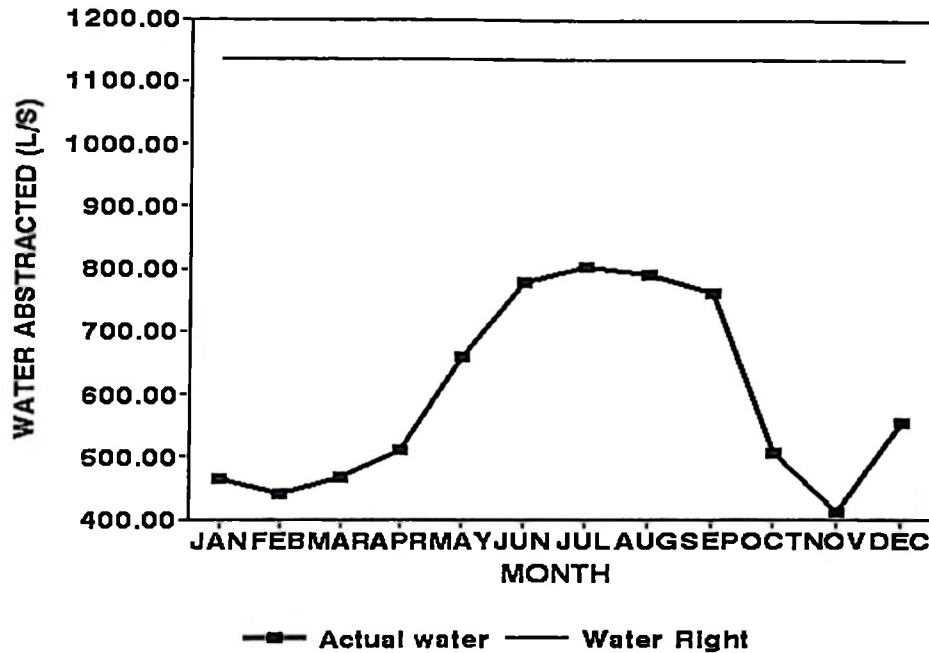


Fig 4.2: Relationship between water right and actual water obtained from Rau River, 1995.

4.4 Water losses in the main irrigation canals

Table 4.4 summarizes the seasonal irrigation water losses in different canals in Mabogini and Rau systems. The total seasonal losses in Mabogini system was found to be $4.667 \times 10^5 \text{ m}^3$ and $5.170 \times 10^5 \text{ m}^3$ for Rau system.

Total seasonal canal losses in Mabogini system is less than total seasonal canal losses in Rau system for about $0.51 \times 10^5 \text{ m}^3$. This is due to canal reach difference in each system.

The canal losses increase as the canal reach increases. The main canal of Rau system is 5.3 km, while, Mabogini system main canal is 4.8 km. Total secondary canal reaches are about 18.1 km and 6.5 km for Rau and Mabogini system respectively.

Table 4.4: Water losses in the main and secondary irrigation canals in Mabogini and Rau systems.

Canal name	Canal length(m)	Seasonal canal losses (m³ x 10⁵)
MI-TMM1-TMS1-2	428	0.141
TMM1-TMM2-TMS2-2	1343	1.060
TMM2-TMM3-TMS3-2	1693	0.976
TMM3-TMM4	500	0.579
TMM4-TMM5-TMS5-2	2265	1.383
TMM4-TMM5-TMS6-3	2237	1.383
TMM5-TMM6	455	0.527
Total losses in Mabogini system	4.667	
RI-TRM1-TRS1-7	280	0.273
TRM1-TRM3-TRS3-4	2152	2.096
TRM3-TRM4-TRS4-7	1707	1.663
TRM4-TRS8-4	1169	1.139
Total losses in Rau system		5.170

4.5 Evaluation of irrigation structures

Table 4.5 and Table 4.6 present identified different irrigation structures for Mabogini and Rau system respectively. The installation dates and the calculated present replacement values are included in these tables. The lifetime horizon of all structures was taken to be 100 years (Kimicho,R. personal communication, 1995). Appendix 3.1 gives details on how the present replacement values for each irrigation structure were calculated. Appendix 3.2 presents the allocation of the present replacement values among the different cost centres in Mabogini system, while Appendix 3.3 presents an allocation of irrigation water right cost for each tertiary block in Mabogini system.

In Appendix 3.4, Appendix 3.5 and Appendix 3.6 present the calculations of present replacement values, allocation of present replacement values and allocation of irrigation water right costs among each tertiary block in Rau system.

The present replacement values of most structures, except for intakes in both system are almost the same. This is because the structures are identical in design and construction. Their installation costs are the same, hence, their present replacement values are the same. The structures differ only in number of turnouts, check drop structures and their respective accessories. For example, consider major structures TMM-1, TMM-2 and TMM-3 in Table 4.4. Each structure has got one turnout of the same size and design. Hence, their present replacement values are the same.

Table 4.5: Evaluation of irrigation structures in Mabogini system.

1	2	3	4	5
Structure	Name	Installation year	Seasonal water delivery (m ³ x10 ⁴)	Replacement cost (Tshs)
MI	Mabogini Intake	1985	846.67	46638390
TMM-1	Turnout & check drop	1986	97.68	1781938
TMM-2	Turnout & check drop	1986	130.17	1781938
TMM-3	Turnout & check drop	1986	75.43	1781938
TMM-4	Turnout & check drop	1986	64.13	3563877
TMM-5	Turnout & check drop	1986	212.27	3563877
TMM-6	Turnout & check drop	1986	139.85	3563877
TMS1-1	Turnout	1986	33.32	1508994
TMS1-2	Turnout & check drop	1986	64.36	2187194
TMS2-1	Turnout	1986	32.00	1508994
TMS2-2	Turnout & check drop	1986	98.22	2187194
TMS3-1	Turnout	1986	22.98	1508994
TMS3-2	Turnout	1986	52.45	546798
TMS5-1	Turnout	1986	69.73	1508994
TMS5-2	Turnout & check drop	1986	70.71	2187194
TMS6-1	Turnout	1986	45.57	1508994
TMS6-2	Turnout	1986	20.08	1508994
TMS6-3	Turnout	1986	6.17	1508994

Source : NIPPON KOEI (1988).

- Key :
1. TMM = Turnout with check drop structure (Major structures) in main canal of Mabogini system.
 2. TMS = Turnout with check drop structure (Minor structures) in secondary canals of Mabogini system.
 3. Replacement value of the structures are taken equal to the present value of the capital costs.

Table 4.6: Evaluation of irrigation structures in Rau system.

Structure	Structure name	Installation year	Seasonal irrigation water delivery (m ³ x10 ⁴)	Present Replacement cost(Tshs)
RI	Rau intake	1986	1196.37	61254892
TRM-1	T/O & C/D	1987	244.84	1565390
TRM-3	T/O & C/D	1987	143.16	1565390
TRM-4	Bifurcation	1987	629.29	5767835
TRS1-1	T/O & C/D	1987	47.43	1268898
TRS1-2	T/O & C/D	1987	46.23	1268898
TRS1-3	T/O & C/D	1987	37.30	1268898
TRS1-4	T/O & C/D	1987	28.51	1268898
TRS1-5	T/O & C/D	1987	28.71	1268898
TRS1-6	T/O & C/D	1987	29.05	1268898
TRS1-7	T/O & C/D	1987	7.59	1268898
TRS1-8	T/O	1987	14.44	433483
TRS3-1	T/O & C/D	1987	23.50	1268898
TRS3-2	T/O & C/D	1987	32.36	1268898
TRS3-3	T/O & C/D	1987	47.80	1268898
TRS3-4	T/O	1987	39.51	433483
TRS4-2	T/O & C/D	1987	69.06	1268898
TRS4-3	T/O & C/D	1987	10.46	1268898
TRS4-4	T/O & C/D	1987	96.50	1268898
TRS4-5	T/O & C/D	1987	147.07	2537797
TRS4-6	T/O & C/D	1987	48.50	2537797
TRS4-7	T/O	1987	47.86	866967
TRS4-9	T/O & C/D	1987	102.35	1268898
TRS8-2	T/O & C/D	1987	142.96	2537797
TRS8-3	T/O & C/D	1987	60.90	1268898

Source: NIPPON KOEI (1988).

Key: T/O & C/D = Turnout and check drop structure.
T/O = Turnout and its accessories.

Structures TMM-4, TMM-5, and TMM-6 each has got two turnouts, check drop structure and their respective accessories. Hence, their present replacement values are the same , but they are twice as much as that of structures TMM-1, TMM-2 and TMM-3. The same trend occurs for Minor structures. The only difference is that some of the structures have no check drop structures e.g TMS1-1, TMS2-1 and TMS3-1. Exceptions exists at turnout TMS3-2 which has got no check drop and it is single, thus, has got least replacement value in Mabogini system structures.

The same situation exists in Rau system, with exception of intake and bifurcation. The present replacement costs for TRM-1 and TRM-3 are the same. And minor structures having the present replacement cost of 1,268,898 Tshs have single turnout with check drop structures and accessories. The design of structure TRS3-4, bifurcation and TRS4-7 are different from the others and therefore, they have different present replacement costs.

In case of intakes, Rau intake has got higher present replacement cost than Mabogini intake. This is due to the area served by each intake. Rau intake was designed to serve large area than Mabogini intake. Thus, to justify its higher installation cost.

4.6 The irrigation water cost in LMIS

Table 4.7 presents the irrigation water costs at the various cost centres for various cost elements calculated manually. Table 4.8 summarises similar costs calculated by

calculated by the use of computer program model in Mabogini system. Similarly Table 4.9 and Table 4.10 summarise the costs obtained from manual calculations and developed computer program model in Rau system respectively.

The mean irrigation water costs for both manually calculated and by the use of computer program, in Rau and Mabogini systems are significantly different at 10% confidence level (Table 4.11). The difference is caused mainly by the presence of large number of irrigation structures and different installation costs in Rau than in Mabogini systems (Table 4.5 and Table 4.6).

Table 4.12 shows that system mean water prices produced by the computer program model and the manually calculated are not significantly different at 10% confidence level for both systems. This proves that the developed computer program produce results that are consistent with those calculated manually. In both systems the tertiary block prices obtained from computer program model slightly deviate from the corresponding manually calculated irrigation water prices (Figure 4.3 and Figure 4.4). The explanation for this is that the deviations are due to approximations of large figures during manual calculations; while in Computer program model everything is processed internally without rounding off the figures. However, these deviations are not significantly different at 10% confidence level; thus both results are acceptable and encouraging.

Table 4.7: Seasonal irrigation water cost in Mabogini system.

Block	ISC(Tshs)	OMC(Tshs)	WRC(Tshs)	TAC(Tshs)	PIW(Tshs/ha)
MS1-1	264861	38405	2109	305375	14377
MS1-2	186535	27048	2006	215589	10667
MS1-3	206609	29958	2136	238703	11092
MS2-1	254853	36954	2065	293872	14128
MS2-2	312150	45262	2711	360123	13186
MS2-3	244497	35452	2399	282348	11682
MS3-1	229137	33225	1751	264113	14972
MS3-2	341122	49463	2646	393231	14755
MS4-1	148899	21590	2070	172559	8276
MS4-2	346802	50286	3159	400247	12578
MS5-1	447472	64883	3938	516293	13015
MS5-2	207902	30146	2739	240787	8727
MS5-3	227956	33054	2868	263878	9134
MS6-1	328687	47660	3184	379531	11834
MS6-2	203533	29512	2113	235158	11045
MS6-3	132754	19249	1171	153174	12981
MS7-1	384474	55749	3934	444157	11208
MS7-2	388169	56285	3953	448407	11261
Mean value		11940			

Source: Appendix 3.2 and Appendix 3.3;

Where:

ISC	=	Irrigation structure cost;
OMC	=	Operation and Maintenance cost;
WRC	=	Water right cost;
TAC	=	Total area cost;
PIW	=	Price of irrigation water.

