FARMERS' UTILITY OF IRRIGATION WATER SUPPLY AS A METHOD OF ASSESSING IRRIGATION SYSTEM'S PERFORMANCE

BY

MAKONGORO, ELFARIJI KOHI

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ENGINEERING OF SOKOINE UNIVERSITY OF AGRICULTURE

1997

ABSTRACT

A model which employ Farmers' Utility of Irrigation Water Supply (FUIWS) in assessing irrigation system's performance has been developed in this study. The methodology was tested through a Case Study at Lower Moshi Farmer Managed Irrigation Scheme (Lower Moshi FMIS). The main objective was to investigate FUIWS as a method of assessing the performance of irrigation systems.

Strong relationship was observed between Relative Water Supply (RWS) and FUIWS. Wherever RWS was high FUIWS was also high and vice versa as proved by positively large covariance value obtained. However, this relationship was identified as non linear correlation by significance correlation coefficient test.

The graphs plotted showed relationship of the type:

$$R = ae^{nU.}$$

Where: R = RWS in paddy fields.

U = FUIWS.

a and n are constants.

In this particular Study, the scheme model obtained was:

$$R = 0.377e^{1.825U}$$

Similar block models were established. The homogeneity test on the block mean values showed that; RWS have the same degree of variability for all levels of FUIWS. This indicated the ability of the scheme model to be used in place of block models.

Different "a" and "n" constant values obtained between blocks indicated different irrigation management levels between blocks.

The method was tested in paddy rice only, therefore more work is needed to test it in upland crops; traditional and improved Farmer Managed Irrigation Scheme (FMIS). Also, more research is required to establish whether threshold values "a" and "n" are universal or not and what factors influencing them.

DECLARATION

I, **MAKONGORO, ELFARIJI KOHI** 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 award in any other University.

Signature:...

Date :..16/10/1997..........

COPYRIGHT

ACKNOWLEDGEMENT

First and foremost I wish to express my sincere gratitude to Dr.Tarimo, A.K.P.R, my supervisor, who was singularly most instrumental in encouraging me to undertake this work, and for generously providing the facilities and logistics that enabled this work to be completed. I appreciate his intuitive criticisms at the various stages of the preparation of this dissertation.

I thank the head of department of water management Lower Moshi FMIS Mr Kimicho, R. and Mr Ngodoki, G. irrigation technician at the water management department for providing useful information at various stages of this work.

Distinctive appreciations are extended to Dr. Kohi,Y. & Mrs. Kohi for their material and moral support to the author's edification and mankind in extensive. Their contributions is highly appreciated, their words are unforgettable and for sure contributed much to the success of this work.

Also, I am sincerely grateful to my postgraduate fellow students Mr. Lutatina, J. , Omari, J.B. and Bakari, A. who in one way or another helped me or made my stay both in Moshi and Morogoro enjoyable. Thanks and appreciation are also extended to all who contributed in one way or another to bring this work to it present state.

Conclusively, I thanks my wife Ashura S. Makongoro, my daughters Wanze, Hamisa and Rahabu for their encouragement and patience during my absence in due to complete this work.

DEDICATION

This work is dedicated to the Late Uncle Paul Mashine Kohi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND SYMBOLS

AIWS	Adequacy of irrigation water supply
B	Bad
BM	Block model
Dep	Dependability
Df	Degree of freedom
DIWS	Dependability of irrigation water supply
EIWS	Equity of irrigation water supply
FC	Famer's convenience of irrigation water supply
FI	Famer's importance
FJ	Farmer's judgement
FMIS	Farmer managed irrigation system
FU/FUIWS	Farmer's utility of irrigation water supply
G	Good
H	High
IW/IWD	Irrigation water delivery
L	Low
M/MED	Medium
MLB	More or less bad
MLG	More or less good
MLH	More or less high
RWS	Relative water supply
SM	Scheme model

VB	Very bad
VG	Very good
VHIGH/VHIG/VH	Very high
VLOW/VL	Very low

CHAPTER ONE

1.0 INTRODUCTION

This chapter defines irrigation system performance, summarizes irrigation system objectives, shows previous effort done in developing performance measures and their application limitations. The objectives of the study and organization of the dissertation are given in the last two sections of this chapter.

1.1 Background Information

Irrigation performance is the degree to which an irrigation system achieves its objectives. The objectives of irrigation system can be "output", "impact" and "management objectives" (Manor,1990). The output objectives are associated with the functions of the irrigation system and measured with reference to the maximum utilization of the available resources. The impact objectives are directly related to agricultural productivity of the system as indicated by intensity of cultivation, level of production, increase of land productivity and farmer's incomes while the management objectives is to ensure the set irrigation objectives and the above two are met.

Performance of irrigation systems has attracted a great attention from researchers, planners and managers of irrigation systems in recent years; this is due to poor level of performance observed in many irrigation systems around the world. However, the large volume of work done on irrigation systems performance has been directed to traditional techniques that uses single operational parameter to evaluate and analyze the performance of irrigation systems(Malano et al., 1992; Nihal, 1992; Sharma et al., 1991; Clemmens et al., 1990).

Most of traditional performance indicators are useful post irrigation season and not day to day indicators and have failed to quantify reliability, adequacy, equity of water distribution and supply satisfactorily (Nihal, 1992 and Weller et al., 1989). Traditional performance indicators however, failed to recognize the position of farmers as customers of irrigation systems and in general have failed to capture all aspects of the complex issues of convenience and utility of irrigation water supply (Gowing et al., 1992 and Nihal,1992). Gowing et al., (1992) pointed out that, farmers are least considered in the performance assessment of most irrigation systems.

Consideration and involvement of farmers in planning, design, monitoring and evaluation of irrigation system is a crucial factor in; changing the traditional top-down approach in planning , designing and assessing irrigation systems.

The consideration of involving farmers in planning and management of irrigation system will help; farmers understand irrigation system problems and their related sources. This in turn will enable them solve conflicts among themselves, contribute their experience on planning and management of irrigation system, consequently will help in attaining the expected level of services and hence achievement of irrigation objectives set (Gowing et al., 1992; Lauraya et al., 1991; Thapa et al., 1991; IIMI, 1990; Spleeman, 1990; Martin, 1986; Upphoff et al., 1985; Rydzewski, 1977 and FAO, 1985).

Several researchers have come up with criteria to evaluate performance of irrigation systems, these includes; crop yield per limited resources (land, water and capital), water application efficiency, adequacy of water supply, water distribution equity, and dependability of irrigation water supply (Nihal, 1992; Molden et al., 1990; Oad et al., 1989; Sampath, 1989; Abernethy, 1986 and Bos, 1979).

However, Sampath (1989) analyzed the goals of water management and indicated that most of indicators violates some of desired properties in performance measurement and this is due to an inconsistency in the selection of the measures.

Malano et al. (1992) reported on the previous effort done to evaluate irrigation systems performance using a single operational parameter that involves direct field measurements which are costly, laborious and time consuming.

Further, it is generally accepted that routine measurements of flow rates to farm level (1-10 hectares) is not feasible because they are both difficult and expensive (Gowing et al., 1992 and Seckler et al., 1988). However, it has been reported that traditional methods of evaluating performance of irrigation systems are very poor in handling problems with fuzziness like performance assessment of irrigation systems (Malano et al. 1992).

In Tanzania performance assessment of irrigation systems such as Majengo, Lower Moshi, Mwamapuli, Kitivo, etc. is not carried out due to combination of reasons. These includes lack of flow measuring devices, illiteracy on the part of water users and lack of fund required for the whole exercise. This situation has led to poor level of performance of most of Farmer Managed Irrigation Schemes (FMIS) which has led into decline in crop production, deterioration of systems as sometimes noted in Mombo and Majengo schemes (FAO, 1987). It is against this background that the author found a need to carry out a study and develop a technique that is cost effective, potentially capable to keep track with the irrigation water supply at field level. The method is aimed at assessing and evaluating performance of irrigation system within and after irrigation season. The method developed uses the fuzzy set theory approach developed by Gowing et al.(1992). To achieve the objectives a case study was conducted in Lower Moshi Farmer Managed Irrigation Scheme for one season (November, 1995-March, 196).

1.2 Objective of the Study

The main objective of the study was to investigate FUIWS as a method to assess the performance of irrigation system. The specific objectives included:

(i) Determination of irrigation system performance using field measurements.

(ii) Determination of Farmers' perception on the irrigation water supply utility.

(iii) Establishment of the correlation between (i) and (ii) above and build up a performance measure that uses FUIWS to assess irrigation systems.

1.3 Organization of the Dissertation

In this study literature review is given in chapter two. The main aim of the review is to present the reasons for selection of different study parameters and tools, their use and practical limitations. Chapters three presents discussion on the field work and general findings of the study. In this chapter materials and methods used to collect and analyze data are discussed. Chapter four presents results and its discussion while summary, main conclusions drawn from the study and recommendations for future work are presented in chapter five.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter survey the relevant literatures related to the study. It is divided into two main sections; field measurement performance indicators and FUIWS. The two sections discus on the performance indicators that were selected and utility factors that were considered in the study.

2.1 Performance Indicators

2.1.1 Adequacy Of Irrigation Water Supply (AIWS)

The adequacy of irrigation water supply is a measure of the reliability of supply and in turn, a measure of the quality of system operation.

As a measure of reliability of supply adequacy is a good indicator of the water delivery systems' ability to deliver the amount of water required to meet farmer's irrigation water requirement (Sakthivadiel et al., 1992 and Oad et al., 1991).

One of the parameter that can be used to evaluate AIWS is Relative Water Supply (RWS). RWS is a ratio of water supply to irrigation water requirement that is associated with the crop grown with the actual cultural practice. This ratio is the most crucial factors in design, planning, management and operation of irrigation systems. RWS values are obtained from field measurements (Sakthivadivel et al., 1993 and Nihal, 1992).

The RWS concept suggested by Levine (1974) as cited by Nihal (1992) has proved to be a useful tool in monitoring and evaluating irrigation water supply at various filed levels. Its worldwide acceptance as a multi-dimensional performance indictor lies in its ability in evaluating satisfactorily productivity. relative equity and adequacy of irrigation water supply & distribution (Sakthivadivel et al.,1993; Nihal,1992; Weller et al., 1989 and Green, 1987).

The RWS concept however, has proved to be useful monitoring tool in indicating; the behavior & decision rule that are associated with the system operation of the irrigation management personnel and farmers at different periods within irrigation season. For example during land preparation period for paddy rice fields RWS values: equal to 1 indicate that irrigation water supply meet irrigation requirement. RWS greater than 1 implies that the entire irrigated area is devoted to paddy rice whereas RWS values less than 1 or below 0.8 indicates a rapid decline of the cropped area to paddy (Sakthivadivel et al.,1992).

During the crop growth period; RWS values approximating 2 shows the monitoring levels of secondary canals, day time and limited communication between system managers & farmers and relative farmer independence; while values greater than or equal to 2.5 indicate systems with minimal operational control at the main system distribution level (Sakthivadivel et al., 1993).

Despite of its numerous advantages RWS concept has some few weaknesses which may be overcome by the use of Cumulative Relative Water Supply (CRWS) as explained by Sakthivadivel et al. (1993). CRWS is the cumulative RWS over a given time interval. It is against these facts that has made the RWS was selected as a performance indicator of AIWS for the Study.

2.1.2 Equity of Irrigation Water supply (EIWS)

Equity of irrigation water supply can be defined as the delivery of a fair share of irrigation water to all irrigators throughout the system. Its concept deals with supply of irrigation water among irrigators in a fairly equal and justice manner. Most researchers consider equity of irrigation water supply as a major features of FMIS (Abernethy, 1991; Gates et al.,1991 and Molden et al.,1990).

Inequity of water distribution can occur within the fields, between users of the same field channel or between the flow issued from the main system to distributaries or to field channels. Some studies carried in Asia and Africa have shown that variation in water supply may be due to the nature of supply, design faults, poor maintenance of canals and drains, construction faults, lack of farmers' participation during irrigation project development and management faults (Spleeman, 1990; Abernehty, 1986 and FAO, 1989 , 1985).

According to Bhutta et al. (1992) the degree of inequity is mostly readily demonstrated through the Inter-Quartile Ratio (IQR) a measure suggested by Abernethy in 1984. This measure compares the performance of the poorest performing quartile and the top quartile along a channel. However, it is preferred to take the average depth of water received by all land in the best quarter divided by the average depth received in the poorest quarter. This ratio is termed as the modified inter-quartile ratio (I_2) (Abernethy, 1984).

The modified inter-quartile ratio provides a satisfactory measure of equity and facilitate communication among irrigators involved in the inequity problem. For example if $I_2 = 2$ it implies that the farmer in the best quarter got 2 times as much water as those in the least favoured quarter. However, the use of this indicator is restricted to variables that have a zero as minimum (Abernethy, 1991).

Another parameter used to quantify inequity is the Christiansen's coefficient (UCC). This parameter has the advantages that it is easy to compute and it values ranges from zero to unity. When UCC is zero the degree of inequity is high and there is totally non uniform distribution of water and vice versa when it is unity. The parameter however at field level, is nowadays least applied as it seems to be too general (Green et al., 1987).

Although IQR and UCC offers simple computations and reveal non-uniformity in water distribution and supply among irrigators, at the farm levels the concept of RWS and CRWS gives better representation of the inequity situation (Sakthivadivel et al., 1993 & 1992; Nihal, 1992; Weller et al., 1989; Abernethy et al., 1987, and Green, 1987).

Due to the better ability of RWS to represent the inequity situation at field level, the parameter was selected for this study as indicator of inequity between paddy fields.

2.1.3 Dependability Of Irrigation Water Supply (DIWS)

DIWS may be defined as the supply of a fairly uniform quantity of irrigation water to farmers to meet crop irrigation water requirement and in time throughout the irrigation system. As a performance indicator DIWS reveals the combined effect of reliability and predictability. It describes the arrival of right amount of irrigation water at a given place in a given time.

DIWS is quantified by the coefficient of variation of the ratio of water supply to demand over the time period in consideration. DIWS in other words is a measure of variation of RWS over time period at a given area.

Therefore, DIWS is a good performance indicator of the ability of irrigation system and management to supply the right amount of scheduled irrigation water at a given place at a given time (Gates et al., 1991; Oad et al., 1991; Manor et al., 1990 and Molden et al. 1990).

In this study DIWS was used to quantify the ability of both irrigation system and management in supplying the required amount of irrigation water into paddy fields as scheduled.

2.1.4 Crop Yield Measurements

Evaluation of irrigation system performance based upon crop yield per area do not reflect an adequate assessment of performance in water scarce environments; but yield per unit area is a complementary measure and more appropriate in areas where water is not a problem. Yield per unit area is most useful indicator in assessing the technical efficiency of use of water (Batti et al.,1991). This performance indicator reveals farmers' technical efficiency in utility of irrigation water supply. Besides its ability to reveal irrigators technical efficiency in irrigation water utilization; it has been reported that specific yield is nowadays widely used in place of yield per irrigated area (Weller et al., 1987). The term Specific Yield means the weight of crop produced per volume of water issued(Kg/m^3).

In this study specific yield and yield per unit irrigated area were adopted to indicate the farmers technical efficiency in irrigation water utilization. The two parameters were compared with RWS and FUIWS to see their correlation if any.

2.2 Farmers' Utility of Irrigation Water Supply

The term utility of irrigation water supply refers to the ease with which an irrigator handles and manages the irrigation water issued or supplied to his field.

As customers of irrigation systems, farmers are most concerned with the quantity and quality levels of irrigation services provided to them at any given time in an irrigation season. According to Gowing et al.(1992) Farmers are most concerned with the irrigation water supply as indicated in its adequacy and equity but their perception on services is generally guided with how convenient is the supply to his own field conditions. In other words, farmers' perception on irrigation water supply services involve consideration of utility as identified in its quantity, quality and utility.

The utility of irrigation water supply to a farmer is usually measured by considering its major characteristics. In other words, the utility of a certain supply involve consideration of its characteristics such as supply flow rate, timing of supply and dependability of it. These three characteristics of supply are difficult to be measured by an objective scale due to their nature being more inherently subjective than objectively rated. These supply characteristics are inherently subjective because of their dependence on the specific physical conditions and the socio-economic situation in which an individual farmer is situated. For example, flow rate or timing of supply may be preferred by one or two farmers while it may be difficult for another farmer to handle and manage it. Therefore the question of convenience of irrigation water supply as characterized by dependability, flow rate and timing of supply as related to timing of planting is best determined by the subjective judgement of the individual farmer himself (Gowing et al.,1992 and El-Awad,1991). According to El-Awad (1991) Farmers' perception on utility supply can be measured by considering the characteristics of supply which are easily measured indirectly by using fuzzy set theory .

This study is concerned with the supply utility, therefore it is concerned with how farmers judges and ranks the levels of services provided to them; and how their judgement and preference can be used to assess the performance of an irrigation system.

Therefore in this study the fuzzy set theory was be used to collect farmers' opinions and preferences on utility of irrigation water supply as suggested by El-Awad(1991).

2.2.1 Fuzzy Set Theory and Application

Fuzzy set theory, originated with Prof.L.A.Zadeh in 1965 as cited by Malano et al.(1992) is one of the branches of applied mathematics which studies and handles problems that are characterized by fuzziness. The theory offers a systematic approach for dealing with fuzzy problems.

The fuzzy set theory consist of support functions, $\mu(x_i)$ and universe set U for each factor in consideration. It uses a set of linguistic expression such as very good/ very high, good/high, medium.....and so on to describe the judgement and importance of each factor considered.

The linguistic expression on judgement and importance on each factors considered are assigned numerical values (real numbers) between zero and one. A real number between zero and one indicate the degree of membership of the element x_i. One indicates full membership while zero clearly means non-membership. These numerical values define the support functions of the fuzzy expressions (Gowing et al., 1992 and El-Awad, 1991).

In order to have an interpretation meaning in terms of linguistic expression and numerical values; the fuzzy expression and its support functions are manipulated and aggregated using fuzzy operational rules as explained in El- Awad(1991) to give an overall appropriateness of the judgement and importance on the factors in hand. The process of having an overall appropriateness on judgement and importance on the factor considered, involve making sure that at least one of the fuzzy set element attain a full membership in the fuzzy set.

This process is called Normalization. Normalization gives the nearest fuzzy expression which in the end is converted into a numerical value that shows the utility of the factors considered in the problem in hand. The utility obtained which is a numerical scale then may be manipulated according to the problem to give the required interpretation (El-Awad, 1991).

In this study, the fuzzy set theory was employed in aggregating farmers' opinion and preferences as explained in Gowing et al.,(1992) and El-Awad (1991). The Universe set U is taken to consist of five elements i.e U = {1,2,3,4,5,} this is due to computer memory limitations. Farmer's response were restricted to the fuzzy expressions shown in Table 3.1 for both judgement and the factor of importance.

This Chapter discussed different parameters selected for the Study and the reasons as to why the selection was made. The determination of the parameter selected, materials, methods used to collect data, and the analysis of each parameter is discussed in the next chapter.

CHAPTER THREE

3.0 MATERIALS AND METHODS

Chapter three of this study describes, the study area, materials and methods used to collect and analyze data.

3.1 Description of the study area

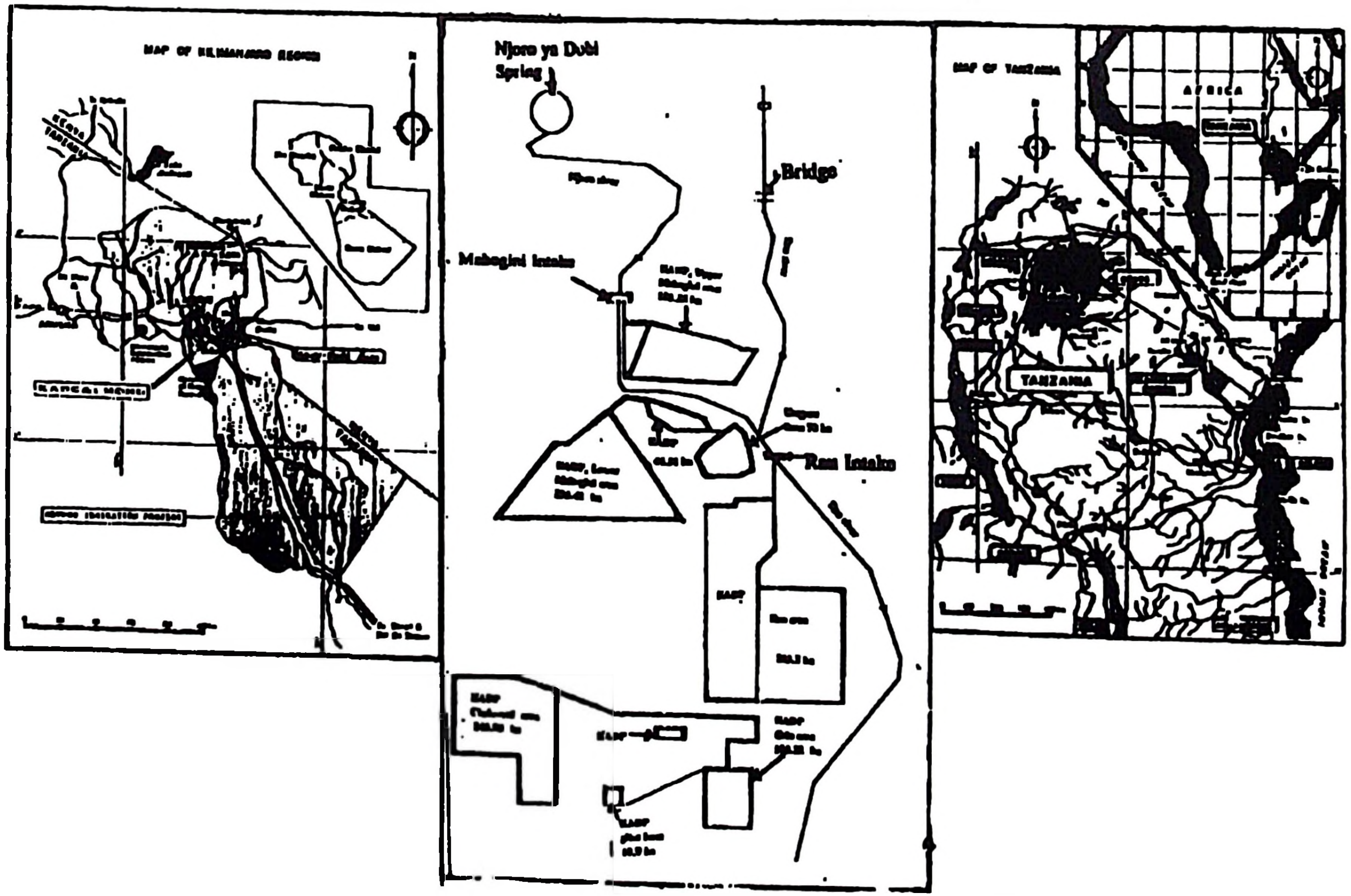
3.1.1 Location

The study was carried in Kilimanjaro region at Lower Moshi Farmer Managed Irrigation Scheme . The Lower Moshi FMIS is located at 3 to 15 km South East of Moshi town and occupies the far western part of Lower Moshi area. Its Latitude is 3° South and Longitude 37.5° East.

The scheme area consists of a relatively narrow strip of land developed on an alluvial plain along the right bank of Rau river as shown in Fig.3.1. The irrigation water distribution system in Lower Moshi FMIS consists of two intake weirs (Rau and Mabogini), diversion structures, regulators and canals of various orders.

