Addis Ababa University

Addis Ababa Institute of Technology

School of Graduate Studies

Water Delivery Performance Evaluation of Koga Irrigation Scheme

A thesis submitted and presented to the school of graduate studies of Addis Ababa University in partial fulfillment of the degree of Masters of Science in Civil and Environmental Engineering (Stream Hydraulic Engineering)

BY

Yeshi Andualem

Advisor: Dr. Yilma Sileshi

Addis Ababa University

Ethiopia

November, 2018

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Approval by Board of Examiners

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CERTIFICATION

The undersigned certify that he has read the Thesis entitled Water Delivery Performance Evaluation of Koga Irrigation Scheme and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science

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Dr. Yilma Sileshi

(Advisor)

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Date

DECLARATION

I, Yeshi Andualem Birhanu, declare that this is my own original work and that it has not been presented and will not be presented to any other University for similar or any degree award.

Signature______________________________

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November, 2018

ACKNOWLEDGMENT

First of all I would like to thank a lot the Almighty God for his gift that cannot be described in words, protection and help.

Then, I would like to express gratitude to my Advisor, Doctor Yilma Sileshi (PhD) for his guidance, respected encouragement and insightful comments during my study.

I also would like to acknowledge to Mr. Tamene Dagnaw (BSc) for his support in my academic career helpful discussions, valuable suggestions, remarks and encouragement throughout the fieldwork. Spatial tanks for operators for their labor support during field measurement.

I want to express my deep appreciation to all irrigation water users and Water User Associations (WUA) of Koga irrigation scheme for their great support during my fieldwork and for providing data. I would also like to express my sincere thanks to Koga irrigation office staffs, for the support and help field materials during my fieldwork in the study area.

Finally, I would like especially to be grateful my friends who encourage me morally, and also my special respect to all individuals who supports me directly or indirectly.

ABSTRACT

Water delivery performance is the degree to which whether the system delivers water at the required rate at the right place and time so, water delivery performance evaluation of irrigation system plays a dynamic role in identifying the gaps and applying mitigation measures. Koga irrigation scheme was designed to irrigate around 7000ha but, it does not meet the proposed objective, hence the objective of the study was evaluating the water delivery performance of Koga irrigation scheme. This study was carried out for three month on a single irrigation season from February to April; 2018. Water delivery performance of the scheme was evaluated by comparing irrigation water demand with actual irrigation water supply by using 7 indicators classified under water delivery and water use or water supply indicators. As per the result, deficit of supply has been progressive in March and April; because actual irrigation water supply in March and April was less than the crop demand. However, supply was exceeding the demand during February. The average, irrigation water supply was observed in shortage of the requirement at the head middle and tail reach of the main canal. The overall relative water supply, relative irrigation supply and deficiency of the scheme were 0.65, 0.75 and 0.28 respectively. As shown from the result water delivery performance indicators; adequacy, dependability, equity and efficiency were found to be 0.68, 0.29, 0.08 and 0.95 respectively. According to these values, performance of water delivery of the main canal was rated as poor in terms of adequacy and dependability; however it was good in relation to efficiency and equity. These values indicate that, actual water level as well as command area was reduced from initially designed. The results from this study are very clear to that of, non-proportionality of irrigation water demand with supply, poor temporal water delivery system, absence of frequent management aspect have been strongly affected the water delivery performance of the schemes. Therefore, it is suggested that, effective water management, supplying irrigation water based on crop demand , optimal crop plan, and apply a strong water delivery plan are required to mitigate these problems.

Keywords: water delivery performance, irrigation water demand and supply, water delivery and supply or use indicators, Koga irrigation scheme.

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LIST OF ABBREVIATIONS

AAiT………………Addis Ababa institute of technology

AB…………………Ambomesk

AD…………………Adbera Mariam

AM………………...Amarit

AN…………………Andnet

BE………………….Bered

CVR………………..Coefficient of spatial variation

CV_T…………………Coefficient of temporal variation

Cm…………………..Centimeter

Ch…………………...Chihona

CWR………………..Crop water requirement

CD…………………..Crop demand

En…………………...Enguti

ER…………………..Effective rainfall

ET…………………..Evapotranspiration

ET_C………………….Actual evapotranspiration

ET_O………………….Referenced evapotranspiration

ET_p…………………..Potential evapotranspiration

Ha…………………....Hectare

h/d…………………...Hour per day

IE…………………Irrigation efficiency

IR…………………Irrigation requirement

IWD………………Irrigation water demand

IWS……………….Irrigation water supply

Ku…………………Kudmi

Kc…………………Crop coefficient

KM………………...Kilometer

L/s/h……………….Liter per second per hectare

La………………….Lasi

MM……………….Millimeter

Q_D………………....The amount of discharge delivered

Q_R………………….The amount of discharge required

R……………………Represents the sub-region of the system

RIS…………………Relative irrigation supply

RWS……………….Relative water supply

SD…………………Standard deviation

T…………………...Represents the time period in which system performance was determined

TA………………....Tagelwedefit

Td…………………Tekledib

Te…………………Teleta

TWS……………....Total water supply

WDP…………………Water delivery performance

S………………………Starting discharge reading across the main canal

M……………………...Discharge reading at the middle across the canal

E………………………Discharge reading at the end across the canal

1. INTRODUCTION

1.1. Background

The majority of population of Ethiopia is dependent on rain fed agricultural production for its livelihood. However, estimated crop production is not close to fulfill the food requirements of the country. One of the best alternatives to consider for reliable and sustainable food security development is expanding irrigation development Robel (2005). To meet the demand of the ever-increasing population in Ethiopia, Irrigation development is essential to inspire the economic growth and rural development, and it is considered as a foundation of food security and poverty reduction in Ethiopia. Irrigation is one means by which agricultural production can be increased to meet the growing food demands in the country Awulachew et al., (2005).

Irrigation schemes face various problems related to operation and maintenance, water management and sustainability, these problems have greatly reduced their benefits and challenged their overall sustainability, so a need arises to identify which arrangement for water management in community managed irrigation schemes functions better Zeleke et al., (2015). Performance evaluation is carried out for such purposes as improving system management, determining the overall state of the system, determining the elements which cause trouble to the system Molden et al., (1998).

There are many variables that influence performance of irrigated agriculture, including infrastructure design, management, climatic conditions, socio-economic settings and the task of comparing performance of systems is difficult. However, if we focus on the communalities of irrigated agriculture water, land and finance and crop production it should be possible to see, in gross sense, how irrigated agriculture is performing with various settings Molden et al., (1998). Efficient operation and management of an irrigation system plays an important role in the sustainability of irrigated agriculture Mishra et al., (2001). Performance evaluation is carried out for the purpose of improving system management Small and Svendsen (1990).

The major reason for the low performance of irrigation systems is inaccurate water distribution due to the lack of a monitoring system for water delivery Lozano and Mateos (2008). Poor distribution and management of water in irrigation systems is a major factor leading to low efficiency, and thus, there is a need to assess the extent to which present irrigation systems in the area achieve their distribution aims Yercan et al., (2009). Irrigation system performance describes the effectiveness of the physical system and operation decisions to deliver irrigation water from a water source Irmak et al., (2011).

1.2. Problem statement

Irrigation can play an important role in raising and stabilizing food production, especially in the less-developed countries like Ethiopia. Mismatch between irrigation water requirement and irrigation water supply affects the proposed objective of irrigation project, since irrigation water requirement estimation is the essential part of planning; development and management of available water resources at the source and in the system.

The study area Mecha is one of great food insecurity, which is a problem for the majority of the rural population (Tesfaye and Fasile, 2011). Koga irrigation project is located in Amhara region west Gojam in Mecha Wereda. This project is designed to irrigate around 7000 ha to increase crop production and sustainable food satisfaction, but from the proposed irrigable land around 6000 ha land is irrigated the remaining 1000hectare land is suffered with shortage of water. This un irrigable land affects the aim of the project and the society.

The cause of underperformance of Koga irrigation scheme is unknown. Since the scheme is established to alleviate poverty and improve the livelihoods of the communities therefore, for Koga irrigation scheme, assessment of water delivery performance of the scheme is important to determine the causes of deficiencies.

1.3. Objective of the study

1.3.1. General Objective

To evaluate the water delivery performance of Koga irrigation project by using water delivery performance indicators.

1.3.2. Specific objective

- To assess the water supply performance indicators in the study area
- To evaluate the water delivery performance indicators in the study area

- To assess the management problems of Koga irrigation project
- To identify the gap and provide mitigation measure

1.4. Research question

- Does the water delivery performance indicator can indicate the performance of water delivery structures of Koga irrigation scheme?
- Does the water supply performance indicator can indicate the performance of Koga irrigation scheme?
- Does the water delivery performance evaluation can identify where the shortage of water is occurred in Koga irrigation project?

1.5. Scope of the study

This study concerns with water delivery performance, with special attention to evaluation of the current operation rules in terms of matching supply with demand, adequacy, equity, dependability and efficiency of water distribution and delivery to various parts of the systems. Moreover, the impacts of the complex hydrodynamic behavior of the systems on water distribution and delivery were evaluated and understood. Based on the results of the evaluation, alternative operation rules that would enhance water delivery performance and water saving will be proposed. CROPWAT model is used as a tool to assess the irrigation water requirement of Koga irrigation scheme.

Selected water supply indicators such as relative water supply, relative irrigation supply and deficiency of the scheme were evaluated. The study will propose formal and operational water management measures that would ensure better irrigation service and sustainability in the irrigation scheme. These water management interventions could also be extended to other similar schemes in Ethiopia. The research will finally make a critical analysis of the issues related to irrigation water management and water delivery performance with respect to Koga irrigation project

2. LITERATURE REVIEW

2.1. Previous research work in Ethiopia

Mamuye Tebebal and Mekonen Ayana(2015) Used nine performance indicators such as water delivery performance indicators (adequacy, dependability and equity), maintenance indicators (effectiveness of infrastructure, water surface elevation ratio, delivery duration ratio and sustainability of irrigated area) and water utility indicators (equity ratio and deficiency) in Hare irrigation project at Gamo Gofa zone. In this study the researcher collected data from primary and secondary sources. The primary data collected direct measurement from fields and filed observations were carried out while secondary data such as Climate data, irrigated crops, actual command areas and designed features of the scheme were collected from different source.

The study was carried out during the irrigation season from September to December, 2014. The results indicate that, the main canal supplies less water than the demand to the delivery points. As per the results of the study, water delivery performance of the scheme can be considered as poor. The researcher generalizes that; the performance of the irrigation system was poor.

The writer recommends that capacity building of users, adequate operation and maintenances of the system, improving diversion capacity of the scheme and providing flow control and measurement structures are required to improve the irrigation system performance.

Kassa and Ayana (2017) in Tigray KolamTembien Woreda used the same method of data collection, length of data and methodology with Mamuye Tebebal and Mekonen Ayana (2015). But Kassa and Ayana (2017) try to include efficiency and sediment analysis instead of deficiency in the methodology and field survey in method of data collection.

The writer came up with the result of fair water delivery of the scheme. The average water surface elevation ratio, delivery performance ratio, and delivery duration ratio of the main canal during the monitoring period becomes low. This is due to the highest sediment accumulation was observed in the canal.

Finally the researchers recommend that, in the irrigation scheme there were a number of irrigation structures which had mal-functioned, and now required to be remodeled with sustainable solution to improve the performance of the irrigation scheme. Hence, it has been recommended that capacity building and awareness creation for irrigation water users, water committee are the main key factor to bring a change in irrigation water managements.

2.2. The concept of performance

Aberenethy (1986) describes the concept of performance is the degree to which a system achieves its objectives; the performance of a system represented by its measured levels of achievement in terms of one or several parameters.

The performance of any irrigation system is defined as the measurement the degree to which it achieves anticipated objectivity, therefore it is important to measure and evaluate their success or failure of objectively and identifies specific areas in need of improvement Cakmak et al., (2004).

Murray-Rust and Snellen (1993) improve the concept of performance; performance of a system as encompassing the totality of both its activity inputs and the transformation of the inputs into intermediate and final outputs, and the effect of these activities on the system itself and on its external environment.

2.3. Performance assessment approaches

As Sajjad Ahmad (2012) irrigation system performance includes efficiencies of various components like storage efficiency, conveyance efficiency of canals, application efficiency, and field efficiency among others. In turn, three main standards could be used to evaluate the performance of irrigation systems, these are: the physical condition of the infrastructure, water delivery services, and agricultural production.

Bos et al., (2005) describes the purpose of performance assessment is to achieve efficient and effective irrigation performance by providing related feedback to management at all levels. As such, it may assist management or policy makers in determining whether performance is satisfactory and, if not, which corrective actions need to be taken in order to remedy the situation.

Performance assessment is key factor to improve daily operation, to identify problems and monitor the effect of interventions to solve these problems. With scarce water resources, the need for better performance of irrigation became obvious. For an effective performance assessment program a framework needs to be defined Gorantiwar & Smout (2005). It is helpful to consider an irrigation system in the context of nested systems to describe different types, uses of performance indicators and address the important question of boundaries within which performance is assessed Small and Svendsen (1992). The performance of irrigation water delivery systems and performance of irrigated agriculture systems relies on the water conveyed by specific set of canals Korkmaz and Avci (2012).

Molden and Gates (1990) and Bos et al., (2005) have tried to standardize performance indicators to permit better comparison of irrigation systems. To assess the performance it is important to confirm the indicators selected in respect to the objectives established for that irrigation system. A good indicator tells a manager what current performance of the system is, and, in combination with other indicators, may help to identify the correct course of action to improve performance within that system.

Gorantiwar and Smout (2005) defined two types of performance measures i.e. the allocate type comprising productivity and equity; and the scheduling type comprising adequacy, reliability, flexibility, sustainability and efficiency.