Table 4.8: Irrigation Service Fees in Mabogini System (Produced by the computer program model)

Area Name	OMC (Tshs)	WRC (Tshs)	ISC (Tshs)	PIW (Tshs/ha)
MS1-1	19874	2507	137063	14570
MS1-2	18143	2385	125121	10792
MS1-3	20571	2540	141871	11296
MS2-1	20640	2457	142345	14324
MS2-2	75279	3223	519167	13425
MS2-3	59436	2852	409904	11891
MS3-1	17592	2082	121322	15200
MS3-2	38739	3145	267167	14977
MS4-1	15419	2461	106336	8479
MS4-2	35911	3755	247660	12801
MS5-1	81221	4682	560142	13190
MS5-2	35817	3256	247014	8935
MS5-3	39271	3409	270836	9330
MS6-1	40782	3785	281254	12016
MS6-2	19719	2513	135992	11247
MS6-3	12259	1393	84545	13187
MS7-1	60006	4677	413836	11407
MS7-2	58133	4699	400915	11646

Source: Own data. 1996.

Seasonal/Annual mean price of irrigation water in Mabogini system is 12.151 Tshs/ha.

Table 4.9: Seasonal irrigation water cost in Rau system.

	ISC	OMC	WRC	TAC	PIW
Block	(Tshs)	(Tshs)	(Tshs)	(Tshs)	(Tshs/ha)
RS1-1	50361	7302	1477	59140	3896
RS1-2	266808	38687	2804	308299	10697
RS1-3	262608	38078	2768	303454	10666
RS1-4	228685	33159	2487	264331	10342
RS1-5	195100	28290	2174	225564	10092
RS1-6	196153	28442	2182	226777	10110
RS1-7	197641	28658	2194	228493	10133
RS1-8	114344	16580	1121	132045	11462
RS1-9	55632	8067	1065	64764	5915
RS3-1	190456	27616	1973	220045	10850
RS3-2	232781	33753	2317	268851	11292
RS3-3	306697	44471	2815	353983	12236
RS3-4	215333	31223	2560	249116	9468
RS4-1	368711	53463	3384	425558	12236
RS4-2	127983	18558	1317	147858	10920
RS4-3	483245	70070	4000	557315	13557
RS4-4	267613	38804	2899	309316	10380
RS4-5	232346	33690	2167	268203	12043
RS4-6	165536	24003	1829	191368	10179
RS4-7	165215	23956	2146	191317	8673
RS4-8	119372	17309	1824	138505	7387
RS4-9	508809	73777	4119	586705	13857
RS8-2	423558	61416	3624	488598	13117
RS8-3	340743	49408	3251	393402	11775
RS8-4	344130	49899	3178	397207	12162
Mean value		10538			

Table 4.10: Irrigation Service Fees in Rau system (Produced by the computer program model).

Area Name	OMC (Tshs)	WRC (Tshs)	ISC (Tshs)	PIW (Tshs/ha)
RS1-1	7300	1757	50348	3913
RS1-2	38590	3335	266139	10689
RS1-3	37979	3292	261923	10657
RS1-4	33070	2958	228067	10332
RS1-5	28200	2586	194480	10079
RS1-6	28356	2595	195559	10099
RS1-7	28558	2609	196950	10116
RS1-8	16464	1333	113543	11401
RS1-9	8071	1267	55665	5936
RS3-1	27513	2347	189745	10829
RS3-2	33661	2755	232145	11279
RS3-3	44374	3348	306025	12228
RS3-4	31193	3044	215121	9478
RS4-1	53375	4025	368101	12234
RS4-2	18470	1567	127383	10888
RS4-3	69980	4757	482622	13558
RS4-4	38809	3448	267648	10400
RS4-5	31338	2577	216126	11228
RS4-6	22336	2175	154039	9497
RS4-7	21652	2553	149323	7866
RS4-8	15642	2170	107873	6703
RS4-9	73686	4899	508177	13858
RS8-2	61423	4310	423604	13137
RS8-3	49412	3866	340772	11794
RS8-4	49807	3779	343498	12158

Source: Own data, 1996

Seasonal/Annual mean price of irrigation water in Rau system is 10.414 (Tshs/ha)

Table 4.11: Comparison of mean system irrigation water price between the two systems using T-test.

Description	Mabogini System	Rau System
Sample size (n)	18	25
Mean price	11940	10538
Sample std	1998	2250
Confidence level	10%	
Degree of freedom	41	
Tabulated critical value	-1.684 and +1.684	
Calculated test statistic (T)	-2.116 and +2.116	
Standard error of the mean	470.93	450.00
Remarks:	The two means are significantly different	

Table 4.12: Comparison of mean system irrigation water price between manually calculated and that of computer program model in each system using T-test.

Description	Mabogini system		Rau system	
	Manual	Computer	Manual	Computer
Sample size (n)	18	18	25	25
Mean price	11940	12151	10538	10414
Sample std	1998	2002	2250	2311
Confidence level	10%		10%	
Degree of freedom (df)	34		48	
Tabulated critical values	-1.692 and +1.692;		-1.679 and +1.679	
Calculated test statistic(T)	-0.316 and +0.316;		-0.192 and +0.192	
Standard error	470.9	471.9	450.0	462.2
Remarks:	The two means are not significantly different in each system.			

In Figure 4.3, the values produced by the computer program model (CPM) in Mabogini system are always greater than the manually obtained values by an average of 2%; while in Figure 4.4, the values of water prices produced manually are greater than CPM values with exception of very few cases, by an average of 1.2%. This is due to difference in the number of irrigation canals in each system. If one irrigation canal serves many blocks like in Rau system where about 9 blocks are served, the computer program model distribute the cost share equally to cost elements. But, if one canal serves few blocks like in Mabogini system where 2 to 4 blocks are served, the programme distribute the losses in each block; thus, the cost share in that block increases due to increase in losses. This is why the results produced manually and Computer program model in Rau system are almost equal, while in Mabogini system, the water price produced by the computer program are always higher than that calculated manually.

Figure 4.3 and Figure 4.4 show that tertiary block prices differ from one tertiary block to another within the same system. These differences depend on many different factors such as number and initial installation cost of irrigation control structures, distance or location of the tertiary block from the intake and the size of the tertiary block. As the number of control structures increases on serving one tertiary block, the price of irrigation water also increases in that block; but this also depends on the initial installation costs of those structures.

Distance of tertiary block from the intake also affects the irrigation water price because water losses and number of control structures increases in the down stream direction. On the other hand size of tertiary block affects the irrigation water price. If the size of the tertiary block is bigger, the water required for irrigation is also abundant, thus increases the total irrigation water cost in that block, although the unit water price might be low. This can be illustrated using block RS4-9 and block RS1-1 in Rau system. Block RS4-9 has the highest daily mean water supply, largest acreage, almost located at the tail end of the system (Figure 3.4), highest total irrigation cost and highest unit irrigation water price (Table 4.3 and Table 4.10). Similarly, tertiary block RS1-1 is located on the upstream part near the intake, and it is served by the least number of irrigation structures, and it has got the lowest irrigation water cost in the system.

For the case of Mabogini system, the situation is slightly different; block MS5-1 has second largest acreage, second highest daily mean irrigation water supplied, largest number of control structures (Table 4.2), located near the tail end of the system (Figure 3.3), and it has got the highest total irrigation cost and high unit irrigation water price (Table 4.7). Similarly, tertiary block MS4-1 can be ranked the second from the least total block irrigation water cost but it has got lowest unity irrigation water cost (Table 4.7). This is because apart of being located near the centre of the system, the major factor is of being served by the least number of irrigation structures. It is just receiving water directly from the main canal and the block is using one common turnout with tertiary block MS4-2 (Figure 3.3).

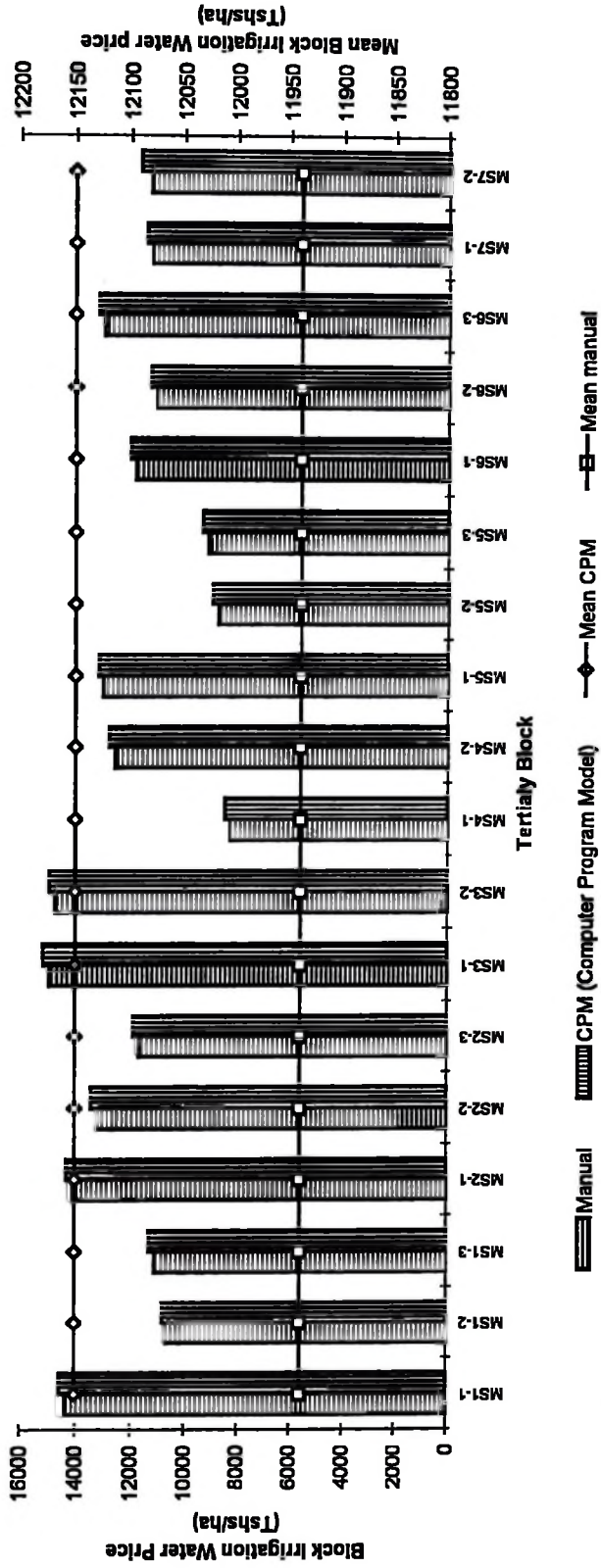


Figure 4.3 The price of irrigation water for different tertiary blocks in Mabogini system.