Two rivers; namely Rau and Njoro are the source of the irrigation water supply. Mabogini system receives irrigation water from Mabogini intake located in Njoro river. It commands a net irrigable area of 955 ha. Out of 955 ha, 473 ha is used for paddy 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 is for paddy production. Due to water scarcity of irrigation water, paddy is the only crop grown under irrigation in both systems.

Fig 3.1 Location Map of Lower Moshi FMIS



3.1.2 Topography

The area consist of gently sloping lands developed along the bank of Rau river with an altitude ranging from 710 to 750 meters above mean sea level.

3.1.3 Climate

The Lower Moshi FMIS experience three distinct seasons, that is a dry season starting from June to October, short rain season from November to February and a rainy season from March to May. Annual rainfall ranges from 370 mm to 570 mm of which 10%, 30% and 60% falls in the dry, short rain and long rain seasons respectively (URT/JICA,1988). Air temperature is fairly constant all the year around, mean value ranges from 21°C to 26°C. The area experience maximum temperature in October to April and minimum temperature in July and August, the mean daily maximum temperature rises above 30°C while the mean daily minimum temperature is close to 16°C. Annual evaporation rates vary from 3 mm/day in May to 9 mm/day in January this makes the annual values be more than 2000 mm.

3.1.4 Hydrology

The major source of irrigation water for Lower Moshi FMIS are the Rau and Njoro rivers. The Njoro river is a tributary of Rau river, originates from springs scattered in the East of Moshi town and flows relatively constant throughout the year. The maximum and minimum discharge of this river varies from 1.2 m^3/sec and 0.9 m^3/sec in May and March respectively. The Rau river start up in mount Kilimanjaro with slope ranging from 1/5 to 1/3 on the mountain slope and 1/200 to 1/400 near the Lower Moshi FMIS scheme. The flow rate of this river fluctuate throughout the year. The maximum and minimum discharge of this river varies from 1.8 m^3/sec and 1.3 m^3/sec in May and March respectively (URT/JICA,1988).

3.1.5 Geology and Soils

The dystric cambisols derived from Rau river alluvial deposits covers most parts of the scheme. Generally these are silty clay or clay and are slightly acidic. The mollic gleysols dominate the low -lying parts of Lower Moshi FMIS. These are clayey textured and free from salinity (URT/JICA,1988).

3.1.6 Land Use

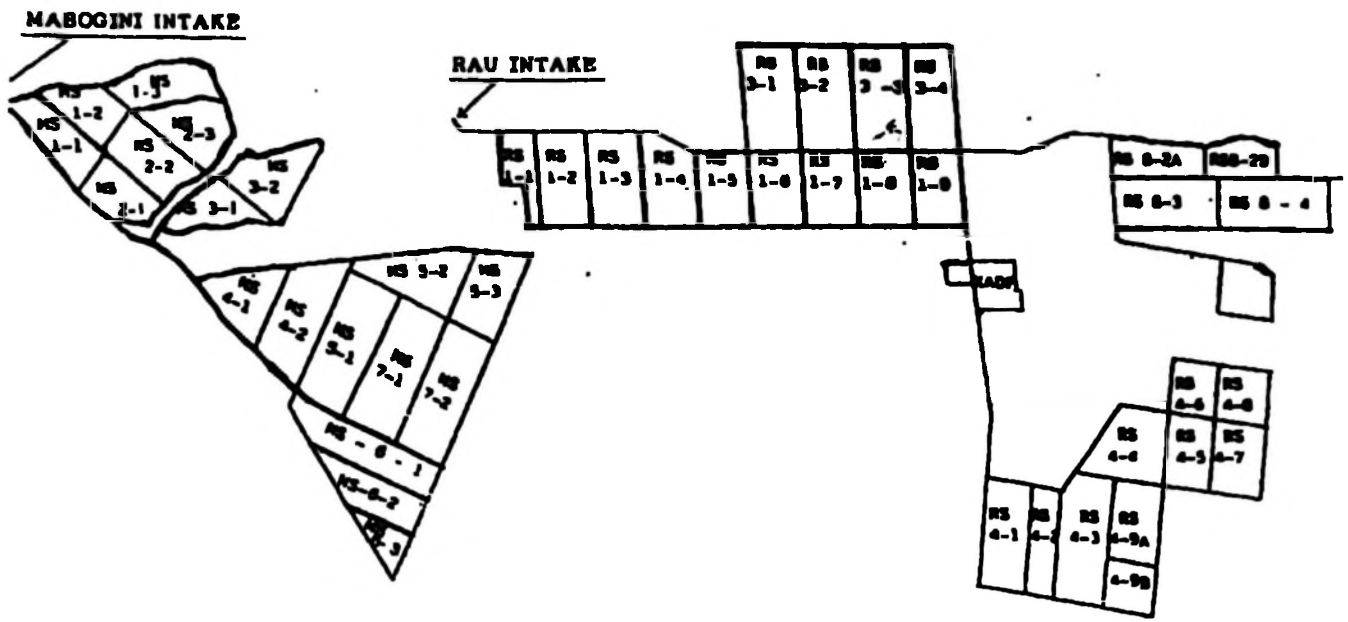
The climate of the scheme area is generally favourable for growing most of upland crops and paddy rice. However, priority is given to the production of paddy rice and maize.

The Lower Moshi FMIS scheme covers a total area of about 2,300 ha of which paddy rice covers a total area of 1,106.9 ha. Owing to the limited available water from the natural discharge of the related rivers, paddy rice is grown in three distinct irrigation seasons. This means that some of the scheme areas are used to grow paddy, left fallow and others are used for upland crops. The first, second and third (dry)irrigation seasons start in January, May and September respectively (URT/JICA, 1986).

3.1.6.1 Layout of paddy rice fields

The scheme is divided into two main paddy rice fields systems, namely Mabogini and Rau systems as shown in Fig 3.2.

Fig 3.2 Layout of paddy rice fields



3.2 Field Measurements and Sampling

The main purpose of this Study was to investigate FUIWS as a method of assessing, evaluating and monitoring performance of irrigation systems. In order to achieve the purpose, the following materials and methodologies were adopted in collecting the data and background information.

3.2.1 Block and Paddy Rice Plots Sampling

Out of eight blocks (MS 2-1,MS 3-1,MS 5-1,MS 6-3,RS 1-1,RS 4-1 and RS 8-2), four blocks (MS 3-1, MS 5-1, RS 1-1 and RS 4-1) which were already selected for production under the scheme rotational cropping pattern basis were selected for this Study. One block from each part of the scheme that is from Mabogini, Lower Mabogini, Rau ya kati and Chekereni was selected as representative of the respective villages of the scheme as shown on Fig. 3.2. A total of 202 farmers and therefore 202 paddy rice plots were sampled in this study taking location into consideration such as head, middle and tail.

The number of plots selected per water course differed from one watercourse to another depending on the length of the water course and the size of the respective sample blocks.

3.2.2 Field Measurements

The primary data for the study were collected on daily basis throughout the irrigation season. The data collected included flow rates into sampled paddy fields, seepage & percolation rates while the Farmers' opinions on utility of irrigation water supply were collected at every crop growth stage changes for FUIWS evaluation.

Other secondary data that were collected were meteorological data from meteorology station located in the scheme: crop yields; cropped area; cropping cycle and dates. The data were collected using different instruments and techniques as explained in the subsequent sections.

3.3 Instrumentation for Field Measurements

3.3.1 Flow Rates Measuring Equipment

Many useful flow rate measuring devices are available; on farm evaluation and monitoring where flow rates are generally less than 0.25 m^3/sec, sharp-crested weirs are commonly used. However, many formulae for overflow coefficients for horizontal sharp-crested weir have been developed but few are correct at farm level flow which are usually less than 0.25 m^3/sec (Dake,1972).

One of the most correct seems to be given by Rehbok (Dake,1972) which gives discharges Q(m^3/sec) as:

$$Q = (1.782+0.24h_e/h_o)Bh_e^{3/2} \quad (1)$$

where:

Q = Discharge in m3/sec

h_e = (h+0.011) (mm)

h = Overflow head above weir plate (m)

h_o = height of the vertical weir plate (m)

B = width of the weir plate (m)

The above equation is valid only within the following limits:

$0.15 < h_o < 1.22$ (m) and $h < 4 h_o$.

Source : Dake (1972).

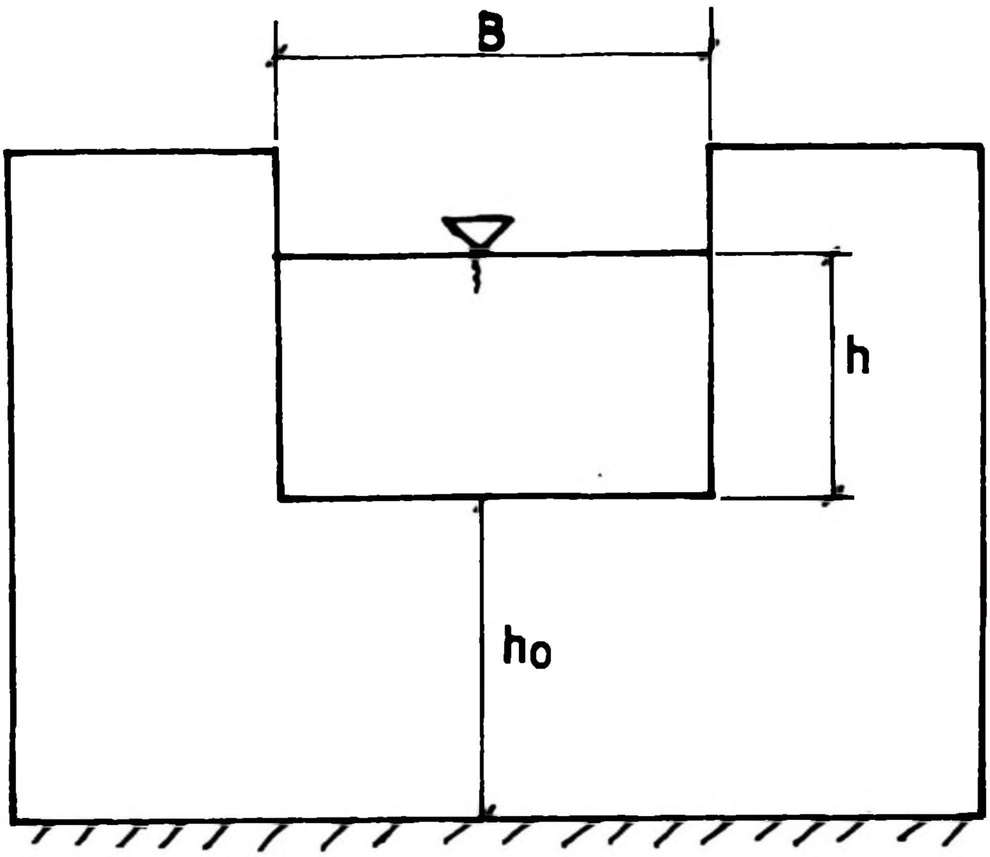


Fig 3.3 The Cross-section of sharp crest rectangular weir used to measure flow discharges into paddy rice fields

The sizing and fabrication of the sharp-crested rectangular weirs (Fig.3.3) was done at Lower Moshi FMIS workshop. The size of the weirs used was height, h_o = 0.25 m and width. B = 0.2 (m).

Flow discharge measurement into the paddy plots were taken at the existing structures using sharp-crested rectangular weirs. The overflow head, h above the crested weir was measured from which flow rates were obtained using the Rehbok's equation.

3.3.2 Seepage & Percolation Measuring Equipment

Seepage & percolation rates were monitored using sloping gauge method. Two sloping gauges were located in two paddy plots in each selected sample block. These were considered as representatives of each of the selected sample blocks. The daily changes in water depth was recorded and used to calculate seepage and percolation losses as suggested by Moya,T.(1990).

3.3.3 Farmers' Utility of Irrigation Water Supply

A set of linguistic expression were used to collect Farmers' perception on utility of irrigation water supply. Every sampled farmer was presented with two simple questions which led him to judge the convenience of each factor and its importance. The questions were formulated according to the field conditions and in this case were as follows:

(i) What was the farmer opinion on Dependability, Flow rate and Timing of planting in relation to the irrigation water supply.

(ii) How important was the Dependability, Flow rate and Timing of planting of the irrigation water supply.

Farmer were restricted to the following fuzzy expression; **Very good/Very High; Good/High; More or Less Good/More or Less High; Medium; More or Less Bad/More or less low, Bad/Low and Very bad/Very low.**

3.4 Determination of Adequacy of Irrigation Water Supply

The adequacy of irrigation water supply was evaluated in terms of RWS of paddy fields as suggested by Sakthivadivel et al,(1992):

For land preparation

$$RWS = (IW + RE)/(E + S\&P + LSP) \quad (2)$$

For crop growth period

$$RWS = (IW + RE)/(ET_c + S\&P) \qquad (3)$$

Where:

RWS	=	Relative water supply
IW	=	Irrigation water delivery (mm)
RE	=	Effective rainfall(assumed as actual rainfall) (mm)
E	=	Open water evaporation (mm)
S&P	=	Seepage and Percolation (mm)
LSP	=	Land soaking and Ponding (mm)
ET_c	=	Crop evapotranspiration (mm)

(An example of RWS calculation is shown in Appendix 4).

The depth of Irrigation Water supplied (IW) and the amount of water for Land Soaking and Ponding (LSP) was calculated from flow rates into the paddy rice plots.

The effective rainfall was assumed to be actual rainfall at this particular season. The actual rainfall and evaporation pan data were collected from the meteorology station located within the scheme as shown in Appendix 2.

The crop water requirement ET_c was derived from the modified Penman equation suggested by Doorenbos and Pruitt (1977). Ten years daily mean values were used to calculate daily ET_o from which daily ET_c over the irrigation season was obtained. The daily ET_c values as shown in Appendix 1 were used to calculate S&P and RWS using equations (2) and (3).

The seasonal mean seepage & percolation rate values as shown in Appendix 3 were used to determine the RWS in the paddy fields in the respective sampled blocks.

Seepage & Percolation (S&P) losses were calculated using the water balance method suggested by Moya,(1990) as :

$$S\&P = RE + W_d - ET_c \tag{4}$$

where:

SP = Seepage and percolation (mm).

RE = Effective rainfall(mm).

W_d = Daily change in paddy water level between t-1 and t(mm).

3.5 Determination of Equity of Irrigation Water Supply

The equity of irrigation water supply into paddy rice plots was evaluated in terms of RWS calculated over the crop growth period. The mean RWS values were used to indicate the degree of inequity between watercourses within a block and inequity between sample blocks.

3.6 Determination of Dependability of Irrigation Water Supply

The dependability of irrigation water supply for Lower Moshi FMIS was calculated using the coefficient of variation of the daily RWS . Season mean values were used to assess the dependability of irrigation water supply of the scheme. Dependability values are as shown in Appendix 8.

3.7 Determination of Farmers' Utility of Irrigation Water Supply

The farmers' opinions on the three factors considered as explained under section 3.3.3 were aggregated according to the fuzzy set operational rules which as explained in Gowing et al.,1992 were converted into numerical values. The support functions and definitions of the fuzzy expressions used are shown in Table 3.1.

Table 3.1 Definitions of support functions for the fuzzy expressions.

Fuzzy expression	$\mu(1)$	$\mu(2)$	$\mu(3)$	$\mu(4)$	$\mu(5)$
(Very good/ Very high)	0.00	0.00	0.10	0.25	1.00
Good/ High	0.00	0.00	0.01	0.50	1.00
More or less good or More or less High)	0.00	0.00	0.40	1.00	0.40
Medium	0.00	0.40	1.00	0.40	0.00
More or less bad or More or less low	0.40	1.00	0.40	0.00	0.00
Bad/ Low	1.00	0.50	0.01	0.00	0.00
Very bad/ very Low	1.00	0.25	0.01	0.00	0.00

Source: Gowing et al. (1992).

Note: Very good, good, more or less good, medium, more or less bad, bad and very bad were among of farmer's judgement.
Very high, high, medium, more or less low, low and very low were farmer's importance responses.

The overall convenience of irrigation water supply to the farmers was obtained as

$$OC=(\sum i^{th} \text{ factor judgement} \times i^{th} \text{ factor importance})/(\sum i^{th} \text{ factor importance}) \quad (5)$$

Where: OC = Overall Convenience of Irrigation water on the factor considered.

The Farmers' Utility of Irrigation Water Supply on the factors considered was calculated using equation:

utility, $U(X_i) = (1/N\text{-}i)[(\sum(i\text{-}1)\ \mu(i)/(\sum\ \mu(i)/(\sum\ \mu(i))]$ (6)

Where:	N	=	Number of elements in a universe set.
	$\mu(i)$	=	Support function.
	i	=	1, 2, 3, 4, 5.

This Chapter has brought together the description of the study area, materials and methodology adopted to collect data in the field. It has explained how each parameter involved in the study was analyzed. The results of the analysis carried and discussion of results obtained are presented in chapter four.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION OF RESULTS

This Chapter present the results of performance assessment using; the selected field measurement indicators, Farmers' perception on irrigation water supply utility and the formulation of FUIWS as a method of assessing irrigation systems performance. The results and discussion of results are explained in the subsequent sections.

4.1 Adequacy of Irrigation Water Supply

The adequacy of irrigation water supply during the land preparation period and over the season as indicated by RWS is presented in Table 4.1 and Table 4.4.

Table 4.1 RWS land preparation period

Block	RWS
MS 3-1	0.7
MS 5-1	0.6
RS 1-1	0.6
RS 4-1	0.6

Table 4.1 indicate that RWS during the land preparation period was less than 1. According to Sakthivadivel et al.(1992) RWS values less than 1 may be due to water scarcity, inefficient management practices, extended land preparation period and a rapid decline in the cropped area. These factors might have contributed to low (less than 1) RWS values obtained in Lower Moshi FMIS. From field observations and interviews; land preparation was extended for more than 14 days instead of the practised 10 days.

Transplanting of seedlings also delayed for 35-45 days instead of 25 days as shown in Table 4.2. However, due to water shortage: rapid decline of the cropped area at this particular season (dry season) is experienced by the scheme. The Lower Moshi FMIS used to cultivate 800 ha as planned at this particular season but since 1986 (Table 4.3) the acreage has been gradually decreasing such that only 200.9 ha were cropped this season (KADP, 1993).

Table 4.2 Transplanting date - November, 1995 - March,1996 season

Block	Planned transplanting date	Actual transplanting date
MS 3-1	27/9/1995	2/11/1995
MS 5-1	27/9/1995	1/11/1995
RS 1-1	27/9/1995	5/11/1995
RS 4-1	27/9/1995	12/11/1995

Source: Lower Moshi FMIS Water Management Department

Table 4.3 Dry season yearly paddy cultivated area

Year	Cultivated area (ha)
1986	524.0
1987	526.0
1988	436.0
1989	455.0
1990	417.0
1991	449.0
1992	454.0
1995	200.9

Source: KADP report(1993).

Table 4.4 Season RWS crop growth period

Block	Mean RWS
MS 3-1	1.3
MS 5-1	1.3
RS 1-1	1.1
RS 4-1	1.1

The mean season RWS (Table 4 4) indicate that all blocks received adequate irrigation water supply. Blocks MS 3-1 and MS 5-1 (upstream blocks) received higher values compared to the downstream located RS 1-1 and RS 4-1 blocks. This show the habit of upstream farmer's in preferring high levels of water in their fields as oversupply is not a problem to the paddy farmers. However, the ranges of RWS values obtained (Table 4.4) indicate different levels of irrigation management practices between blocks as discussed in chapters 2.1.1 and 4.6.

4.2 Equity of Irrigation Water Supply (EIWS)

According to Weller et al., 1989; Abernethy et al., 1987, and Green, 1987, at the farm levels the concept of RWS gives adequate representation of the inequity situation. In this Study; the unequal irrigation water supply in paddy fields between the blocks is as shown in Table 4.4. The non-uniform irrigation water supply between paddy fields located along watercourses is shown by the distribution of RWS values in fields along the watercourses in each sample block as appears in Table 4.5.

From Tables 4.4 and 4.5; High levels of inequity as indicated by RWS values is experienced from upstream to downstream blocks. Paddy fields in the upstream blocks MS3-1 and MS5-1 had similar levels of mean RWS ranging from 1.2 to 1.4 and also had very similar levels of inequity whereas that in downstream blocks; RS 1-1 and 4-1 shows more less similar levels of mean RWS ranging rom 1.0 to 1.3 well as similar degree of inequity .

The mean RWS in paddy fields in all watercourses in the sample blocks is higher than 1 (Table 4.5). However, the supply is not equitable varying from 1.0 and 1.4. A fairly equitable supply in paddy fields was maintained in all watercourses in block RS 1-1.

Table 4.5 Inequity of irrigation water supply in paddy fields

Block	Watercourse number	RWS Mean
MS 3-1	1	1.3
	2	1.2
	3	1.4
	4	1.4
MS 5-1	1	1.4
	2	1.4
	3	1.3
	4	1.2
	5	1.2
	6	1.2
RS 1-1	1	1.1
	2	1.1
	3	1.1
	4	1.1
RS 4-1	1	1.0
	2	1.0
	3	1.1
	4	1.2
	5	1.3

The overall inequity of irrigation water supply in paddy fields is much smaller as shown by the mean RWS values obtained.

Small differences in mean RWS between paddy fields along watercourses show the experience of farmers with the water scarcity problem and their irrigation water supply especially during this dry irrigation season. Field observations and interviews showed that, farmers were more careful in their supply dates and in controlling water in their paddy fields. The habit of farmers of keeping high levels of water in their fields as well as the practice of irrigating paddy fields from downstream to upstream fields along the watercourses reduced reasonably inequity between paddy fields and blocks.

4.3 Dependability Of Irrigation Water Supply

Table 4.6 shows the dependability of the irrigation water supply of Lower Moshi FMIS. The minimum and mean dependability values obtained shows that the irrigation water supply of Lower Moshi FMIS is dependable. According to Gates et al.(1991) the closer the dependability values to zero the more dependable is the irrigation water supply. High dependability values (0.5-0.6) were obtained in few paddy fields in sample blocks. For this case 1 farmer in MS 5-1, 8 farmers in RS 1-1 and 4 farmers in RS 4-1 blocks. The high values obtained shows the habit of these farmers of irrigating frequently and preferring higher levels of water in their fields as shown in Appendix 8.

Table 4.6 Dependability values of irrigation water supply

Block	Dependability mean values
MS 3-1	0.30
MS 5-1	0.30
RS 1-1	0.30
RS 4-1	0.30

4.4 Crop Yields

The mean crop yield per hectare and specific yield; that is weight per volume of irrigation water issued are presented in Table 4.7. Figure 4.1 shows different RWS levels as related to paddy rice production in the sampled blocks. Table 4.8 presents past years (same irrigation season) yield for comparison with the study season yield.

From Table 4.7 the mean specific yields are generally high ranging from 0.6 to 0.7 kg/m^3. The high specific yield values obtained indicate farmer's high water utilization efficiency in all the sampled blocks. Blocks MS 3-1 and MS 5-1 recorded the highest specific yields while RS 4-1 the lowest specific yield was recorded. The yields per hectare are almost high in all blocks compared to the same irrigation season past records as shown in tables 4.7 and Table 4.8.

Table 4.7 Season Crop Yield

Block	Specific yield kg/m^3 mean	Crop Yield ton/ha mean
MS 3-1	0.70	7.90
MS 5-1	0.61	8.08
RS 1-1	0.70	8.10
RS 4-1	0.60	7.10

Table 4.8 Yearly dry irrigation season paddy rice yield

Year	1985	1986	1987	1988	1989	1990	1991	19992
Yield per hectare (ton/ha)	7.02	6.49	6.69	6.14	5.68	5.64	7.30	7.75

Source: KADP report (1993)

Although the specific yields are not very much different in all sampled blocks, low minimum values as shown in Appendix 9 were recorded in upstream blocks MS 3-1 and MS 5-1.