The objective of using comparative indicators is to evaluate outputs and impacts of intervention in individual systems, compare performance of a system over time, and also to allow comparison of systems in different areas and at different system levels Molden et al., (1998).

Renault (1999) developed analytical relationships between the controls of canal water depth, and the sensitivity of irrigation delivery structures. Renault and Hemakumara(1999) attempted to develop an analytical framework to address sensitivity of irrigation off takes. Understanding of delivery takes into account the impacts of the worries on the delivery to the command area of the off take. Renault et al., (2001) observed that, the flow behavior along canal irrigation network can be assessed by determining the sensitivity of the irrigation structures.

2.4. Irrigation performance indicators

Performance indicators measure the value of a particular item such as yield or canal discharge and have to include a measure of quality as well as of quantity, and be accompanied by appropriate standards or permissible tolerances. Performance indicators reflect the level of adequacy in the use of resources to obtain the final outputs in irrigation schemes Bos et al., (2005).

2.4.1. External performance indicators

Molden et al., (1998) described this category of indicators as those that analyze the inputs into and outputs from irrigation projects such as land, labor, water, cost of scheme operation and maintenance as well as the value of production.

The external performance indicators can be subdivided in to four different categories, namely agricultural performance indicators, water use indicators, economic and environmental indicators Greaves (2007). Nine sets of external performance indicators developed by Molden et al., (1998) for describing performance at scheme level. Malano and Burton (2001) developed a similar set of external indicators, but added environmental indicators to the list. They are important for comparison of performance between different schemes for study of the impacts of management interventions. Bos et al., (2005) states that, water related external performance indicators are categorized as water balance, water service and maintenance indicators.

Agricultural performance indicators generally analyze the output from an agricultural system in relation to the inputs into the system; that is agricultural productivity Greaves (2007) and Moldenet al., (1998). But, Molden et al., (1998) focus on the first four indicators. Greaves (2007) summarizes in Table 1.Molden et al., (1998), however, points out that these indicators must be viewed in context to the region in which they are used. Where water is the more constraining resource compared to land, then output per unit water maybe more important than output per unit land. The reverse is true for a region where land is more constrained Greaves (2007).

Moldenet al., (1998) and Burt (2002) also developed water supply indicators some of which were summarized by Greaves (2007). The indicators include Relative Water Supply (RWS) and Relative Irrigation Supply (RIS). Both RWS and RIS relate water demand to the supply of water in a scheme, and thus, they provide information on water availability.

Molden et al., (1998) states that Both RWS and RIS relate supply to demand, and give some indication as the condition of water scarcity, and how strongly supply and demand are matched. A value of 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

2.4.2. Internal performance indicators

These indicators examine the technical or field performance of a project by measuring how close an irrigation event is to an ideal one. An ideal or reference irrigation is one that can apply the right amount of water over the entire region of interest (i.e. depth of root zone) uniformly and without losses Feyen and Dawit (1999). Analysis of the field data allows quantitative definition of the irrigation system performance. The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field Feyen and Dawit (1999).In order to enhance performance, it is necessary to have a comprehensive understanding of the internal processes within an irrigation scheme. Internal indicators examine the mechanisms of water control and allocation at all levels of the project and provide systematic rating of hardware, management and service throughout the entire system Kuscu et al., (2009).

As Burt (2002) states many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated; and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. An example of internal performance indicators is actual water delivery services to irrigation schemes, volume measurement, flexibility and reliability.

The purpose of evaluating both the external and internal indicators of an irrigation scheme is to reflect all the organizational dimensions and identify system components that require maintenance or modernization. In the developing world, where economies are based on agriculture, it is necessary to carry out thorough irrigation performance assessments using both categories of indicators. The inclusion of internal indicators implies that the performance assessment would incorporate corporate and social evaluation, stakeholder satisfaction and participation for continuous improvement of quality, standards and excellence Kuscuet al., (2009).

2.5. Water delivery performance indicators

Gorantiwar and Smout (2005) performance Indicators that measures the different processes involved in irrigation water management. These are allocation of the resources (e.g. productivity, equity, etc.) and scheduling of the resources (e.g. adequacy, reliability, etc.).

Clemmens (2001) states that water delivery performance indicators are useful tools to understand the internal operational processes of the system. Internal indicators enable a comprehensive understanding of the processes that influence water delivery service and the overall performance of a system Renault et al., (2007). Hence, they are useful to show what would have to be done to improve the internal and hence the external performance. Water delivery indicators are evaluating whether the system delivers water at the required rate at the right place and time and to assess whether the water delivery service is healthy. Adequacy (PA), Efficiency (PF), Equity indicator (PE) and Dependability indicator (PD) are the main indicators of internal water delivery performance.

Adequacy indicators:

Gorantiwar & Smout (2005) defines Adequacy deals with water supply to the crop relative to its demand. The measure of adequacy, relative water supply (RWS) is the most comprehensive. When the supply matches demand exactly, adequacy is one, however when supply exceeds demand, adequacy will be more than one. Hence the water supplied or allocated in excess of demand (if any) should not be considered for estimating the adequacy." The adequacy may be reduced with deficit irrigation as less water may be delivered than the maximum crop water requirement or the interval between irrigation water deliveries may be prolonged.

Adequacy is influenced by water availability at the source, delivery capacity and the operational situation of the scheme (predictable water demand in relation to supply) and type of the division system. Adequacy of water delivery is a measure of the degree to which water deliveries meet soil-plant water requirements. Adequacy of water delivery is dependent on water supply, specified delivery schedules, the capacity of the hydraulic structures to deliver water according to the schedules and the operation and maintenance of hydraulic structures Mishra et al., (2010). Adequacy specifies the capacity of an irrigation system to meet water demands of the farm; it is a measure of the ability of a system to reach targeted deliveries in terms of quantity Renault and

Wahaj (2005).Won-Ho Nam et al., (2016) defines Adequacy as the ability of an irrigation system to meet the required irrigation water.

Equity indicators:

Gorantiwar & Smout (2005) describes equity in different form depending on the objectives of irrigation water management in the irrigation scheme, equity can be for Area to be irrigated (planning) or area irrigated (operation),Water allocated (planning) or delivered (operation), Crop production expected (planning) or crop production obtained (operation) for mono crop irrigation scheme and Benefits expected (planning) or generated (operation).

Equity, as related to water delivery system can be defined as the delivery of the fair shares of water to the users throughout the system. Equitable water distribution is attained when the ratio of water delivery to head outlets to the outlet at the tail outlets equal to one. In irrigation system water delivered to the beneficiary farmers in an equitable manner in its command area to ensure maximum agricultural production. Equity of water distribution is the operational objective of the canal irrigation system in Pakistan Bhutta et al., (1992).

Equity of water distribution is an appearance of the share of each individual or considered fair by all system members. A perfectly equitable distribution will result if all locations receive an adequate water supply or if each location receives the same supply Murray-Rust and Snellen (1993). The water allocation process principally affects the equity performance indicator Tariq and Kaka (2004). The parameter to be considered for equity in water allocation may vary: depth, volume and discharge Gorantiwar and Smout (2005). Won-Ho Nam et al., (2016) expresses Equity as the degree of variability in relative water delivery from point to point over the irrigated area.

Dependability indicators:

Abernethy (1986) defined dependability as deliveries according to some schedule and according to him; unreliable water supplies are undesirable to a system's overall health. The successful results of the allocation plans depend on reliable supply. The maximum reliability of water supply is often more important than maximum adequacy. Gorantiwar and Smout (2005) defines dependability is "the ability of the water delivery system and the schedule to meet the scheduled demand of the crop". This involves matching both the duration of supply or volume delivered to the planned duration of supply or volume to be delivered and the, time during the season when these volumes were supplied to those planned times.

Dependability of water supply is an appearance of confidence in the irrigation system to deliver water as promised and is indicative of the timeliness and adequacy of deciding deliveries Makadho (1994). Dependability of water delivery is an indicator for the degree of conformity of water deliveries to prior expectations. It implies the achievement of temporal uniformity of the relative water delivery over a region R. Water supply of dependability is influenced by the mode of water delivery and type of distribution system. Depending on the mode of water delivery, variability and predictability of water supply are important aspects of dependability of water delivery system.

Dependability is defined as temporal uniformity of the ratio of the delivered amount of water to be required or scheduled amount. A system that dependably delivers an inadequate amount of water may be more desirable than one that delivers on the average an adequate yet unpredictable supply Gorantiwat &Smout (2005). The dependability of water delivery can be taken as the temporal variability of the ratio of amount of water required that occurs over a region. Won-Ho Nam et al., (2016) expresses dependability as the ability to find water at the time desired and in the place desired in the system.

Efficiency indicators:

Efficiency is the conservation of water resource, it plays an important role in water delivery for the authority and government because water saved may result in less expenditure on infrastructure and can possibly be allocated to fully meet the existing requirement or irrigate more land Paul, J.M., (1996).

Efficiency values indicate that the proportions of excess water lost as deep percolation to saline groundwater. The off taking efficiency indicators hence settle that the excess water diverted is lost in the main system (seepage), into the drainage within the system (mainly to saline groundwater and part of it back to the river), and at system tail end (to saline marshes), Zeleke et al., (2015).

Efficiency is defined as the ratio of the volume of water required for a specific purpose to the volume of water delivered for this purpose. It is commonly interpreted as the volume of water stored in the soil for evapotranspiration compared to the volume of water delivered for this purpose Binoy et al., (2013).

Gorantiwat & Smout (2005) realizes Efficiency in two ways. Firstly, appropriate optimum allocation plans cannot be developed if proper consideration is not given to efficiency. Inaccurate or simplified estimates also have a major influence on other performance parameters such as productivity, adequacy, equity and reliability. Secondly, the inspection of efficiencies over space and time at different levels enables the irrigation authorities to learn which part of the scheme is inefficient, where it is inefficient and how it is failing.

Won-Ho Nam et al., (2016) Efficiency is the measure of the excess of water delivered in comparison with the requirements. It embodies the ability to conserve water by matching the water deliveries with water requirements.

2.6. CROPWAT model description

Allen et al., (1998) define and describe CROPWAT model is a software program for the computation of crop water demand and irrigation programming. Moreover, the software provides options for the design of diverse water supply scenarios and the computation of a number of water supplies for several crop patterns. The program is subdivided into in eight distinct modules, five of which are for data enter and three for computations. The entry to the modules is through menu in the tool bar or alternatively using the navigation bar at the left-hand side of the main view. The data entry modules include climate, rain, crop type (dry crop or rice, Soil and Crop pattern. The computation modules are CWR, schedules and scheme, for the calculation of crop water requirement, irrigation schedule and scheme supply, respectively.

Despite the fact that the physical determination of crop-water requirements (CWR), irrigation schedules and depths, is complicated and time-consuming, they remain vital to irrigation water management and planning Abdelhadi et al., (1999). The introduction of computer models has made it easier and possible to schedule irrigation and supply the exact amounts of water required by crops at every physiological stage in their growth cycle. Examples of such models include CROPWAT Clarke et al., (1998).

2.6.1. Consumptive use (Evapotranspiration)

Consumptive use is the sum of Evaporation which is defined by Michael (1997) stated that evaporation from natural surface, such as open water, bare soil or vegetative cover is a diffusive process, by which water in the form of vapor is transferred from the underlay surface to the atmosphere and Transpiration which is defined and described by Allen et al., (1998) as the vaporization of liquid water contained in plant tissues and the vapor removal to the atmosphere. The vaporization occurs within the leaf, namely in the intercellular spaces, and the vapor exchange with the atmosphere is controlled by the stomata aperture. Hanson et al., (2007) describes Evapotranspiration of crops is the sum of water vapor fluxes from transpiration of leaves and evaporation from soils and wet leaves. Crop water requirements depend on the balance between evapotranspiration (ET) and precipitation and resulting soil moisture conditions. It is driven by meteorological conditions, crop management practices and by the amount of soil water available to their roots Pereira et al., (2006). Crop water requirement is an important practical consideration for improved water-use efficiency. Crop water requirements vary during the growing period, mainly due to variation in crop canopy and climatic conditions, and are governed by crop evapotranspiration (ETc) Benli et al., (2006).

The other process is actual evapotranspiration (ETc), the amount of water actually removed from a surface due to the processes of crop transpiration and soil evaporation. The effects of both crop transpiration and soil evaporation are integrated into a single crop coefficient (Kc), incorporating crop characteristics and average effects of evaporation from the soil Pereira and Alves (2005).

The water requirements of each crop are calculated on the basis of meeting the evapotranspiration rate (ETcrop) of crops under standard condition. The net irrigation requirements of the crops (NIR) are calculated using the field water balance. The variables include crop evapotranspiration (ETcrop), rainfall (Pe), groundwater contribution (Ge) and stored soil water at the beginning of each period (Wb). To determine the irrigation requirements, in addition to meeting the net irrigation requirements, water may be required for leaching of accumulated salts from the root zone (FAO 1977).

3. MATERIAL AND METHODOLOGY

3.1. Location and description of the study area

The catchment of Koga irrigation project lies in the Tana Basin between 11°10’ and 11°22’ North Latitude and 37°02’ and 37°17’ East Longitude. It covers an area of 22,000 hectares at dam site (37o08’ E and 11o20’ N) that drains into Koga River. The basin covers an area of 266 km2. The Koga River is a tributary of the Gilgel Abay River in the headwaters of the Blue Nile. The Gilgel Abay flows into Lake Tana. The monthly flow characteristics of the Koga River follow the rainfall pattern. Minimum flow occurs in April. Flow begins to increase in May, in response to the early rains, reaching a peak in August. About 70% of the runoff occurs in the three months from July to September. Its average annual rainfall is 1578 mm Birhanu et al., (2015).