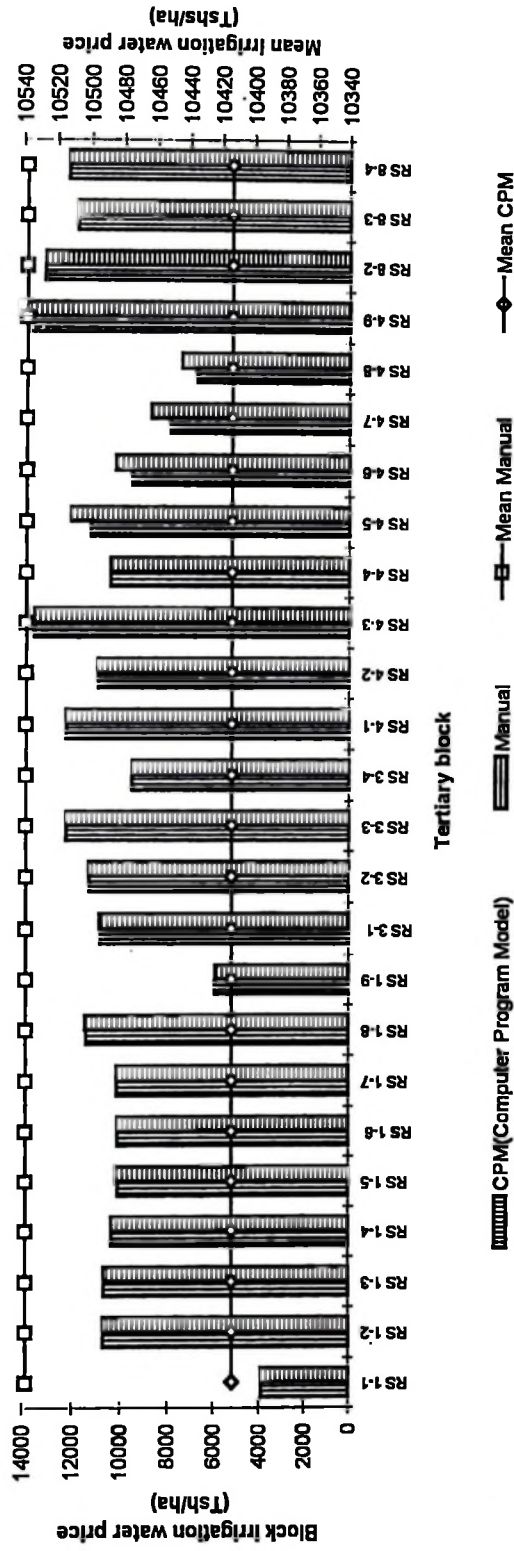


Figure 4.4 The price of irrigation water for different tertiary blocks in Rau system.

The two turnouts share the present replacement cost of the turnout. So the irrigation water price in each tertiary block obviously must differ from each other due to these factors.

The irrigation water prices presented are for one cropping season (3rd season). Hence, to have realistic values which cater for the three seasons, the Study should have continued for all the seasons. Also, there is a danger of developing conflicts among the water users due to different irrigation water prices for different seasons in LMIS. This is because different blocks have irrigation water at different seasons. Therefore, a farmer may refuse to pay more money when it is the turn for his block considering some of his colleagues located at different blocks paid less in the previous season. Thus a common price have to be adopted.

The price estimated for the third season is not expected to differ much from the price in the other two seasons because only two parameters are expected to change. These parameters are volume of water received by the tertiary block, or delivered by the structure and volume of water loss. The water received during the first season is expected to be less than the other seasons because it is supplementary irrigation. Also because of wetness, the land will be saturated and the water losses are expected to be minimum. Thus the price on the first season is also expected to be less than that of second season, and that of second season to be less than that of third season due to cool weather. The third season price which is the one being evaluate is probably the maximum price the farmer can pay in LMIS.

However, to avoid conflicts and sometimes farmers' movement from one tertiary block of high water price to another of low water price, the systems' mean prices are recommended rather than tertiary block prices.

4.7 Criteria used by LMIS to set irrigation water charges

No regulations or rules on the setting and collection of water charges have been established in LMIS as well as in Tanzania as a whole at the moment. The farmers in LMIS started in May, 1988 (i.e. in the second season) to pay water charges. The amount paid per plot (0.3 ha) was 290 Tshs which was equivalent to 967 Tshs/ha. Under this system of water charges the scheme managed to collect 446,897 Tshs in May to October season and 366,548 Tshs in September to February season, 1989. The total amount collected was 813,445 Tshs. The money collected were used to buy diesel and lubricants for tractors and other machines use (Kimicho, R. Personal communication, 1996), but no money allocated for maintenance of the irrigation structures. Moreover, means or procedures used to come up with that unit price was just by estimating the amount of fuel used during plot preparation and puddling. Sometimes estimates were based on the cost of the facilities to be repaired or replaced in that season. So the criteria was ad-hoc.

4.8 Yields of paddy in LMIS

The anticipated net return of paddy per hectare under the full development of the scheme was estimated based on the yield data collected from 1985 to November 1995 as presented in Appendix 4.1 and Appendix 4.2.

The mean production for the first three years of production (i.e. 1985 to 1987) was 6.70 tons/ha during wet season and 6.67 tons/ha during dry season (Table 4.13). Because of severe shortage of water, in 1988 the seasons were changed from two to three seasons. The first season was from January to June, the second season was from May to October, and the third season was from September to February. The average production data at LMIS from 1985 to 1994 are presented in Appendix 4.1 and summarised in Table 4.13. Average production was 6.80 tons/ha in the first season, 6.37 tons/ha in the second season and 6.66 tons/ha in the third season. The production data for paddy in the second season in 1995 are presented in Appendix 4.2 and summarised in Table 4.14. The calculated scheme mean production is 6.23 tons per hectare (Table 4.14).

Table 4.13 Average production of paddy in LMIS from 1985 to 1994.

Season	Average yield Tons/ha	Standard Deviation	Standard Error
Wet	6.70	0.30	0.21
Dry	6.67	0.24	0.14
First	6.80	0.62	0.25
Second	6.37	0.98	0.40
Third	6.66	0.68	0.26

Source: Appendix 4.1

Table 4.14: Yield data in LMIS in the second season 1995

Mabogini system		Rau system	
Block name	Average production (Tons/ha)	Block name	Average Production (Tons/ha)
MS6-2	5.98	RS1-7	4.43
MS6-2	7.09	RS8-3	6.16
MS4-1	7.19	RS8-3	5.78
MS4-1	7.33	RS1-4	7.63
MS5-2	5.97	RS1-7	5.13
MS5-2	5.07	RS1-7	6.11
MS7-1	6.15	RS1-4	7.15
Mean	6.40		6.06
STD	0.83		1.10
STD error	0.44		0.50

Scheme mean production = 6.23

Source: Appendix 4.2

Table 4.15: Comparison of paddy yield means between the two systems using T-test.

Description	Mabogini System	Rau System
Sample size (n)	7	7
Mean yield	6.40	6.06
Sample std	0.83	1.10
Confidence level	10%	
Degree of freedom	12	
Tabulated critical values	-1.782	and +1.782
Calculated test statistic (T)	-0.653	and +0.653
Remarks:	The two means are not significantly different	

The mean production for Rau system is 6.06 tons/ha, while in Mabogini system is 6.40 tons/ha (Table 4.14). The standard error of their means are 0.5 and 0.44 respectively. The slight deviation in production between the two may be due to reliable supply of irrigation water in Mabogini system (located in upstream part of the scheme) than in Rau system, assuming that the farm management and other factors are the same in both systems.

For calculation purposes and since the difference in production between the two systems is not significant at 10% confidence level (Table 4.15). The mean of two means, that is 6.23 tons/ha was used to estimate the ability of the farmers to pay irrigation service fee. The assumption here is that this is the true mean of the population for the whole scheme.

4.9 Farmers' capacity to pay ISF in LMIS

Table 4.16 summarises the revenue and cost items used in calculating farmers' capacity to pay. As can be seen from the table the capacity to pay ISF per season per family is 194,309 Tshs and 154,309 Tshs for landowner and tenant farmers respectively. NIPPON KOEI (1985) recommended that the water charge should generally be less than one third of the farmers' capacity to pay ISF, so that the charge would not lower farmers' volition to cultivate paddy in the scheme area. In this view it is recommended to charge farmers the amount equal to or less than 33% of the capacity to pay for the supply of irrigation water under the scheme.

Therefore the irrigation water price should be less than 64,770 Tshs for landowner farmers and 51,436 Tshs for tenant farmers. The two figures differ because the landowner farmers do not suffer from hiring costs like tenant farmers.

The program model produced the mean water prices of 10,414 Tshs/ha and 12,151 Tshs/ha for Rau and Mabogini system respectively. Both values are less than 33% of the farmers' capacity to pay ISF. The price is reasonable to encourage farmers' to pay ISF, because farmers in most parts of Tanzania are used to contribute one bag of paddy with an estimated value of 10,000 Tshs for maintenance.

Table 4.16: Farmers' capacity to pay ISF

Total seasonal mean yield of paddy(Mw)	1,869
Clean rice (kg)	1,246
Gross income (Tshs)	373,800
Farmers' costs (Tshs)	
Tractor Costs	11,630
Seed costs	2,101
Personal Expenses	3,167
Maintenance cost	1,283
Miscellaneous	819
Dehusking cost	26,166
Other costs such as Transplanting, weeding, fertilizer, empty bags, Transportation, harvesting etc:	75,000
Total cost (Tshs)	120,166
Net income (Tshs)	253,634
Capacity to pay for Landowner farmer (Tshs)	194,309
Hiring cost (Tshs)	40,000
Total cost (Tshs)	160,166
Net income(Tshs)	213,634
Capacity to pay for a tenant farmer (Tshs)	154,309

Source: Own data (1996).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- (i) Generally it is concluded that the objective of developing and testing the computer program model was met. The program model fits Tanzanians' conditions and it produced encouraging results. The manually calculated irrigation water price is not significantly different ($p > 0.1$) from those obtained using the developed computer program, proving that the computer program is well developed and can be put into use.
- (ii) The collected ISF from water users, is believed to be able to generate as much as possible of its own funds to keep the scheme in good working order. The cost recovery for operation, maintenance and management is to occur from system water users only, in a manner and timing which reflects services obtained through the system.
- (iii) The systems' mean price, of 12,138 Tshs for Mabogini and 10,414 Tshs for Rau should be adopted. The tertiary block prices should be

avoided so as to have a uniform water price. Otherwise, the mean value of 11,276 Tshs should be adopted for the whole scheme. These prices, are expected to be reasonable and enough to maintain good irrigation service. But, this conclusion needs further data collection on the implementation of ISF for confirmation.