From Tables 4.4 and 4.5, the low specific yields values obtained in these two blocks shows that the availability of more or excess irrigation water supply does not necessarily mean higher yield per unit volume of water issued particularly if the water is not properly managed.

The small differences in specific yield and yield per hectare shown in Appendix 9 indicate that there are small differences in technical efficiencies in water utilization among the sampled farmers.

Late transplanting, unequal distribution of irrigation water supply among paddy fields in a block and agronomy management factors might have contributed to individual farmers and block wise yield differences observed. However, despite of the yield difference shown or obtained among farmers; block RS 1-1 in which a fairly equitable supply of irrigation water was observed (Table 4.5) has on average higher yields (yield/ha) compared to other blocks (Appendix 9).

Fig 4.1 indicate that both Specific yield and yield per hectare were maximized at 1.5 RWS value. A slightly consistent increase in yield is observed between 0.90 and 1.00 as well as between 1.4 and 1.5 RWS values whereas RWS values greater than 1.8 show low yields in relation to the volume of irrigation water issued as well as irrigated area.

Low yield values at RWS greater than 1.8 indicates that the excess water issued is not serving a productive purpose; instead reduced much the productivity of the available irrigation water supplied.

In short the excess water delivered was just a waste. The maximum Specific yield obtained is 1 49 kg/m^3 while maximum yield per hectare is 17.89 ton/ha (Appendix 9).

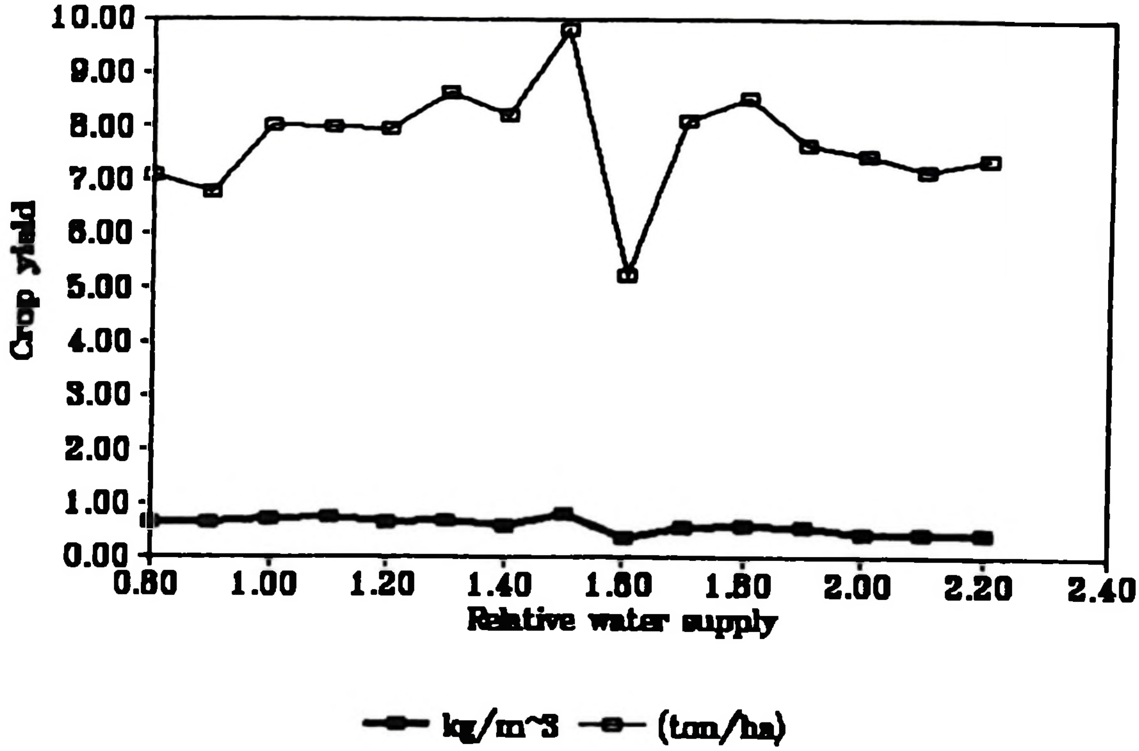


Fig 4.1 Relationship between Crop yield and RWS

4.5 Farmers' Utility of Irrigation Water Supply

Farmers' convenience and utility of irrigation water supply is as summarized in Table 4.9 the individual judgement and importance appears in Appendix 5. The overall farmers' utility on irrigation water supply is presented in Table 4.10.

Table 4.9 Farmer's convenience and Utility of irrigation water supply

Block	Farmers convenience on irrigation water supply	Farmers' Utility on irrigation water supply (range)	Number of Farmers
MS 3-1	Very high	0.88-0.89	05
	High	0.78-0.88	17
	More or less high	0.63-0.78	27
	Medium	0.61-0.63	01
MS 5-1	Very high	0.89	02
	High	0.72-0.88	11
	More or less high	0.62 0.78	24
	Medium	0.47-0.62	11
	More or less low	0.47-0.48	03
RS 1-1	More or less high	0.65-0.70	23
	Medium	0.49- 0.61	22
	More or less low	0.24- 0.44	05
RS 4-1	More or less high	0.64 - 0.74	23
	Medium	0.45 -0.63	22
	More or less low	0.32 - 0.46	05
	Very low	0.14	01

Table 4.10 Overall Farmers' Utility on the factors considered

	Factor					
Block	Dependability		Flow rate		Timing of planting	
	FJ	FI	FJ	FI	FJ	FI
MS3-1	0.74	0.74	0.82	0.84	0.82	0.84
	(G)	(H)	(MLG)	(H)	(G)	(H)
MS5-1	0.55	0.74	0.56	0.74	0.56	0.84
	(M)	(H)	(M)	(H)	(M)	(H)
RS1-1	0.56	0.85	0.61	0.90	0.24	0.85
	(M)	(H)	(M)	(H)	(B)	(H)
RS4-1	0.56	0.74	0.56	0.74	0.25	0.72
	(M)	(H)	(M)	(H)	(B)	(H)

Note: FJ means Farmer's judgement on the factors considered.
FI means Farmer's opinion on importance on the factors considered.
G, H, MLG, M and B means Good, High, More or Less Good and Bad respectively.

Table 4.9 and 4.10 shows how the upstream farmers (MS 3-1 and MS 5-1, FJ values) are happier with the service they are getting than that provided to the downstream farmers (RS 1-1 and RS 4-1).

High overall utility values obtained (Table 4.10) in MS 3-1 and low values from block RS 4-1 shows how farmer were happy and unhappy with the service they are getting from the irrigation authority.

Farmers in MS 3-1 enjoyed the flow rate. dependability of irrigation water supply and timing of planting as provided by the irrigation management while the situation was different to farmers in RS 1-1 and RS 4-1. This is clearly shown by the range of RWS and FUIWS values in Table 4.10.

The factors of importance among the sampled farmers were not very much different (Table 4.10). The most important factor for MS 3-1 farmers was flow rate and timing of planting. MS 5-1. RS 1-1 and RS 4-1 farmers have the feeling that they was getting low flow rate and preferred the higher flow rate than they were getting. The reason for their preference as cited by most farmers interviewed is that higher flow rates will enable them irrigate their fields for a shorter time than what they are doing now. Field observations and Table 4.12, show that, there was no much flow rate difference between the sampled blocks. as short as possible. The only thing observed was that farmers prefer higher flow rates of irrigation water as they have no problems with unneccessarily Ponding their fields with water and want to work in their fields

Timing of planting was bad for RS 1-1 and RS 4-1 farmers. In these two blocks transplanting took place very late (Table 4.2). This situation was observed during the study period. Most farmers interviewed showed their concern on that factor as far as management of the scheme is concerned.

4.6 Correlation between FUIWS and Field Measurements Performance Indicators

The correlation between the field performance indicators selected (adequacy, equity and dependability of irrigation water supply) and FUIWS is presented and discussed in the subsequent sections.

4.6.1 Correlation between Dependability, Equity and Farmers' Utility of Irrigation Water Supply

The correlation between DIWS, EIWS and FUIWS as indicated by field measurements and Farmers' judgement and factor of importance on the respective utility factors is presented in Tables 4.11. Fig.4.2 show the relationship between DIWS and FUIWS.

Tables 4.11 Correlation between DIWS and FUIWS

Block	DIWS mean	FUIWS mean	Overall Farmer's utility on Dependability FJ	FI
MS 3-1	0.3	0.8	0.74(G)	0.74(H)
MS 5-1	0.3	0.7	0.55(M)	0.74(H)
RS 1-1	0.3	0.6	0.56(M)	0.85(H)
RS 4-1	0.3	0.6	0.56(M)	0.74(H)

NOTE: FJ, FI means Farmer's judgement and preference on the factor considered respectively.

G, M and H means Good, Medium and High respectively.

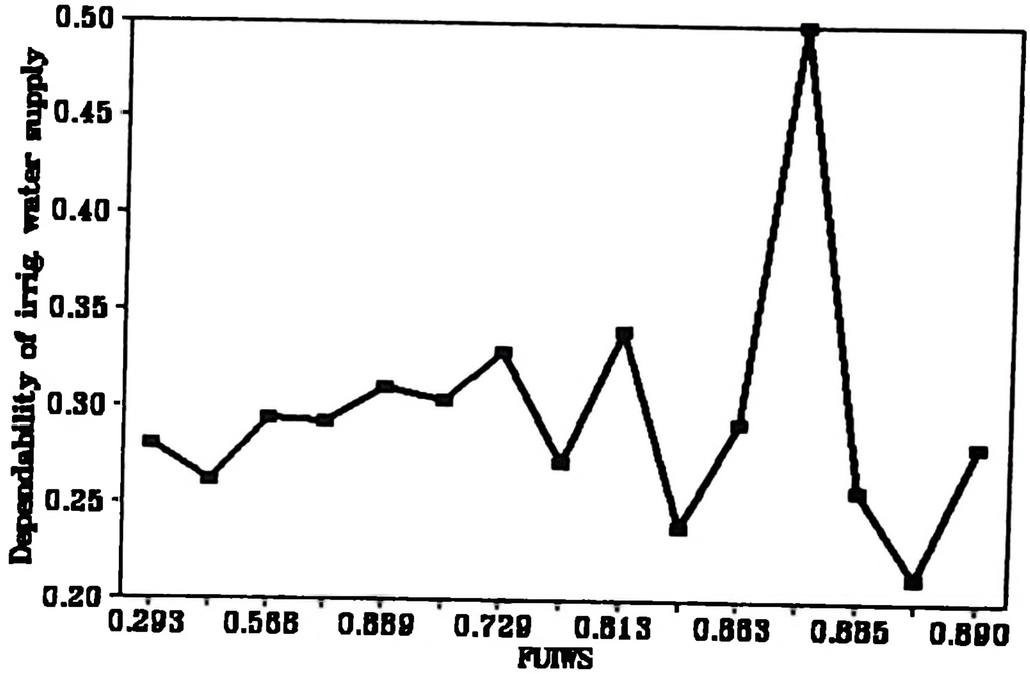


Fig 4.2 Correlation between DIWS and FUIWS

From Table 4.11 and the shape of Fig 4.2 no clear and good correlation is shown between DIWS and FUIWS. However, from Fig 4.2 wherever DIWS was low FUIWS was also low; although the correlation was somehow erratic at both low and higher values of FUIWS. For example at FUIWS values greater than 0.863 DIWS was continuously decreasing up to close to 0.20 whereas at FUIWS values greater than 0.887 DIWS started increasing. Therefore at such situation no sound scientific or mathematical conclusion can be made.

The overall farmers' utility on dependability factor shown in Table 4.11 shows that judgements of MS 3-1 farmers corresponds to the field measurements result obtained.

Farmers in MS 3-1 block showed that the irrigation water supply in their block was dependable; the same results were obtained from the field measurements (Table 4.11)

MS 5-1, RS 1-1 and RS 4-1 farmers' judgement shows that the irrigation water supply of the scheme was moderately dependable whereas field measurement revealed that the supply was dependable to a greater extent compared to that indicated by these farmers (Table 4.11 minimum dependability values and Overall utility FJ values). According to Gates et al., (1991) dependability values close to zero indicates a more dependable irrigation water supply. Therefore, Lower Moshi irrigation water supply is generally dependable than the way the farmers' judged it.

Table 4.12: Correlation between EIWS and FUIWS

Block	EIWS Flow rate (l/sec) mean.	RWS mean.	FUIWS Overall Farmers' Utility on flow rate FJ	FI
MS 3-1	26.3	1.3	0.82(MLG)	0.84(H)
MS 5-1	29.2	1.3	0.56(M)	0.74(H)
RS 1-1	23.7	1.1	0.61(M)	0.90(H)
RS 4-1	26.5	1.1	0.56(M)	0.74(H)

NOTE:FJ, FI means Farmers' judgement and importance on the factor considered.
MLG, M, H means More or Less Good, Medium and High respectively.

Table 4.11 generally indicate absolute correlation of farmers' judgement and the situation in their fields only. No clear relationship indicated between EIWS and FUIWS. However, on average the judgements produced by the sampled farmers corresponded to the field measured.

4.6.2 Correlation between Crop Yield and FUIWS

The correlation between crop yield as indicated in terms of yield per hectare and specific yields and FUIWS is shown in Table 4.13 and Fig 4.3.

Table 4.13 shows low correlations between crop yields and FUIWS.
This shows that crop production especially of paddy rice is influenced by many factors and not only timing of planting.

Fig 4.3 shows a magnitude correlation; that is whenever FUIWS is high both specific yield and yields per hectare are also high. However, at low FUIWS values that are between 0 28 and 0.75 crop yields per hectare increases erratically to maximum values whereas at higher FUIWS values the reverses occur. Similarly specific yields also is erratically correlated with FUIWS at all levels. The two crop yields indicators that are crop yield per hectare and specific yield has shown an erratic correlation with FUIWS, to make any conclusion as far as the Study objectives is concerned. This indicate that crop production especially paddy rice is influenced by many factors and not only timing of planting.

Table 4.13 Correlation between Crop yield and FUIWS

Block	Crop yield ton/ha mean	Crop yield kg/m^3 mean	FUIWS Overall Farmers' Utility on timing of planting FJ	FI
MS 3-1	7.90	0.70	0.82(G)	0.84(H)
MS 5-1	8.08	0.61	0.56(M)	0.84(H)
RS 1-1	8.10	0.70	0.24(B)	0.85(H)
RS 4-1	7.10	0.60	0.25(B)	0.72(H)

NOTE: G, H, M, B = Good, High, Medium and Bad respectively.

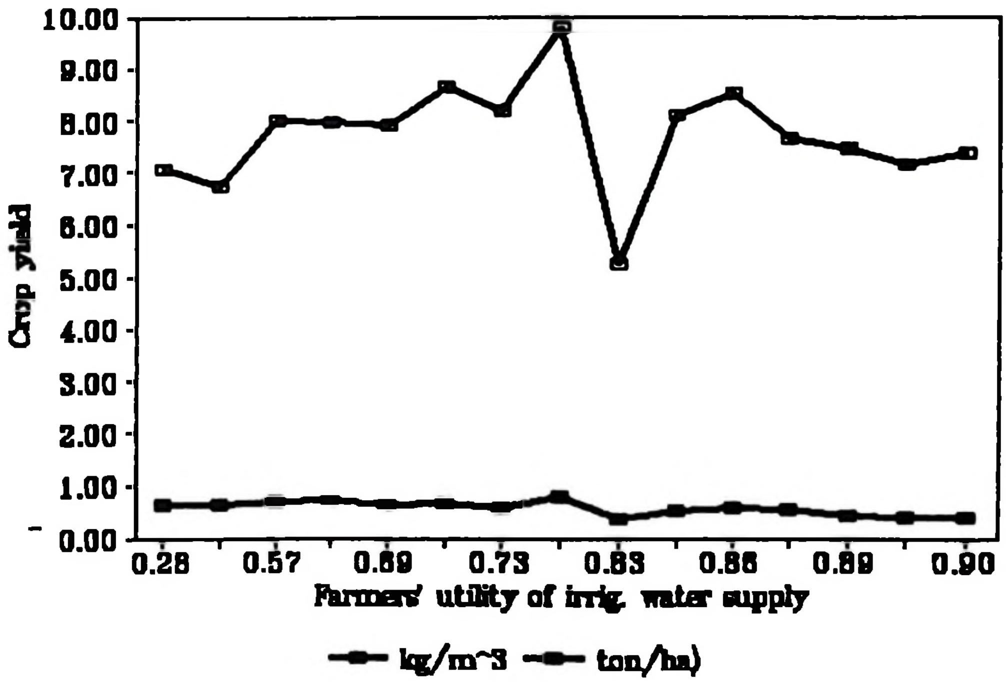


Fig 4.3 Correlation between Crop yield and FUIWS

4.6.3 Correlation between RWS and FUIWS

The formulation of FUIWS as a method of assessing irrigation system performance is developed from the strong relationship shown between RWS and FUIWS as appears in Tables 4.16 and Figure 4.3 respectively.

Table 4.14 Comparison between RWS and FUIWS

RWS	FUIWS
0.8	0.356
0.9	0.444
1.0	0.559
1.1	0.657
1.2	0.679
1.3	0.706
1.4	0.728
1.5	0.789
1.6	0.824
1.7	0.863
1.8	0.863
1.9	0.850
2.0	0.887
2.1	0.890
2.2	0.890

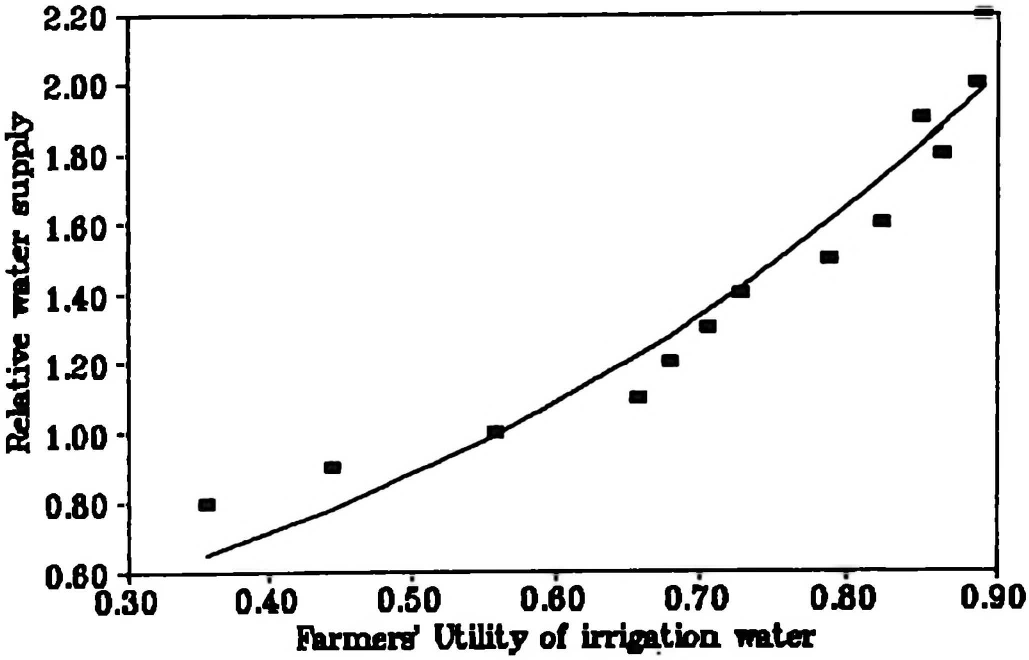


Fig 4.4 Correlation between RWS and FUIWS

The results in Table 4.14 show that whenever the RWS is high the FUIWS is also high and vice versa. This association of the magnitude between the two variables was proved by the covariance test shown in Appendix 10.

The positively large covariance value obtained in Appendix 10 indicate that large values of RWS are associated with large values of FUIWS and vice versa. The correlation coefficient test (on values in Table 4.14) showed the correlation coefficient with 13 degree of freedom at 5 % and 10 % levels is 0.514 and 0.641.These values are much less than 0.994 the calculated correlation coefficient. This evidently shows that the above correlation is not true linear association (Freese, 1980).

The graphs plotted (Fig 4.4) evidently showed an exponential relationship between the two variables. The equation that represents that relationship is of the type (Grewal, 1978) :

$$R = a\,e^{nU} \qquad (7)$$

Where :

R = RWS in paddy fields.

U = Farmers' Utility of Irrigation Water Supply.

a and n are constants.

Since the covariance is positively large then the large values of RWS is associated by the large values of FUIWS (Freese,1980). From Tables (Freese, 1980) the Correlation coefficient at 5 % and 10 % significance levels with 13 degree of freedom are 0.514 and 0.641. Since r-calculated is much larger than r-tabulated then there is no linear association between RWS and FUIWS.

From figure 4.5 the two constants " a" and "n" in the equation (8) was established for the whole Lower Moshi FMIS. For this particular scheme the mathematical model obtained is : $R = 0.377e^{1.825U}$. (8)

Similar equations from similar sampled block graphs (Figures 4.6 , 4.7, 4.8 and 4.9 4.9) were established for each sampled block as shown in Table 4.15. However, the values for the constants" a" and "n" were different from one block to another, giving an evidence that these constants are managerial factors and shows the different irrigation management and service levels between the sampled blocks.