The Koga dam and Irrigation project is situated adjacent to the town of Merawi in the Mecha Woreda, West Gojam Zone in the Amhara regional state Merawi lies in the middle of the Woreda and is situated 35 km south of Bahir Dar, the capital city of Amhara region. The main purpose of the project is to irrigate 7,000 ha, and to improve crop yield. Forestry, livestock, soil conservation, water use and sanitation on the 22,000 ha catchment area is also supposed to improve Eguavoenw Tesfai (2011).

The project comprises of the main dam is 1860 m length and two saddle dams; In addition, to the main dam 18.50 m high and 1,106 m long saddle dam about 6km to the northeast of the main dam is constructed. The storage capacity of the reservoir at full supply level (2015.25m.a.s.l) is 83.1 Mm^3.TheFeasibility Study for Koga Irrigation Project was carried out by Acres International Ltd (Canada) in association with Shawel Consult Intl. Detailed Design Work started in April 2003 by Mott MacDonald Limited (UK) in association with Metaferia Consulting Engineers (Ethiopia) and Water Works Design & Supervision Enterprise (Ethiopia) MacDonald (2005).

Koga Irrigation project includes 19.7 km long concrete lined main canal with discharge capacity of 9.1 m^3/s, 42.4 km of lined 12 secondary canals (blocks) with different discharge capacity, 150 km of lined and some of it unlined tertiary canals, about 905km of unlined 469 quaternary and Field canals, and 11 night storages MacDonald (2004).

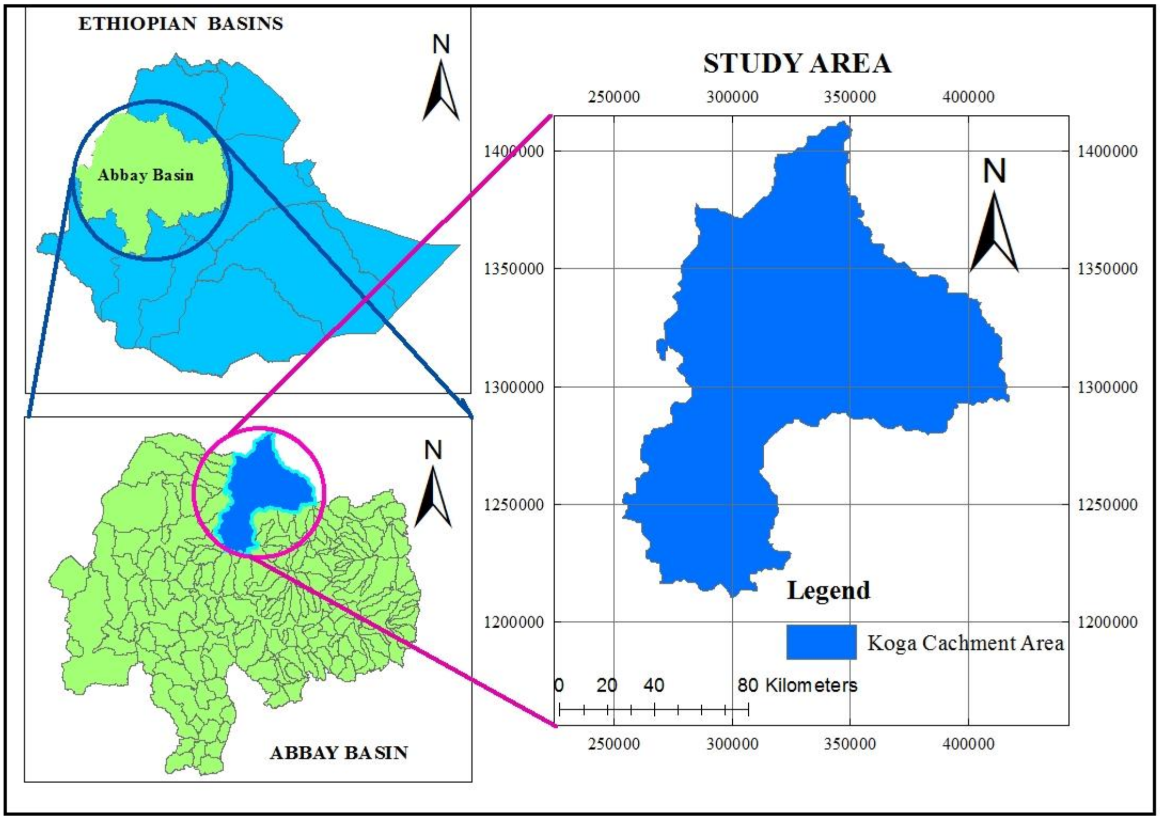

Figure 1 Location of the study area

3.1.1. Climate

The monthly flow characteristics of the Koga River follow the rainfall pattern. Minimum flow occurs in April. Flow begins to increase in May, in response to the early rains, reaching a peak in August. About 70% of the runoff occurs in the three months from July to September. Its average annual rainfall is 1578 mm. The rainfall usually begin in May and increase gradually in frequency to reach a maximum in July or August. The annual precipitation ranges from 800 to 2200 mm, with a mean of 1,420 Birhanu, et al., (2015).

The average day time temperature of the study area is 24ºC. Mean maximum temperature varies from 30.1ºC in April to 24.3ºC in July and August; mean minimum temperature varies from

8.9ºC in January to 15.5ºC in May. The highest mean temperatures are always between March and May. The mean monthly relative humidity is 58.4%.The value of Relative humidity is highest during the humid rainy season from July to August, it becomes 75% and lowest during March 42.9%. Mean monthly sunshine hour varies from a low value of 4.4 h/d during the month of August (rainy season) to as high as 9.9 h/d during the month of December Tesfaye and Fasile (2011).

3.1.2. Soils

The reddish brown soils in the irrigation area are relatively homogeneous and show the same physical and chemical characteristics. As much as 87% of the area is believed to consist of silt clay soils suitable for irrigation Macdonald (2006). These are generally, well drained soils formed in the upland positions mainly in the downstream of the dam site and on both sides of the Koga River.

These soils are intensively cultivated in the study area and possess good drainage and workability Tesfaye and Fasile, (2011). Overall, the soils are well suited for irrigation, with Foundations Red silty clay with (c(KN/m^2) 5,Φ' 29°, density 16 KN/m^3), Pale sol with (c'(KN/m^2) 0, Φ'13°, density 16 KN/m^3), Completely weathered basalt with (c'(KN/m^2) 0, Φ' 30°, density 16 KN/m^3) and with Fill Material Red silty clays with (c(KN/m^2) 5, Φ' 30°, density 17.5(KN/m^3) Macdonald (2006).

3.2. Method of data collection and source of data

The data collection was carried out in collaboration with agronomists, irrigation engineers, gate operators and other individuals of the irrigation Project. Data were collected both from primary and secondary sources. Primary data were collected by formal and informal communication with respective organization, interview, physical measurements and field observations. Fields were selected from the head, middle and tail-end of the main canal for primary data collection (discharge measurement).Primary data was collected from the study area, Koga Irrigation Development Project, during three consecutive months from February up to April 2018. Secondary data were collected from Addis Ababa Metrological Station, Amhara region water resource and irrigation project office and Koga Dam and irrigation project office and housing.

3.2.1. Primary data

Primary data collection include frequent field observations made to observe and investigate the method of water applications, practices related to water management techniques made by the assigned persons and farmers and to understand the condition of the water delivery structures. Measurements of discharge at the main canal were taken frequently and average discharge coupled with the total flow time and the total volume of water diverted by the irrigation scheme was estimated. The discharge of the main canal was measured by using the main dam controlling systems, propeller type current meter, canal cross section (top width, bottom width and water depth), GPS coordinates and altitudes of site locations, and taking references of gauges.

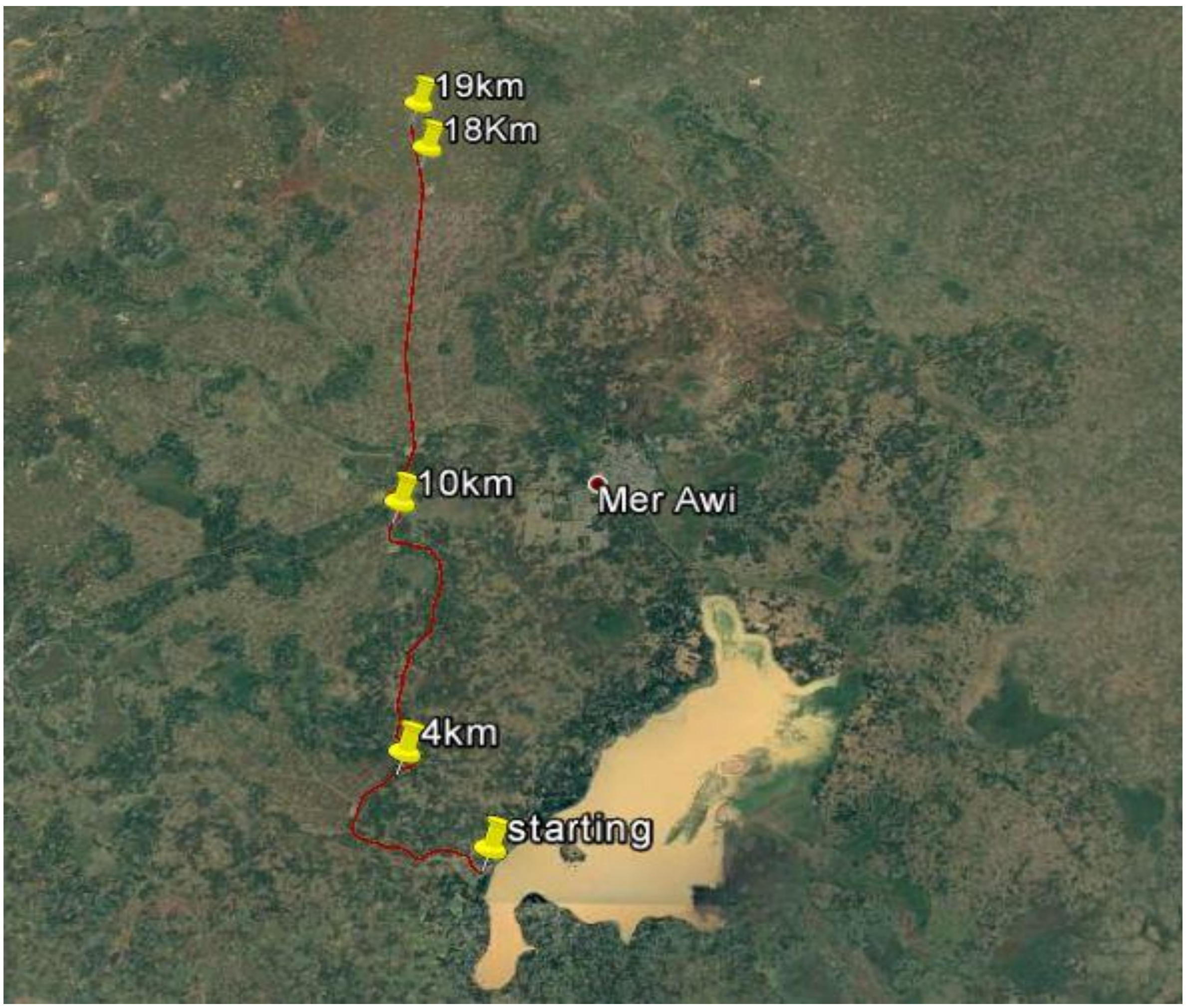

Figure 2 Velocity and canal cross section reading points on the main canal by using global mapper

3.2.1.1. Measuring of delivered irrigation water

To calculate the total amount of water diverted to the total irrigated areas within a season, the flow velocity measurement is taken at three location in the main canal (head, middle and end) of the main canal two times a week and three times of reading and the average velocity was used.

The amount of water diverted to the main canal and the starting time was measured and recorded throughout the irrigation season by computerized automatic recorder at the outlet of the reservoir. The flow velocities measured by the current meter and it is multiplied by the areas of flow cross sections to change in to discharge. If the velocity distribution in a vertical is close to the regular classical form then it can be assumed that the mean velocity occurs at 0.6 of the depth (D) from the surface i.e. 0.6D. The one (0.6D) and two point (0.2D & 0.8D) methods are adequate for most routine fieldwork. The former is used for depths less than 1.0 m and the latter for depths greater than a 1.0m (Srivastava 2016).

Discharges were measured for three consecutive months from February to April for each week at a given measuring point (head, middle and tail) the average of weekly discharge was taken as monthly discharge. The main canal system performance with respect to water delivery indicators was estimated based on the monthly required and delivered discharge. Flow depth and top width were measured by graduated staff gauge and measuring tape respectively.

Figure 3 Discharge measurement of the main canal by using current meter (photo in 07/07/2010)

3.2.1.2. Field observation

In this study frequent field observation was conducted to understand the conditions of existing irrigation structures, current water delivery system, method of irrigation and the management system. During field observation the overall operational activities, overall water conveyance structure, water distribution at secondary, tertiary, quaternary and field canals were observed. Field visit enables to visualize and identify the visible factors which affect the performance of the scheme.

3.2.2. Secondary data

For this study secondary data were collected from Koga project site office and housing, Amhara region water resource and irrigation project office and Federal Meteorological station. Secondary data included discharge data, design reports, operation and maintenance and progress necessary report, project documents, studies and other useful written materials. These data included design and layout of the scheme, design of conveyance, design discharge working sheet and water control structures, irrigated area, area irrigated per crop per season/year were collected.

3.2.2.1. Meteorological data

For this thesis , 11 years meteorological data (1993 to 2003) were taken from National meteorological agency, Addis Ababa for Bahirdar (airport) meteorological station used to compute the crop water requirement and the irrigation water demand. Such data include; monthly average temperature (maximum and minimum), relative humidity, sunshine hours, wind speed and rainfall. The study area have mean monthly maximum and minimum temperature are 31.44 ^oC and 7.4 ^oC respectively while the average monthly maximum and minimum effective rainfall was 438.1mm and 0.73mm respectively. In the area, the maximum reference evapotranspiration (ETO) is 3.97mm/day. These meteorological data was presented in Figure 4. The detail of meteorological data is summarized in Appendix A.