- (iv) The ISF is also a significant step in decentralization of responsibilities and financial arrangements to various associations e.g CHAWAMPU - (The Lower Moshi- WUA), and it will be a first step towards resources management at a local level by local institutions, including foremost the WUA in FMIS.
- (v) Increased farmer participation in operation and maintenance activities is desirable, encouraged and in the long term, necessary particularly in bearing the cost of running the irrigation system. Therefore, moves in this direction should be an important part of irrigation policy in Tanzania. The importance of ISF is unlikely to diminish in the near future and therefore, the results of the study are encouraging.
- (vi) Unless a water supply is reliable in FMIS, it is unlikely that improved cost of irrigation water can be achieved and sustained. Although a reliable water supply may be a necessary condition for improved cost of irrigation water, it is not sufficient. Due to lack of flow measuring

devices, the distribution of water in FMIS is based on experience and feedback from the paddy growing areas, this inevitably means that the more accessible parts of the system are favoured during water shortage.

- (vii) Since successful cost of irrigation water is possible even without water measurement at the tertiary block level it follows that sophisticated water measurement technology is not necessary for improved cost of irrigation water in FMIS.

5.2 Recommendations

- (i) It is recommended that more data should be collected from LMIS in the first and second seasons, and analyzed using the developed computer program model. The irrigation water prices in all seasons should be compared to see if there is significant difference between them and finally to come up with annual irrigation water price of the scheme. The mean of the three season prices may be taken as the standard price of the scheme.
- (ii) More research should be done to test the program model in different FMIS in Tanzania with similar conditions so as to make it universal.

- (iii) **The policy on means to transfer responsibilities and implementation of ISF to farmers for support services should be encouraged in Tanzania; as a way of reducing public expenditure. The policy undertaken should be consistent with the realities faced by the public sector in terms of financial, personnel and policy limitations. It should analyze specific successful interfaces that join necessary Governmental and farmer contributions so as to optimise system benefits and the sharing of system responsibilities.**

- (iv) **Collection of ISF should be carried out in each season in order to make the farmers easy to complete the payment. The best timing to collect the water charges is right after the harvesting period for those who contribute produce and after sell of produce for those who pay cash.**

- (v) **The WUA committee should discuss the collection of ISF with water users as early as possible. The discussion should include items like collection commencement date, collection period and total amount expected to be collected at the end of the period.**

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APPENDICES

Appendix 1: Recorded irrigation duration in different plots LMIS.

Plot number	Irrigation duration		
	Hours	Minutes	Hours
321	2	0	2.00
322	2	30	2.50
226	2	35	2.58
225	2	30	2.50
222	2	35	2.58
211	2	30	2.50
425	2	20	2.33
424	2	5	2.08
405	2	5	2.08
406	2	0	2.00
513	2	10	2.17
512	2	5	2.08
521	2	20	2.33
520	1	0	1.00
313	1	30	1.50
327	2	5	2.08
410	2	20	2.33
409	2	15	2.25
405	2	10	2.17
416	2	30	2.50
113	2	20	2.33
112	2	25	2.42
104	1	30	1.50
105	1	25	1.42
509	2	15	2.25
508	2	20	2.33
209	2	5	2.08
206	2	6	2.10
323	2	30	2.50
308	2	40	2.67
304	1	30	1.50
316	1	20	1.33
109	1	45	1.75
107	1	35	1.58
102	1	30	1.50
101	1	5	1.08
216	1	45	1.75
217	1	50	1.83

Appendix 1 Continue

224	2	5	2.08
211	1	3	1.05
319	2	5	2.08
318	2	15	2.25
320	2	30	2.50
308	2	40	2.67
309	2	15	2.25
307	2	25	2.42
525	1	20	1.33
423	1	30	1.50
512	2	5	2.08
111	1	45	1.75
110	1	15	1.25
106	1	20	1.33
401	2	5	2.08
402	2	15	2.25
403	2	15	2.25
327	2	25	2.42
313	2	5	2.08
307	2	15	2.25
320	2	20	2.33
319	2	10	2.17
Total	102	1194	121.9
Mean	1.7	0.33	2.03
Standard deviation			0.44

Source: Own data, 1996.

APPENDIX 2

Appendix 2.1: Recorded daily water flow measurements for Mabogini system (L/S)-LMIS Third season 1995/96.

DATE	INTAKE	TMM NO.						TMS NO.							
		P/FLUME	1	2	3	4	5	6	MS1-1	MS2-1	MS3-1	MS3-3	MS4-1	MSS-1	MS6-3
DECI	642	46	107	118	69	192	81	46	106	52	U/F	69	190	69	52
2	669	46	118	181	81	205	81	46	118	52	58	81	203	69	52
3	669	46	118	181	81	205	81	46	118	52	58	81	203	69	52
4	669	46	118	181	81	205	81	46	118	52	58	81	203	69	52
5	669	45	97	118	113	233	81	97	97	52	58	113	230	69	52
6	616	46	97	107	81	205	60	46	97	47	54	81	205	49	52
7	616	46	97	107	81	205	60	46	97	47	54	81	205	49	52
8	564.5	46	118	118	69	192	51	46	118	52	58	69	192	42	52
9	696	46	118	118	100	205	104	46	118	52	58	100	205	93	52
10	696	46	118	118	113	233	81	46	118	52	58	113	230	69	52
11	696	46	118	118	106	218	81	46	118	52	58	106	218	69	52
12	616	46	118	118	69	190	53	46	118	52	58	69	190	42	52
13	642	46	107	97	120	218	81	46	97	42	47	120	218	69	52
14	696	46	118	97	120	218	93	46	97	42	47	120	218	81	52
15	642	46	118	118	106	205	81	46	118	52	58	106	205	69	52
16	724	46	118	118	106	205	104	46	118	52	58	106	205	93	52
17	724	46	118	118	106	205	104	46	118	52	58	106	205	93	52
18	724	46	118	118	106	205	104	46	118	52	58	106	205	93	52
19	724	46	118	118	106	205	104	46	118	52	58	106	205	93	52
20	724	46	118	118	106	205	104	46	118	52	58	106	205	93	52
21	724	46	118	118	106	205	104	46	118	52	58	106	205	93	52
22	590	46	107	107	100	153	60	46	106	47	54	100	150	47	52
23	590	46	107	107	100	153	60	46	106	47	54	100	150	47	52
24	616	46	118	118	100	153	60	46	118	52	58	100	150	47	52
25	809	94	118	118	120	205	143	94	118	52	58	120	205	134	52
26	696	46	107	107	120	218	81	46	106	47	54	120	218	69	52
27	669	94	118	118	13	205	93	94	118	52	58	13	205	81	52
28	669	94	118	118	118	218	93	94	118	52	58	218	218	81	52
29	669	94	118	118	218	218	100	94	118	52	58	218	218	93	52

Appendix 2.1 Continue

30	669	94	118	107	218	100	94	106	47	54	218	93	52
31	669	94	118	107	218	100	94	106	47	54	218	93	52
JAN1	642	92	118	118	205	81	46	58	52	58	205	69	
2	590	85	107	107	192	70	37	52	42	58	192	58	
3	669	131	118	118	205	81	42	58	52	58	205	69	
4	669	131	118	118	205	81	42	58	52	58	205	69	
5	669	131	118	118	205	81	42	58	52	58	205	69	
6	669	131	118	107	205	81	42	58	52	58	205	69	
7	669	131	118	107	205	81	42	58	52	58	205	69	
8	669	131	118	118	205	81	42	58	52	58	205	69	
9	669	131	118	118	205	81	42	58	52	58	205	69	
10	669	131	118	118	205	81	42	58	52	58	205	69	
11	669	131	118	118	205	81	42	58	52	58	205	69	
12	669	131	118	118	205	81	42	58	52	58	205	69	
13	669	131	118	118	205	81	42	58	52	58	205	69	
14	669	131	118	118	205	81	42	58	52	58	205	69	
15	669	131	118	118	205	81	42	58	52	58	205	69	
16	669	131	118	118	205	81	42	58	52	58	205	69	
17	669	131	118	118	205	81	42	58	52	58	205	69	
18	669	131	118	118	205	81	42	58	52	58	205	69	
19	669	131	118	118	205	81	42	58	52	58	205	69	
20	669	131	118	118	205	81	42	58	52	58	205	69	
21	669	131	118	118	205	81	42	58	52	58	205	69	
22	669	131	118	118	205	81	42	58	52	58	205	69	
23	442		58	107	192	70		58	42	58	205	58	
24	669	131	118	118	205	81	42	58	52	58	205	69	
25	603	103	97	107	205	81	24	42	46	46	205	69	
26	629	103	118	107	205	81	24	58	52	58	205	69	
27	629	103	118	107	205	81	24	58	52	58	205	69	
28	629	103	118	118	205	81	24	58	52	58	205	69	
29	629	103	118	118	205	81	24	58	52	58	205	69	
30	629	103	118	118	205	81	24	58	52	58	205	69	
31	629	103	118	118	205	81	24	58	52	58	205	69	
Mean	659.49	9.86	114.61	114.84	95.52	203.98	83.11	46.73	85.23	50.69	95.52	203.82	71.56
STD	49.12	3.97	9.42	5.70	22.99	13.98	14.67	18.05	28.54	2.90	22.99	14.26	15.25
													0

Source: Own data, 1995/96.

Appendix 2.2: Recorded daily water flow measurements for Rau system (L/S)-LMIS third season 1995/96.

DATE	TRM NO.		BIFURCATION				TRS NO.							
	INTAKE P/FLUME	1	3	RS 4 CHEKELENI		RS 5 ORIA	RS1-1	RS1-8	RS1-9	RS4-1	RS3-2	RS7-1 P/F	RS8-2B	RS4-6
				RS 4	RS 5									
DECI	583		130	157	177	177	87	58	58	146	127	63	106	
2	643	130	141	128	137	137	78	58	58	120	138	24	106	
3	553		141	137	177	177	81			127	138	63	106	
4	553		107	137	177	177	87			127	106	63	106	
5	674	130	107	128	201	201	87	58	58	120	106	47	149	
6	583	81	130	137	118	118	78	33	37	120	127	5	106	
7	612	70	141	128	177	177	81	29	29	120	138	47	106	
8	643	130	130	147	137	137	78	58	58	134	127	24	106	
9	314			157	128	128				20		20	106	
10	612	70	141	147	137	137	78	29	29	134	138	24	106	
11	612	70	141	167	118	118	78	29	29	157	138	24	106	
12	738	200	118	221	100	100	81	93	93	190	113	5	100	
13	674	130	130	157	147	147	75	58	58	146	128	29	106	
14	612	70	141	157	147	147	75	29	29	146	138	29	106	
15	643	70	141	177	147	147	78	29	29	165	138	29	106	
16	612	70	141	157	147	147	78	29	29	146	138	29	106	
17	643	70	166	167	147	147	78	29	29	157	165	29	106	
18	643	70	153	147	157	157	87	29	29	134	150	29	116	
19	612	130	166	118	84	84	87	58	58	106	165	75	75	
20	553	70	166	118	100	100	78	29	29	106	165	93	93	
21	674	130	179	157	100	100	78	58	58	146	165	93	93	
22	674	130	141	137	157	157	76	58	58	127	138	29	116	
23	553		166	157	137	137	81			146	165	13	116	
24	553		130	157	137	137	87			146	127	13	116	
25	612	130	141	118	110	110	81	58	58	106	138	100	100	
26	553	70	130	137	110	110	87	29	29	127	127	100	100	
27	612	143	77	157	110	110	87	63	63	146	75	100	100	
28	553	93	77	157	137	137	81	40	42	146	75	127	127	
29	583	130	67	118	157	157	78	58	58	106	63	149	149	
30	583	130	67	137	147	147	81	58	58	127	63	142	142	
31	583	130	70	157	100	100	87	58	58	146	69	93	93	