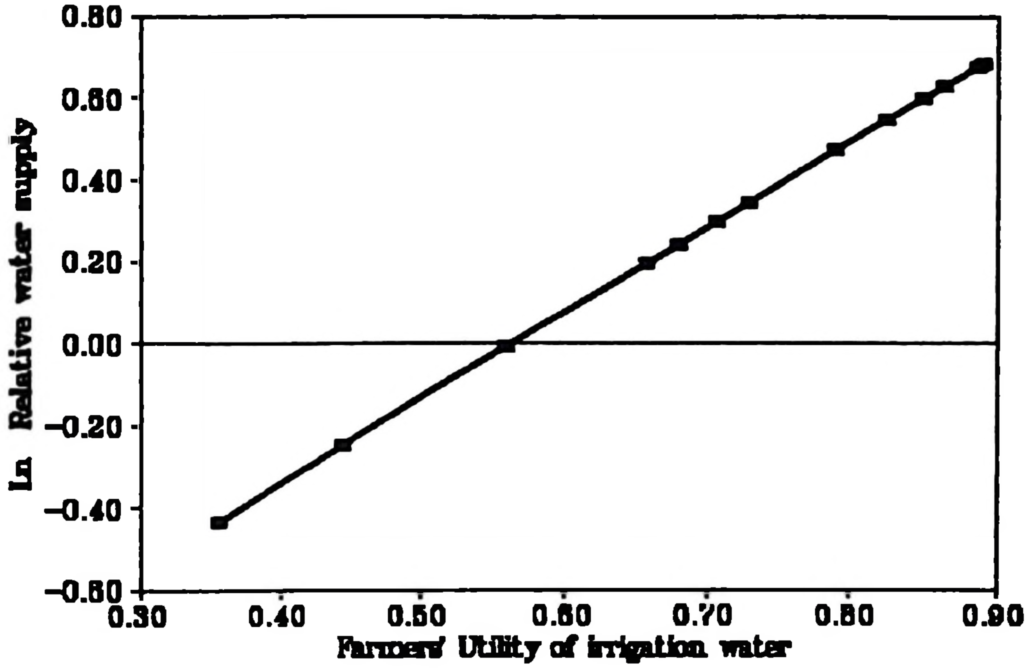


Fig 4.5 Graph of Ln RWS and FUIWS

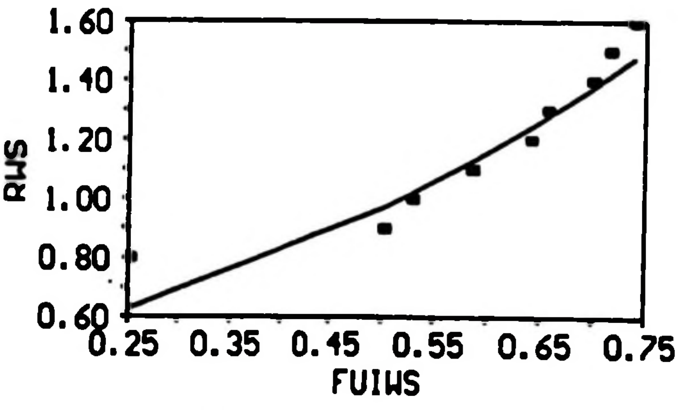
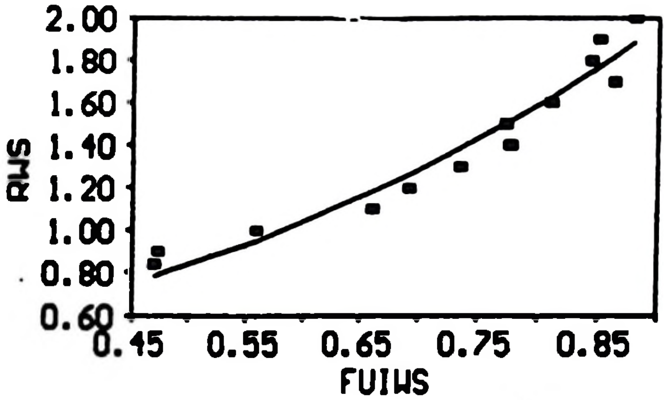
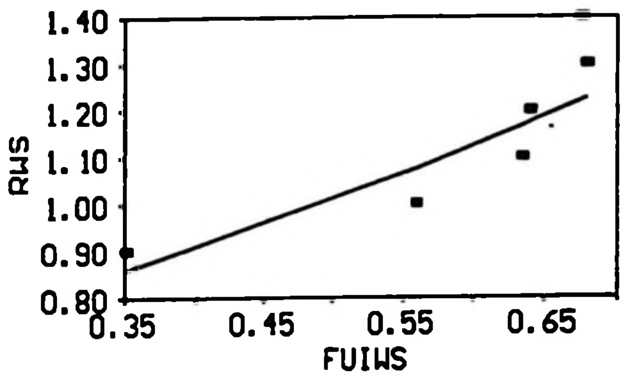


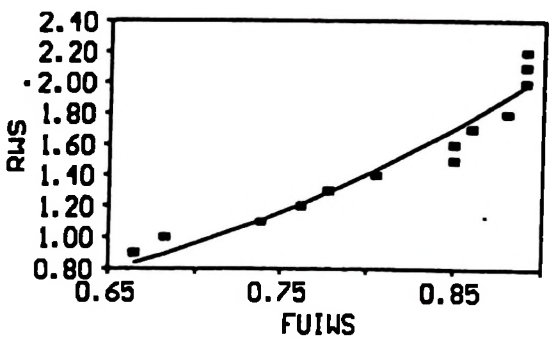
Fig 4.6 Block RS 4-1 Correlation between RWS and FUIWS



Block MS5-1 Correlation between RWS and FUIWS



Block RS 1-1 Correlation between RWS and FUIWS



Block MS 3-1 Correlation between RWS and FUIWS

Table 4.15 Mathematical model for sample blocks

Block	Model	Position of the block from upstream
MS 3-1	$R=0.0664e^{3.814U}$	U_m
MS 5-1	$R=0.2895e^{2.129U}$	U_2
RS 1-1	$R=0.5848e^{1.087U}$	D_2
RS 4-1	$R=0.4101e^{1.761U}$	D_m

Note: U_m = Upstream most located block
U_2 = Second upstream most located block
D_2 = Second downstream most located block
D_m = Downstream/downstream most located block

4.7 Comparison between Simulated and Measured RWS

Table 4.17 show the comparison between season mean measured and scheme model simulated RWS.

Table 4.16 Comparison between measured and Scheme model simulated RWS

RWS (measured)	RWS (simulated)
0.800	0.649
0.900	0.780
1.000	0.992
1.100	1.217
1.200	1.275
1.300	1.348
1.400	1.413
1.500	1.604
1.600	1.726
1.700	1.870
1.800	1.873
1.900	1.820
2.000	1.969
2.100	1.985
2.200	1.981

Comparison between measured and scheme model simulated RWS values using t-student distribution test at 5% and 10% significance levels showed that there is no significant difference between simulated and measured means (Table 4.16 and Appendix 11).

Similar comparison at similar significance levels was carried between block and scheme models to see whether there was a difference between the result produced with the respective models. The results showed that there were no significant difference between the results produced by the two models.(Tables 4.19 and 4.20).

Form Appendix 11 , the pooled within - group variance S^2 is:

$$= (CSSs + CSSm)/(NS + Nm - 2) \quad (9)$$

$$= (2.800 + 2.785)/(15 + 15 - 2)$$

$$= 0.1995$$

The t-statistic $= (Xmm - Xms)/[(S^2 \times (Nm + Ns)/(Nm \times Ns)]^{1/2} \quad (10)$

Where:

Xmm	=	Mean measured RWS
Xms	=	Mean simulated RWS
Nm	=	Number of elements Measured RWS
Ns	=	Number of elements Simulated RWS

Therefore, t-statistic $= (1.5 - 1.4)/[0.19 \times (15+15)/(15 \times 15)]^{1/2}$

$= 0.62$

From tables(Freese,1980) t-tabulated with Degree of Freedom (DF) of 28:

at α = 5% = 2.048

at α = 10% = 1.701

Since t-calculated is much less than t- tabulated; there is no significant difference between simulated and measured means RWS.

Table 4.17 Block MS 3-1 Comparison between Measured and Simulated RWS

Measured	Simulated	
	Block Model	Scheme Model
0.9	0.839	1.268
1.0	0.895	1.308
1.1	1.111	1.451
1.2	1.213	1.513
1.3	1.288	1.557
1.4	1.431	1.637
1.5	1.699	1.777
1.6	1.699	1.778
1.7	1.765	1.810
1.8	1.905	1.878
2.0	1.979	1.912
2.1	1.979	1.912
2.2	1.979	1.912

Table 4.18 Block MS 5-1 Comparison between Measured and Simulated RWS

Measured RWS	Simulated RWS using Block Model	Simulated RWS using Scheme Model
0.8	0.787	0.888
0.9	0.793	0.894
1.0	1.183	1.044
1.1	1.263	1.259
1.2	1.384	1.332
1.3	1.384	1.441
1.4	1.513	1.555
1.5	1.502	1.545
1.6	1.624	1.652
1.7	1.819	1.821
1.8	1.743	1.756
1.9	1.768	1.778
2.0	1.885	1.878

Table 4.19 Block RS 1-1 comparison between Measured and Simulated RWS

Measured RWS	Simulated RWS using block Model	Simulated RWS using Scheme Model
0.9	0.858	0.716
1.0	1.075	1.047
1.1	1.167	1.202
1.2	1.174	1.214
1.3	1.225	1.303
1.4	1.220	1.294

Table 4.20 Block RS 4-1 Comparison between Measured and Simulated RWS

Measured RWS	Simulated RWS using block Model	Simulated RWS using Scheme Model
0.8	0.627	0.598
0.9	0.974	0.944
1.0	1.021	0.991
1.1	1.130	1.101
1.2	1.244	1.217
1.3	1.279	1.253
1.4	1.377	1.352
1.5	1.418	1.394
1.6	1.478	1.454

The results of the above comparison between measured and simulated RWS is summarized as appears in Appendices 12 and 13.

From Appendix 13, No significance difference between Block and Scheme simulated mean RWS. However, the Bartlett's test of homogeneity shown in Appendix 14 indicated that RWS have the same degree of variability for all levels of FUIWS. Both tests were carried at 5 % and 10 % significance levels. Bartlett's test prove that any changes in FUIWS is associated with changes in RWS with the same degree of variability at all levels of FUIWS. This characteristic of the method proves that; the methodology can be adopted in place of RWS and give the same level of accuracy. However, the above analysis and results shown in Appendices 11 and 13 shows that the scheme model developed can be adopted to assess the whole scheme in place of block models.

From Appendix 14 , the pooled within group- variance So^2 is:

$$S_o^2 = \Sigma SS_i / \Sigma(n_i-1) \qquad (11)$$

$$= 2.895/37$$

$$= 0.08$$

The test of homogeneity for the data in Appendix 14 is:

$$\chi^2 \text{ with } 3 \text{ df} = 2.036[\log S_o^2 \Sigma (n-1) - \Sigma (n-1) \log S_i^2] \qquad (12)$$

$$= 2.875$$

From χ^2 Tables; with 3 degree of freedom :

at 5 % significance level = 7.81

at 10 % significance level = 6.25

at 25% significance level = 4.11

The χ^2 calculated is much less than χ^2 tabulated; this indicate that there is nonsignificant variability between dependent (RWS) and independent (FUIWS) variables at all levels.

The analysis above show that, there is a clear and 'strong' relationship between RWS and FUIWS. Therefore the developed method can be used to asses, monitor and evaluate the performance of irrigation system in place of RWS.

However, the proven ability of RWS to evaluate reliably productivity, relative equity, adequacy and the general management trend & decision making (as explained by Sakthivadiel et al., 1993&1992; Nihal, 1992; Weller et al.,1989 and Green, 1987) make the developed methodology a possible multi-dimensional irrigation system performance indicator.

The developed method can be used as dependability indicator, an adequacy of irrigation water supply indicator as well as it can give qualitative feeling of non-spatial uniformity of irrigation water supply. In other words , all the three mentioned performance indicators of water distribution in irrigation system can be estimated without having flow measurements from the field by simply knowing the utility of irrigation water supply.

Chapter four presented the results and discussion of the results as obtained from the study. The summary of the major findings of the study, conclusions drawn from the case study and recommendation for future work or research are presented in the next chapter.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

Chapter five summarizes the major study findings, conclusions from the case study and recommendations for further investigation as appears in the subsequent sections.

The major objectives of the study was to investigate FUIWS as a method of assessing irrigation system performance. The study consisted of three parts. The first part dealt with field measurement that was aimed at determining irrigation system performance using adequacy, dependability and equity of irrigation water supply. The second part involved, determination of farmers' perception on the irrigation water supply utility. Three utility factors were considered in this part namely as; dependability, flow rate and timing of planting as related to irrigation water supply. The third part of the study consisted of the establishment of the correlation between the first and the second parts.

The study has shown that, the irrigation water supply of Lower Moshi FMIS during the crop growing period is adequately supplied as indicated by RWS. However, low RWS values were obtained during land preparation period. These values indicated that; one, inefficient management as shown by the late transplanting of seedlings and two, a gradual decline in the fraction of the irrigated area during the same season. On average higher RWS values were observed in the crop growth period throughout the irrigation season. This implied that the paddy rice fields were adequately irrigated.

Although in general similar inequity levels as indicated by RWS were observed between upstream blocks and more or less similar level of inequity between downstream blocks; high levels of inequity was experienced from upstream to downstream blocks.

A fairly and equitable irrigation water supply was observed in paddy fields along all watercourses in block RS 1-1.

Dependability of irrigation water supply of Lower Moshi FMIS was almost highly dependable if one leave a lone some few cases observed. The dependability values obtained ranged from 0.1 to few 0.6.

In this study, farmers' opinions on flow rate and dependability of irrigation water supply were more or less equal on these two factors. Block MS 3-1 farmers judged the flow rate and dependability of irrigation water supply as Good and more or less good respectively.
Farmers in blocks MS 5-1, RS 1-1 and RS 4-1 said that flow rate and dependability of the irrigation water supply in their paddy rice fields was Medium.

Timing of planting is some how localized, while upstream farmers were moderate on the factor, downstream farmers were unhappy with the management of the system on this aspect as they judged it as bad.

The factor of importance among the sampled farmer was not very much different. However, flow rate and timing of planting were important factors for MS 3-1 farmers, whereas MS 5-1 and RS 4-1 farmers had feeling that were getting less flow rates. RS 4-1 farmers preferred higher flow rate than that was issued.

Good relationship was observed between both dependability, equity of irrigation water supply and FUIWS. Wherever FUIWS showed a certain trend; FUIWS behaved in the same manner. However, the observed trend was sometimes erratic to indicate any strong relationship. In other words no clear trend was obtained between the two indicators and FUIWS.

The Farmers' perception on irrigation water supply utility observed in this study indicated that farmers are more concerned with the quality (in terms of services) and quantity of irrigation water supply as indicated on its adequacy and utility. This was clearly indicated by the strong relationship between RWS and FUIWS from which the methodology was developed.

The methodology developed relates RWS and FUIWS and considers FUIWS as the only data to be collected from the filed. The model that relates the two variable is of the form:

$$R = ae^{nU}$$

where: R = RWS in paddy rice fields .

U = Farmers' Utility of Irrigation Water Supply.

a and n are constants.

For this case study the model obtained is $R = 0.377e^{1.825U}$. The comparison between block and scheme model using t-student distribution test and homogeneity test of variability showed that the scheme model can be adopted in place of the block models.

5.1 Conclusions

The study has shown that Specific yield and yield per hectare were maximized at 1.5 RWS value. A slightly consistent increase in yield, however, was observed between 0.90 and 1.00 as well as between 1.4 and 1.5 RWS values. RWS values greater than 1.8 showed low yields in relation to the volume of irrigation water issued as well as irrigated area (Fig 4.1).

Low yield values at RWS greater than 1.8 indicates that the excess water issued is not serving a productive purpose; instead reduced much the productivity of the available irrigation water supplied. In short the excess water delivered was just a waste.

The maximum Specific yield obtained is 1.49 kg/m^3 while maximum yield per hectare is 17.89 ton/ha (Appendix 9).

Although it may be early to make firm conclusion on the developed method; few observations can be made:
The method for assessing irrigation system performance is developed using RWS and FUIWS. The method uses FUIWS concept, to accommodate a number of variable performance indicators. It considers farmers opinion and preference at field level to be the data to be collected . The methodology was applied at Lower Moshi FMIS as a Case Study for one season (November,1995 - March,1996) which is a dry irrigation season for this scheme.

The use of fuzzy set approach in this method and the decomposition of the question used into its component make easy data collection from farmers and enables them to give their opinions and preferences easily. This makes the method more robust and quick appraisal than the traditional techniques which require laborious and costly field measurements.

However, the incorporation of the fuzzy set theory in data analysis enabled the methodology to capture all aspects of the farmers subjective judgement and preferences which cannot be captured with the traditional methods.

The use of RWS in the developed model make it to be a useful irrigation water supply managerial tool. Managers can keep track of the performance of irrigation water supply at different field levels within an irrigation season or as post harvest performance indicator.

5.2 Recommendations

From the study the following are highly recommended:
The method was demonstrated and tested in paddy rice only, therefore more work is needed to test it in upland crops as well as in both traditional and improved FMIS so as to make it more widely applicable.

As explained in Chapter four, the relationship between RWS and FUIWS is of the form: $R = ae^{nU}$.
Therefore, more work is required to establish whether the values "a" and "n" which are constants in the developed model are universal or not and what are the exact factors influence these constants.

6.0 REFERENCES

Abernethy. C.L.(1991). Overview in performance measurements in Farmer Managed Irrigation Systems. In: *Proceedings of International Workshop on Farmer Managed Irrigation Systems Network.*(Edited by Manor,S. and J. Chambouleyron), Organized by the International Management Institute(IIMI) and the Instituto Nacional de Cienciay Te'cnicia Hindricas(INCYTH), Mendoza, Argentina, 12-15 November,1991.pp 266.

Abernethy, C.L and J.A. Weller (1987). Water distribution within small farmer groups at Kaudulla, Sri Lanka. *Hydraulics research*; Wallingford, England, Report No. OD 67, May, 1987. pp 32.

Abernethy, C.L (1986). Performance measurement in canal water management; A discussion ODI/IIMI Irrigation Network 86/2d. London. pp 25.

Abernethy, C.L. (1984). Methodology for studies of irrigation water management; *Hydraulics Research;* Wallingford, England, Report OD/TN 9 October, 1984. pp 27.

Batti, A.M, F.E.Schulze and G.Levine (1991). Yield measures of irrigation performance in Pakistan. *Irrigation and Drainage System an International Journal*, vol 5 No 2 May, 1991. Kluwer Academic Publishers. pp 183-190.

Bhutta, M.N and E.J.Vander Velde (1992). Performance of secondary canals in Pakistan Punjab:Research on Equity and Variability at the Distributary Level. In: Advancements in IIMI's Research 1989-1991. A selection of papers presented at Internal programme reviews, International Irrigation Management Institute(IIMI) 1992. pp 235-260.

Bos, M.G.(1979). Standards for irrigation efficiencies of ICID, *Journal of Irrigation and Drainage Division, ASCE*, 105:37-43.

Clemmens, A. J. and M.G.Bos (1990). Statistical methods for irrigation system water delivery performance evaluation. In: *Irrigation and Drainage System* 4:345-365.

Dakes, J.M.K. (1972). *Essentials of Engineering Hydraulics*, Macmillan, University of Science and Technology, Kumasi Ghana.pp 392.

Doorenbos, J. and Pruitt, W.O., (1977). Crop Water Requirement, *Irrigation and Drainage paper* 24, FAO, Rome, pp 144.

El- Awad, O.M; Gowing, J.W and Mawdsley, J.A (1991). An approach to multi-criterion evaluation of irrigation system performance. *Irrigation and Drainage System.* vol 5.61-75.

El-Award, O.M (1991). Multi-criterion approach to evaluation of irrigation system performance. Unpublished PhD Thesis university of New castle Upon Tyne. pp 147-182.

FAO, (1989). Guidelines for designing and evaluating surface irrigation systems. *FAO Irrigation and Drainage paper 45*, Rome .pp 137.

FAO, (1987) *Institutional support for irrigation development (Preparatory phase) Tanzania Mission Report*, Rome. pp 83.

FAO, (1985). Participating Experience in Irrigation System for Small holder Agriculture in South Africa. *Technical paper* 3/2 pp 284.

Freese, F.(1980). *Elementary statistical methods for foresters*. Agriculture Hand book 317. US Department of Agriculture Us. pp 90.

Gates, T. K; W.E.Heyder, D.F.Fontane and J.D.Salas (1991). Multi-criterion strategic planning for improved irrigation delivery: Approach. *Journal of irrigation and drainage Engineering* vol.117 no.6 Nov/Dec,1991. American Society of Civil Engineers Irrigation and Drainage Division. pp 430-555

Gowing, J. and O. El-Award (1992). Farmers perspectives on irrigation performance: Evaluation of water supply utility. In: *Advances in planning, Design and Management of irrigation systems as related to sustainable land use*. Vol.2. Leuven, Belgium. September 14-17,1992. (Edited by J.Feyen, E.Mwendera, and M. Badji). Centre for Irrigation Engineering. K.U. Leuven, Leuven, Belgium. pp 555-561.

Green, A.P.E.(1987). Water distribution at Porac Gumain, Philippines-Dry season 1985/86. *Hydraulics research*. Report No. OD 92,July 92.

Grewal, B.S.(1978). *Higher Engineering Mathematics*. Khanna publishers, Nath Market, Delhi.pp 146-188.

International Irrigation Management Institute, (1990). *IMMI Newsletter of the farmer Managed Irrigation systems Network.* International management institute. No 7 pp 23.

Kilimanjaro Development Project (KADP) (1993). *Project Outline Report* , September, 1993.pp 21.

Lauraya, F.M, A.R.Lea and Wijjayarantha.(1991). Self- Assessment of performance of performance by Irrigators; Associations. In: *Performance Measure in Farmer-Managed Irrigation Systems.* Proceeding of an International Workshop of Farmer-Managed Irrigation System Network.(Edited by Manor, S. and J.Chambouleyron), Organized by the International Irrigation Management Institute(IIMI) and The Instituto Nacional de Cienciay Te'cnia Hindricas(INCYTH),Mendoza, Argentina, 12-15 November,1991.pp 41-52.

Malano, H.M. and G.Gao.(1992). Ranking and classification of irrigation system performance using fuzzy set theory: Case studies in Australia and China. 1992. *Irrigation and drainage systems* 6:129-148.

Manor, S. (1990). Performance measurement of farmer managed irrigation systems. *Newsletter of farmer managed irrigation systems.* New York, No.8 IIMI.

Martin, E.D.(1986). Resource Mobilization: Water allocation and Farmer organization in Hill systems in Nepal. PhD Dissertation (Unpublished): Ithaca. Cornell University. pp 294.

Molden, D.J and T.K. Gates (1990). Performance Measures For Evaluation of Irrigation-Water-Delivery Systems. *Journal of Irrigation and Drainage Engineering*, Vol, 116,no 6. pp 804-823.

Moya. T.B. (1990). *Instruments and structures commonly used for operating irrigation systems*: Water Management Department, IRRI college, Laguna. pp 3-5.

Nihal, F. (1992). Monitoring Irrigation Water delivery performance: Concept of Cumulative Water Supply. In : *Advances in planning, design and management of irrigation system as related to sustainable land use.* Vol.2 Leuven, Belgium. 14-17 September, 1992.(Edited by Feyen,J and Moussa, B). Centre for irrigation Engineering. K.U Leuven, Leuven, Belgium. pp 525-534.

Oad, R. and T. Podmore. (1989). Irrigation Management in rice based agriculture: Concept of Relative Water Supply. *ICID Bulletin*, Vol.38. No. 1; pp 1-12.

Oad, R and R.K. Sampath (1991). Performance measurement for improved irrigation management. In: *Performance Measure in Farmer-Managed Irrigation system.* Proceeding of an International Workshops of Farmer-Managed irrigation system Network. (Edited by Manor,S.and J.Chambouleyron) Organized by the International irrigation management Institute(IIMI) and the Instituto NACIONAL de cienccua y Te'cncia Hindricas(INCYTH), Mendoza, Argentina, 12-15 November, 1991.IIMI. pp 35.

Palmer, J.D; A.J.Clemens and A.R.Dedrick (1991). Field study on irrigation delivery performance. *Journal of irrigation and drainage engineering.* American society of Civil engineering vol.117 No.4 Jul/Aug.1991.pp 567-577.

Rydzewski. J.R. (1971). Project Formulation, Appraisal and Monitory. In: Rydzewski.J.R.(Ed) *Irrigation Development Planning*, Southampton University. Southampton, UK. pp 135-156 .

Sakthivadivel, R.; N.Fernando and D.J.Merrey.(1992). Performance of irrigation Settlement Schemes: A case study from Kirindi Oya, Sri Lanka.In: *Advancements in IIMI's Research* 1989-1991. A selected papers presented at International Irrigation Management Institute (IIMI)1992.pp 208-232.

Sakthivadivel, R.; D.Merrey and F.Nihal (1993). Cumulative Relative Water Supply: A methodology for assessing Irrigation performance. *Irrigation and drainage system* 7: 43-67,1993.pp 208-232.

Sampath, R.K.(1989). Measures of managerial performance of irrigation systems. *Irrigation and Power journal*, 46 (4): 9:112.

Seckler, D.; R.Oad and S.K.Raheja(1988). An index for measuring the performance of irrigation management systems with application. *Water Bulletin,* Vol.24 no 4. pp 855-860.

Sharma, D.N.; R. Oad and R.K. Sampath (1991). Performance measure for water delivery systems. *ICID Bulletin* Vol.4 No. pp 1-11.