3.3. Methodology and data interpretation

3.3.1. Estimation of missing data

Before using the rainfall records of the station, it is necessary to check the data Continuity. The continuity of the record may be broken with missing data due to absence of recorder, failure of the instrument and wind effect. Therefore, it is often necessary to estimate missing records by using the data of neighboring station Subramanya (1982). There are different methods of filling the missing data

Linear regression method: from the given rainfall data, as there are three gauging stations linear regression equation between the preceding and the following days of the year is use to fill the missing flow records. If the coefficient of correlation obtained between successive months are greater than 0.6, then the data obtained by regression adopted as the representative value of the missing record. However if the coefficient of correlation is less than 0.6, then regression is not adopted Chow (1956).

Arithmetic average method: if the average annual rainfall at each of the neighboring stations differs within 10% of the average annual rainfall of the missed station, then simple arithmetic average method is used Garg (2005).

$$Px = \frac{1}{n}(P1 + P2 + \cdots + Pn) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots *$$

Where Px= missed annual precipitation at x station

P1, P2…Pn= annual precipitation values at neighboring n station

N1, N2…Nn= normal annual precipitation at each of the above (x+1) stations including station x are known

Normal ratio method: when the average annual precipitation at any of the neighboring stations differs from that at the station by more than 10%, the normal ratio method is used Garg (2005).

$$Px = \frac{Nx}{n}\left(\frac{P1}{N1} + \frac{P2}{N2} + \cdots \frac{Pn}{Nn}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .**$$

3.3.2. Determination of crop demand and irrigation water requirement

To estimate the crop water requirements and irrigation water requirement of the project CROPWAT for windows (CROPWAT8:0) which have five data input modules (climate/ET_O, rain, crop, soil and crop pattern) and three calculation modules (crop water requirement, schedule and scheme) was used. This program uses monthly average minimum and maximum temperature, sunshine, relative humidity, wind speed and precipitation as an input to calculate reference crop evapotranspiration and effective rainfall by using Penman-Monteith equation.

The determination of the crop water requirement (CWR) and irrigation requirement (IR) by CROPWAT model depends on soil type, Crop types, plantation date and area covered by each crop. The results are obtainable in graphs and tables.

To evaluate water delivery and utility of water supply indicator, the flow rate to feed the each block was converted in to flow volume (Q_R, in m^3/s), which is the product of IR in l/s/ha per month and the command area (ha) served for irrigation practice. The irrigation requirement (IR) indicates the difference between the Evapotranspiration of the crop under ideal conditions (ETc) and the Effective Rainfall (ER) contributions during the same time period Aksara and Pasin, (2015) and it is expressed in mm or m^3

3.3.3. Determination of performance indicators

According to Won-Ho Nam et al., (2016) the performance indicators of water delivery were divided into water supply/use indicators of the irrigated area and water delivery indicators of the irrigation canal.

3.3.3.1. Water supply indicators

The water supply indicators like relative water supply (RWS) and relative irrigation supply (RIS) have been proposed by Molden et al., (1998) and Greaves (2007).

Relative Water Supply (RWS): According to both Molden et al., (1998) and Greaves (2007), the relative water supply is defined as the total water supply divided by the crop demand. The total water supply is defined as the total rainfall plus diverted irrigation supply. The Crop demand was determined with CROPWAT model.

$$\text{Relative Water Supply (RWS)} = \frac{\text{total water supply}}{\text{crop demand}} \qquad \text{.......1}$$

Where

Total water supply= Surface diversions plus net groundwater draft plus rainfall.

Crop demand= Potential crop ET, or the ET under well-watered conditions.

Relative Irrigation Supply (RIS): The term relative irrigation supply was presented to be consistent with the term relative water supply, and to avoid any confusing value judgments inherent in the word efficiency Molden et al., (1998).

$$\text{Relative Irrigation Supply (RIS)} = \frac{\text{Irrigation supply}}{\text{Irrigation demand}} \qquad \text{.......2}$$

Where

Irrigation supply = only the surface diversions and net groundwater draft for irrigation.

Irrigation demand= the crop ET less effective rainfall.

Deficiency (D)

Deficiency is a quantitative measure of the dissatisfaction's of users. According to Mamuye and Mekonen (2015) Deficiency is given as the ratio of water deficiency to the required amount. Estimation of deficiency is given as the ratio of water deficiency to the required amount. A measure of deficiency is given as the ratio of temporal and spatial average of water deficiency to the required amount (QR). Water deficiency was the difference between water required (QR) and delivered discharge (QD).If water does not arrive at farms in an adequate and timely amount, crop yields may suffer and farm net returns decrease. The degree of the deficiency is another parameter that the users more concerned. Knowledge of the amount of deficiency is quantitative measure to evaluate the satisfaction of the user.

When the deficiency (D) value equal to or close to zero; indicates that conveyance system supply water relative to the required; in this case the performance of the scheme was acceptable. If D value is greater than zero (D > 0); there was a deficiency happened in the scheme, this specifies that the conveyance system supplied less water than the required. In this case, the performance of the scheme is unsatisfactory Binoy et al., (2013).

$$D = 1/T \sum_{T=1}^{T} (1/R \sum_{R=1}^{R} \left(\frac{QR - QD}{QR} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3$$

$D = \frac{QR-QD}{QR}$ If QR>QD otherwise D=0

3.3.3.2. Water delivery performance indicators

The water delivery performance indicators such as adequacy, equity, dependability and efficiency have been proposed by Molden and Gates (1990), the performance of a given system is evaluated based on performance standards proposed by Molden and Gates (1990).

Table 1 Performance standards for water delivery performance indicators Molden & Gates (1990)

Indicators	Good	Fair	Poor
Adequacy (P_A)	0.90-1.0	0.8-0.89	<0.80
Efficiency (P_F)	0.85-1.0	0.70-0.84	<0.70
Dependability (P_D)	0.00-0.10	0.11-0.20	>0.20
Equity (P_E)	0.00-0.10	0.11-0.25	>0.25

Adequacy (PA): Adequacy shows the degree to which the total water deliveries are sufficient to satisfy the needs of the crops in the crop season. According to Molden & Gates (1990) Adequacy is the ratio of actual amount of water delivered by the system to the amount of water required for consumptive use, leaching, land preparation and the conveyance losses.

$$PA = 1/T \sum_{T=1}^{T} 1/R \sum_{R=1}^{R} (Pa) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where,

$Pa = \frac{QD}{QR}$, if $Q_D \leq Q_R$, otherwise P_a=1

Q_D and Q_R are actual delivered and required amount of discharge respectively

T = Represents the time period in which system performance was determined and

R = Represents the sub-region of the system whose performance is to be determined.

Q_D is found from discharge measurement by automatic recorder at the head of the canal and by using current meter at the middle and tail reach of the canal as the amount of water delivered, and Q_R is obtained from the design document as the amount of water required (design). Then adequacy was calculated as a spatial and temporal average of Q_D/Q_R Concerning the adequacy, when the volume of water delivered (Q_D) exceeded the volume of the water required (Q_R), the amount delivered was accepted as adequate without taking into consideration the amount of the excess, and the ratio P_A was determined to be 1. Q_D/Q_R= 1 this means enough water is being supplied in order to meet the requirements, Q_D/Q_R< 1 indicates that the supply is less than the requirement, and Q_D/Q_R> 1 indicates that more water is being supplied than is required. A value of 1.00 or close to 1.00 for P_A indicated adequacy of water delivery, while a value less than 0.80 for P_A presented inadequacy of water delivery.

Efficiency (P_F): According to Won-Ho Nam et al.,(2016) Efficiency is the measure of the excess of water delivered in comparison with the requirements. It embodies the ability to conserve water by matching the water deliveries with water requirements.

$$PF = 1/T \sum_{T=1}^{T} 1/R \sum_{R=1}^{R} (Pf) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .5$$

Where

$Pf = \frac{QR}{QD}$, if $Q_R \leq Q_D$, otherwise P_f=1

When $Q_R < Q_D$, the value of P_F was calculated, but otherwise, pF was assumed to be equal to 1.00. If P_F was equal to or near 1.00, this meant that the water in the system was being used efficiently, but if the value was less than 0.70, it meant that the water in the system was not being used efficiently.

Dependability (P_D): According to Gorantiwat &Smout (2005) and Won-Ho Nam et al., (2016) dependability states that the ability to find water at the time desired and in the place desired in the system, as well as the degree of the temporal variability of the irrigation delivery in comparison with the requirements. In this respect, dependability comes to mean that the water can be delivered at the assured flow rate and duration.

$$PD = \frac{1}{R} \sum_{R=1}^{R} CVT(Pa) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots ..6$$

Where: $Pa = \frac{QD}{QR}$, $CVT = \frac{SD}{Meam}$

SD= Standard deviation

$CVT \left(\frac{QD}{QR}\right)$=coefficient of temporal variation of the ratio QD/QR in time period T.

When the value of dependability approaches to zero, it indicates that the water delivery is working properly for the time period. The reverse is true when the value of P_D becomes above 0.2. This means the water delivery is not working properly.

Equity (PE): Gorantiwar and Smout (2005) expresses, Equity is the degree of variability in the relative water delivery from point to point over the irrigated area and it is a measure of the spatial uniformity of the water deliveries and shows the fairness of water delivery across the delivery points.

$$PE = \frac{1}{T}\sum_{T=1}^{T} CVR(Pa) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots 7$$

Where: $Pa = \frac{QD}{QR}$

$CVR\left(\frac{QD}{QR}\right)$ is the coefficient of the spatial variation of the ratio Q_D/Q_R in area R.

When P_E approaches to zero there is equitable water distribution in the system for the time period; but as P_E becomes greater than 0.25 the equitable distribution of water becomes low.

4. RESULT AND DISCUSSION

4.1. Irrigation water supply and demand of the scheme

During the assessment period (February, March and April), estimation of irrigation water demand of the command area served, finally comparison of the actual irrigation water supply with demand on the system was evaluated.

4.1.1. Irrigation water supply

The amount of irrigation water supplies in the main canal on the system over three months (from February up to April, 2018) was estimated. The discharge data was found in two ways. The first one, discharge data taken from the project site which is recorded by using automatic recorder (at the head of the canal); used to compare with the measured one and the second one was calculated as area of the canal section times average real velocity. Velocity reading was taken at three reaches of the main canal (head at the main outlet, middle at 4& 10 km and tail at 18 and 19km reach) by using current meter. The reading points were indicated in the Figure 2. Monthly irrigation water supplies to the system were determined as average monthly supplies for each month (Table 2). The average monthly maximum irrigation water supply was observed in February, it was 6.31m^3/s and the minimum was in April, it was 1.86m^3/s. The values of irrigation water supply in the main canal system were summarized in the Table 2.

Table 2 Average irrigation water supply of the main canal (m^3/s)

Month	Period	Reach (chain age)				
		Head	Middle		Tail	
		outlet	4KM	10KM	18KM	19KM
February	Week1	6.24	5.82	5.21	0.71	0.69
	Week2	6.33	5.92	5.25	0.69	0.67
	Week3	6.30	5.93	5.36	0.69	0.68
	Week4	6.38	6.00	5.35	0.71	0.69
	Average	**6.31**	**5.92**	**5.30**	**0.70**	**0.68**
March	Week1	4.73	4.52	4.28	0.67	0.64
	Week2	4.79	4.53	4.13	0.68	0.63
	Week3	4.79	4.52	4.19	0.67	0.64
	Week4	4.77	4.55	4.18	0.66	0.65
	Average	**4.77**	**4.53**	**4.20**	**0.67**	**0.64**
April	Week1	1.85	1.73	1.51	0.19	0.17
	Week2	1.86	1.72	1.57	0.20	0.17
	Week3	1.87	1.69	1.46	0.19	0.18
	Week4	1.85	1.68	1.48	0.20	0.18
	Average	**1.86**	**1.71**	**1.51**	**0.20**	**0.18**

4.1.2. Estimation of irrigation water requirements

4.1.2.1. Reference Evapotranspiration (ETO)

By using CROPWAT software the ET_O of all months in the study area was ranging from 2.97 to 3.97 mm/day by multiplying with the day in each month ETo ranges from 92 to 122.8mm. Minimum ET_O value was observed in December and maximum in April as Shown in Appendixes-A (Appendixes Table 1). This indicates that the differences reflection in meteorological parameters. The effective rainfall value for all months also ranges between 0.7mm and 168.8mm; the maximum average monthly effective rain fall was observed in July while the minimum was observed in January. The value was shown in Figure 4.