Appendix 2.2 continue

JAN1	495	81	86	118	109	81	33	37	106	81	100		
2	553	130	86	118	109	81	58	58	106	81	100		
3	583	130	118	118	109	78	58	58	106	113	100		
4	468	51	58	118	137	81	20	20	106	55	127		
5	539	130	42	157	100	81	58	58	100	37	93		
6	539	130	42	157	100	81	58	58	100	37	93		
7	510	93	58	167	84	81	40	42	100	52	75		
8	659	130	97	167	147	87	58	58	100	93	138		
9	643	93	67	221	147	87	40	42	149	63	138		
10	553	117	58	177	147	87	52	52	113	52	138		
11	583	117	50	157	147	87	52	52	100	46	138		
12	468	118	118	177	137	78	69	72	113	113	127		
13	643	157	58	177	137	87	69	72	113	52	127		
14	583	130	42	167	137	87	58	58	106	37	127		
15	568	157	42	157	127.5	87	58	58	100	37	120		
16	598	157	42	157	127.5	87	69	72	100	37	120		
17	706	130	58	210	199	81	58	58	157	55	190		
18	553	117	42	167	118	78	52	52	113	37	113		
19	495	70	42	157	118	78	29	29	100	37	113		
20	482	70	34	157	118	78	29	29	100	29	113		
21	454	70	34	147	100	78	29	29	106	29	113		
22	363	25	27	118	100	75	20	20	106	24	93		
23	401	25	34	157	84	75	20	20	100	29	93		
24	414	70	42	177	68	75	20	37	113	29	75		
25	414	70	42	177	68	75	20	37	113	29	58		
26	363	25	27	147	68	75	20	20	113	24	58		
27	524	81	58	177	100	78	33	37	113	52	93		
28	468	70	34	177	76	78	20	37	113	29	69		
29	468	60	42	177	84	78	24	24	113	37	75		
30	268	157	42	157	84	78	24	24	93	37	75		
31	414	25	27	157	100	78	20	20	93	24	93		
TOTAL	34417	5201	5357	9547	7749	4767	2234	2309	7434	5143	614	6605	1238
MEAN	555.11	98.13	93.98	153.98	124.98	80.80	43.80	45.27	121.87	90.23	30.70	106.53	47.62
STD	96.35	38.57	46.93	23.52	31.34	4.20	17.28	16.33	21.35	47.47	17.59	23.65	5.43

Source: Own data, 1995/96.

APPENDIX 3

Appendix 3.1: Evaluation of irrigation structures in Mabogini system.

Structure	Name	Installation year	Component capital cost (Tshs).										Present replacement cost (Tshs)
			Seasonal water		Intake		Check & drop structures	Gates and accessories		Total capital cost			
			delivery (m ³ x10 ⁴)	weir	weir	drop structures		Turnouts	Intake & Checks	Turnouts	Tshs		
MI	Intake	1985	846.67	5578915	NIL	NIL	698052	NIL	6275967	46638390			
TMM-1	T & CD	1986	97.68		26140	59254	144888	57511	287793	1781938			
TMM-2	T & CD	1986	130.17		26140	59254	144888	57511	287793	1781938			
TMM-3	T & CD	1986	75.43		26140	59254	144888	57511	287793	1781938			
TMM-4	T & CD	1986	64.13		52280	118508	289776	115022	575586	3563877			
TMM-5	T & CD	1986	212.27		52280	118508	289776	115022	575586	3563877			
TMM-6	T & CD	1986	139.85		52280	118508	289776	115022	575586	3563877			
TMS1-1	T/O	1986	33.32		10512	30800	144888	57511	243711	1508994			
TMS1-2	T & CD	1986	64.36		NIL	61600	NIL	115022	353244	2197194			
TMS2-1	T & CD	1986	32.00		10512	30800	144888	57511	243711	1508994			
TMS2-2	T & CD	1986	98.22		NIL	61600	NIL	115022	353244	2187194			
TMS3-1	T/O	1986	22.98		10512	30800	144888	57511	243711	1508994			
TMS3-2	T/O	1986	52.45		NIL	30800	NIL	57511	88311	545798			
TMS5-1	T/O	1986	69.73		10512	30800	144888	57511	243711	1508994			
TMS5-2	T & CD	1986	70.71		NIL	61600	NIL	115022	353244	2187194			
TMS6-1	T/O	1986	45.57		10512	30800	144888	57511	243711	1508994			
TMS6-2	T/O	1986	20.08		10512	30800	144888	57511	243711	1508994			
TMS6-3	T/O	1986	5.17		10512	30800	144888	57511	243711	1508994			

Key: 1. TMM = Turnout (T/O) with check drop structure in the main canal of Mabogini system.

2. TMS = Turnout (T/O) with check drop structure in the secondary canals of Mabogini system; and T & CD means turnout & check drop structure.

3. Replacement value of the structures are taken equal to the present value of their capital costs.

Source: NIPPON KOEI (1988).

Appendix 3.2: Allocation of the present replacement cost of the irrigation structures in Mabogini system.

1	2	3	4	5	6	7	8	9	10	11	12	13
Seasonal	Name of area served	Canal length (km)	Seasonal irrigation water requirement (m ³)	COL3×COL4	(COL5 *WL)/Σ(IR*L)	COL4+COL6	Area share of the present cost of the irrigation structures (Tshs)	Major structures	Minor structures	Total annual share	Seasonal O&M cost	Seasonal irrigation replacement cost AC _i (Tshs)
Canal losses (m ³)	WL X 10 ⁵	L (km)	IR _i (m ³)	IRxL	WL _i (m ³)	Q _{req} (m ³)	Intake wear	TMM	TMS	cost ISC _i (Tshs)	OMC _i (Tshs)	cost AC _i (Tshs)
MI-TMM1-TMS1-2	MS1-1	0.122	333168	40646.50	1813	334981	184523	TMM-1	1508994	3962012	38405	264861
0.141	MS1-2	0.428	301639	129101.49	5758	307397	191991	607785	546798	2790355	27048	186535
	MS1-3	0.428	342010	146380.28	6529	348539	191991	550268	546798	3090630	29958	206609
				316128.27				TMM-2				
TMM1-TMM2-TMS2-2	MS2-1	0.915	319508	292349.82	19230	338738	186592	437385	1508994	3812308	36954	254853
1.060	MS2-2	1.343	550805	739731.12	48658	599463	330212	754014	613275	4669413	45262	312150
	MS2-3	1.343	431427	579406.46	38112	465539	256644	590594	480358	3657394	35452	244497
				1611487.40				TMM-3				
TMM2-TMM3-TMS3-1	MS3-1	0.993	229801	228192.39	19953	249754	137576	542876	1508994	3427635	33225	229137
0.976	MS3-2	1.693	524504	887985.27	77647	602151	331692	1239074	546798	5102801	49463	341122
				1116177.67				TMM-4				
TMM3-TMM4	MS4-1	0.500	192627	96313.50	17392	210019	115688	1070480	NIL	2227364	21590	148899
0.579	MS4-2	0.500	448648	224324.00	40508	489156	269450	2493258	NIL	5187759	50286	346802
				320637.50				TMM-5				
TMM4-TMM5-TMS5-2	MS5-1	1.198	697317	835385.77	31365	728682	401392	1170750	1508994	6693670	64883	447472
	MS5-2	2.265	337294	763970.91	28684	365978	201597	566295	527702	3109975	30146	207902
0.915	MS5-3	2.265	369829	837662.69	31451	401280	221043	620919	578603	3409960	33054	227956
				2437019.36				TMM-5				
TMM4-TMM5-TMS6-3	MS6-1	1.198	455726	545959.75	24019	479745	264266	765135	1508994	4916789	47660	328687
	MS6-2	1.892	200843	379994.96	16717	217560	119842	337203	1508994	3044622	29512	203533
0.468	MS6-3	2.234	61698	137833.33	6064	67762	373264	103587	1508994	1955845	19249	132754
				1063788.04				TMM-6				
TMM5-TMM6	MS7-1	0.455	695911	316639.51	26224	722135	397786	1773430	NIL	5751289	55749	384474
0.527	MS7-2	0.455	702600	319683.00	26476	729076	401609	1790475	NIL	5806570	56285	388169
				638322.51								

**Appendix 3.3: Allocation of irrigation water right cost for
Mabogini system.**

Area/Block	Size(ha)	Area share(Tshs)	Remarks
MS1-1	21.24	2109	Upper Mabogini
MS1-2	20.21	2006	Upper Mabogini
MS1-3	21.52	2136	Upper Mabogini
MS2-1	20.8	2065	Upper Mabogini
MS2-2	27.31	2711	Upper Mabogini
MS2-3	24.17	2399	Upper Mabogini
MS3-1	17.64	1751	Upper Mabogini
MS3-2	26.65	2646	Upper Mabogini
MS4-1	20.85	2070	Lower Mabogini
MS4-2	31.82	3159	Lower Mabogini
MS5-1	39.67	3938	Lower Mabogini
MS5-2	27.59	2739	Lower Mabogini
MS5-3	28.89	2868	Lower Mabogini
MS6-1	32.07	3184	Lower Mabogini
MS6-2	21.29	2113	Lower Mabogini
MS6-3	11.8	1171	Lower Mabogini
MS7-1	39.63	3934	Lower Mabogini
MS7-2	39.82	3953	Lower Mabogini
Total	472.97		

Source: NIPPON KOEI (1988) and Own data (1996)

Appendix 3.4: Evaluation of irrigation structures in Rau system.

Structure	Structure name	Installation year	Seasonal		Capital cost at installation (Tshs)				Total capital		Prese Replacer cost Tshs
			water delivery (m ³ x 10 ⁴)	Intake wear	Check & drop structures	Turnouts	Intake & checks	Gates & Accessories Turnouts	Cost at installation Tshs	Tshs	
RI	Rau Intake	1986	1196.37	8793215	NIL	NIL	1099792	NIL	9893007	612548	
TRM-1	T/O & C/D	1987	244.84		39082	57283	149550	57468	303383	156531	
TRM-3	T/O & C/D	1987	143.16		39082	57283	149550	57468	303383	156531	
TRM-4	Bifurcation	1987	629.29		39082	871745	149550	57468	1117845	576781	
TRS1-1	T/O & C/D	1987	47.43		12359	26544	149550	57468	245921	126881	
TRS1-2	T/O & C/D	1987	46.23		12359	26544	149550	57468	245921	126881	
TRS1-3	T/O & C/D	1987	37.30		12359	26544	149550	57468	245921	126881	
TRS1-4	T/O & C/D	1987	28.51		12359	26544	149550	57468	245921	126881	
TRS1-5	T/O & C/D	1987	28.71		12359	26544	149550	57468	245921	126881	
TRS1-6	T/O & C/D	1987	29.05		12359	26544	149550	57468	245921	126881	
TRS1-7	T/O & C/D	1987	7.59		12359	26544	149550	57468	245921	126881	
TRS1-8	T/O	1987	14.44		NIL	26544	NIL	57468	84012	43348	
TRS3-1	T/O & C/D	1987	23.50		12359	26544	149550	57468	245921	126881	
TRS3-2	T/O & C/D	1987	32.36		12359	26544	149550	57468	245921	126881	
TRS3-3	T/O & C/D	1987	47.80		12359	26544	149550	57468	245921	126881	
TRS3-4	T/O	1987	39.51		NIL	26544	NIL	57468	84012	43348	
TRS4-2	T/O & C/D	1987	69.06		12359	26544	149550	57468	245921	126881	
TRS4-3	T/O & C/D	1987	10.46		12359	26544	149550	57468	245921	126881	
TRS4-4	T/O & C/D	1987	96.50		12359	26544	149550	57468	245921	126881	
TRS4-5	T/O & C/D	1987	147.07		24718	53088	299100	114936	491842	253771	
TRS4-6	T/O & C/D	1987	48.50		24718	53088	299100	114936	491842	253771	
TRS4-7	T/O	1987	47.86		NIL	53088	NIL	114936	168024	86696	
TRS4-9	T/O & C/D	1987	102.35		12359	26544	149550	57468	245921	126881	
TRS8-2	T/O & C/D	1987	142.96		24718	53088	299100	114936	491842	253771	
TRS8-3	T/O & C/D	1987	60.90		12359	26544	149550	57468	245921	126881	

Source: NIPPON KOEI (1988).