Spleeman, J.J. (Compiler) (1990). Design for sustainable farmer managed irrigation schemes in Sub Saharan Africa. *ODI/IIMI management network paper* 90/F, London. pp 18.

Thapa. G and M.Banskotta(1991). Performance Evaluation of selected FMIS. In: Performance Measure in Farmer- Managed Irrigation System. In: *Proceedings of an International Workshop of Farmer Managed Irrigation System Network.*(Edited by Manor. S and J. Chambouleyron), Organized by the Instituto Nacional de ciencia Te'cnia Hindricas (INCYTH), Mendoza, Argentina, 12-15 November,1991. pp 95-106.

Upphoff, N., R. Meinzein-Dick and N.S. Julien (1985). Improving policies and programs for farmer organization and participation in irrigation management synthesis II project, *USAID contract DAN-1427-C-00-0086-00 to the consortium for International Development*; Ithaca, Cornell University. pp 35.

URT/JICA. (1988). Lower Moshi Agricultural Development Project. *(Rau system) project completion report. Vol. 1. Main report, March 1988.* NIPPON KOEI Co. LTD. Consulting Engineers, Tokyo, pp 388.

URT/JICA. (1986) United Republic of Tanzania. Regional Development Project (Rau system). *Design Note on Farm-Works, May, 1986.* NIPPON KOEI Co.LTD. Consulting Engineers. Tokyo. pp 350.

Weller, J.; E. Payawal and S. Salandanan (1989). Performance assessment of the Porac River Irrigation system. Hydraulics research, *Wallingford, Modernization and Rehabilitation of irrigation and drainage systems. Asian Regional Symposium.* The Philippines, 13-15 February, 1989. OD/P 74.

Appendix 1 CROP WATER REQUIREMENT (ET_C)

Month	Date	Mean ET_o	crop coefficient k_c	Daily ETc
November	03	6.10	1.10	6.72
November	04	5.81	1.10	6.39
November	05	6.50	1.10	7.15
November	06	6.82	1.10	7.50
November	07	6.02	1.10	6.62
November	08	6.07	1.10	6.68
November	09	6.65	1.10	7.32
November	10	6.80	1.10	7.48
November	11	6.60	1.10	7.26
November	12	6.58	1.10	7.24
November	13	6.91	1.10	7.63
November	14	6.68	1.11	7.41
November	15	6.90	1.11	7.67
November	16	6.78	1.12	7.57
November	17	6.61	1.12	7.42
November	18	6.50	1.13	7.31
November	19	6.69	1.13	7.56
November	20	6.93	1.13	7.86
November	21	6.93	1.14	7.89
November	22	6.86	1.14	7.84
November	23	7.11	1.15	8.16
November	24	6.72	1.15	7.74
November	25	6.84	1.16	7.90
November	26	6.78	1.16	7.86
November	27	6.44	1.16	7.49
November	28	6.54	1.17	7.64
November	29	6.70	1.17	7.86
November	30	6.59	1.18	7.76
December	01	6.31	1.18	7.45

Apppendix 1 continued

December	02	6.14	1.19	7.28
December	03	6.24	1.19	7.43
December	04	6.47	1.19	7.73
December	05	5.84	1.20	7.00
December	06	5.86	1.20	7.05
December	07	6.12	1.21	7.39
December	08	6.10	1.21	7.39
December	09	6.07	1.22	7.37
December	10	5.78	1.22	7.05
December	11	5.71	1.22	7.00
December	12	6.07	1.23	7.46
December	13	6.17	1.23	7.60
December	14	5.98	1.24	7.40
December	15	6.41	1.24	7.96
December	16	6.38	1.25	7.94
December	17	6.31	1.25	7.89
December	18	6.29	1.25	7.86
December	19	6.47	1.25	8.09
December	20	6.37	1.25	7.96
December	21	6.40	1.25	8.00
December	22	6.61	1.25	8.27
December	23	6.41	1.25	8.01
December	24	6.53	1.25	8.16
December	25	6.52	1.25	8.15
December	26	6.46	1.25	8.07
December	27	6.32	1.25	7.90
December	28	6.04	1.25	7.55
December	29	6.38	1.25	7.98
December	30	6.27	1.25	7.84
December	31	6.38	1.25	7.97

Appendix 1 continued

January	01	6.51	1.25	8.13
January	02	7.02	1.25	8.77
January	03	6.45	1.25	8.06
January	04	6.60	1.25	8.25
January	05	6.70	1.25	8.37
January	06	6.29	1.25	7.86
January	07	6.29	1.25	7.87
January	08	5.74	1.25	7.17
January	09	6.71	1.25	8.39
January	10	6.34	1.25	7.93
January	11	5.94	1.25	7.42
January	12	6.23	1.25	7.79
January	13	6.64	1.25	8.30
January	14	6.99	1.25	8.74
January	15	5.99	1.25	7.49
January	16	6.60	1.25	8.26
January	17	6.49	1.24	8.05
January	18	6.77	1.23	8.33
January	19	6.93	1.22	8.45
January	20	6.49	1.21	7.86
January	21	6.58	1.20	7.90
January	22	6.72	1.19	8.00
January	23	6.69	1.18	7.89
January	24	6.44	1.17	7.54
January	25	6.27	1.16	7.27
January	26	6.77	1.15	7.78
January	27	6.91	1.14	7.88
January	28	6.77	1.13	7.65
January	29	7.35	1.12	8.23
January	30	7.16	1.11	7.95
January	31	7.08	1.10	7.79

Appendix 1 continued

February	01	7.60	1.09	8.28
February	02	7.13	1.08	7.70
February	03	6.91	1.07	7.39
February	04	6.33	1.06	6.71
February	05	6.70	1.05	7.04
February	06	6.93	1.04	7.21
February	07	6.48	1.03	6.68
February	08	6.65	1.02	6.79
February	09	6.53	1.01	6.60
February	10	6.54	1.00	6.54
February	11	6.57	0.99	6.50
February	12	6.34	0.98	6.22
February	13	6.88	0.97	6.67
February	14	6.66	0.96	6.40
February	15	6.60	0.95	6.27

Appendix 2 **Meteorological Data at Lower Moshi FMIS-Chekereni Station**
November 1995-March 1996 season

Month	Day	Maximum temp °c	Minimum temp °c	Relative humidity %
November	01	32.50	16.30	72.00
November	02	32.50	19.50	68.00
November	03	32.00	19.00	58.00
November	04	32.50	19.50	62.00
November	05	31.90	19.60	62.00
November	06	32.50	19.00	61.00
November	07	33.00	16.00	65.00
November	08	33.00	17.00	62.00
November	09	33.60	17.50	65.00
November	10	33.50	15.50	68.00
November	11	33.60	16.80	68.00
November	12	34.00	17.30	66.00
November	13	34.60	18.00	66.00
November	14	34.60	17.80	62.00
November	15	33.50	09.50	69.00
November	16	3.50	18.00	64.00
November	17	32.50	18.30	61.00
November	18	33.00	18.50	64.00
November	19	33.40	19.30	62.00
November	20	35.50	19.00	66.00
November	21	32.50	20.00	65.00
November	22	32.30	19.90	76.00
November	23	33.50	19.00	68.00
November	24	33.50	20.00	66.00
November	25	33.50	21.00	65.00
November	26	34.20	20.90	62.00

Appendix 2 Continued

November	27	34.00	21.40	70.00
November	28	34.50	20.00	68.00
November	29	25.20	18.00	68.00
November	30	30.00	19.50	59.00
December	01	31.00	16.80	80.00
December	02	32.90	17.00	76.00
December	03	32.80	16.50	68.00
December	04	33.20	17.00	59.00
December	05	32.80	16.00	55.00
December	06	33.50	17.20	66.00
December	07	33.50	18.80	63.00
December	08	29.90	16.50	66.00
December	09	33.50	16.50	66.00
December	10	34.20	16.30	63.00
December	11	35.50	16.50	66.00
December	12	33.50	18.00	73.00
December	13	32.90	17.50	72.00
December	14	33.00	18.50	72.00
December	15	32.90	19.00	72.00
December	16	33.50	18.50	55.00
December	17	33.00	18.00	66.00
December	18	33.50	18.50	59.00
December	19	33.80	18.00	68.00
December	20	33.00	19.00	66.00
December	21	34.10	17.50	59.00
December	22	35.00	20.00	62.00
December	23	34.00	18.30	66.00
December	24	35.00	19.60	59.00
December	25	35.00	18.40	66.00
December	26	34.50	17.50	68.00
December	27	34.50	17.50	66.00

Appendix 2 Continued

December	28	33.00	18.00	69.00
December	29	35.00	18.00	66.00
December	30	33.50	17.30	66.00
December	31	33.00	16.80	65.00
January	01	33.50	16.70	66.00
January	02	36.00	16.00	58.00
January	03	35.00	18.50	62.00
January	04	34.50	16.80	62.00
January	05	36.00	17.00	65.00
January	06	35.00	17.60	66.00
January	07	33.20	17.80	62.00
January	08	32.30	18.00	63.00
January	09	34.80	16.90	62.00
January	10	36.00	17.00	66.00
January	11	35.60	18.50	66.00
January	12	34.50	17.20	62.00
January	13	34.00	17.60	69.00
January	14	35.00	17.00	62.00
January	15	35.00	17.00	64.00
January	16	36.00	17.00	53.00
January	17	35.00	18.00	62.00
January	18	33.00	17.50	68.00
January	19	33.50	18.50	62.00
January	20	34.00	17.60	64.00
January	21	36.50	17.30	62.00
January	22	36.00	15.80	55.00
January	23	36.50	16.00	62.00
January	24	36.50	18.00	62.00
January	25	36.40	17.80	62.00
January	26	34.50	18.50	62.00
January	27	34.80	19.00	66.00
January	28	35.00	19.00	62.00

Appendix 2 Continued

January	29	36.00	19.50	62.00
January	30	34.00	20.00	66.00
January	31	35.00	20.00	66.00
February	01	36.50	19.00	62.00
February	02	35.50	20.50	63.00
February	03	36.00	20.50	62.00
February	04	36.50	19.00	63.00
February	05	36.80	19.00	63.00
February	06	35.60	19.00	76.00
February	07	35.80	18.50	76.00
February	08	31.00	19.90	78.00
February	09	32.50	19.90	68.00
February	10	33.50	19.50	68.00
February	11	34.50	19.00	72.00
February	12	34.00	18.90	73.00
February	13	34.00	19.00	59.00
February	14	34.30	19.40	62.00
February	15	34.00	18.50	63.00
February	16	34.60	21.00	66.00
February	17	35.00	21.20	62.00
February	18	34.60	19.00	63.00
February	19	35.00	19.00	68.00
February	20	31.50	19.50	73.00
February	21	33.80	18.90	73.00
February	22	32.50	19.50	73.00
February	23	34.50	19.00	66.00
February	24	34.00	19.00	66.00
February	25	34.30	18.60	69.00
February	26	34.50	18.00	73.00
February	27	34.00	20.50	62.00
February	28	34.00	20.20	62.00
February	29	34.00	20.00	62.00

Appendix 2 Continued

March	01	34.00	19.00	55.00
March	02	35.00	19.00	62.00
March	03	35.00	17.80	62.00
March	04	34.50	18.00	62.00
March	05	35.00	17.50	69.00
March	06	35.00	19.00	65.00
March	07	35.00	19.40	66.00
March	08	35.50	20.50	59.00
March	09	35.00	20.00	73.00
March	10	35.50	20.00	73.00
March	11	35.00	20.00	62.00
March	12	36.00	21.00	70.00
March	13	34.50	21.50	66.00
March	14	33.50	20.00	66.00
March	15	33.80	21.20	66.00
March	16	34.90	20.50	59.00
March	17	35.00	20.00	62.00
March	18	34.70	20.00	59.00
March	19	35.00	20.00	66.00
March	20	35.50	20.00	73.00
March	21	33.50	20.00	66.00
March	22	32.00	21.50	69.00
March	23	33.50	21.00	73.00
March	24	33.00	21.50	66.00
March	25	33.50	21.00	66.00
March	26	35.00	20.60	66.00
March	27	35.90	18.00	80.00
March	28	28.00	19.00	81.00
March	29	31.80	19.00	76.00
March	30	29.00	18.50	81.00
March	31	30.00	19.40	81.00

Appendix 2 continued

Month	Day	Maximum temp °c	Minimum temp °c	Mean temp °c
November	01	32.50	16.30	24.40
November	02	32.50	19.50	26.00
November	03	32.00	19.00	25.50
November	04	32.50	19.50	26.00
November	05	31.90	19.60	25.75
November	06	32.50	19.00	25.75
November	07	33.00	16.00	24.50
November	08	33.00	17.00	25.00
November	09	33.60	17.50	25.55
November	10	33.50	15.50	24.50
November	11	33.60	16.80	25.20
November	12	34.00	17.30	25.65
November	13	34.60	18.00	26.30
November	14	34.60	17.80	26.20
November	15	33.50	19.50	26.50
November	16	03.50	18.00	10.75
November	17	32.50	18.30	25.40
November	18	33.00	18.50	25.75
November	19	33.40	19.30	26.35
November	20	35.50	19.00	27.25
November	21	32.50	20.00	26.25
November	22	32.30	19.90	26.10
November	23	33.50	19.00	26.25
November	24	33.50	20.00	26.75
November	25	33.50	21.00	27.25
November	26	34.20	20.90	27.55
November	27	34.00	21.40	27.70
November	28	34.50	20.00	27.25
November	29	25.20	18.00	21.60
November	30	30.00	19.50	24.75
December	01	31.00	16.80	23.90

Appendix 2 continued

December	02	32.90	17.00	24.95
December	03	32.80	16.50	24.65
December	04	33.20	17.00	25.10
December	05	32.80	16.00	24.40
December	06	33.50	17.20	25.35
December	07	33.50	18.80	26.15
December	08	29.90	16.50	23.20
December	09	33.50	16.50	25.00
December	10	34.20	16.30	25.25
December	11	35.50	16.50	26.00
December	12	33.50	18.00	25.75
December	13	32.90	17.50	25.20
December	14	33.00	18.50	25.75
December	15	32.90	19.00	25.95
December	16	33.50	18.50	26.00
December	17	33.00	18.00	25.50
December	18	33.50	18.50	26.00
December	19	33.80	18.00	25.90
December	20	33.00	19.00	26.00
December	21	34.10	17.50	25.80
December	22	35.00	20.00	27.50
December	23	34.00	18.30	26.15
December	24	35.00	19.60	27.30
December	25	35.00	18.40	26.70
December	26	34.50	17.50	26.00
December	27	34.50	17.50	26.00
December	28	33.00	18.00	25.50
December	29	35.00	18.00	26.50
December	30	33.50	17.30	25.40
December	31	33.00	16.80	24.90
January	01	33.50	16.70	25.10
January	02	36.00	16.00	26.00

Appendix 2 continued

January	03	35.00	18.50	26.75
January	04	34.50	16.80	25.65
January	05	36.00	17.00	26.50
January	06	35.00	17.60	26.30
January	07	33.20	17.80	25.50
January	08	32.30	18.00	25.15
January	09	34.80	16.90	25.85
January	10	36.00	17.00	26.50
January	11	35.60	18.50	27.05
January	12	34.50	17.20	25.85
January	13	34.00	17.60	25.80
January	14	35.00	17.00	26.00
January	15	35.00	17.00	26.00
January	16	36.00	17.00	26.50
January	17	35.00	18.00	26.50
January	18	33.00	17.50	25.25
January	19	33.50	18.50	26.00
January	20	34.00	17.60	25.80
January	21	36.50	17.30	26.90
January	22	36.00	15.80	25.90
January	23	36.50	16.00	26.25
January	24	36.50	18.00	27.25
January	25	36.40	17.80	27.10
January	26	34.50	18.50	26.50
January	27	34.80	19.00	26.90
January	28	35.00	19.00	27.00
January	29	36.00	19.50	27.75
January	30	34.00	20.00	27.00
January	31	35.00	20.00	27.50
February	01	36.50	19.00	27.75
February	02	35.50	20.50	28.00
February	03	36.00	20.50	28.25

Appendix 2 continued

February	04	36.50	19.00	27.75
February	05	36.80	19.00	27.90
February	06	35.60	19.00	27.30
February	07	35.80	18.50	27.15
February	08	31.00	19.90	25.45
February	09	32.50	19.90	26.20
February	10	33.50	19.50	26.50
February	11	34.50	19.00	26.75
February	12	34.00	18.90	26.45
February	13	34.00	19.00	26.50
February	14	34.30	19.40	26.85
February	15	34.00	18.50	26.25
February	16	34.60	21.00	27.80
February	17	35.00	21.20	28.10
February	18	34.60	19.00	26.80
February	19	35.00	19.00	27.00
February	20	31.50	19.50	25.50
February	21	33.80	18.90	26.35
February	22	32.50	19.50	26.00
February	23	34.50	19.00	26.75
February	24	34.00	19.00	26.50
February	25	34.30	18.60	26.45
February	26	34.50	18.00	26.25
February	27	34.00	20.50	27.25
February	28	34.00	20.20	27.10
February	29	34.00	20.00	27.00
March	01	34.00	19.00	26.50
March	02	35.00	19.00	27.00
March	03	35.00	17.80	26.40
March	04	34.50	18.00	26.25
March	05	35.00	17.50	26.25

Appendix 2 continued

March	06	35.00	19.00	27.00
March	07	35.00	19.40	27.20
March	08	35.50	20.50	28.00
March	09	35.00	20.00	27.50
March	10	35.50	20.00	27.75
March	11	35.00	20.00	27.50
March	12	36.00	21.00	28.50
March	13	34.50	21.50	28.00
March	14	33.50	20.00	26.75
March	15	33.80	21.20	27.50
March	16	34.90	20.50	27.70
March	17	35.00	20.00	27.50
March	18	34.70	20.00	27.35
March	19	35.00	20.00	27.50
March	20	35.50	20.00	27.75
March	21	33.50	20.00	26.75
March	22	32.00	21.50	26.75
March	23	33.50	21.00	27.25
March	24	33.00	21.50	27.25
March	25	33.50	21.00	27.25
March	26	35.00	20.60	27.80
March	27	35.90	18.00	26.95
March	28	28.00	19.00	23.50
March	29	31.80	19.00	25.40
March	30	29.00	18.50	23.75
March	31	30.00	19.40	24.70

Appendix 2 Continued

Month	Date	wind speed km/day	sun shine hours	Day length hours
November	01	275.30	07.90	12.20
November	02	180.30	07.20	12.20
November	03	204.30	06.80	12.20
November	04	203.40	06.70	12.20
November	05	201.50	11.20	12.20
November	06	215.60	11.50	12.20
November	07	279.80	07.10	12.20
November	08	206.30	06.20	12.20
November	09	291.30	04.50	12.20
November	10	286.90	09.20	12.20
November	11	238.50	09.90	12.20
November	12	222.10	08.30	12.20
November	13	275.80	09.60	12.20
November	14	315.00	05.20	12.20
November	15	234.00	09.40	12.20
November	16	359.30	08.00	12.20
November	17	311.30	07.80	12.20
November	18	315.60	09.50	12.20
November	19	204.50	10.80	12.20
November	20	223.20	11.50	12.20
November	21	252.10	09.80	12.20
November	22	033.10	10.50	12.20
November	23	382.40	10.60	12.20
November	24	388.00	06.80	12.20
November	25	314.30	09.10	12.20
November	26	269.20	10.90	12.20
November	27	245.60	07.90	12.20
November	28	222.80	08.90	12.20
November	29	216.70	10.80	12.20

Appendix 2 Continued

November	30	281.10	11.80	12.20
December	01	304.40	10.50	12.20
December	02	251.60	11.10	12.20
December	03	239.40	09.60	12.20
December	04	393.60	11.20	12.20
December	05	187.00	08.70	12.20
December	06	133.50	11.20	12.20
December	07	173.20	11.10	12.20
December	08	187.30	09.20	12.20
December	09	181.10	11.50	12.20
December	10	203.90	08.20	12.20
December	11	200.10	07.50	12.20
December	12	293.70	09.40	12.20
December	13	286.70	08.70	12.20
December	14	242.10	08.90	12.20
December	15	223.80	09.50	12.20
December	16	283.10	08.10	12.20
December	17	216.80	06.00	12.20
December	18	258.90	09.30	12.20
December	19	411.40	11.40	12.20
December	20	256.50	10.70	12.20
December	21	204.00	09.40	12.20
December	22	423.80	08.10	12.20
December	23	353.30	11.40	12.20
December	24	267.90	10.70	12.20
December	25	273.60	10.20	12.20
December	26	257.90	10.00	12.20
December	27	277.80	09.90	12.20
December	28	219.70	08.50	12.20
December	29	286.70	08.20	12.20
December	30	249.80	09.10	12.20
December	31	247.30	09.70	12.20
January	01	278.30	09.20	12.20

Appendix 2 Continued

January	02	292.50	10.38	12.20
January	03	395.60	10.27	12.20
January	04	314.90	07.51	12.20
January	05	296.60	10.95	12.20
January	06	241.40	07.86	12.20
January	07	303.70	08.41	12.20
January	08	206.20	06.56	12.20
January	09	281.20	10.96	12.20
January	10	218.50	10.32	12.20
January	11	166.00	09.50	12.20
January	12	256.20	08.12	12.20
January	13	321.00	11.50	12.20
January	14	298.20	09.25	12.20
January	15	291.50	11.98	12.20
January	16	269.00	10.40	12.20
January	17	314.30	10.30	12.20
January	18	387.20	11.94	12.20
January	19	324.80	11.50	12.20
January	20	309.50	11.08	12.20
January	21	325.00	09.20	12.20
January	22	315.10	10.30	12.20
January	23	344.20	11.52	12.20
January	24	279.60	06.34	12.20
January	25	268.80	10.89	12.20
January	26	278.90	10.20	12.20
January	27	214.60	09.80	12.20
January	28	264.30	09.70	12.20
January	29	339.60	10.20	12.20
January	30	388.30	09.15	12.20
January	31	390.60	09.70	12.20
February	01	418.40	08.27	12.20
February	02	354.60	09.20	12.20

Appendix 2 Continued

February	03	498.25	07.30	12.20
February	04	202.40	07.50	12.20
February	05	208.70	08.50	12.20
February	06	417.20	09.20	12.20
February	07	282.70	10.10	12.20
February	08	389.70	08.30	12.20
February	09	301.60	07.10	12.20
February	10	303.50	06.17	12.20
February	11	283.40	08.08	12.20
February	12	259.60	07.14	12.20
February	13	248.60	10.95	12.20
February	14	299.40	08.04	12.20
February	15	206.50	11.57	12.20
February	16	310.50	00.59	12.20
February	17	177.10	05.88	12.20
February	18	271.50	07.84	12.20
February	19	371.30	09.22	12.20
February	20	188.60	09.05	12.20
February	21	264.40	09.55	12.20
February	22	277.50	08.91	12.20
February	23	289.10	04.96	12.20
February	24	370.80	10.67	12.20
February	25	352.40	12.25	12.20
February	26	309.50	09.28	12.20
February	27	336.60	08.32	12.20
February	28	385.50	10.93	12.20
February	29	316.40	08.23	12.10
March	01	283.60	04.35	12.10
March	02	224.30	09.81	12.10
March	03	345.00	11.57	12.10
March	04	216.10	09.40	12.10
March	05	313.90	09.10	12.10