Table 3 Average monthly ER and ETO of the study area

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ER(mm)	0.7	1.3	22.4	34.3	53.8	142.3	168.8	162.4	134.8	75.2	11.3	3.7
ET_O(mm)	93.3	93.2	114	119.1	122.8	109.2	96.4	94.6	104.1	108.8	95.1	92

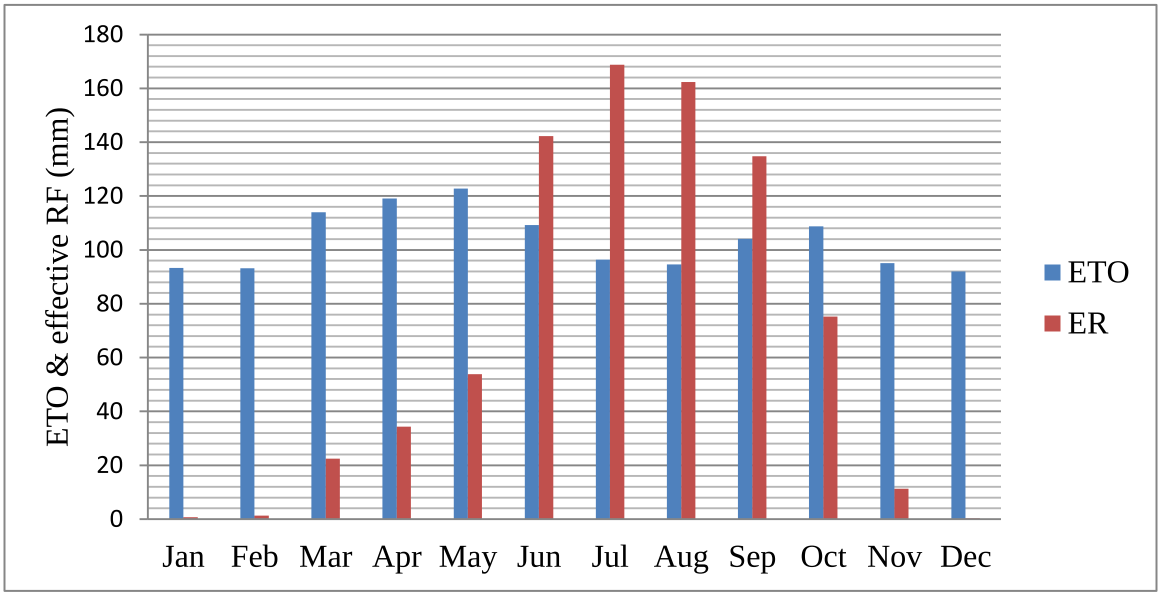

Figure 4 Effective rainfall and referenced evapotranspiration

4.1.2.2 Crop water requirement (CWR)

There are different crop types which are cultivated in Koga irrigation scheme. Those crops have different crop water requirement. The crop water requirement (CWR) of each crop was estimated for one irrigation season (from January to May 2018) using CROPWAT 8.0 software program. Multiplying the result from CROPWAT by the area covered by each crop type (Appendixes -E Appendixes Table 41) the CWR in flow rate was determined. The total crop water requirement results are summarized below in Table 5.

Table 4 Area covered by each crop and the total irrigated area

Crop type	Barley	Beans	Maize	Peppers	Vegetable	Wheat	Total
Area covered (ha)	157.5	9.9	538.7	53.4	2196	2750	5705

(Source: Koga irrigation project and housing site office)

Table 5 Average monthly crop water requirement of cultivated crops in the scheme

Month	CWR(m^3/s)						Average Monthly Total
	Barley	Bean	Maize	Pepper	Vegetable	Wheat	
Jan	0.077	0.005	0.20	0.034	1.70	0.87	2.89
Feb	0.20	0.012	0.59	0.050	2.50	2.40	5.75
Mar	0.23	0.014	0.81	0.070	2.88	3.96	7.97
Apr	0.15	0.007	0.65	0.073	0.94	3.52	5.34
May	0.00	0.000	0.10	0.022	0.00	0.54	0.66
Total	0.66	0.038	2.35	0.250	8.00	11.29	22.58

As shown in Table 5, the total monthly crop water requirement for five consecutive months (from January to May) has been fluctuating; higher from March (7.97m^3/s) and relatively minimum in May (0.66m^3/s). The result displays that the crop water requirement is very high during the dry season and low during wet (rainy) season, therefore crops grown in the dry season needs more water than those grown during the rainy season and the stage of the crop is the other reason.

The total water requirement in the study area fluctuated from 0.038 to 11.29 m^3/s during the growing season as shown in (Table 5). The lowest water requirement of the irrigated area is recorded for Bean (0.038 m^3/s) and the higher requirement for Wheat (11.29m^3/s). This indicates that the crop water requirement is higher for crops which have longer growing period than for those which have shorter growing period as Surendran et al., (2015) states.

4. 1.2.3. Irrigation water requirement

The monthly irrigation water demand of the scheme (in m^3/s) was estimated only for one irrigation season (from January to May, 2010 E.C) using CROPWAT 8.0 model. It was estimated based on ETc, the recorded rainfall and effective rainfall. The effective rainfall is derived from observed rainfall. Therefore irrigation water requirement was calculated from the difference between the total water requirement and effective rainfall. Irrigation water demand (IWD) on the system was estimated by using CROPWAT model.

Table 6 Monthly average irrigation water requirement (m^3/s)

Month	Irrigation water requirement (m^3/s)						Average total
	Barley	Bean	Maize	Pepper	Vegetable	Wheat	
Jan	0.076	0.0046	0.194	0.033	1.65	0.85	2.81
Feb	0.183	0.010	0.583	0.048	2.26	2.10	5.13
Mar	0.195	0.012	0.700	0.060	2.40	3.40	6.77
Apr	0.083	0.004	0.432	0.052	0.81	2.43	3.81
May	0.000	0.000	0.008	0.007	0.00	0.10	0.12
Total	0.54	0.031	1.92	0.20	7.12	8.88	18.7

As shown in Table 6, the CROPWAT model simulated results shows that irrigation water requirement in the system was varying from 0.12 to $6.77m^3/s$. The highest irrigation requirement was recorded in March ($6.77m^3/s$) and the lowest was recorded in May ($0.12m^3/s$). This is because of due to the stage of the crops; crops need maximum water at mid stage. The total irrigation requirements of each crop varies from 0.031 to $8.88m^3/s$. The highest irrigation water requirement was recorded in Wheat crop ($8.88m^3/s$) and the lowest was in Bean ($0.031m^3/s$). It was happened because of Bean was having a small command area compared to Wheat crop. This result is similar with Ullah (1998).

4.2. Comparison of irrigation water supply and demand

The comparison of IWS and IWD in the scheme has been considered only for three months from March to April; the situation is either deficit in demand or excess of supply. The comparisons of irrigation water supply and irrigation water demand have been shown below graphically.

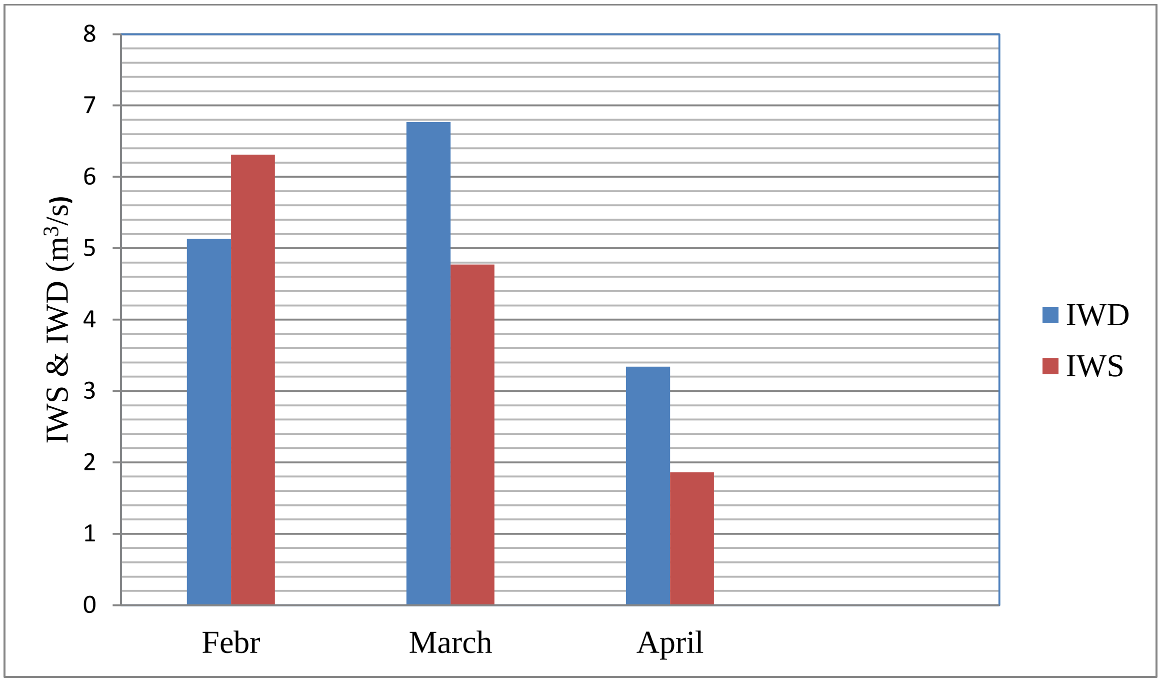

Figure 5 Irrigation water supply and irrigation water demand

As shown from the results in Figure above, in February the actual irrigation water supply was in excess of the requirements. In this month, the average irrigation water supply was 6.31m^3/s and the irrigation water demand was 5.13m^3/s. This indicates that in this month the scheme was affected by water logging. In March and April the irrigation water demands were exceeding irrigation water supply here the crops may be suffering water stress.

4.3. Assessment of water delivery performance

The performance indicators of water delivery were divided into water supply/use indicators of the irrigated area and water delivery indicators of the irrigation canal.

4.3.1. Water supply indicators

4.3.1.1. Relative Water Supply (RWS)

The average monthly water supply (as delivered) for three consecutive months; February (6.31), March (4.77) and April (1.86) m^3/s as shown in Table 2. While the average monthly crop demand of each months were 5.75 in February, 7.97 in March and 5.34 in April as shown in Table 5. By using (equation 1) the average relative water supplies of the scheme for the three consecutive months were 1.0, 0.59 and 0.35 in February, March and April respectively. The overall relative water supply of the scheme was 0.65 as shown in Table 7. This indicates miss much between irrigation supply and crop demand was happened. When the crop demand is not meet by the irrigation supply a condition of under irrigation is occurred, with the irrigation scheme. The monthly average relative water supply of the scheme was illustrated in the Table below.

Table 7 Average relative water supply of the scheme

Month	TWS (m^3/s)	CWR (m^3/s)	RWS	Average
February	6.31	5.75	1.00	0.65
March	4.77	7.97	0.59	
April	1.86	5.34	0.35	

Where TWS, CD and RWS total water supply, crop demand and relative water supply respectively

4.3.1.2. Relative Irrigation Supply (RIS)

The irrigation water supply of the scheme for the three month was (February 6.31, March 4.77 and April 1.86m^3/s). The irrigation water demand was (February 5.13, March 6.77 and April 3.34m^3/s) as shown in Table 6. By using (equation 2) the average relative irrigation supply was calculated as1.0, 0.70 and 0.55 in February, March and April respectively. The overall relative irrigation supply of the scheme was 0.75 as shown in Table 8. The RIS is less than one, indicates a situation of under irrigation is occurred, this indicates that the irrigation demand not being met by the irrigation supply. This is agreed by Greaves (2007). The average monthly RIS value the scheme was showed in the Table below

Table 8 Average relative irrigation supply of the scheme

Month	IWS (m^3/s)	IWD (m^3/s)	RIS	Average
February	6.31	5.13	1.00	0.75
March	4.77	6.77	0.70	
April	1.86	3.34	0.55	

Where IWS, IWD and RIS are irrigation water supply, irrigation water demand and relative irrigation supply respectively.

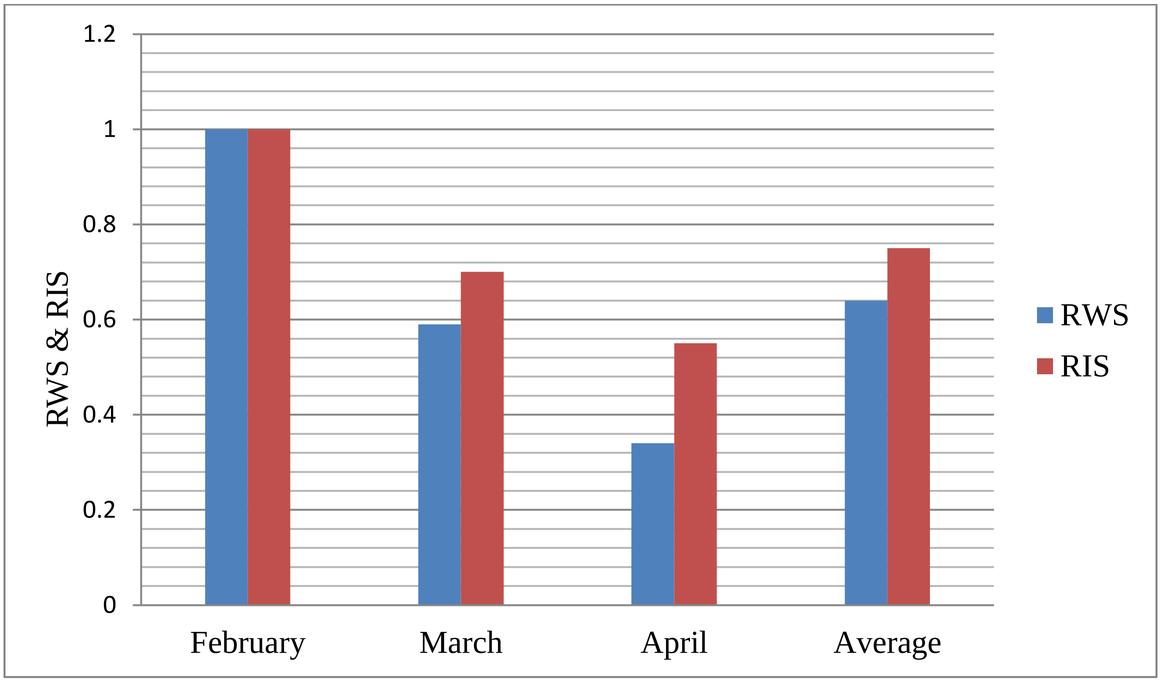

Figure 6 Relative water supply and relative irrigation supply of the scheme

4.3.1.3. Deficiency (D)

Deficiency is the important parameter of the water supply indicator; this parameter was calculated by using equation (3). The average value of temporal deficit at the head, middle and tail reach was 0.24, 0.23 and 0.37 respectively (Table 9).