Appendix 3.5: Allocation of the present replacement cost of irrigation structures in Rau system.

Canal losses (m ³ x 10 ⁴)	Name of area served	Canal length L (km)	Seasonal irrigation		Area				Area share of the present cost of irrigation structures (Tshs)				Sea: irrig replace cost (Tshs)
			IR (m ³ x 10 ⁴)	water requirements (m ³ x 10 ⁴)	Col3 x Col4	Seasonal losses (m ³ x 10 ⁴)	IR ₁ + WL ₁ (m ³ x 10 ⁴)	Intake weir	Major structures	Minor structures	Total annual share cost ISC.	Seasonal O&M cost (Tshs)	
WL			IR		IR x L	WL ₁	OL ₁	RI	TRM	TRS	OMC	A	
	RI-TRM1-TRS1-7								TRM-1				
	RS1-1	0.280	13.06	36568	0.023	13.08	669847	83499	NIL	753346	7302	503	
	RS1-2	0.793	47.06	373186	0.233	47.29	2421410	300879	1268898	3991187	38687	2661	
0.273	RS1-3	1.243	45.86	570040	0.355	46.22	2366250	293207	1268898	3928355	38078	2621	
	RS1-4	1.731	37.01	640643	0.399	37.41	1915378	236624	1268898	3420900	33159	2281	
	RS1-5	2.181	28.30	617223	0.385	28.68	1468673	180937	1268898	2918508	28290	1951	
	RS1-6	2.631	28.50	749835	0.467	28.97	1483145	182215	1268898	2934258	28442	1961	
	RS1-7	3.081	28.81	887636	0.553	29.36	1503414	184197	1268898	2956510	28558	1971	
	RS1-8	3.531	7.52	265531	0.165	7.69	393502	48079	1268898	1710479	16580	1141	
	RS1-9	3.531	6.79	239755	0.149	6.94	355303	43412	433483	832198	8067	556	
				4380417					TRM-3				
	TRM1-TRM3-TRS3-4							254775	1268898	2849035	27616	1901	
	RS3-1	2.352	23.30	548016	2.586	25.89	1325362	1325362	1268898	2849035	27616	1901	
	RS3-2	2.803	32.12	900324	4.248	36.37	1882060	351218	1268898	3482176	33753	2321	
2.098	RS3-3	3.252	47.42	1542098	7.276	54.70	2800467	518516	1268898	4587881	44471	3061	
	RS3-4	3.702	39.22	1451924	6.850	46.07	2358838	428853	433483	3221174	31223	2151	
				4442362					TRM-4 (BFF)				
	TRM3-TRM4-TRS4-7							628120	1268898	5515561	53463	3681	
	RS4-1	4.375	68.53	2998188	2.144	70.67	3618543	95231	1268898	1914498	18558	1271	
	RS4-2	4.836	10.39	502460	0.359	10.75	550370	877608	1268898	7228864	70070	4831	
	RS4-3	5.132	95.75	4913890	3.514	99.26	5082358	461123	1268898	4003221	38504	2671	
1.663	RS4-4	5.324	50.31	2678504	1.915	52.23	2673964	257554	868135	3475667	33690	2321	
	RS4-5	6.472	28.10	1818632	1.300	29.40	1508318	183496	1712795	3475667	33690	2321	
	RS4-6	6.472	20.02	1295694	0.926	20.95	1072472	252696	1220290	2476258	24003	1651	
	RS4-7	6.922	27.57	1908395	1.385	28.93	1481468	182579	737290	2471454	23956	1651	
	RS4-8	6.922	19.92	1378862	0.986	20.91	1070397	930952	532710	1785886	17309	1191	
	RS4-9	5.674	101.57	5763082	4.121	105.69	5411434	930952	1268898	7611285	73777	5081	
				23257708					TRM-4 (BFF)				
	TRM4-TRM6-TRS8-4							720510	1995468	6336017	61416	4235	
	RS8-2	1.819	78.61	1429916	3.812	82.42	4220040	578634	1122623	5097185	49408	3407	
	RS8-3	1.819	63.24	1150336	3.086	66.31	3394928	553879	1268898	5147847	48899	3441	
1.139	RS8-4	2.801	60.43	1692644	4.512	64.94	3325070						
				4272896									

Source: NIPPON KOEI (1988) and Own data (1998)

Appendix 3.6: Allocation of the irrigation water right cost for Rau system.

Area/Block	Size(ha)	Area share(Tshs)	Remarks
RS1-1	15.18	1477	Rau river village
RS1-2	28.82	2804	Rau river village
RS1-3	28.45	2768	Rau river village
RS1-4	25.56	2487	Rau river village
RS1-5	22.35	2174	Rau river village
RS1-6	22.43	2182	Rau river village
RS1-7	22.55	2194	Rau river village
RS1-8	11.52	1121	Rau river village
RS1-9	10.95	1065	Rau river village
RS3-1	20.28	1973	Rau river village
RS3-2	23.81	2317	Rau river village
RS3-3	28.93	2815	Rau river village
RS3-4	26.31	2560	Rau river village
RS4-1	34.78	3384	Chekeleni village
RS4-2	13.54	1317	Chekeleni village
RS4-3	41.11	4000	Chekeleni village
RS4-4	29.80	2899	Chekeleni village
RS4-5	22.27	2167	Chekeleni village
RS4-6	18.80	1829	Chekeleni village
RS4-7	22.06	2146	Chekeleni village
RS4-8	18.75	1824	Chekeleni village
RS4-9	42.34	4119	Oria village
RS8-2	37.25	3624	Oria village
RS8-3	33.41	3251	Oria village
RS8-4	32.66	3178	Oria village
Total	633.91	61675	

Source: NIPPON KOEI (1988) and Own data (1996)

APPENDIX 4

Appendix 4.1: Production data in Lower Moshi irrigation scheme.

Year	Season	Acreage	Average Yield	Average Yield	Average Yield	Average Yield	Average Yield	Average Yield
		[ha]	[Tons/ha]	Wet season (Tons/ha)	Dry season (Tons/ha)	First season (Tons/ha)	second season (Tons/ha)	Third season (Tons/ha)
1985	Dry	93.52	7.00		7.00			
1986	Wet	119.12	7.00	7.00				
	Dry	472.97	6.50		6.50			
1987	Wet	414.00	6.40	6.40				
	Dry	473.29	6.50		6.50			
1988	First season	432.80	7.00			7.00		
	Second season	463.02	6.50				6.50	
	Third season	391.02	6.50					6.50
1989	First season	500.60	6.50			6.50		
	Second season	517.51	6.00				6.00	
	Third season	413.30	6.00					6.00
1990	First season	518.00	6.00			6.00		
	Second season	571.51	8.40				8.40	
	Third season	425.15	5.60					5.60
1991	First season	351.46	7.10			7.10		
	Second season	476.00	6.10				6.10	
	Third season	449.00	7.30					7.30
1992	First season	437.00	7.90			7.90		
	Second season							
	Third season	454.00	7.75					7.75
1993	First season	318.18	6.30			6.30		
	Second season	392.80	5.90				5.90	
	Third season	266.90	6.70					6.70
1994	First season	No cultivation						
	Second season	421.00	5.30				5.30	
	Third season	224.00	6.80					6.80
	Mean Value		6.63	6.70	6.67	6.80	6.37	6.66
	Standard deviation		0.71	0.30	0.24	0.62	0.98	0.68

Source: Paddy section in LMIS (1995).

Appendix 4.2: Yield data in LMIS in the second season 1995.

Block name	Sample No: Area = 2m ²	Plot No:	Field weight [kg]	Moisture content [%]	Actual weight [kg]	Average production [Tons/ha]
RS1-7	1	303	1.60	23.20	0.97	
	2	303	1.10	17.50	0.88	
	3	303	1.20	20.70	0.81	
					2.66	4.43
RS8-3	1	505	1.20	17.80	0.94	
	2	505	2.00	20.50	1.37	
	3	505	2.20	22.20	1.39	
					3.70	6.16
RS8-3	1	503	1.80	20.30	1.24	
	2	503	1.20	18.20	0.92	
	3	503	1.90	20.40	1.30	
					3.47	5.78
RS1-4	1	403	1.40	15.70	1.25	
	2	403	2.20	19.70	1.56	
	3	403	2.80	22.20	1.77	
					4.58	7.63
RS1-7	1	211	1.90	24.50	1.09	
	2	211	2.00	24.50	1.14	
	3	211	1.40	23.00	0.85	
					3.08	5.13
RS1-7	1	222	2.10	25.20	1.17	
	2	222	2.00	20.30	1.38	
	3	222	2.20	27.50	1.12	
					3.67	6.11
RS1-4	1	414	2.00	18.50	1.51	
	2	414	2.70	22.90	1.65	
	3	414	1.10	13.70	1.12	
					4.29	7.15

Mean production for Rau system (tons/ha) = 6.06 tons/ha;

Standard deviation of the means = 1.10.

Appendix 4.2 continue

MS6-2	1	307	1.50	18.80	1.12	<hr/>	5.98
	2	307	2.20	20.00	1.54		
	3	307	1.20	18.00	0.93		
					3.59		
MS6-2	1	426	2.00	21.50	1.30	<hr/>	7.09
	2	426	2.50	24.00	1.46		
	3	426	2.40	22.50	1.49		
					4.25		
MS4-1	1	602	2.80	22.20	1.77	<hr/>	7.19
	2	602	1.80	18.60	1.35		
	3	602	1.50	17.60	1.19		
					4.31		
MS4-1	1	411	2.40	24.40	1.38	<hr/>	7.33
	2	411	2.40	25.20	1.33		
	3	411	2.80	23.20	1.69		
					4.40		
MS5-2	1	619	2.00	24.60	1.14	<hr/>	5.97
	2	619	2.20	25.00	1.23		
	3	619	1.90	22.00	1.21		
					3.58		
MS5-2	1	615	0.80	18.00	0.62	<hr/>	5.07
	2	615	1.90	22.20	1.20		
	3	615	1.70	19.50	1.22		
					3.04		
MS7-1	1	501	2.00	23.00	1.22	<hr/>	6.15
	2	501	1.80	18.90	1.33		
	3	501	2.20	27.10	1.14		
					3.69		

Mean for Mabogini system = 6.40 tons/ha.