Appendix 2 Continued

March	06	340.20	10.20	12.10
March	07	335.50	10.10	12.10
March	08	423.40	09.28	12.10
March	09	363.70	08.10	12.10
March	10	320.00	09.18	12.10
March	11	412.60	09.70	12.10
March	12	424.80	10.10	12.10
March	13	370.10	09.20	12.10
March	14	356.90	05.45	12.10
March	15	379.50	11.99	12.10
March	16	426.10	11.64	12.10
March	17	355.50	10.50	12.10
March	18	363.70	10.62	12.10
March	19	320.10	08.12	12.10
March	20	412.60	03.95	12.10
March	21	424.80	07.90	12.10
March	22	364.60	11.48	12.10
March	23	356.90	09.18	12.10
March	24	380.00	09.20	12.10
March	25	429.60	08.60	12.10
March	26	355.50	11.15	12.10
March	27	293.60	11.53	12.10
March	28	434.90	11.85	12.10
March	29	351.90	10.43	12.10
March	30	314.40	11.22	12.10
March	31	316.20	12.10	12.10

Appendix 2 continued

Date		Evaporation mm	Rainfall mm
November	01	08.20	0.00
November	02	07.40	0.00
November	03	08.80	0.00
November	04	07.70	0.00
November	05	08.30	0.00
November	06	09.20	0.00
November	07	09.70	0.00
November	08	10.20	0.00
November	09	09.90	0.00
November	10	10.20	0.00
November	11	09.80	0.00
November	12	10.70	0.00
November	13	10.00	0.00
November	14	10.60	0.00
November	15	09.80	0.00
November	16	10.30	0.00
November	17	10.80	0.00
November	18	10.60	0.00
November	19	11.00	0.00
November	20	09.60	0.00
November	21	07.20	0.00
November	22	07.70	0.00
November	23	07.40	0.00
November	24	08.30	0.00
November	25	07.30	0.00
November	26	08.20	0.00
November	27	07.50	0.00
November	28	07.20	7.50
November	29	06.80	0.00
November	30	06.80	0.00

Appendix 2 continued

December	01	07.30	0.00
December	02	06.60	0.00
December	03	07.40	0.00
December	04	07.60	0.00
December	05	07.90	0.00
December	06	08.00	0.00
December	07	08.30	0.00
December	08	07.90	0.00
December	09	08.60	0.00
December	10	08.00	0.00
December	11	07.70	0.00
December	12	08.60	0.00
December	13	08.30	0.00
December	14	07.20	13.70
December	15	07.60	0.00
December	16	08.40	0.00
December	17	08.00	0.00
December	18	07.60	6.20
December	19	08.70	0.00
December	20	09.00	0.00
December	21	08.30	0.00
December	22	07.80	0.00
December	23	08.30	0.00
December	24	09.40	0.00
December	25	07.60	18.30
December	26	08.10	0.00
December	27	07.20	0.00
December	28	09.20	0.00
December	29	09.00	0.00
December	30	07.80	0.00
December	31	08.80	0.00
January	01	08.40	0.00
January	02	09.40	0.00
January	03	08.30	0.00
January	04	04.00	0.00
January	05	04.20	0.00

Appendix 2 continued

January	06	04.50	20.70
January	07	05.30	0.00
January	08	07.70	0.00
January	09	07.70	0.00
January	10	09.10	0.00
January	11	07.90	0.00
January	12	08.00	0.00
January	13	10.00	0.00
January	14	07.10	0.00
January	15	04.50	0.00
January	16	010.60	0.00
January	17	06.00	0.00
January	18	11.00	0.00
January	19	08.90	0.00
January	20	09.40	0.00
January	21	08.50	0.00
January	22	09.10	0.00
January	23	04.60	0.00
January	24	06.70	0.00
January	25	08.20	0.00
January	26	07.20	0.00
January	27	06.90	7.30
January	28	04.30	0.00
January	29	06.50	0.00
January	30	06.40	0.00
January	31	07.20	0.00
February	01	05.80	5.50
February	02	06.40	0.00
February	03	07.30	0.00
February	04	07.80	0.00
February	05	08.00	0.00
February	06	08.60	64.20
February	07	07.40	0.00
February	08	08.60	0.00
February	09	07.20	0.00
February	10	08.00	0.00

Appendix 2 continued

February	11	08.80	0.00
February	12	70.60	0.00
February	13	08.20	0.00
February	14	07.40	0.00
February	15	08.80	0.00
February	16	08.20	0.00
February	17	07.40	29.50
February	18	08.20	0.00
February	19	08.60	13.80
February	20	08.00	0.00
February	21	02.70	0.00
February	22	07.80	0.00
February	23	08.20	3.20
February	24	08.60	0.00
February	25	10.10	0.00
February	26	09.60	0.00
February	27	08.60	0.00
February	28	08.20	0.00
February	29	07.80	0.00
March	01	08.20	0.00
March	02	07.40	0.00
March	03	08.80	0.00
March	04	07.70	0.00
March	05	08.30	0.00
March	06	09.20	0.00
March	07	09.70	0.00
March	08	10.20	0.00
March	09	09.90	0.00
March	10	10.20	0.00
March	11	09.80	0.00
March	12	10.70	0.00
March	13	10.00	0.00
March	14	10.60	0.00
March	15	09.80	0.00
March	16	10.30	0.00
March	17	10.80	0.00

Appendix 2 continued

March	18	10.60	0.00
March	19	11.00	0.00
March	20	09.60	0.00
March	21	07.20	0.00
March	22	07.70	0.00
March	23	07.40	11.40
March	24	08.30	0.00
March	25	07.30	0.00
March	26	08.20	0.00
March	27	07.50	8.20
March	28	07.20	1.30
March	29	06.80	72.70
March	30	06.80	0.00
March	31	07.30	0.00

Appendix 3 Mean Seepage & Percolation (S&P) values

Block	S&P
MS 3-1	1.86
MS 5-1	3.98
RS 1-1	5.26
RS 4-1	5.29

t-student distribution test for S&P values

Block	Plot	Number of	Average	Std	Vars	Sum	SS
RS4-1		Observation	value				
RS 4-1	103	29	5.9	3.2	10.2	170.4	1284.48
	204	30	4.7	3.2	10.2	142.2	0963.82

Corrected sum of squares-plot 103 = 285.90
Corrected sum of squares -plot 204 = 291.69
The pooled within group variance = 10.13
Mean value Xm = 5.29
t-statistic calculated = 1.75
From tables t- tabulated at 5 % level with degree of freedom 57 is 2.00
Since t-cal < t- tab then no significant difference between the two means.
For the Confidence Interval (CI):
Standard Error = 0.99
Therefore the CI at 5% confidence level = 4.3 < u< 6.28
The mean seepage and percolation rate for Block RS 4-1 is 5.29 mm/day

Block	Plot	Number of	Average	Stds	Vars	Sum	SS
RS 1-1		Observation	value				
	105	19	5.5	2.3	5.29	102.7	656.03
	201	13	4.9	2.32	5.38	63.7	376.47

Appendix 3 continued

Corrected sum of squares-plot 105 = 100.91
Corrected sum of squares-plot 201 = 64.34
The pooled within group variance = 5.51
Mean value Xm = 5.26
t-statistic calculated = 0.70
From tables t tabulated at 5 % level with degree of freedom = 30 is 2.042
Since t-cal < t-tab then no significant difference between the two means.
For the Confidence Interval (CI):
Standard Error = 1.02
Therefore the CI at 5% confidence level is 4.24 $< \mu < 6.28$
From which the mean Seepage & Percolation rate for Block RS 1-1 is 5.26 mm/day

Block MS3-1	Plot	Number of Observation	Average value	Stds	Vars	Sum	SS
	110	9	2.52	2.11	4.44	22.7	92.79
	301	10	1.26	1.28	1.649	12.6	30.72

Corrected sum of squares-plot 110 = 34.75
Corrected sum of squares-plot 301 = 14.84
The pooled within group variance = 2.92
Mean value Xm = 1.86
t-statistic calculated = 2.04
From tables t- tabulated at 5% level with degree of freedom = 17 is 2.11
Since tcal < t tab then no significant difference between the two means.
For the Confidence Interval(CI):
Standard Error = 1.01
Therefore, the CI at 5% confidence level 0.85 $< \mu <$ 2.87
From which the mean S&P rate for MS 3-1block is 1.86 mm/day

Appendix 3 Continued

Block MS 5-1	Plot	Number of Observation	Average value	Stds	Vars	Sum	SS
	203	9	3.42	3.42	11.68	32.9	213.71
	315	13	4.36	3.00	9.00	56.7	355.35

Corrected sum of squares = 93.44
Corrected sum of squares = 108.05
The pooled within group variance = 10.07
Mean value Xm = 03.98
t-statistic = 0.05
t- tabulated at 5% level with degree of freedom 20 is 2.09
Since t-cal < t-tab then no significant difference between the two means.
For the Confidence Interval (CI):
standard Error = 1.70
Therefore the CI at 5% confidence level $3.81 < \mu < 5.68$
The mean seepage and percolation rate for MS 5-1 block 3.98 mm/day

Appendix 4 RELATIVE WATER SUPPLY(RWS)

BLOCK MS 3-1 Farmer No. F42/3-1

RWS = (IW+RE)/(ETc+S&P)

Date of IWD	IW mm	RE mm		ETc mm/day		S&P mm/day		RWS
03-Nov-95	38.0	0.00	0.00	6.7	27.8	1.9	7.4	1.1
04-Nov-95		0.0		6.4		1.9		
05-Nov-95		0.0		7.2		1.9		
06-Nov-95		0.0		7.5		1.9		
07-Nov-95	39.0	0.0	0.0	6.6	57.6	1.9	14.9	0.5
08-Nov-95		0.0		6.7		1.9		
09-Nov-95		0.0		7.3		1.9		
10-Nov-95		0.0		7.5		1.9		
11-Nov-95		0.0		7.3		1.9		
12-Nov-95		0.0		7.2		1.9		
13-Nov-95		0.0		7.6		1.9		
14-Nov-95		0.0		7.4		1.9		
15-Nov-95	50.0	0.0	0.0	7.7	30.0	1.9	7.4	1.3
16-Nov-95		0.0		7.6		1.9		
17-Nov-95		0.0		7.4		1.9		
18-Nov-95		0.0		7.3		1.9		
19-Nov-95	75.	0.0	0.0	7.6	62.8	1.9	14.9	1.0
20-Nov-95		0.0		7.9		1.9		
21-Nov-95		0.0		7.9		1.9		
22-Nov-95		0.0		7.8		1.9		
23-Nov-95		0.0		8.2		1.9		
24-Nov-95		0.0		7.7		1.9		
25-Nov-95		0.0		7.9		1.9		
26-Nov-95		0.0		7.9		1.9		
27-Nov-95	37.0	0.0	7.5	7.5	30.8	1.9	7.4	1.2
28-Nov-95		7.5		7.6		1.9		
29-Nov-95		0.0		7.9		1.9		
30-Nov-95		0.0		7.8		1.9		

Appendix 4 continued

01-Dec-95	79.0	0.0	0.0	7.5	58.7	1.9	14.9	1.1
02-Dec-95		0.0		7.3		1.9		
03-Dec-95		0.0		7.4		1.9		
04-Dec-95		0.0		7.7		1.9		
05-Dec-95		0.0		7.0		1.9		
06-Dec-95		0.0		7.0		1.9		
07-Dec-95		0.0		7.4		1.9		
08-Dec-95		0.0		7.4		1.9		
09-Dec-95	48.0	0.0	0.0	7.4	28.9	1.9	7.4	1.3
10-Dec-95		0.0		7.1		1.9		
11-Dec-95		0.0		7.0		1.9		
12-Dec-95		0.0		7.5		1.9		
13-Dec-95	61.0	0.0	19.9	7.6	62.7	1.9	14.9	1.0
14-Dec-95		13.7		7.4		1.9		
15-Dec-95		0.0		8.0		1.9		
16-Dec-95		0.0		7.9		1.9		
17-Dec-95		0.0		7.9		1.9		
18-Dec-95		6.2		7.9		1.9		
19-Dec-95		0.0		8.1		1.9		
20-Dec-95		0.0		8.0		1.9		
21-Dec-95	63.0	0.0	18.3	8.0	64.1	1.9	14.9	1.0
22-Dec-95		0.0		8.3		1.9		
23-Dec-95		0.0		8.0		1.9		
24-Dec-95		0.0		8.2		1.9		
25-Dec-95		18.3		8.2		1.9		
26-Dec-95		0.0		8.1		1.9		
27-Dec-95		0.0		7.9		1.9		
28-Dec-95		0.0		7.5		1.9		
29-Dec-95	53.0	0.0	0.0	8.0	31.9	1.9	7.4	1.3
30-Dec-95		0.0		7.8		1.9		
31-Dec-95		0.0		8.0		1.9		
01-Jan-96		0.0		8.1		1.9		

Appendix 4 continued

02-Jan-96	54.0	0.0	20.0	8.8	49.2	1.9	11.2	1.2
03-Jan-96		0.0		8.1		1.9		
04-Jan-96		0.0		8.2		1.9		
05-Jan-96		0.0		8.4		1.9		
06-Jan-96		20.7		7.9		1.9		
07-Jan-96		0.0		7.9		1.9		
08-Jan-96	33.0	0.0	0.0	7.2	30.9	1.9	7.4	0.9
09-Jan-96		0.0		8.4		1.9		
10-Jan-96		0.0		7.9		1.9		
11-Jan-96		0.0		7.4		1.9		
12-Jan-96	41.0	0.0	0.0	7.8	32.3	1.9	7.4	1.0
13-Jan-96		0.0		8.3		1.9		
14-Jan-96		0.0		8.7		1.9		
15-Jan-96		0.0		7.5		1.9		
16-Jan-96	47.0	0.0	0.0	8.3	33.1	1.9	7.4	1.2
17-Jan-96		0.0		8.0		1.9		
18-Jan-96		0.0		8.3		1.9		
19-Jan-96		0.0		8.5		1.9		
20-Jan-96	36.0	0.0	0.0	7.9	31.6	1.9	7.4	0.9
21-Jan-96		0.0		7.9		1.9		
22-Jan-96		0.0		8.0		1.9		
23-Jan-96		0.0		7.9		1.9		
24-Jan-96	40.0	0.0	7.3	7.5	30.5	1.9	7.4	1.2
25-Jan-96		0.0		7.3		1.9		
26-Jan-96		0.0		7.8		1.9		
27-Jan-96		7.3		7.9		1.9		
28-Jan-96	42.0	0.0	0.0	7.7	31.6	1.9	7.4	1.1
29-Jan-96		0.0		8.2		1.9		
30-Jan-96		0.0		8.0		1.9		
31-Jan-96		0.0		7.8		1.9		
01-Feb-96	53.0	5.5	69.7	8.3	57.8	1.9	14.9	1.7
02-Feb-96		0.0		7.7		1.9		
03-Feb-96		0.0		7.4		1.9		
04-Feb-96		0.0		6.7		1.9		
05-Feb-96		0.0		7.0		1.9		

Appendix 4 continued

06-Feb-96		64.2		7.2		1.9		
07-Feb-96		0.0		6.7		1.9		
08-Feb-96		0.0		6.8		1.9		
09-Feb-96	64.0	0.0	0.0	6.6	25.9	1.9	7.4	1.9
10-Feb-96		0.0		6.5		1.9		
11-Feb-96		0.0		6.5		1.9		
12-Feb-96		0.0		6.2		1.9		
13-Feb-96	48.0	0.0	0.0	6.7	19.3	1.9	5.6	1.9
14-Feb-96		0.0		6.4		1.9		
15-Feb-96		0.0		6.3		1.9		
				Season mean RWS				1.2

NOTE: IWD = Irrigation water delivery

Appendix 5 FARMERS' UTILITY OF IRRIGATION WATER SUPPLY

Block MS 3-1 Farmers' Utility of Irrigation Water Supply.

Farmer No.	Depend.	Factor Timing of Planting	Flow rate		
	FJ/FI	FJ/FI	FJ/FI	FC	FU
F01/3-1	VG/H	VG/H	VG/H	HIGH	0.85
F02/3-1	VG/H	VG/VH	MLG/VH	HIGH	0.79
F03/3-1	G/H	M/VH	G/H	MLH	0.72
F04/3-1	MLG/H	MLG/H	VG/H	MLH	0.78
F05/3-1	MLG/H	VG/H	MLG/VH	MLH	0.75
F06/3-1	M/VH	M/H	G/H	MLH	0.65
F07/3-1	MLG/VH	MLG/VH	MLG/VH	MLH	0.72
F08/3-1	VG/H	VG/H	VG/VH	MLH	0.72
F09/3-1	M/H	M/VH	MLG/H	MLH	0.78
F10/3-1	M/H	M/VH	MLG/H	MED	0.61
F11/3-1	MLG/VH	MLG/VH	G/VH	MLH	0.75
F12/3-1	G/H	MLG/MLH	G/H	MLH	0.71
F13/3-1	VG/H	VG/MLH	VG/H	HIGH	0.85
F14/3-1	VG/VH	VG/H	MLG/VH	HIGH	0.79
F15/3-1	VG/VH	VG/H	MLG/VH	HIGH	0.79
F16/3-1	VG/VH	VG/VH	MLG/VH	HIGH	0.78
F17/3-1	G/VH	G/H	MLG/H	MLH	0.77
F18/3-1	VG/VH	G/H	G/H	HIGH	0.84
F19/3-1	VG/H	VG/H	MLG/VH	MLH	0.78
F20/3-1	VG/MLH	MLG/H	VG/VH	MLH	0.78
F21/3-1	VG/VH	MLG/VH	MLG/VH	MLH	0.77
F22/3-1	VG/H	VG/H	MLG/H	MLH	0.77
F23/3-1	MLG/H	MLG/H	G/VH	MLH	0.73
F24/3-1	G/H	VG/H	G/VH	HIGH	0.85
F25/3-1	MLG/H	VG/H	MLG/H	MLH	0.73
F26/3-1	MLG/VH	MLG/VH	MLG/H	MLH	0.73

Appendix 5 continued

F27/3-1	VG/H	VG/VH	G/VH	HIGH	0.88
F28/3-1	VG/VH	VG/VH	MLG/VH	HIGH	0.78
F29/3-1	VG/VH	VG/VH	VG/VH	VHIGH	0.89
F30/3-1	VG/VH	VG/VH	VG/VH	VHIGH	0.89
F31/3-1	VG/VH	VG/VH	VG/VH	VHIGH	0.89
F32/3-1	VG/H	VG/H	MLG/VH	MLH	0.78
F33/3-1	MLG/H	G/MLH	MLG/H	MLH	0.70
F34/3-1	G/MLH	VG/MLH	G/MLH	HIGH	0.80
F35/3-1	VG/H	VG/H	VG/H	HIGH	0.85
F36/3-1	VG/H	VG/VH	VG/VH	VHIGH	0.89
F37/3-1	G/VH	MLG/H	MLG/M	MLH	0.72
F38/3-1	M/VH	MLG/MLH	MLG/MLH	MLH	0.63
F39/3-1	VG/H	MLG/H	G/MLH	MLH	0.72
F40/3-1	G/H	MLG/VH	G/MLH	MLH	0.73
F41/3-1	VG/H	VG/HV	G/H	HIGH	0.85
F42/3-1	G/VH	MLG/H	G/H	MLH	0.74
F43/3-1	VG/VH	VG/VH	G/VH	VHIGH	0.89
F44/3-1	MLG/H	MLG/H	MLG/VH	MLH	0.73
F45/3-1	G/H	VG/H	G/H	HIGH	0.82
F46/3-1	G/VH	G/H	M/H	MLH	0.73
F47/3-1	G/VH	G/VH	M/VH	MLH	0.70
F48/3-1	VG/VH	G/H	G/VH	HIGH	0.86
F49/3-1	VG/H	VG/H	VG/VH	HIGH	0.88
F50/3-1	VG/MLH	G/MLH	VG/MLH	HIGH	0.80

Appendix 5 continued

Block MS 5-1 Famers' Utility of Irrigation Water Supply

Farmer	Dep	Factor Timing of	Flow rate planting	FC	FU
F01/5-1	MLG/H	G/H	VG/VH	HIGH	0.88
F02/5-1	MLG/VH	MLG/VH	G/VH	MLH	0.75
F03/5-1	VG/H	G/H	VG/H	HIGH	0.85
F04/5-1	MLB/H	G/H	MLB/M	MED	0.57
F05/5-1	B/VH	G/VH	MLB/H	MED	0.49
F06/5-1	VG/VH	MLB/MLH	G/MLH	MLH	0.68
F07/5-1	MLB/MLH	G/HML	B/H	MED	0.61
F08/5-1	VG/VH	MLH/VH	G/H	MLH	0.78
F09/5-1	VG/VH	G/H	VG/MLH	HIGH	0.85
F10/5-1	VG/MLH	VH/H	G/H	HIGH	0.83
F11/5-1	G/MLH	MLB/H	MLG/MLH	MLH	0.62
F12/5-1	G/H	MLG/H	MLG/VH	MLH	0.73
F13/5-1	B/H	VG/H	M/VH	MED	0.56
F14/5-1	MLG/H	VG/VH	MLB/VH	MLH	0.64
F15/5-1	VG/H	VG/VH	VG/VH	VHIG	0.89
F16/5-1	VG/H	VG/VH	VG/VH	VHIG	0.89
F17/5-1	G/MLH	MLB/H	MLG/MLH	MLH	0.62
F18/5-1	MLG/H	G/H	MLG/VH	MLH	0.73
F19/5-1	B/H	MLB/H	G/VH	MED	0.47
F20/5-1	G/H	MLG/VH	G/M	MLH	0.73
F21/5-1	G/H	G/VH	VG/H	HIGH	0.85
F22/5-1	MLG/VH	MLG/H	VG/H	MLH	0.75
F23/5-1	VG/VH	G/VH	VG/VH	MLH	0.77
F24/5-1	VG/MLH	G/VH	VG/H	HIGH	0.85
F25/5-1	G/MLH	G/H	VG/H	HIGH	0.81
F26/5-1	MLB/H	MLG/M	MLB/H	MLL	0.48
F27/5-1	MLB/VH	MLG/M	MLB/H	MLL	0.47
F28/5-1	MLB/VH	MLG/M	MLB/H	MLL	0.47
F29/5-1	MLG/H	VG/H	MLG/VH	MLH	0.75
F30/5-1	MLG/VH	G/H	M/H	MLH	0.71
F31/5-1	G/VH	G/VH	G/H	HIGH	0.85

Appendix 5 continued

F32/5-1	M/MLH	MLG/MLH	M/MLH	MED	0.57
F33/5-1	VG/H	MLG/H	VG/H	MLH	0.77
F34/5-1	MLB/H	MLG/VH	MLB/VH	MED	0.47
F35/5-1	M/H	MLG/M	MLG/H	MLH	0.63
F36/5-1	G/VH	MLG/H	MLB/H	MLH	0.66
F37/5-1	G/H	MLB/M	MLG/H	MLH	0.68
F38/5-1	G/M	MLB/H	MLG/H	MED	0.61
F39/5-1	VG/M	MLB/VH	MLG/VH	MED	0.62
F40/5-1	G/H	G/H	G/H	HIGH	0.81
F41/5-1	MLG/MLH	G/MLH	VG/MLH	HIGH	0.72
F42/5-1	MLG/H	G/H	VG/H	MLH	0.74
F43/5-1	VG/H	VB/H	MLG/M	MED	0.61
F44/5-1	VG/H	MLB/H	VG/H	MLH	0.73
F45/5-1	MLG/H	MLG/MLH	MLG/MLH	MLH	0.67
F46/5-1	MLG/H	MLG/H	VG/M	MLH	0.70
F47/5-1	VG/H	MLG/MLH	G/MLH	HIGH	0.75
F48/5-1	MLG/VH	MLG/VH	MLH/H	MLH	0.73
F49/5-1	B/M	MLG/H	G/H	MED	0.59
F50/5-1	VG/VH	MLG/H	H/H	MLH	0.77
F51/5-1	G/H	M/H	H/H	MLH	0.71