According to this result, the maximum average temporal deficit was observed at the tail reach and the lowest was at the middle reach of the main canal. This indicates that, the management of irrigation water supply was comparatively low and they cannot allocate the water to fulfill the crop water requirement. This shows that the crop at the head and middle reach of the scheme gates more water than the tail reach. The results of spatial and temporal average value of deficiency are presented below, in Table 9.

Table 9 The average value of spatial and temporal deficiency, D

Month	Reach					Spatial average D
	Head	Middle		Tail		
	outlet	4KM	10KM	18KM	19KM	
February	0.00	0.00	0.00	0.04	0.07	**0.02**
March	0.29	0.29	0.27	0.27	0.34	**0.29**
April	0.44	0.42	0.36	0.73	0.75	**0.54**
Temporal average D	0.24	0.23	0.21	0.35	0.39	
	0.24	**0.23**		**0.37**		**0.28**

As shown in the result Table 9, spatial average values of deficiency (D) was 0.02, 0.29 and 0.54 in February, March and April respectively. According to the result, the spatial scarcity in the scheme has been observed in all three months. The highest spatial deficit is happened in April (0.54) and the minimum deficit in February (0.02). This occurs due to the fact that, water scarcity, loess rainfall and higher evapotranspiration demand of crops was very high these in April. This is approved Ullah (1998). The scarcity in February (0.02) was low it approaches to zero. According to Binoy et al., (2013) the supplied water almost fulfills the requirement of the crop. The temporal average values of the scheme in the analysis period were 0.24, 0.23 and 0.37 at the head outlet, middle; and tail respectively. This is because of lake of fair division or distribution of irrigation water between each reaches. The overall deficiency in the scheme was 0.28 or 28 percent (Table 9). Generally, both spatial and temporal deficit in supply was existed in the scheme for the assessment period, but the scarcity was increased from head to tail and from February to April. This is because of that the irrigation water allocation is not done based on the crop demand rather; it is based on storage or available irrigation water.

4.3.2. Water delivery indicators of the irrigation canal

The water delivery performance indicators of the main canal was computed for spatial and temporal performance indicators. The spatial and temporal average values of the performance indicators for the main canal in a single season were discussed.

The water delivery performance indicators of the canal such as adequacy, efficiency, dependability and equity was computed for three successive months (February, March and April)in a single irrigation season. To estimate these indicators, the values of delivered water (QD) and required (QR) of the irrigation scheme were taken as basic variables. The number of irrigations in one season (T) was considered as the time period; and the number of fields (R) was taken as the sub-region. The averaged values of delivered discharge of the main canal was measured at three location (head, middle and tail), for three months. The delivered discharge at the head of the main canal was recorded by using automatic recorder as shown in (Appendixes- B). This discharge is used to compare with the measured discharge. The required amount of discharge was calculated as flow velocity time’s canal cross section. Flow velocity was measured by using current meter as shown in (Appendixes –D).

The average delivered discharge as supply (QD) and the average crop demand (QR) of the scheme was presented in the Table 10.

Table 10 Average required (QR) and delivered (QD) discharge on the main canal (m^3/s)

Month	Recording season	Reaches									
		Head		Middle				Tail			
		Outlet		(4KM)		(10KM)		(18KM)		(19KM)	
	Week	Q_D	Q_R	Q_D	Q_R	Q_D	Q_R	Q_D	Q_R	Q_D	Q_R
February	1	6.24	5.13	5.82	4.76	5.51	4.87	0.71	0.73	0.69	0.73
	2	6.33	5.13	5.92	4.76	5.25	4.87	0.69	0.73	0.67	0.73
	3	6.30	5.13	5.93	4.76	5.2	4.87	0.70	0.73	0.68	0.73
	4	6.38	5.13	6.00	4.76	5.27	4.87	0.72	0.73	0.69	0.73
March	1	4.73	6.77	4.52	6.40	4.28	4.87	0.54	0.73	0.50	0.73
	2	4.79	6.77	4.53	6.40	4.13	4.87	0.52	0.73	0.49	0.73
	3	4.79	6.77	4.52	6.40	4.07	4.87	0.53	0.73	0.44	0.73
	4	4.77	6.77	4.55	6.40	4.18	4.87	0.55	0.73	0.49	0.73
April	1	1.85	3.34	1.73	2.97	1.23	4.87	0.19	0.73	0.17	0.73
	2	1.86	3.34	1.72	2.97	1.21	4.87	0.20	0.73	0.17	0.73
	3	1.87	3.34	1.69	2.97	1.13	4.87	0.19	0.73	0.18	0.73
	4	1.85	3.34	1.68	2.97	1.17	4.87	0.20	0.73	0.18	0.73

Where QD and QR are delivered and required discharge respectively.

4.3.2.1. Adequacy (P_A)

The adequacy of irrigation water at Koga dam and irrigation scheme was calculated as spatial and temporal average by using (equation 4).The average spatial values of adequacy were 0.98, 0.66 and 0.39 in February, March and April respectively (Table 11). According to performance standard Molden and Gate (1990) the spatial average value of adequacy of the scheme for the analysis period as shown in Table 11 with an average values 0.98 (good), 0.66 (poor) and 0.39 (poor) in February, March and April respectively.

Adequacy of the scheme was calculated as both spatial and temporal average values. The average temporal values of the scheme were 0.75, 0.66and 0.63 at head, middle and tail reaches respectively (Table 11). According to performance standard Molden and Gate (1990) the temporal average value of adequacy of the scheme for the analysis period was 0.75 (poor), 0.66 (poor) and 0.63 (poor) at head, middle and tail reach respectively as shown in Table 11.

From these results the overall adequacy, value of the system is found to be 0.68 (Table 11).Therefore, water delivery performance in the supply canal for the entire command during the irrigation season (February to April 2018) was found to be poor Molden&Gats (1990) water delivery performance standard. This indicates that the poor supply of water from the Koga reservoir. This is approved by Chandra and Sharma (2018) and Mamuye and Mekonnen (2015) from another site. The tabulated results of spatial and temporal average values of the adequacy in the scheme system are summarized below in Table below.

Table 11 Average spatial and temporal adequacy of water distribution

Month	period	Reach					
		Head	Middle		Tail		Average spatial PA
	week	Outlet	4KM	10KM	18KM	19KM	
February	1	1.00	1.00	1.00	0.97	0.94	**0.98**
	2	1.00	1.00	1.00	0.94	0.92	
	3	1.00	1.00	1.00	0.94	0.93	
	4	1.00	1.00	1.00	0.97	0.94	
	Average	**1.00**	**1.00**		**0.94**		
March	1	0.69	0.56	0.40	0.73	0.68	**0.66**
	2	0.70	0.73	0.67	0.71	0.67	
	3	0.70	0.72	0.55	0.72	0.60	
	4	0.70	0.59	0.61	0.75	0.67	
	Average	**0.70**	**0.60**		**0.69**		
April	1	0.55	0.32	0.37	0.26	0.23	**0.39**
	2	0.55	0.38	0.25	0.27	0.23	
	3	0.56	0.48	0.38	0.26	0.24	
	4	0.55	0.46	0.33	0.27	0.24	
	Average	**0.55**	**0.37**		**0.25**		
Temporal Average (PA)		**0.75**	**0.66**		**0.63**		**0.68**

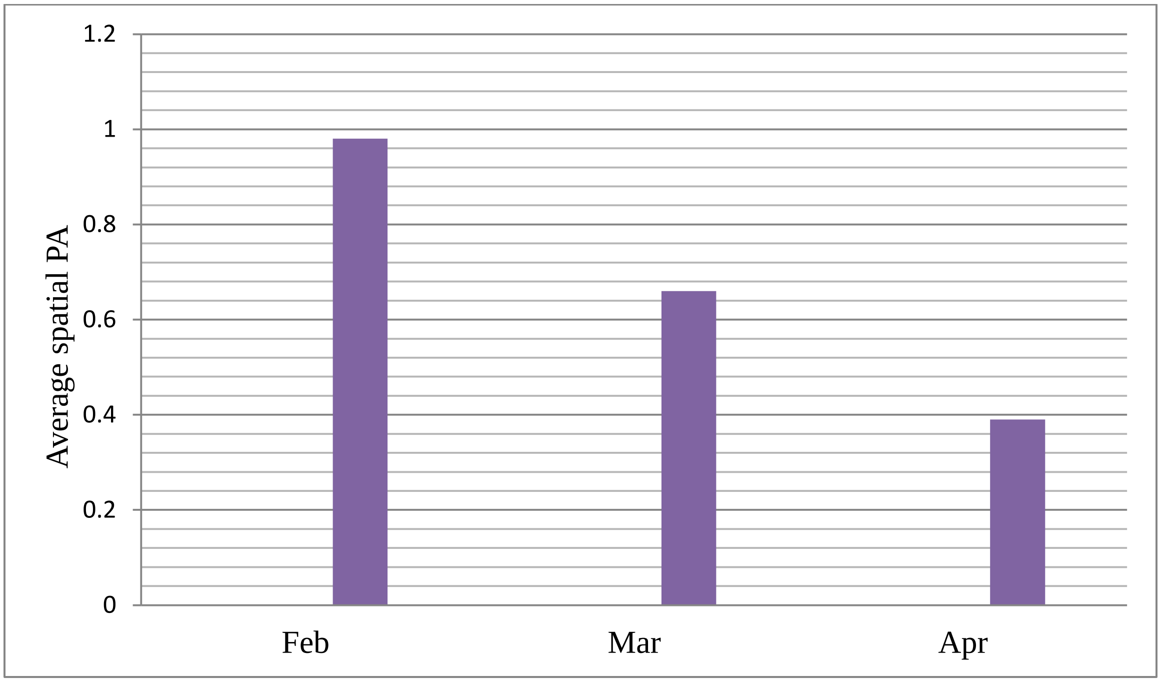

Figure 7 Average spatial adequacy of the scheme

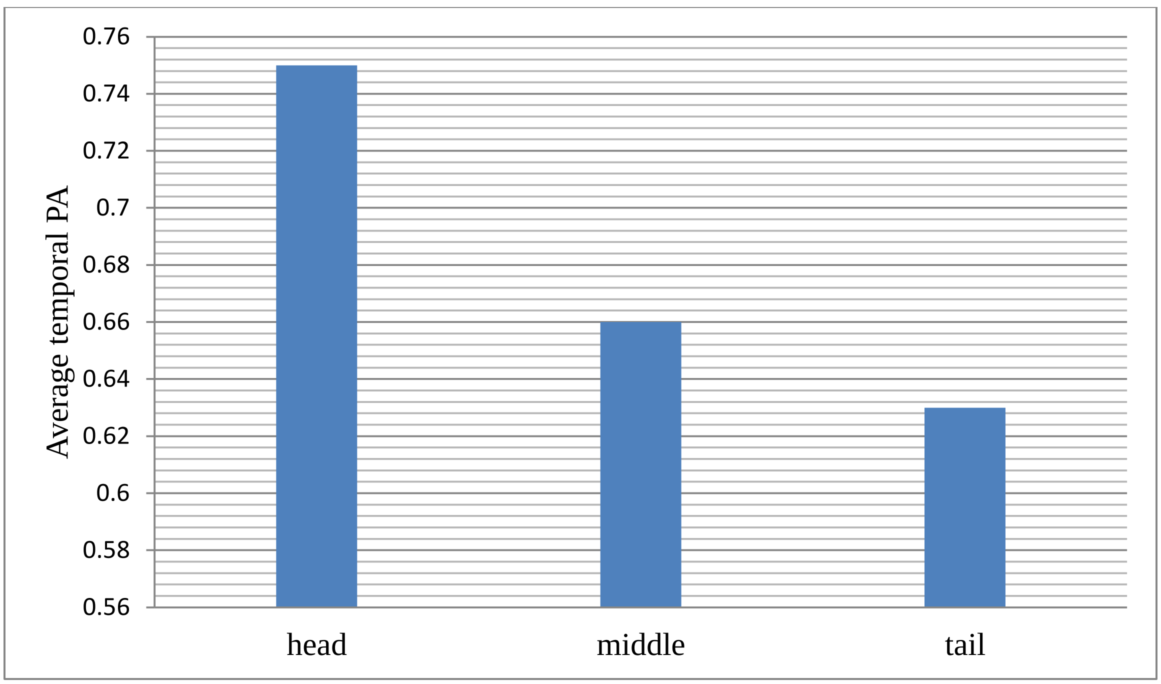

Figure 8 Average temporal adequacy of the scheme

4.3.2.2. Efficiency (P_F)

The temporal and spatial value of efficiency, performance indicator was evaluated at the three reaches of the main canal (head, middle and tail) reach of the system for three consecutive months (February, March and April) by using (equation 5).

As shown from Table 12 the average temporal PF value at the head, middle and tail reach of the main canal was 0.93, 0.93 and 1.00 respectively. The result indicates that the water delivery performance of the main canal was good at the three reach (head, middle and tail) reaches of the main canal according to Molden& Gats (1990). This is because of that, the farmers are used the supplied water more efficiently at the tail reach of the system, when compared to the middle and head.

The spatial average value of PF was 0.87 in the month February, 1.00 in the month March and 1.00 in the month of April for the given assessment period. This indicates that the supplied water is used more efficiently in the month of March and April than the month of February. This indicates that even if, there is low supply the farmer used the supplied water more efficiently.

The overall efficiency of the scheme was 0.95 therefore, during the assessment period the scheme has a good performance in case of efficiency according to performance standard both spatially and temporally as shown in Table 12. This was assured by Chandra and Sharma (2018). This means that the scheme have 95 percent conveyance efficiency during the assessment period.