Sample standard deviation of means = 0.83

Source: Own data (1995/96).

Note: Actual weight was calculated at recommended moisture content of 14%.

APPENDIX 5

(*****)

PROGRAM IRRIGATION_SERVICE_FEES_ISF);

(*****)

(* The program determines the annual/seasonal irrigation water price to be paid by irrigation water users in a farmers' managed irrigation scheme.*)

USES CRT;

CONST

Factor = 439.2;
 Sample = 100;
 Fact = 0.33425;

TYPE

Irr_Areas = Record
 Area_Name: string[6];
 Area_Size:real;
 Water_Requirement, SM : Real;
 Water_Supplied :Real;
 Area_serving_structures : string[30]; End;
 Areas = Array[1..sample] of Real;

```

StructureCost = Record
    Structure_name :String[20];
    Installation_year, S_waterDel,
    CapitalCost, Present_RepCost: Real;
End;

```

VAR

```

Directory, DataSum : File of irr_Areas;
Individual : Array[1..sample] of Irr_Areas;
Data_file, myfile,Filename: text;
Name,YourFile :string[20];
Blocks,Number,i,area,choice,num,Counter: integer;
Director : File of structureCost;
Each: Array [1..sample] of StructureCost;
ICj, r,y,MTC,TC, Length,losses,IR, Qmj, sum, TB,
T,It,Present_RepCost,WRC,mean,Tot :Real;
st,sq,sr,sa,A,IC,OMC,PIW,AC,BCost,TAC,sb: Areas;

```

(*****)

Procedure Pause;

(*****)

VAR

Proceed:char;

Begin

```

Writeln;

Writeln('Press < enter > key to continue...');

Read(procced);

End;

(*****)

Procedure Create_Data_File ;

(*****)

Begin

Writeln;

Write(' <Enter> Irrigation duration (hrs/ha):');

Read(T); writeln;

Write (' <Enter> Irrigation frequency (days):');

Read(It); Writeln;

Write(' <ENTER> How many blocks to consider: '); Readln(Blocks);

Writeln;

Writeln('Do you want to load new data in the file?'); Write('(1:YES, 2:NO

)');Writeln;

Write(' <ENTER> your choice:');Readln(choice);

IF choice = 1 then begin

Assign (Directory, 'A:Input_1.pas');

Rewrite(Directory);

For i := 1 to Blocks do

```

```

With individual[i] do Begin
  Writeln('Area name: '); Readln(Area_name); writeln;
  Write('Area size (ha): '); Readln(Area_size); Writeln;
  Write('Water supplied (l/s): '); Readln(Water_supplied); writeln;
  Write('Area serving structures: ');
  Readln(Area_serving_structures); Writeln;
  Water_Requirement := (Factor * Water_supplied * T * Area_size)/(It);
  Write(Directory , individual[i] );
end;

Close(directory);

End

ELSE

Writeln;

writeln('.....CONTINUE.....');

END;

(*****

Procedure Correction;

(*****

VAR

      Comp, correct: integer;

Begin

Assign(directory, 'A:Input_1.pas');

```

```
Reset(Directory);

Repeat

Writeln;

Write('Give component number to be corrected:');

Read(comp);

Until comp < Filesize (Directory);

Seek(Directory, comp);

Read(Directory, individual[i]);

With individual[i] do begin

Writeln; pause;

Writeln('Old area name :',Area_name:6);

Write('New name :');Readln(Area_name); writeln;

Writeln('Old area size:',area_size:8:2);

Write('New area size:'); Readln(area_size);writeln;

Writeln('Old water supplied:',Water_supplied:8:2);

Write('New water supplied:');

Readln(Water_supplied);writeln;

Writeln('Old area serving structures:' ,Area_serving_structures);

Write('New area serving structures:'); writeln;

Readln(Area_serving_structures);

Water_Requirement :=(Factor * Water_supplied * T * Area_size)/(It);

Seek(directory, comp);

Write(Directory, individual[i]); Writeln;
```

```

Close (directory);

Writeln('Do you have another component to correct?'); Write('1:YES,
2:NO');Writeln;

Write(' < ENTER > your choice number:'); Readln(choice);

IF choice = 1 then begin

Correction;

End

ELSE

Writeln;

Writeln('****CONTINUE****');

End;

End;

(*****)

Procedure Read_data1(i, counter:integer);

(*****)

Begin

Writeln;

Write(' < ENTER > Name of the scheme:'); Readln(Name);

Writeln;

Writeln(' THE IRRIGATED AREAS IN',name: 16);

Writeln('-----');

Writeln('Daily ':10,' Seasonal'); Write('irrigation':5 , ' Area':3);

```

```

Writeln(' Area':10,' Area':8,' Water ':10, ' water');
Write('requirement':20,'Serving ':6);

Writeln(' name':10,' size(ha)':8,' supplied(l/s)':10,' ); Write('(m3) ':15,'
Structures':17);

Writeln('-----');

Begin

Assign(Directory, 'A:Input_1.pas');

Reset(Directory);

While not eof (directory) do

Begin

Read (directory,individual[i]);

With individual[i] do

Writeln ('Area_Name:8, Area_Size :11:2,
water_Supplied:12:2,water_Requirement:12:2,
Area_Serving_Structures:24);

End;End;

Writeln('-----');

Close(directory);

Writeln;

Writeln('Do you want to make any corrections ?:( 1:YES, 2:NO )'); writeln;

Write(' <Enter> choice number:');

Readln(Choice);

IF Choice = 1 then begin

```

```

Writeln;

Correction;

End

ELSE

Writeln;

Writeln('Thanks for not making a mistake!');Pause;

End;

(*****)

Procedure Structure_Cost;

(*****)

BEGIN

Write(' <Enter> the discount rate, r(%):');Read(r); Writeln;

Write(' <Enter> Current year,y:');Read(y); Writeln;

Write(' <ENTER> How many structures to evaluate:');

Readln(number); writeln;

Writeln('Do you want to load new structures in the file?');

Write(' 1: Yes, 2:No'); Writeln;

Write(' <ENTER> your choice:'); Readln(Choice);

IF choice = 1 then begin

Assign (Director, 'A:Input_2.pas');

Rewrite(Director);Writeln;

For i := 1 to number do

```

With each[i] do begin

Write('Structure name: ');Readln(Structure_name);

Writeln;

Write('Installation year: ');Readln(Installation_year); Writeln;

Write('Seasonal water delivery (cub.meters):');

Readln(S_WaterDel);Writeln;

Write('Capital cost at installation(T.shs) :'); Readln(CapitalCost);Writeln;

Present_RepCost :=exp ((y - Installation_year) * ln(1 +(r/100)) + ln(CapitalCost))

;

Write(Director, Each[i]);

END;

Close(Director);

End

ELSE

Writeln;

Writeln('....CONTINUE....');

END;

```
(*****)
```

```
Procedure Correction_2;
```

```
(*****)
```

```
VAR
```

```
    Comp_2, correct_2: integer;
```

```
Begin
```

```
Assign(director, 'A:Input_2.pas');
```

```
Reset(Director);
```

```
Repeat
```

```
Writeln;
```

```
Write('Give component number to be corrected:');
```

```
Read(comp_2);
```

```
Until comp_2 < Filesize (Director);
```

```
Seek(Director, comp_2);
```

```
Read(Director, Each[i]);
```

```
With Each[i] do begin
```

```
Writeln; pause;
```

```
Writeln('Old structure name :',Structure_name:6);
```

```
Write('New structure name :');Readln(structure_name); Writeln;
```

```
Writeln('Old installation year:',Installation_year:8:0);
```

```
Write('New installation year:');
```

```
Readln(installation_year);writeln;
```

```
Writeln('Old seasonal water delivery:',S_WaterDel:8:2);
```

```
Write('New seasonal water delivery:'); Readln(S_WaterDel);writeln;
Writeln('Old capital cost at installation:', CapitalCost:10:0);
Write('New capital cost at installation:');writeln;
Readln(CapitalCost);
Present_RepCost := exp ((y - Installation_year) * ln(1+(r/100))+ln(CapitalCost))
;
Seek(director, comp_2);
Write(Director, Each[i]);
Close (director);
Writeln('Another component to correct? (1:YES , 2:NO)'); Writeln;
Write(' <ENTER> your choice number:');Readln(choice);
IF choice = 1 then begin
Correction_2;
End
ELSE
Writeln;
Writeln('****CONTINUE****');
End; End;
```

(*****)

Procedure Read_data2;

(*****)

Begin

Writeln('DEFINITIONS OF IRRIGATION STRUCTURES IN',name: 16);

Writeln('-----'); Writeln(' Seasonal':5 , '

Write('Capital cost at':7 , ' Present':13);

Writeln ('Structure':4, 'Installation':2, ' Water delivery':2,
'installation':15,'replacement':16);

Writeln(' name':5, ' year':10, ' (m3)':5 , ' (T.shs)':12, 'cost(T.shs)':22);

Writeln('-----');

Begin

Assign(Director,'A:Input_2.pas');

Reset(Director);

While not eof (Director) do

Begin

Read(Director,each[i]);

With each[i] do

Writeln(structure_name:8, Installation_year:9:0, S_WaterDel:20:0,

CapitalCost:16:0, present_repCost:16:0);

End;End;

Writeln('-----');

Close(director);

```

Writeln;

Writeln('Do you want to make any corrections ?:( 1:YES, 2:NO )'); writeln;

Write(' <Enter> choice number:');

Readln(Choice);

IF Choice = 1 then begin

Correction_2;

End

ELSE

Writeln;

Writeln('Excellent; Keep on!');

End;

(*****)

Procedure Share_cost(st,sq,sr,IC:areas;var ICj, sum :real;

                    num:integer);

(*****)

Var

    Canal :string[20];

    LT:real;

Begin

Assign(Directory,'A:Input_1.pas');

Reset(directory);Writeln;

Write(' <Enter> Canal name:'); Readln(canal); Writeln;

```

```

Write(' <Enter> Seasonal canal losses(m3:'); Readln(losses); Writeln;
Write(' <Enter> How many areas served by the canal:'); Readln(Area); Writeln;
For i := 1 to area do begin
  With individual[i] do begin
    Write(' <Enter> Area component number:'); Readln(num); Writeln;
    Write(' <Enter> Canal length to this area(km:'); Readln(Length); Writeln;
    Seek(directory, num);
    Read(directory, individual[i]);
    With individual[i] do
      IR := Water_Requirement * Length;
    st[i] := ir;
  End; end;
Begin
  sum := 0;
  For i := 1 to area do begin
    sum:= sum + st[i];
  end;end;
Begin
  Assign(Director, 'A:input_2.pas');
  Reset(Director);
  Write(' <Enter> Intake component number:');
  Readln(num);
  For i := 1 to area do begin