Appendix 5 Continued

Block RS 1-1 Farmers' Utility of Irrigation water Supply

Farmer No	Factor Dep	Timing of planting	Flow rate	FC	FU
F 01/1-1	VB/H	VB/H	M/H	MLL	0.33
F 02/1-1	M/VH	VB/H	MLG/H	MED	0.51
F 03/1-1	M/MLH	VB/MLH	MLG/H	MED	0.56
F 04/1-1	G/VHV	B/VH	MLG/H	MED	0.61
F 05/1-1	VG/VH	VB/VH	VG/H	MLH	0.68
F 06/1-1	VG/VH	VB/VH	VG/H	MLH	0.68
F 07/1-1	VG/VH	VB/H	VG/VH	MLH	0.70
F 08/1-1	G/VH	B/H	VG/VH	MLH	0.67
F 09/1-1	G/VH	B/H	VG/VH	MLH	0.67
F 10/1-1	G/VH	B/VH	MLG/H	MED	0.61
F 11/1-1	MLG/VH	VB/VH	M/H	MED	0.49
F 12/1-1	G/H	B/H	MLG/VH	MED	0.61
F 13/1-1	G/H	B/VH	VG/H	MLH	0.65
F 14/1-1	G/H	B/H	VG/H	MLH	0.70
F 15/1-1	MLG/H	B/H	MLG/H	MED	0.59
F 16/1-1	VG/VH	VB/H	VG/VH	MLH	0.70
F 17/1-1	VG/VH	VB/H	VG/VH	MLH	0.70
F 18/1-1	VG/VH	VB/H	M/H	MED	0.55
F 19/1-1	VG/VH	B/H	G/VH	MLH	0.67
F 20/1-1	MLG/H	VB/MLH	G/H	MED	0.63
F 21/1-1	G/H	B/H	G/VH	MLH	0.65
F 22/1-1	VG/H	B/H	MLG/H	MED	0.64
F 23/1-1	VG/VH	VB/H	M/H	MED	0.55
F 24/1-1	M/VH	M/VH	M/VH	MED	0.54
F 25/1-1	VB/VH	VB/H	MLB/H	MLL	0.24
F 26/1-1	G/H	VB/H	MLB/H	MED	0.59
F 27/1-1	G/VH	VB/VH	MLG/H	MED	0.61

Appendix 5 Continued

F 28/1-1	VG/VH	VB/VH	VG/VH	MLH	0.68
F 29/1-1	VG/HV	B/H	VG/H	MLH	0.65
F 30/1-1	VG/VH	VB/VH	VG/H	MLH	0.68
F 31/1-1	VG/VH	VB/H	VG/VH	MLH	0.70
F 32/1-1	VG/VH	VB/H	VG/H	MLH	0.67
F 33/1-1	VG/VH	VB/VH	G/H	MLH	0.65
F 34/1-1	VG/VH	VB/VH	M/VH	MED	0.51
F 35/1-1	VB/VH	VB/VH	M/VH	MLL	0.26
F 36/1-1	VB/VH	VB/VH	M/VHMLL	MED	0.26
F 37/1-1	VB/VH	VB/H	M/H	MED	0.55
F 38/1-1	M/VH	VB/H	M/VH	MLL	0.44
F 39/1-1	G/VH	VB/H	M/H	MED	0.52
F 40/1-1	VG/H	VB/H	VG/H	MLH	0.65
F 41/1-1	VG/VH	VB/VH	G/H	MLH	0.65
F 42/1-1	G/VH	VB/H	M/H	MED	0.52
F 43/1-1	G/VH	VB/VH	M/H	MED	0.52
F 44/1-1	VG/H	B/H	VG/VH	MLH	0.67
F 45/1-1	G/H	VB/VH	VG/H	MLH	0.65
F 46/1-1	VG/H	B/H	VG/H	MLH	0.70
F 47/1-1	MLG/VH	VB/H	G/H	MED	0.61
F 48/1-1	MLG/H	B/H	MLG/H	MED	0.59
F 49/1-1	MLG/VH	B/VH	M/VH	MED	0.52
F 50/1-1	VG/H	B/H	VG/VH	MLH	0.67

Appendix 5 continued

Block RS 4-1 Farmers' Utility of Irrigation Water Supply

Farmer	Depend FJ/FI	Factor Timing of planting FJ/FI	Flow rate FJ/FI	FC	FU
F 01/4-1	VG/H	VB/VH	G/H	MLH	0.65
F 02/4-1	M/H	B/H	G/M	MED	0.55
F 03/4-1	M/H	B/H	M/M	MLL	0.46
F 04/4-1	MLG/VH	VB/VH	MLG/H	MED	0.56
F 05/4-1	G/VH	VB/VH	MLG/H	MED	0.61
F 06/4-1	G/H	B/H	M/H	MED	0.53
F 07/4-1	VG/M	VB/H	M/H	MED	0.54
F 08/4-1	G/H	B/H	M/VH	MED	0.54
F 09/4-1	MLB/H	VB/VH	M/VH	MLL	0.32
F 10/4-1	MLB/H	VB/VH	G/H	MED	0.46
F 11/4-1	MLB/VH	VB/VH	M/VH	MLL	0.30
F 12/4-1	MLB/H	VB/H	VG/H	MLL	0.33
F 13/4-1	VB/H	VB/H	VB/H	VLOW	0.14
F 14/4-1	MLB/VH	B/VH	G/VH	MED	0.45
F 15/4-1	VG/HV	B/H	B/H	MLL	0.44
F 16/4-1	VG/VH	VB/H	M/MLH	MED	0.57
F 17/4-1	G/H	B/VH	G/H	MLH	0.64
F 18/4-1	G/H	B/H	M/H	MED	0.53
F 19/4-1	MLG/H	VB/VH	MLG/VH	MED	0.56
F 20/4-1	MLG/H	VBVH	MLG/VH	MED	0.56
F 21/4-1	VG/H	M/H	VG/H	MLH	0.74
F 22/4-1	MLG/H	MLB/VH	MLG/M	MED	0.59
F 23/4-1	MLG/VH	MLB/H	VG/H	MLH	0.67
F 24/4-1	G/M	B/H	M/H	MED	0.55
F 25/4-1	G/M	VB/H	M/H	MED	0.51
F 26/4-1	VG/H	B/VH	VG/H	MLH	0.65
F 27/4-1	VG/VH	MLB/H	VG/MLH	MLH	0.70
F 28/4-1	MLG/H	VB/H	MLG/H	MED	0.56

Appendix 5 Continued

F 29/4-1	G/H	B/VH	G/H	MLH	0.64
F 30/4-1	B/H	B/H	VG/VH	MED	0.51
F 31/4-1	G/M	VB/VH	G/MLH	MED	0.60
F 32/4-1	VG/VH	B/H	G/MLH	MLH	0.66
F 33/4-1	VG/VH	B/H	G/MLH	MLH	0.66
F 34/4-1	VG/VH	B/H	G/MLH	MLH	0.66
F 35/4-1	VG/VH	B/H	G/MLH	MLH	0.66
F 36/4-1	G/H	MLB/H	G/H	MLH	0.71
F 37/4-1	VG/H	VB/H	VG/VH	MLH	0.67
F 38/4-1	VG/VH	VB/H	VG/H	MLL	0.67
F 39/4-1	MLG/MLH	VB/H	MLG/MLH	MED	0.59
F 40/4-1	MLG/MLH	VB/H	MLG/MLH	MED	0.59
F 41/4-1	G/VH	VB/VH	G/VH	MED	0.63
F 42/4-1	G/H	VB/VH	VG/VH	MLH	0.65
F 43/4-1	G/H	VB/VH	VG/VH	MLH	0.65
F 44/4-1	G/H	VB/VH	VG/VH	MLH	0.65
F 45/4-1	VG/H	VB/M	G/H	MLH	0.72
F 46/4-1	VG/H	VB/H	G/H	MLH	0.65
F 47/4-1	G/VH	B/VH	G/VH	MLH	0.65
F 48/4-1	MLG/H	MLB/H	MLG/MLH	MED	0.60
F 49/4-1	G/H	VB/H	VG/H	MLH	0.65
F 50/4-1	G/H	VB/VH	VG/VH	MLH	0.65
F 51/4-1	VG/H	VB/M	G/H	MLH	0.72

Appendix 6 Aggregation of Farmer's opinions into utility values

Block MS 3-1 Farmer's judgment on dependability of irrigation water supply November, 1995 - March, 1996 season.
Opinions on judgement

Farmer No.	FJ	Dependability $\mu(1)$	$\mu(2)$	Judgement support function definition $\mu(3)$	$\mu(4)$	$\mu(5)$
F01/3-1	VG	0.00	0.00	0.01	0.25	1.00
F02/3-1	VG	0.00	0.00	0.01	0.25	1.00
F03/3-1	G	0.00	0.00	0.10	0.50	1.00
F04/3-1	MLG	0.00	0.00	0.40	1.00	0.40
F05/3-1	MLG	0.00	0.00	0.40	1.00	0.40
F06/3-1	M	0.00	0.40	1.00	0.40	0.00
F07/3-1	M	0.00	0.40	1.00	0.40	0.00
F08/3-1	MLG	0.00	0.00	0.40	1.00	0.40
F09/3-1	VG	0.00	0.00	0.01	0.25	1.00
F10/3-1	M	0.00	0.40	1.00	0.40	0.00
F11/3-1	MLG	0.00	0.00	0.40	1.00	0.40
F12/3-1	G	0.00	0.00	0.10	0.50	1.00
F13/3-1	VG	0.00	0.00	0.01	0.25	1.00
F14/3-1	VG	0.00	0.00	0.01	0.25	1.00
F15/3-1	VG	0.00	0.00	0.01	0.25	1.00
F16/3-1	VG	0.00	0.00	0.01	0.25	1.00
F17/3-1	G	0.00	0.00	0.01	0.50	1.00
F18/3-1	VG	0.00	0.00	0.01	0.25	1.00
F19/3-1	VG	0.00	0.00	0.01	0.25	1.00
F20/3-1	VG	0.00	0.00	0.01	0.25	1.00
F21/3-1	VG	0.00	0.00	0.01	0.25	1.00
F22/3-1	VG	0.00	0.00	0.01	0.25	1.00
F23/3-1	MLG	0.00	0.00	0.40	1.00	0.40
F24/3-1	G	0.00	0.00	0.10	0.50	1.00
F25/3-1	MLG	0.00	0.00	0.40	1.00	0.40

Appendix 6 continued

F26/3-1	MLG	0.00	0.00	0.40	1.00		0.40
F27/3-1	VG	0.00	0.00	0.01	0.25		1.00
F28/3-1	VG	0.00	0.00	0.01	0.25		1.00
F29/3-1	VG	0.00	0.00	0.01	0.25		1.00
F30/3-1	VG	0.00	0.00	0.01	0.25		1.00
F31/3-1	VG	0.00	0.00	0.01	0.25		1.00
F32/3-1	VG	0.00	0.00	0.01	0.25		1.00
F33/3-1	MLG	0.00	0.00	0.40	1.00		0.40
F34/3-1	G	0.00	0.00	0.10	0.50		1.00
F35/3-1	VG	0.00	0.00	0.01	0.25		1.00
F36/3-1	VG	0.00	0.00	0.01	0.25		1.00
F37/3-1	G	0.00	0.00	0.10	0.50		1.00
F38/3-1	M	0.00	0.40	1.00	0.40		0.00
F39/3-1	VG	0.00	0.00	0.01	0.25		1.00
F40/3-1	G	0.00	0.00	0.10	0.50		1.00
F41/3-1	VG	0.00	0.00	0.01	0.25		1.00
F42/3-1	G	0.00	0.00	0.10	0.50		1.00
F43/3-1	VG	0.00	0.00	0.01	0.25		1.00
F44/3-1	MLG	0.00	0.00	0.40	1.00		0.40
F45/3-1	G	0.00	0.00	0.10	0.50		1.00
F46/3-1	G	0.00	0.00	0.10	0.50		1.00
F47/3-1	G	0.00	0.00	0.10	0.50		1.00
F48/3-1	VG	0.00	0.00	0.01	0.25		1.00
F49/3-1	VG	0.00	0.00	0.01	0.25		1.00
F50/3-1	VG	0.00	0.00	0.01	0.25		1.00
MAX. VALUES		0.00	0.40	1.00	1.00		1.00
MIN. VALUES		0.00	0.00	0.01	0.25		0.00
(MAX-MIN)		0.00	0.40	0.99	0.75		1.00
Average Opinion on Judgement:							
		0.00	0.21	0.58		0.73	0.91

Appendix 6 continued

Normalizing average Opinion on Judgement:

=	Fuzzy Set A =				
	0.00	0.23	0.64	0.80	1.00
Making Fuzzy Set "A' Convex =					
	0.00	0.23	0.64	0.80	1.00

The difference between two fuzzy sets is given by:

DIF. (Ai,Zi) = $(\text{sum}[\,Ua(xi)-Uz(xj)]^2)^{1/2}$

DIFF.(A,VERY GOOD)	=	0.87
DIFF.(A, GOOD)	=	0.66
DIFF.(A, MORE OR LESS GOOD)	=	0.71
DIFF.(A, MEDIUM)	=	0.82
DIFF.(A, MORE OR LESS BAD)	=	1.57
DIFF.(A, BAD)	=	1.73
DIFF.(A, VERY BAD)	=	1.74

The least difference is 0.66 therefore the nearest fuzzy estimate of the support of set A is GOOD.

The Utility on Judgement =

$1/4 \times (0.00+1\times 10.23+2\times 0.64 + 3\times 0.80 + 4 \times 1.00)/(0.00 + 0.23 + 0.64 + 0.80 + 1.00)$

= 0.74

Appendix 6 continued

Block MS 5-1 Farmer's preference on Irrigation water supply.
November, 1995- March,1996.
Opinions on importance

		Dependability Importance				
Farmer					support function definition	
No.	FJ	$\mu(1)$	$\mu(2)$	$\mu(3)$	$\mu(4)$	$\mu(5)$
F01/3-1	H	0.00	0.00	0.10	0.50	1.00
F02/3-1	H	0.00	0.00	0.10	0.50	1.00
F03/3-1	H	0.00	0.00	0.10	0.50	1.00
F04/3-1	H	0.00	0.00	0.10	0.50	1.00
F05/3-1	H	0.00	0.00	0.10	0.50	1.00
F06/3-1	VH	0.00	0.00	0.01	0.25	1.00
F07/3-1	VH	0.00	0.00	0.01	0.25	1.00
F08/3-1	VH	0.00	0.00	0.01	0.25	1.00
F09/3-1	H	0.00	0.00	0.10	0.50	1.00
F10/3-1	H	0.00	0.00	0.10	0.50	1.00
F11/3-1	VH	0.00	0.00	0.01	0.25	1.00
F12/3-1	H	0.00	0.00	0.10	0.50	1.00
F13/3-1	H	0.00	0.00	0.10	0.50	1.00
F14/3-1	VH	0.00	0.00	0.01	0.25	1.00
F15/3-1	VH	0.00	0.00	0.01	0.25	1.00
F16/3-1	VH	0.00	0.00	0.01	0.25	1.00
F17/3-1	VH	0.00	0.00	0.01	0.25	1.00
F18/3-1	VH	0.00	0.00	0.01	0.25	1.00
F19/3-1	H	0.00	0.00	0.1	0.50	1.00
F20/3-1	MLH	0.00	0.00	0.04	1.00	0.40
F21/3-1	VH	0.00	0.00	0.01	0.25	1.00
F22/3-1	H	0.00	0.00	0.10	0.50	1.00
F23/3-1	H	0.00	0.00	0.10	0.50	1.00
F24/3-1	H	0.00	0.00	0.10	0.50	1.00

Appendix 6 continued

F25/3-1	H	0.00	0.00	0.10	0.50	1.00
F26/3-1	VH	0.00	0.00	0.40	1.00	0.40
F27/3-1	H	0.00	0.00	0.01	0.25	1.00
F28/3-1	VH	0.00	0.00	0.01	0.25	1.00
F29/3-1	VH	0.00	0.00	0.01	0.25	1.00
F30/3-1	VH	0.00	0.00	0.01	0.25	1.00
F31/3-1	VH	0.00	0.00	0.01	0.25	1.00
F32/3-1	H	0.00	0.00	0.10	0.50	1.00
F33/3-1	H	0.00	0.00	0.10	0.50	1.00
F34/3-1	MLH	0.00	0.00	0.40	1.00	0.40
F35/3-1	H	0.00	0.00	0.10	0.50	1.00
F36/3-1	H	0.00	0.00	0.10	0.50	1.00
F37/3-1	VH	0.00	0.00	0.01	0.25	1.00
F38/3-1	VH	0.00	0.00	0.01	0.25	1.00
F39/3-1	H	0.00	0.00	0.10	0.50	1.00
F40/3-1	H	0.00	0.00	0.10	0.50	1.00
F41/3-1	H	0.00	0.00	0.10	0.50	1.00
F42/3-1	VH	0.00	0.00	0.01	0.25	1.00
F43/3-1	VH	0.00	0.00	0.01	0.25	1.00
F44/3-1	H	0.00	0.00	0.10	0.50	1.00
F45/3-1	H	0.00	0.00	0.10	0.50	1.00
F46/3-1	VH	0.00	0.00	0.01	0.25	1.00
F47/3-1	VH	0.00	0.00	0.01	0.25	1.00
F48/3-1	VH	0.00	0.00	0.01	0.25	1.00
F49/3-1	H	0.00	0.00	0.10	0.50	1.00
F50/3-1	MLH	0.00	0.00	0.40	1.00	0.40
MAX VALUES		0.00	0.40	1.00	1.00	1.00
MIN VALUES		0.00	0.00	0.01	0.25	0.00
MAX-MIN		0.00	0.40	0.99	0.75	1.00
Average Opinion on Importance:		0.00	0.21	0.58	0.73	0.91

Appendix 6 continued

Normalizing Opinion on Importance
= Fuzzy set A =

0.00	0.23	0.64	0.80	1.00

MAKING FUZZY SET "A" CONVEX :

0.00	0.23	0.64	0.80	1.00

The difference between two fuzzy sets is given by:

DIF. (Ai,Zi) = $(\text{sum}[\ Ua(xi)-Uz(xj)]^2)^{1/2}$

DIFF.(A,VERY HIGH) = 0.87
DIFF.(A, HIGH) = 0.66
DIFF.(A,MORE OR LESS HIGH) = 0.71
DIFF.(A,MEDIUM) = 0.82
DIFF.(A,MORE OR LESS LOW) = 1.57
DIFF.(A,LOW) = 1.73
DIFF.(A,VERY LOW) = 1.74

The least difference is 0.66 therefore the nearest fuzzy estimate of set A is HIGH.
The Utility on Importance is:

$1/4\times(0\times0.000+1\times0.23 + 2 \times0.64 + 3 \times0.80 + 4 \times1.00)/(0.00 + 0.23 +0.64 + 0.80 + 1.00) = 0.74$

Appendix 7 Season Mean measured RWS and FUIWS

Block	Farmer Number	RWS	FUIWS
MS 3-1	F 01/3-1	1.6	0.85
	F 02/3-1	1.4	0.79
	F 03/3-1	1.1	0.72
	F 04/3-1	1.2	0.78
	F 05/3-1	1.3	0.75
	F 06/3-1	1.0	0.65
	F 07/3-1	1.2	0.72
	F 08/3-1	1.2	0.72
	F 09/3-1	1.3	0.78
	F 10/3-1	1.0	0.61
	F 11/3-1	1.2	0.75
	F 12/3-1	1.2	0.71
	F 13/3-1	1.5	0.85
	F 14/3-1	1.3	0.79
	F 15/3-1	1.3	0.79
	F 16/3-1	1.2	0.78
	F 17/3-1	1.2	0.77
	F 18/3-1	1.2	0.84
	F 19/3-1	1.2	0.78
	F 20/3-1	1.1	0.78
	F 21/3-1	1.2	0.77
	F 22/3-1	1.1	0.77
	F 23/3-1	1.1	0.73
	F 24/3-1	1.5	0.85
	F 25/3-1	1.1	0.73
	F 26/3-1	1.1	0.73
	F 27/3-1	1.8	0.88
	F 28/3-1	1.2	0.78
	F 29/3-1	2.1	0.89
	F 30/3-1	2.0	0.89

Appendix 7 continued

F 31/3-1	2.1	0.89
F 32/3-1	1.3	0.78
F 33/3-1	1.0	0.70
F 34/3-1	1.3	0.80
F 35/3-1	1.5	0.85
F 36/3-1	2.2	0.89
F 37/3-1	1.0	0.72
F 38/3-1	0.9	0.63
F 39/3-1	1.1	0.72
F 40/3-1	1.0	0.73
F 41/3-1	1.6	0.85
F 42/3-1	1.2	0.74
F 43/3-1	2.0.	0.89
F 44/3-1	1.1	0.73
F 45/3-1	1.4	0.82
F 46/3-1	1.3	0.73
F 47/3-1	0.9	0.70
F 48/3-1	1.7	0.86
F 49/3-1	1.8	0.88
F 50/3-1	1.3	0.80

Appendix 7 continued

Block	Farmer number	RWS	FUIWS
MS 5-1	F 01/5-1	2.0	0.88
	F 02/5-1	1.2	0.75
	F 03/5-1	1.7	0.85
	F 04/5-1	1.0	0.57
	F 05/5-1	1.1	0.49
	F 06/5-1	1.2	0.68
	F 07/5-1	1.2	0.61
	F 08/5-1	1.5	0.78
	F 09/5-1	1.8	0.85
	F 10/5-1	1.9	0.83
	F 11/5-1	1.2	0.62
	F 12/5-1	1.3	0.73
	F 13/5-1	1.0	0.56
	F 14/5-1	1.1	0.64
	F 15/5-1	1.8	0.89
	F 16/5-1	1.7	0.89
	F 17/5-1	1.2	0.62
	F 18/5-1	1.3	0.73
	F 19/5-1	0.8	0.47
	F 20/5-1	1.3	0.73
	F 21/5-1	1.9	0.85
	F 22/5-1	1.3	0.75
	F 23/5-1	1.5	0.77
	F 24/5-1	1.7	0.85
	F 25/5-1	1.4	0.81
	F 26/5-1	0.9	0.48
	F 27/5-1	0.9	0.47
	F 28/5-1	1.0	0.47
	F 29/5-1	1.4	0.75
	F 30/5-1	1.0	0.71
	F 31/5-1	1.8	0.85
	F 32/5-1	1.1	0.57
	F 33/5-1	1.4	0.77

Appendix 7 continued

F 34/5-1	0.9	0.47
F 35/5-1	1.1	0.63
F 36/5-1	1.2	0.66
F 37/5-1	1.2	0.68
F 38/5-1	1.1	0.61
F 39/5-1	1.0	0.62
F 40/5-1	1.6	0.81
F 41/5-1	1.1	0.72
F 42/5-1	1.1	0.74
F 43/5-1	1.0	0.61
F 44/5-1	1.2	0.73
F 45/5-1	1.1	0.67
F 46/5-1	1.2	0.70
F 47/5-1	1.2	0.75
F 48/5-1	1.2	0.73
F 49/5-1	1.0	0.59
F 50/5-1	1.5	0.77
F 51/5-1	1.1	0.71