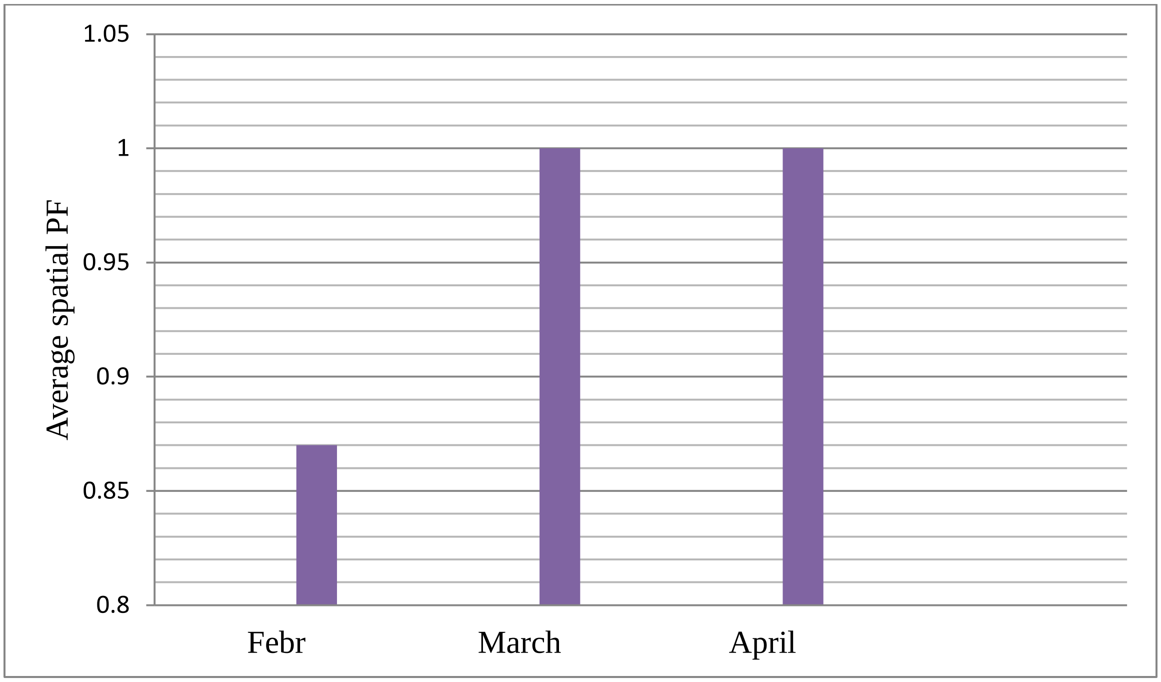

Figure 9 Average spatial efficiency of the scheme

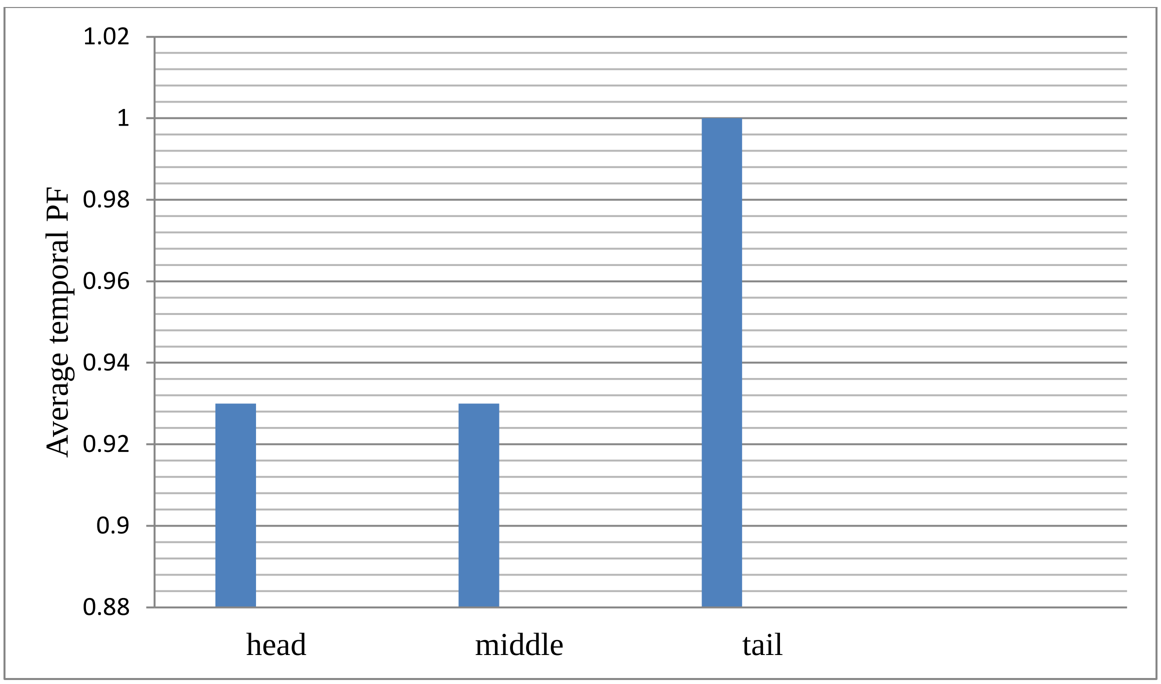

Figure 10 Average temporal efficiency of the scheme

Table 12 Average spatial and temporal value of efficiency

Month	Period	Reach					
	week	head	middle		tail		Spatial average (PF)
			4KM	10KM	18KM	19KM	
February	1	0.82	0.81	0.80	1.00	1.00	**0.87**
	2	0.81	0.80	0.79	1.00	1.00	
	3	0.81	0.80	0.77	1.00	1.00	
	4	0.80	0.79	0.78	1.00	1.00	
	Aver	**0.81**	**0.79**		**1.00**		
March	1	1.00	1.00	1.00	1.00	1.00	**1.00**
	2	1.00	1.00	1.00	1.00	1.00	
	3	1.00	1.00	1.00	1.00	1.00	
	4	1.00	1.00	1.00	1.00	1.00	
	Aver	**1.00**	**1.00**		**1.00**		
April	1	1.00	1.00	1.00	1.00	1.00	**1.00**
	2	1.00	1.00	1.00	1.00	1.00	
	3	1.00	1.00	1.00	1.00	1.00	
	4	1.00	1.00	1.00	1.00	1.00	
	Aver	**1.00**	**1.00**		**1.00**		
Temporal average (PF)		**0.93**	**0.93**		**1.00**		**0.95**

4.3.2.3. Dependability (P_D)

Dependability shows the temporal coefficient of variation of water delivery (degree of reliability) at each reach (head, middle and tail) reaches of the main canal. By using (equation 6) average dependability of the scheme was calculated as shown in the Table 13.

As shown from the results presented in the Table 13, the average temporal values of PD (temporal coefficient of variation) at the head, middle and tail reach of the main canal was 0.22, 0.31 and 0.35 respectively. According to water delivery performance standards given by Molden& Gats (1990), the reliability of flow was poor at the three reaches (head, middle and tail) reaches of the main canal. This indicates that water delivery performance of the main canal was rated as poor. During assessment period, the highest PD value was observed on the tail reach of the canal (0.35) and the lowest at the head of the main canal (0.22). This shows that water is not supplied to the secondary canals at the right times, this is due to the absence of well-organized water delivery plan and management.

The overall average dependability of the flow in the main canal for the three assessment period was found to be 0.29 as shown in Table 13. According to performance standard Molden and Gates (1990) the overall dependability of the scheme was poor, since dependability (PD) greater than 0.2 is rated as poor. This indicates that, the time of irrigation water supply and the amount of water supplied have been inconsistent throughout the assessment period and then the supply is unreliable. This is agreed by Mamuye and Mekonnen (2015) and Chandra and Sharma (2018) from another site.

Table 13 Average value of dependability of water distribution

Month	period	Reach					Overall PD
		head	middle		tail		
	Week	outlet	4KM	10KM	18KM	19KM	
February	1	1.00	1.00	1.00	0.97	0.94	
	2	1.00	1.00	1.00	0.94	0.92	**0.29**
	3	1.00	1.00	1.00	0.94	0.93	
	4	1.00	1.00	1.00	0.97	0.94	
	Average	**1.00**	**1.00**		0.94		
March	1	0.69	0.56	0.40	0.73	0.68	
	2	0.70	0.73	0.67	0.71	0.67	
	3	0.70	0.72	0.55	0.72	0.60	
	4	0.70	0.59	0.61	0.75	0.67	
	Average	**0.70**	**0.60**		**0.69**		
April	1	0.55	0.32	0.37	0.26	0.23	
	2	0.55	0.38	0.25	0.27	0.23	
	3	0.56	0.48	0.38	0.26	0.24	
	4	0.55	0.46	0.33	0.27	0.24	
	Average	**0.55**	**0.37**		**0.25**		
mean		0.75	0.66		0.63		
SD		0.23	0.32		0.35		
CV_R		0.30	0.48		0.55		
CV_R(PD)		**0.22**	**0.31**		**0.35**		

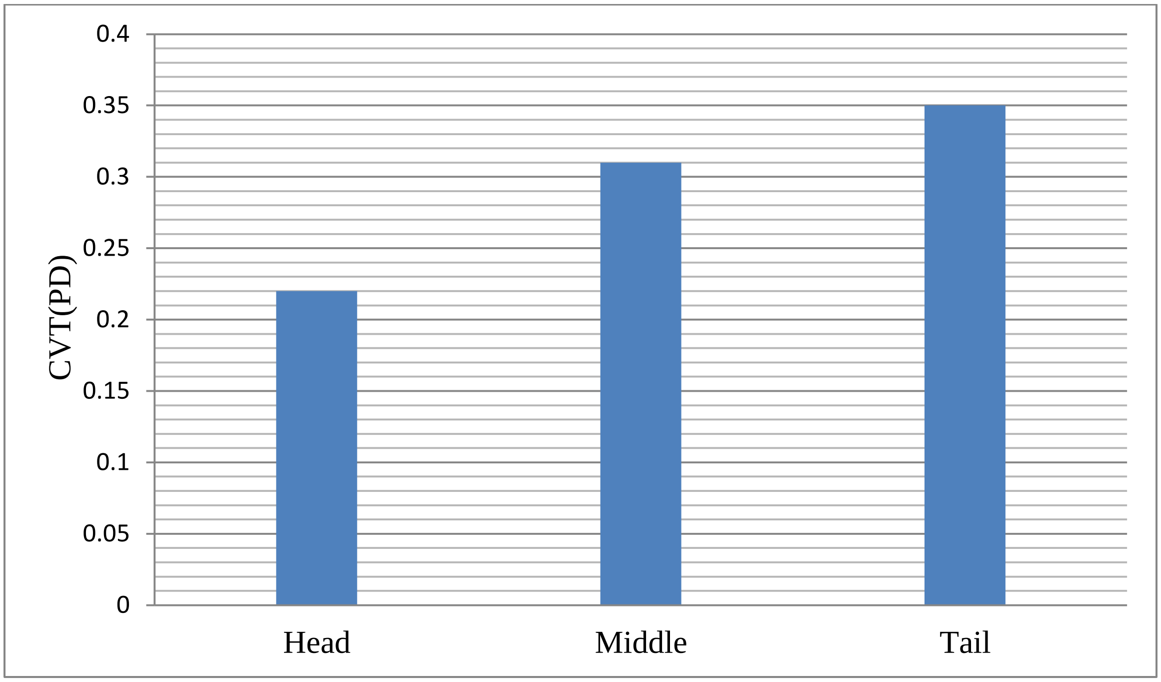

Figure 11 Dependability of water delivery of the scheme

4.3.2.4. Equity (PE)

The degree of spatial variation of water delivery performance of the main canal was evaluated by using (equation 7) at three reaches (head, middle and tail) reaches over three months (February, March and April) is presented in Table 14.

As showed the result in Figure 11 equity of water distribution during February, March and April was 0.03, 0.086 and 0.123 respectively. According to water delivery performance standards given by Molden & Gats, (1990) the spatial distribution of water in the main canal during the evaluation period was good in February and March which is (0.03) and 0.08 respectively and fair in April (0.12). Because PE value between zero and 0.1 is good. However PE value from 0.11 up to 0.25 was fair according to the performance standard (Table 1). Therefore, result indicates that, in these months, the spatial coefficient of variation of adequacy between the three reaches (head, middle and tail) reaches was equitable.

The average value of overall equity of the delivery system in the canal was found to be 0.08 (Table 14). The value demonstrations that relatively, the equity of water distribution (spatial coefficient of variation of adequacy) is good over the scheme according to the water delivery performance standards Molden& Gats, (1990). The values of spatial coefficient of variation at each reaches (head, middle and tail) were presented in Table below.