```

```

Seek(director, num);

Read(director, each[i]);

With each[i] do begin

With individual[i] do begin

ICj := (((st[i]*LOSSES)/SUM)+ WATER_REQUIREMENT)* Present_RepCost/
s_waterDel;

st[i] := ICj;

End; end; end; end;

Begin

Writeln;

Write(' <ENTER> major turnout component number:');

Readln(num);

For i := 1 to area do begin

Seek(director, num);

Read(director, each[i]);

With each[i] do begin

With individual[i] do begin

MTC := Water_Requirement * Present_RepCost/S_WaterDel ;

sq[i] := MTC;

End;End; end; end;

Writeln;

Writeln('Hint: <Enter> Negative number if the area is not served by minor
structure.');
```

```

For i := 1 to area do Begin
Write(' <Enter> Minor structure component number serving the area:');
Readln(num);
If num >= 0 then begin
Seek(director, num);
Read(director, each[i]);
With each[i] do
With individual[i] do
TC := Water_Requirement * Present_RepCost/S_WaterDel ;
End
ELSE Begin
TC := 0;
End;
sr[i] := TC;
End;
Begin
Writeln;
Write(' <Enter> Lifetime horizon of the structures:');
Readln(LT); writeln;
IC[i] := 0;
For i := 1 to Area do begin
IC[i] := IC[i] + st[i] + sq[i] + sr[i];
End;End;

```

For i := 1 to area do begin

AC[i] := (Exp(ln(r/100) + LT*ln(1+(r/100)) + ln(IC[i]) -
ln((Exp(LT*(ln(1+(r/100))))- 1)))*(Fact);

OMC[i] := 0.029 * Fact*IC[i];

End;

Close(directory);

Close(director);

End;

(*****)

Procedure Water_RightCost(tb:real);

(*****)

Var

AF,RT:real; WR:integer;

Begin

Assign(director,'A:Input_2.pas');

Reset(director);

Write(' <Enter> Water right application fee:');Readln(AF); Writeln;

Write(' <Enter> Rate paid by users per 1000 cubic meters of water annually
(Tshs):');

Readln(RT); Writeln;

Write(' <ENTER> Intake component number:'); Readln(WR);

Seek(director, WR);

Read(directory, each[i]);

With each[i] do

WRC := (AF + (RT*S_waterDel)/1000)*Fact;

End;

(*****)

Procedure summation(var TB:real;num:integer;sa:areas);

(*****)

Begin

Assign(Directory, 'A:Input_1.pas');

{I-}Reset(directory){I+};

i := IOResult;

IF i < > 0 Then begin

Writeln('**File A:Input_1.pas is missing or damaged.');

Writeln('Please investigate and run the program again.');

End

ELSE

Begin

TB := 0;

While not eof(directory) do begin

Read(directory, individual[i]);

With individual[i] do begin

sa[i] := Area_size;

```
TB := TB + sa[i];
```

```
End; End;End;
```

```
Close(directory);
```

```
End;
```

```
(*****)
```

```
Procedure sumsum(var SM:Real; area:integer; PIW : Areas);
```

```
(*****)
```

```
Begin
```

```
SM := 0;
```

```
For i := 1 to area do
```

```
SM := SM + PIW[i];
```

```
End;
```

```
(*****)
```

```
Procedure Price_IrrWater( sa:areas;area:integer;wrc,TB :
```

```
real);
```

```
(*****)
```

```
Var
```

```
Comp_num: integer;
```

```
Begin
```

```
Assign(Directory, 'A:Input_1.pas');
```

```
Reset(Directory); Writeln;
```

```
For i := 1 to arca do begin
  With individual[i] do begin
    Write(' <Enter> Area Component number:');
    Readln(comp_num);
    Seek(directory, comp_num);
    Read(directory, individual[i]);
    With individual[i] do begin
      sa[i] := Area_size;
      Bcost[i] := (sa[i] * WRC)/TB;
      TAC[i] := (AC[i] + OMC[i] + Bcost[i]);
      PIW[i] := (TAC[i]/sa[i]);
    End;End;End;
  Close(directory);
End;

(*****)

  Procedure AddData;

(*****)

Begin
  Assign(DataSum, 'A:Input_3.pas');
  Rewrite(DataSum);
  With individual[i] do
    SumSum(SM, Area, PIW);
```

```
Write(DataSum, individual[i]);
```

```
Close(DataSum);
```

```
End;
```

```
(*****)
```

```
Procedure AddData_1;
```

```
(*****)
```

```
Begin
```

```
Assign(DataSum, 'A:Input_3.pas');
```

```
Reset(DataSum); Seek(DataSum, Filesize(DataSum));
```

```
With individual[i] do Sumsum(SM, Area, PIW);
```

```
Write(DataSum, Individual[i]); Close(DataSum);
```

```
End;
```

```
(*****)
```

```
Procedure total(var tot:Real; i,counter,blocks:integer;
```

```
sb: areas);
```

```
(*****)
```

```
Var
```

```
sm:real;
```

```
Begin
```

```
Assign(DataSum, 'A:Input_3.pas');
```

```
{$I-} Reset(DataSum) {$I+};
```

```

i := IOResult;

IF i < > 0 Then begin

Writeln('**File A:Input_1.pas is missing or damaged.');
```

Writeln('Please investigate and run the program again.');

```

End

ELSE

Begin

Tot := 0; counter := 0;

While not eof(DataSum) do begin

With individual[i] do begin

Read(DataSum, individual[i]);

Counter := counter + 1;

sb[i] := SM;

Tot := tot + sb[i] ;

End; end; END; Close(dataSum);

Mean := Tot/blocks; End;

(*****)
```

Procedure SaveData (area:integer; OMC,AC,PIW,Bcost:areas;

WRC:Real; name:string);

```

(*****)
```

Begin

```

Assign(Filename, 'A:YourFile.pas'); Rewrite(Filename);
```

```

WriteLn(Filename, ' IRRIGATION SERVICE FEES IN ', name:16);
WriteLn(Filename, '-----');
WriteLn(Filename, ' Area Name':10, ' OMC ':12, ' WRC ':12, 'ISC ':11,
'PIW ':13);
WriteLn(Filename, ' (T.shs)':18, ' (T.shs)':12, ' (T.shs)':10, '(T.shs/ha)':14);
WriteLn(Filename, '-----');
Assign(Directory, 'A:Input_1.pas');
Reset(Directory);
For i := 1 to area do begin
  With individual[i] do begin
    WriteLn(Filename, Area_name:6, OMC[i]:17:0, BCost[i]:12:0, AC[i]:12:0,
    PIW[i]:12:0);
  End; END; Close(directory);
Close(Filename); END;

(*****)

  Procedure File_Extention (OMC,BCost,AC,PIW:Areas;
    area:integer);

(*****)

Begin
Assign(Filename, 'A:YourFile.pas');
Append(Filename);
Assign(Directory, 'A:Input_1.pas');

```

```

Reset(Directory);

For i := 1 to area do begin

With individual[i] do begin

Writeln(Filename, Area_name:6, OMC[i]:17:0, BCost[i]:12:0, AC[i]:12:0,
PIW[i]:12:0);

End; End; Close(directory); Close(Filename);

End;

```

```

(*****

```

```

Procedure MeanValue(Mean: Real);

```

```

(*****

```

```

Begin

```

```

Assign(Filename, 'A:YourFile.pas');

```

```

Append(Filename);

```

```

Writeln(Filename,

```

```

'-----');

```

```

Writeln(Filename, 'Seasonal/Annual mean price of irrigation water in', name:16, '
is', Mean:8:0, '(Tshs/ha)');

```

```

Writeln(Filename);

```

```

Writeln(Filename, '      Where:');

```

```

Writeln(Filename, ' OMC = Operation and maintenance cost;');

```

```

Writeln(Filename, ' WRC = Water Right cost;');

```

```

Writeln(Filename, ' ISC = Irrigation structures cost;');

```

```
Writeln(Filename,' PIW = Price of irrigation water;');
```

```
Close(Filename);
```

```
End;
```

```
(*****)
```

```
Procedure End_Program;
```

```
(*****)
```

```
Begin
```

```
WRITE(CHAR(7),CHAR(7),CHAR(7));WRITELN;WRITELN;
```

```
WRITE('H');Delay(200);WRITE('E');Delay(200); WRITE('R');
```

```
Delay(200);WRITE('E');Delay(200); WRITE(' I'); Delay(200);
```

```
WRITE('S');Delay(200); WRITE(' T'); Delay(200); WRITE('H');
```

```
Delay(200);WRITE('E'); Delay(200);WRITE(' E'); Delay(200);
```

```
WRITE('N');Delay(200);WRITE('D');Delay(200); WRITE(' O');
```

```
Delay(200);WRITE('F');Delay(200);WRITE(' T'); Delay(200);
```

```
WRITE('H');Delay(200); WRITE('E'); Delay(200) ; WRITE(' P'); Delay(200);
```

```
WRITE('R'); Delay(200); WRITE('O');Delay(200); WRITE('G'); Delay(200);
```

```
WRITE('R'); Delay(200); WRITE('A'); Delay(200); WRITE('M');
```

```
WRITELN;WRITELN; WRITELN('GO TO FILE NAME A: YOURFILE.PAS
```

```
FOR RESULTS.');
```

```
WRITE(CHAR(7),CHAR(7),CHAR(7));End;
```

(*****)

Procedure Repetition(VAR IC:areas);

(*****)

Var

Choice: integer;

Begin

Writeln;

Writeln('Do you have another canal to consider?');writeln;

Writeln(' 1: YES 2: NO');writeln;

Write (' <ENTER> choice number:'); Readln(Choice);

IF Choice = 1 then begin

Share_Cost(st,sq,sr,ic,icj,sum,num);

Price_irrWater(sa,area,WRC,TB);

AddData_1; File_Extention(OMC,BCost,AC,PIW,area);

Repetition(IC);

End

ELSE

Writeln; Writeln('....PLEASE WAIT....');

End;

```

(*****)
Procedure Start_Program(i:integer);
(*****)

Begin

For i := 1 to 2 do begin

WRITE(CHAR(7),CHAR(7),CHAR(7));

End;

WRITELN('=====');
WRITELN('WELCOME TO IRRIGATION SERVICE FEES COMPUTER
P R O G R A M   M O D E L . ' ) ;
WRITELN('=====');
WRITELN;   WRITELN('-----');
WRITELN('THE MODEL DETERMINES THE REQUIRED ANNUAL/
SEASONAL IRRIGATION');
WRITELN('WATER PRICE TO BE PAID BY IRRIGATION WATER USERS
IN A FARMER-');
WRITELN('MANAGED IRRIGATION SYSTEMS IN TANZANIA AND THE
COUNTRIES ALIKE');
WRITELN('-----');

End;

```

```
(*****)  
(**MAIN BODY OF THE PROGRAM STARTS HERE**)  
  
(*****)  
  
BEGIN  
  
CLRSCR;  
  
Start_Program(i);  
  
Create_data_file;  
  
Read_data1(i,counter);  
  
Structure_Cost;  
  
Read_data2;  
  
Share_Cost(st,sq,sr,ic,icj,sum,num);  
  
Water_rightCost(tb);  
  
Summation(TB,num,sa);  
  
Price_IrrWater(sa,area,WRC,TB);  
  
SaveData(area,OMC,AC,PIW,Bcost,WRC,name);  
  
AddData;  
  
Repetition(IC);  
  
Total(Tot,i,counter,blocks,sb);  
  
MeanValue(Mean);  
  
End_Program;  
  
Pause;  
  
END.
```