Appendix 7 continued

Block	Farmer number	RWS	FUIWS
RS 1-1	F 01/1-1	0.9	0.33
	F 02/1-1	1.0	0.51
	F 03/1-1	1.0	0.56
	F 04/1-1	1.1	0.61
	F 05/1-1	1.2	0.68
	F 06/1-1	1.1	0.68
	F 07/1-1	1.3	0.70
	F 08/1-1	1.1	0.67
	F 09/1-1	1.2	0.67
	F 10/1-1	1.0	0.61
	F 11/1-1	0.9	0.49
	F 12/1-1	1.2	0.61
	F 13/1-1	1.0	0.65
	F 14/1-1	1.4	0.70
	F 15/1-1	1.2	0.59
	F 16/1-1	1.3	0.70
	F 17/1-1	1.2	0.70
	F 18/1-1	1.0	0.55
	F 19/1-1	1.2	0.67
	F 20/1-1	1.1	0.63
	F 21/1-1	1.1	0.65
	F 22/1-1	1.1	0.64
	F 23/1-1	1.0	0.55
	F 24/1-1	1.2	0.54
	F 25/1-1	0.9	0.24
	F 26/1-1	1.0	0.59
	F 27/1-1	1.0	0.61
	F 28/1-1	1.4	0.68
	F 29/1-1	1.4	0.65
	F 30/1-1	1.3	0.68
	F 31/1-1	1.3	0.70
	F 32/1-1	1.2	0.67
	F 33/1-1	1.3	0.65
	F 34/1-1	1.0	0.51

Appendix 7 continued

F 35/1-1	0.8	0.26
F 36/1-1	0.9	0.26
F 37/1-1	1.0	0.55
F 38/1-1	0.9	0.44
F 39/1-1	1.0	0.52
F 40/1-1	1.3	0.65
F 41/1-1	1.4	0.65
F 42/1-1	1.1	0.52
F 43/1-1	1.0	0.52
F 44/1-1	1.1	0.67
F 45/1-1	1.1	0.65
F 46/1-1	1.4	0.70
F 47/1-1	1.2	0.61
F 48/1-1	1.0	0.59
F 49/1-1	1.0	0.52
F 50/1-1	1.2	0.67

Appendix 7 Continued

Block	Farmer number	RWS	FUIWS
RS 4-1	F 01/4-1	1.3	0.65
	F 02/4-1	1.0	0.55
	F 03/4-1	0.9	0.46
	F 04/4-1	1.0	0.56
	F 05/4-1	1.2	0.61
	F 06/4-1	0.9	0.53
	F 07/4-1	0.9	0.54
	F 08/4-1	1.0	0.54
	F 09/4-1	0.9	0.32
	F 10/4-1	0.9	0.46
	F 11/4-1	0.8	0.30
	F 12/4-1	1.0	0.33
	F 13/4-1	0.8	0.14
	F 14/4-1	0.9	0.45
	F 15/4-1	1.0	0.44
	F 16/4-1	1.0	0.57
	F 17/4-1	1.2	0.64
	F 18/4-1	0.9	0.53
	F 19/4-1	0.9	0.56
	F 20/4-1	0.9	0.56
	F 21/4-1	1.6	0.74
	F 22/4-1	1.0	0.59
	F 23/4-1	1.3	0.67
	F 24/4-1	1.0	0.55
	F 25/4-1	1.0	0.51
	F 26/4-1	1.2	0.65
	F 27/4-1	1.4	0.70
	F 28/4-1	1.1	0.56
	F 29/4-1	1.2	0.64
	F 30/4-1	1.0	0.51

Appendix 7 Continued

F 31/4-1	1.1	0.60
F 32/4-1	1.3	0.66
F 33/4-1	1.2	0.66
F 34/4-1	1.3	0.66
F 35/4-1	1.3	0.66
F 36/4-1	1.5	0.71
F 37/4-1	1.3	0.67
F 38/4-1	1.3	0.67
F 39/4-1	1.1	0.59
F 40/4-1	1.0	0.59
F 41/4-1	1.2	0.63
F 42/4-1	1.3	0.65
F 43/4-1	1.3	0.65
F 44/4-1	1.2	0.65
F 45/4-1	1.5	0.72
F 46/4-1	1.2	0.65
F 47/4-1	1.3	0.65
F 48/4-1	1.1	0.60
F 49/4-1	1.3	0.65
F 50/4-1	1.2	0.65
F 51/4-1	1.5	0.72

Appendix 8 DEPENDABILITY OF IRRIGATION WATER SUPPLY VALUES

Block	Farmer Number	Season mean RWS	Dependability of irrigation water supply
MS 3-1	F01/3-1	1.59	0.42
	F02/3-1	1.39	0.36
	F03/3-1	1.14	0.29
	F04/3-1	1.16	0.23
	F05/3-1	1.34	0.24
	F06/3-1	1.01	0.28
	F07/3-1	1.17	0.33
	F08/3-1	1.15	0.40
	F09/3-1	1.33	0.25
	F10/3-1	1.01	0.26
	F11/3-1	1.22	0.30
	F12/3-1	1.50	0.30
	F13/3-1	1.45	0.27
	F14/3-1	1.26	0.45
	F15/3-1	1.32	0.33
	F16/3-1	1.18	0.16
	F17/3-1	1.24	0.31
	F18/3-1	1.24	0.26
	F19/3-1	1.18	0.22
	F20/3-1	1.11	0.15
	F21/3-1	1.24	0.31
	F22/3-1	1.10	0.16
	F23/3-1	1.08	0.22
	F24/3-1	1.51	0.30
	F25/3-1	1.13	0.18
	F26/3-1	1.11	0.26
	F27/3-1	1.75	0.33
	F28/3-1	1.16	0.29
	F29/3-1	2.05	0.22
	F30/3-1	1.96	0.31
	F31/3-1	2.06	0.21
	F32/3-1	1.30	0.22
	F33/3-1	1.02	0.12

Appendix 8 continued

	F34/3-1	1.25	0.32
	F35/3-1	1.52	0.20
	F36/3-1	2.18	0.28
	F37/3-1	1.04	0.18
	F38/3-1	0.92	0.23
	F39/3-1	1.09	0.27
	F40/3-1	1.01	0.27
	F41/3-1	1.56	0.25
	F42/3-1	1.20	0.28
	F43/3-1	1.95	0.25
	F44/3-1	1.07	0.31
	F45/3-1	1.35	0.35
	F46/3-1	1.30	0.28
	F47/3-1	0.94	0.36
	F48/3-1	1.67	0.22
	F49/3-1	1.75	0.29
	F50/3-1	1.26	0.27
MS 5-1	F01/5-1	1.98	0.27
	F02/5-1	1.24	0.26
	F03/5-1	1.71	0.25
	F04/5-1	1.02	0.29
	F05/5-1	1.05	0.29
	F06/5-1	1.20	0.36
	F07/5-1	1.15	0.29
	F08/5-1	1.45	0.30
	F09/5-1	1.75	0.30
	F10/5-1	1.85	0.31
	F11/5-1	1.18	0.29
	F12/5-1	1.32	0.32
	F13/5-1	1.00	0.31
	F14/5-1	1.06	0.33
	F15/5-1	1.84	0.26
	F16/5-1	1.71	0.31
	F17/5-1	1.24	0.42
	F18/5-1	1.26	0.25
	F19/5-1	0.84	0.29
	F20/5-1	1.33	0.45

Appendix 8 continued

	F21/5-1	1.86	0.50
	F22/5-1	1.29	0.33
	F23/5-1	1.49	0.28
	F24/5-1	1.65	0.18
	F25/5-1	1.35	0.29
	F26/5-1	0.93	0.19
	F27/5-1	0.93	0.22
	F28/5-1	1.03	0.31
	F29/5-1	1.38	0.29
	F30/5-1	1.07	0.24
	F31/5-1	1.75	0.27
	F32/5-1	1.10	0.35
	F33/5-1	1.44	0.37
	F34/5-1	0.92	0.28
	F35/5-1	1.12	0.31
	F36/5-1	1.16	0.22
	F37/5-1	1.19	0.23
	F38/5-1	1.12	0.25
	F39/5-1	1.04	0.28
	F40/5-1	1.56	0.30
	F41/5-1	1.10	0.20
	F42/5-1	1.14	0.32
	F43/5-1	1.01	0.23
	F44/5-1	1.19	0.27
	F45/5-1	1.14	0.28
	F46/5-1	1.19	0.32
	F47/5-1	1.21	0.22
	F48/5-1	1.17	0.24
	F49/5-1	1.05	0.22
	F50/5-1	1.48	0.25
	F51/5-1	1.14	0.20
RS 01-1	F01/1-1	0.94	0.20
	F 02/1-1	1.04	0.21
	F 03/1-1	1.05	0.29
	F 04/1-1	1.12	0.33
	F 05/1-1	1.21	0.38
	F 06/1-1	1.13	0.48

Appendix 8 continued

F 07/1-1	1.29	0.49
F 08/1-1	1.05	0.24
F 09/1-1	1.19	0.44
F 10/1-1	1.02	0.57
F 11/1-1	0.93	0.36
F 12/1-1	1.24	0.52
F 13/1-1	1.02	0.57
F 14/1-1	1.36	0.34
F 15/1-1	1.17	0.40
F 16/1-1	1.27	0.20
F 17/1-1	1.25	0.43
F 18/1-1	1.05	0.55
F 19/1-1	1.18	0.40
F 20/1-1	1.09	0.51
F 21/1-1	1.08	0.26
F22/1-1	1.11	0.31
F23/1-1	1.03	0.25
F24/1-1	1.15	0.41
F25/1-1	0.94	0.18
F26/1-1	1.04	0.30
F27/1-1	1.05	0.31
F28/1-1	1.36	0.49
F29/1-1	1.40	0.35
F30/1-1	1.33	0.50
F31/1-1	1.25	0.18
F32/1-1	1.22	0.41
F33/1-1	1.26	0.36
F34/1-1	0.96	0.19
F35/1-1	0.84	0.22
F36/1-1	0.94	0.20
F37/1-1	1.01	0.20
F38/1-1	0.94	0.19
F39/1-1	1.03	0.17
F40/1-1	1.27	0.26
F41/1-1	1.37	0.28
F42/1-1	1.15	0.26

Appemdix 8 continued

	F43/1-1	1.04	0.27
	F44/1-1	1.14	0.25
	F45/1-1	1.08	0.26
	F46/1-1	1.36	0.25
	F47/1-1	1.16	0.47
	F48/1-1	1.04	0.29
	F49/1-1	1.05	0.29
	F50/1-1	1.17	0.29
RS4-1	F01/4-1	1.33	0.24
	F 02/4-1	1.03	0.47
	F 03/4-1	0.93	0.31
	F 04/4-1	1.03	0.32
	F 05/4-1	1.17	0.42
	F 06/4-1	0.94	0.39
	F 07/4-1	0.93	0.44
	F 08/4-1	0.98	0.38
	F 09/4-1	0.85	0.24
	F 10/4-1	0.94	0.30
	F 11/4-1	0.81	0.28
	F 12/4-1	1.05	0.22
	F 13/4-1	0.82	0.34
	F 14/4-1	0.94	0.18
	F 15/4-1	0.95	0.26
	F 16/4-1	1.04	0.28
	F 17/4-1	1.21	0.19
	F 18/4-1	0.91	0.26
	F 19/4-1	0.95	0.24
	F 20/4-1	0.94	0.17
	F 21/4-1	1.56	0.39
	F 22/4-1	0.95	0.37
	F 23/4-1	1.27	0.48
	F 24/4-1	1.04	0.31
	F 25/4-1	1.04	0.16
	F 26/4-1	1.16	0.31
	F 27/4-1	1.36	0.25
	F 28/4-1	1.07	0.34
	F 29/4-1	1.20	0.24

Appendix 8 continued

F 30/4-1	0.99	0.34
F 31/4-1	1.05	0.52
F 32/4-1	1.26	0.25
F 33/4-1	1.22	0.47
F 34/4-1	1.25	0.36
F 35/4-1	1.33	0.28
F 36/4-1	1.45	0.31
F 37/4-1	1.28	0.36
F 38/4-1	1.33	0.31
F 39/4-1	1.06	0.43
F 40/4-1	1.05	0.24
F 41/4-1	1.17	0.29
F 42/4-1	1.26	0.18
F 43/4-1	1.32	0.22
F 44/4-1	1.22	0.18
F 45/4-1	1.46	0.27
F 46/4-1	1.16	0.18
F 47/4-1	1.29	0.30
F 48/4-1	1.11	0.25
F 49/4-1	1.26	0.14
F 50/4-1	1.16	0.23
F 51/4-1	1.47	0.26

Appendix 9 Crop yield

Block	Farmer number	Specific yield (kg/m^3)	Yield per irrigated area (ton/ha)
MS3-1	F01/3-1	0.37	04.82
	F02/3-1	0.43	05.10
	F03/3-1	0.83	07.95
	F04/3-1	0.68	06.80
	F05/3-1	0.58	07.08
	F06/3-1	0.74	06.23
	F07/3-1	0.78	07.37
	F08/3-1	0.76	07.65
	F09/3-1	0.66	07.65
	F10/3-1	1.49	12.55
	F11/3-1	1.25	13.22
	F12/3-1	0.63	08.22
	F13/3-1	0.68	08.68
	F14/3-1	0.83	08.90
	F15/3-1	0.79	08.85
	F16/3-1	0.90	09.31
	F17/3-1	0.87	09.20
	F18/3-1	0.59	06.38
	F19/3-1	0.56	05.73
	F20/3-1	0.82	07.98
	F21/3-1	0.73	07.54
	F22/3-1	0.74	06.80
	F23/3-1	1.21	11.17
	F24/3-1	0.57	07.37
	F25/3-1	1.33	12.75
	F26/3-1	0.89	08.22
	F27/3-1	0.59	08.50
	F28/3-1	0.73	06.80
	F29/3-1	0.43	07.85
	F30/3-1	0.61	10.20
	F31/3-1	0.34	06.32
	F32/3-1	0.45	05.10
	F33/3-1	1.36	11.81

Appendix 9 continued

	F34/3-1	0.57	05.95
	F35/3-1	0.59	07.65
	F36/3-1	0.40	07.37
	F37/3-1	0.64	05.67
	F38/3-1	0.79	05.95
	F39/3-1	1.00	05.38
	F40/3-1	0.77	06.52
	F41/3-1	0.24	03.40
	F42/3-1	0.71	07.08
	F43/3-1	0.40	07.08
	F44/3-1	0.73	06.80
	F45/3-1	0.69	08.22
	F46/3-1	0.95	10.73
	F47/3-1	1.02	07.93
	F48/3-1	0.83	12.28
	F49/3-1	0.58	08.75
	F50/3-1	0.63	06.93
MS 4-1	F 01/5-1	0.24	05.10
	F 02/5-1	0.35	04.82
	F 03/5-1	0.44	08.50
	F 04/5-1	0.68	07.37
	F 05/5-1	1.22	13.22
	F 06/5-1	0.63	0 7.93
	F 07/5-1	0.66	07.93
	F 08/5-1	0.71	11.17
	F 09/5-1	0.47	09.07
	F 10/5-1	0.40	07.93
	F 11/5-1	0.67	08.50
	F 12/5-1	0.57	08.22
	F 13/5-1	0.77	08.08
	F 14/5-1	0.66	07.37
	F 15/5-1	0.40	07.65
	F 16/5-1	0.46	08.50
	F 17/5-1	0.58	07.93
	F 18/5-1	0.58	08.22
	F 19/5-1	0.63	08.50

Appendix 9 continued

	F 20/5-1	0.54	07.65
	F 21/5-1	0.66	06.10
	F 22/5-1	1.31	08.42
	F 23/5-1	0.53	07.65
	F 24/5-1	0.58	07.93
	F 25/5-1	0.49	06.80
	F 26/5-1	0.60	07.37
	F 27/5-1	0.54	07.08
	F 28/5-1	0.68	08.80
	F 29/5-1	0.57	06.94
	F 30/5-1	0.46	06.23
	F 31/5-1	0.42	06.67
	F 32/5-1	0.53	06.52
	F 33/5-1	0.87	11.18
	F 34/5-1	0.45	05.67
	F 35/5-1	0.44	05.95
	F 36/5-1	0.58	07.37
	F 37/5-1	0.65	08.22
	F 38/5-1	0.49	06.80
	F 39/5-1	0.46	06.52
	F 40/5-1	0.41	07.08
	F 41/5-1	0.54	0 6.52
	F 42/5-1	0.97	11.81
	F 43/5-1	0.68	06.80
	F 44/5-1	0.62	07.95
	F 45/5-1	0.57	06.80
	F 46/5-1	1.18	14.73
	F 47/5-1	0.62	07.93
	F 48/5-1	0.53	06.80
	F 49/5-1	0.78	08.81
	F 50/5-1	0.51	08.22
	F 51/5-1	0.63	07.65
RS 1-1	F 01/1-1	0.71	07.93
	F 02/1-1	1.06	13.22
	F 03/1-1	0.60	07.65
	F 04/1-1	0.55	07.08
	F 05/1-1	0.57	07.65

Appendix 9 continued

F 06/1-1	0.58	07.08
F 07/1-1	0.53	07.37
F 08/1-1	0.52	06.23
F 09/1-1	1.29	17.89
F 10/1-1	0.70	07.37
F 11/1-1	0.67	07.08
F 12/1-1	0.61	06.93
F 13/1-1	1.00	10.48
F 14/1-1	0.50	07.93
F 15/1-1	0.52	07.08
F 16/1-1	0.77	11.84
F 17/1-1	0.43	06.80
F 18/1-1	0.55	06.52
F 19/1-1	0.53	07.37
F 20/1-1	0.62	07.37
F 21/1-1	0.79	10.12
F 22/1-1	0.49	06.23
F 23/1-1	0.63	07.65
F 24/1-1	0.56	07.37
F 25/1-1	0.54	06.23
F 26/1-1	0.77	09.82
F 27/1-1	0.88	11.02
F 28/1-1	0.77	11.90
F 29/1-1	0.71	10.77
F 30/1-1	0.74	10.77
F 31/1-1	0.75	10.63
F 32/1-1	0.52	07.08
F 33/1-1	0.62	08.04
F 34/1-1	0.72	09.07
F 35/1-1	0.74	09.07
F 36/1-1	0.72	08.74
F 37/1-1	0.60	07.37
F 38/1-1	0.74	07.50
F 39/1-1	0.65	08.22
F 40/1-1	0.49	07.37
F 41/1-1	0.48	07.93

Appendix 9 continued

	F 42/1-1	0.53	07.37
	F 43/1-1	0.79	10.00
	F 44/1-1	0.69	09.69
	F 45/1-1	0.53	07.08
	F 46/1-1	0.43	06.80
	F 47/1-1	1.01	13.22
	F 48/1-1	0.61	07.65
	F 49/1-1	0.90	10.79
	F 50/1-1	0.67	09.35
RS 4-1	F 01/4-1	0.35	09.67
	F 02/4-1	0.46	05.10
	F 03/4-1	0.46	04.82
	F 04/4-1	0.47	05.38
	F 05/4-1	0.48	05.95
	F 06/4-1	0.56	05.67
	F 07/4-1	0.63	06.23
	F 08/4-1	0.56	06.30
	F 09/4-1	0.56	05.38
	F 10/4-1	0.65	06.80
	F 11/4-1	1.37	02.28
	F 12/4-1	0.52	06.52
	F 13/4-1	0.62	05.67
	F 14/4-1	0.42	05.53
	F 15/4-1	0.50	05.38
	F 16/4-1	0.39	04.82
	F 17/4-1	0.30	04.25
	F 18/4-1	0.42	04.53
	F 19/4-1	0.54	05.95
	F 20/4-1	0.48	05.38
	F 21/4-1	0.35	06.23
	F 22/4-1	0.61	06.52
	F 23/4-1	0.50	07.08
	F 24/4-1	0.51	05.95
	F 25/4-1	0.39	04.82
	F 26/4-1	0.47	06.80
	F 27/4-1	0.50	08.22

Appendix 9 continued

F 28/4-1	0.41	05.10
F 29/4-1	0.30	04.25
F 30/4-1	0.74	08.22
F 31/4-1	1.44	15.87
F 32/4-1	0.57	08.50
F 33/4-1	0.46	06.23
F 34/4-1	0.40	05.67
F 35/4-1	0.73	11.33
F 36/4-1	0.51	08.22
F 37/4-1	0.23	07.65
F 38/4-1	0.46	07.37
F 39/4-1	0.61	07.08
F 40/4-1	0.54	06.52
F 41/4-1	0.36	04.82
F 42/4-1	0.61	06.80
F 43/4-1	0.75	07.93
F 44/4-1	0.71	07.37
F 45/4-1	0.99	10.20
F 46/4-1	0.56	05.57
F 47/4-1	0.98	10.09
F 48/4-1	1.43	14.34
F 49/4-1	1.36	13.81
F 50/4-1	0.50	05.67
F 51/4-1	1.01	10.77

Appendix 10 Covariance and Correlation coefficient test on season mean measured RWS and FUIWS

	RWS	FUIWS
N_i	15.000	15.000
ΣX_i	22.500	11.200
ΣX_i^2	36.550	8.442
ΣUR	17.456	

The covariance of RWS and FUIWS, Cru is given as:

Cru = [(ΣU$\times$ ΣR) - (ΣU$\times$ ΣR)/N][N-1]

Where:
U = FUIWS
R = RWS
N_i,N = Number of elements
ΣX_i = Sum of R or U
ΣUR = Sum of product of season FUIWS and RWS
Cru = [(10.985$\times$22.5) - (10.985$\times$22.5)/(15)] /[15]
= 16.478

Appendix 11 **t-student distribution test for simulated and measured RWS using Scheme Model**

	Simulated RWS	Measured RWS
Ni	15.000	15.000
Xm	01.400	01.500
ΣXi	21.200	22.500
ΣXi^2	36.500	32.580
CSS	02.785	02.800

Note: Ni = Number of elements in each group

Xm = Mean value

ΣXi = Sum of Xi

$\Sigma(Xi)^2$ = Sum of squares of Xi

CSS = Corrected sum of squares

Appendix 12 t-student distribution test for comparison between Measured and Simulated mean RWS Block Models

Block	N_i	Xm	Σxi	Σxi2	CSS
MS 3-1BM	13	1.5215	19.7795	32.1748	2.0803
SM	13	1.6703	21.7143	36.9108	0.6471
MS 5-1BM	13	1.4012	18.2160	27.2745	1.7497
SM	13	1.4495	18.8438	28.7370	1.4253
RS 1-1BM	06	1.1196	06.7179	07.6186	0.0970
SM	06	1.1294	06.7762	07.9000	0.2471
RS 4-1BM	09	1.1719	10.5473	12.9341	0.5735
SM	09	1.1448	10.3032	12.3768	0.5816

NOTE: BM = Block Model SM = Scheme Model

Appendix 13 Results of t-student distribution test for comparison between Block and Scheme models

Block	Df	t-calculated	t-tabulated		result
			5%	10%	
MS 3-1	24	1.127	2.064	1.711	NS
MS 5-1	24	0.013	2.064	1.711	NS
RS 1-1	10	0.916	1.812	2.228	NS
RS 4-1	16	0.214	2.120	1.746	NS

NOTE: Df = Degree of freedom NS= No significant difference.

Appendix 14 Bartlett's test of homogeneity

Block	Mean RWS simulated	variance s^2	Df (n-1)	SS	$\log s^2$	$(n-1)\log s^2$
MS 3-1	1.671	0.053	12.000	0.641	-1.272	-15.266
MS 5-1	1.450	0.119	12.000	1.424	-0.926	-11.109
RS 1-1	1.130	0.049	05.000	0.247	-1.306	-06.528
RS 4-1	1.145	0.073	08.000	0.582	-1.138	-09.104
Total			37.000	2.895		-42.006

NOTE: SS = Corrected sum of squares = $(n-1)s^2$

The pooled within group- variance So^2 is:

$$S_o^2 = \Sigma SS_i / \Sigma(n_i-1)$$

$$= 2.895/37$$

$$= 0.08$$