Table 14 Average equity of water distribution of the scheme

Month	Period	Reach								
	week	head	middle		tail		mean	SD	CV_T	**CV_T(PE)**
		outlet	4KM	10KM	18KM	19KM				
February	1	1.00	1.00	1.00	0.97	0.94	0.98	0.030	0.031	**0.03**
	2	1.00	1.00	1.00	0.94	0.92				
	3	1.00	1.00	1.00	0.94	0.93				
	4	1.00	1.00	1.00	0.97	0.94				
March	1	0.69	0.56	0.40	0.73	0.68	0.66	0.084	0.13	**0.086**
	2	0.70	0.73	0.67	0.71	0.67				
	3	0.70	0.72	0.55	0.72	0.69				
	4	0.70	0.59	0.61	0.75	0.67				
April	1	0.55	0.32	0.37	0.26	0.23	0.36	0.123	0.34	**0.123**
	2	0.55	0.38	0.25	0.27	0.23				
	3	0.56	0.48	0.38	0.26	0.24				
	4	0.55	0.46	0.33	0.27	0.24				
Overall PE										**0.08**

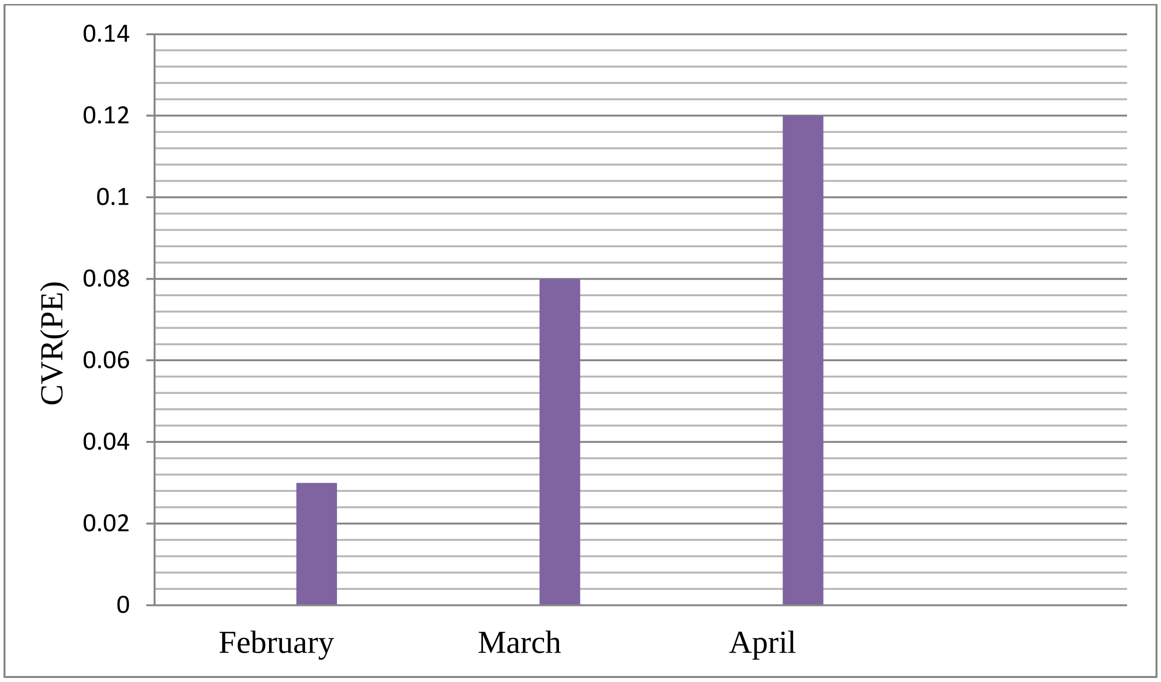

Figure 12 Equity of water delivery of the scheme

4.3.2.5. Overall water delivery performance indicators

In this assessment water delivery performance indicator shows the performance of existing hydraulic features of water delivery canal in the scheme. All parameters of water delivery performance indicators; Adequacy (PA), Dependability (PD), Efficiency (PF) and Equity (PE) were classified using standards developed by Molden and Gates (1990) (Table 1 chapter-3).

Average values of water delivery performance indicator over three months (assessment period) are summarized in Table 15.

Table 15 Overall average water delivery performance indicators value

Indicators	Adequacy (PA)	Dependability (PD)	Efficiency (PF)	Equity (PE)
Value	0.68	0.29	0.95	0.08
Standard	poor	poor	good	good

As shown in Table 15, the overall PA, PD, PF and PE values were found to be 0.68, 0.29,0.95 and 0.08 respectively. According to the performance standard developed by Molden and Gate (1990) the water delivery performance of the canal was poor in terms of the adequacy and dependability. This occurred due to two important reasons such as water scarcity and inadequate flow management. Water shortages resulted from inadequate regulation and losses However, it was good in terms of efficiency and equity. This indicates that, even if water deliveries were inadequate and unreliable (variable from time to time), farmers effectively used this supplied irrigation water.

4.4. Identification of the gap and suggestion of the remedial measure

Based on the result of the study, the main problems and limits that reduced the existing performance of the scheme are mismatch between irrigation water supply with irrigation water demand, temporal and spatial variation in water delivery system and miss understand between water supplier and water users.

4.4.1. Identification of the gap

4.4.1.1. Irrigation water supply with demand

As rule irrigation water supply is dependent on crop water requirement (demand), the supply must fulfill the demand of the crop unless; the effect should be water supply excess (surplus) or deficit. This results water logging and water stress in the crop. This affects the performance of the scheme. The reduction of the performance of the scheme affects the result (economic revenue). So, irrigation water supply must be proportional to the crop water demand.

Mismatching between irrigation water demand and irrigation water supply has been occurred as shown in the result. Irrigation water supply was observed in shortage of the requirement in some portion of the canal (head to tail) in March and April and tail in February, whereas in excess of the requirement in other portions (head and middle of the canal reach) in February. This problem occurred due to; water scarcity (shortage of water), inappropriate delivery schedules or allocation error and miss communication with water users (farmers).

Inadequate water supply may be affected due to; If cleaning of the sediments and maintenance of the canals are not on time, Water availability is not estimated professionally,(which means the supply is less than crop water requirement of cultivated crops) and Canal capacity is low compared to the command area.

4.4.1.2. Temporal and spatial variation in water delivery system

The amount of water flow into delivery canal was insufficient to fulfill the requirement of the crop and it is varies from month to month and reach to reach over the season; hence water is not supplied to the canal at the right times and in a sufficient amount. The problems of inadequate and unreliable water delivery to the scheme can be worse water productivity and affect canal performance.

4.4.2. The remedial measure

4.4.2.1. Improving timeliness and spatial variation

Due to uneven distribution of irrigation water, both spatial and temporal the irrigation withdrawals vary substantially along the canal. The variation of irrigated area is the primary reason of spatial biases of irrigation withdrawals. The other factor which account for the spatial and temporal variation of water withdrawal was crop water requirements of the scheme. The irrigation water requirement of all crops are depends on several factors including cropping patterns, crop growth periods, crop coefficients, potential evapotranspiration, effective rainfall, percolation etc. There for knowing these variables enable to improve the timeliness and the spatial variation of the scheme.

The problem of time the mismatch between supply and demand may be solved by giving training and creating awareness to the water users, because the farmers irrigate over the plan. There for, the agronomists follow up the water users when and where they use the water. The variation at each reach may be solved by allocating water based on the crop water requirement. This is due to the supply is not crop demand oriented rather than storage oriented, it is possible to allocate water based on the demand by determining the crop demand.

4.4.2.2. Optimal crop plan development

In fact, crops are cultivated in irrigated command area based on available water resource and maximum economic return. However, due to the absence of an optimal crop plan for existing available water and cropping pattern, irrigation water supply was in excess and deficit of crop water demand both spatially and temporally over the season. As a result of this, crops suffering from water logging and stress respectively. In order to mitigate this limitation, it is suggested that the size of irrigated command and cultivated crops should be proportional to available water, in which crops are achieved maximum yield. Therefore an optimal crop plan development is essential, by considering the existing cropping pattern and available water supply.

A linear programming model has been recommend for optimal cropping pattern for maximizing net returns and ensuring significant savings of available resource. Optimum Resources allocation is dependent on land area availability and utilization, working capital, irrigation Water-use, crop maxima and minima and canal water availability. Knowing about these constraints is mandatory for optimal crop water plan. However, further study should be required for develop optimal crop plans in relation to the existing water supply.

4.4.2.3. Improvement in adequacy

Water supply scheduling has to design based on type of crops, all the crops which farmers have propose to cultivate and the need of each crop type. Due to a perceived mismatch between available resources and potential uses of water, the entire command area has not been fully advanced. Even though improvement is not complete, cropping intensity in the irrigated areas has not reached the expected levels.

Inadequate water supply may be managed in two ways: before starting the irrigation and after starting the cultivation. By matching cropping season and calendars with estimated seasonal water availability before the start of the cultivation, and by adjusting operational targets in response to actual demand during the season; the division system is based on the requirement of the crop. This means crop water need varies as the stage of the crop varies; the crop need at initial stage is not the same with the crop need at developmental stage. Therefore, it is possible to manage adequacy more carefully. Hence, there are significant opportunities for actual deliveries to exceed crop water requirements.

4.4.2.4. Improvement of water management

Effective management of irrigation water needs clarity and coordination between the water users and the operators. Implementation of the agreed plan will require all water users and other stakeholders with a devolved notice to know what needs to be done where, when and by whom. Critically, this will include rules in relation to the timing and volume of water abstractions and the regulatory approaches paired with these arrangements. Regulatory approaches that invest effort in education and awareness raising, standard-setting, and supporting system users to achieve compliance will typically be most effective. All stakeholders must be clear on the value of rule and recognize that it is fundamental to the achievement of the system performance.

The specific goal of water delivery management is possible to change over time, as environmental conditions and the user need changes, and as new knowledge and experience is developed. As water supply and demand conditions change, the scientific knowledge base on which management of water for the water user is also continuously expanding and developing. Repeated communication with the water user, adaptive water management and improvement are required to ensure that system performance is maintained and improved over time.

Due to poor management from the head to tail, the head reach receive more water than the tail reach of the scheme while some reaches receive excess water at the middle, this is due to less water is received by secondary canals above the middle reach. Therefore, the management of water delivery should be strongly implemented by understood and fix effective water allocation plan, based on a percentage share of available water and crop water need.

When irrigation water is not managed or is poorly managed, the impacts on system condition can impose additional consequences on all other users and the society. Generally, poor management of water delivery in the system between the head and tail reach has improved by awareness creation for the users, setting rules and implementing well organized water management plan successfully; it might have been reduce unscheduled water abstraction from the canal and possible to irrigate the entire service area with rotational water distribution in the system.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

According to the result of the study, irrigation water supplied by the main canal was maximum in February, and minimum in April. However, irrigation water demand was maximum in March and minimum in April. During the evaluation period, the highest amount of irrigation water supply was observed at the head reach of the main canal, and the lowest supply was recorded at the tail reach. Irrigation water demand was very high at head of the main canal. Therefore, the irrigation water supply varies both spatially and temporally. And the month February have been getting the discharges in excess of the requirement, whereas the rest months in deficit of the requirement.

According to the result, the relative water supply is perfect (1.0) in the month February, 0.59 in March and becomes worst (0.35) in the month April. The overall relative water supply of the scheme was 0.65 which indicates poor water supply in the canal. The relative irrigation supply was 1.0, 0.7 and 0.55 in February, March and April respectively. The overall relative irrigation supply was 0.75. This illustrates that the supply meets the demand in February only while under irrigation is occurred in the rest two months. The highest temporal average deficit of water was advanced at the Tail reach of the main canal which was 0.37. The higher spatial deficit has been occurred in month April which was 0.54 and the lowest deficit was occurred in February, so crops suffer water shortage during the season especially in April.

The spatial and temporal delivery performances of indicators were computed for each reaches(head, middle and tail reach) during the assessment period (February, March, April). As shown from the result, water delivery performance of the scheme were adequacy (0.68), dependability (0.29), efficiency (0.95) and equity (0.08) good in terms of efficiency and equity. while the performance of the canal was poor in terms of dependability and adequacy. From this result, even if, supply in the canal was inadequate and unreliable, the users were used the water more effectively and equitably.

Generally, poor performance of the irrigation scheme was due to unreliable water deliveries, poorly control and distribution system, inflexible irrigation planning, varied cropping pattern, lack of proper management, inadequate supply improper operation of water delivery system, and lake of awareness in case of farmers. Therefore, it is suggested that, effective water management, supplying irrigation water based on crop demand , optimal crop plan, and apply a strong water delivery plan are required to alleviate these problems.

5.2. Recommendations

Based on the results of the study, the following recommendations are given to improve the performance of the scheme.

- Applying proper water distribution plan in the system, avoiding traditional water division structures and applying a gated division system might enhancing water distribution capacity of the canals this maybe vital for improve proportionality of irrigation water supply and irrigation water demand.

Figure 13 Water delivery structures at tertiary canal

- Scarcity of water is one of the constraints to fulfill the requirements of the crop water need. So to mitigate this problem, water supply must be based on the crop water requirement and crop developmental stage because the need of crop varies from stage to stage. This means crops having less water requirement at initial stage than developmental stage. There for delivering and scheduling irrigation water based on the crop demand is essential to fulfill the crop water requirement.

- Water delivery systems between the head to tail reach is not uniform spatially as well as temporally; the head receives more water than the tail and in February there was excess of water but there was maximum deficit in March and April during the evaluation period. Therefore it suggested that, introducing of proper water allocation system on water delivery system at the head, middle and tail reach of the watercourse.

- Water User Association of the scheme is not well-organized; they have been the management gaps. So, reforming or giving training to them is essential for ensuring healthier water management, fair distributing of irrigation water, resolving conflicts among users in the irrigation scheme.
- In our country Ethiopia water is free for agricultural production. Free water use for agriculture has to be changed (water fee must be introduced) and water has to be projected as a valuable good which will improve accountability of water use. This will prevent water losses and will also help the irrigation system to become financially sustainable.

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7. APPENDIX

Appendix -A: Climatic, precipitation, soil and crop data results of the study area

Appendixes Table 1 Monthly average reference evapotranspiration data of the scheme

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\BDR clim.PEM

Country: Ethiopia | Station: Bahirdar (Airport)

Altitude: 1827 m. | Latitude: 11.60 °N | Longitude: 37.32 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	7.2	28.1	39	1	9.9	21.4	3.01
February	9.4	30.0	34	1	9.6	22.5	3.33
March	11.9	30.8	34	1	9.0	22.9	3.68
April	14.0	31.4	36	1	9.0	23.4	3.97
May	14.8	30.2	45	1	8.4	22.1	3.96
June	14.1	27.4	60	1	7.0	19.7	3.64
July	14.1	24.4	73	1	4.8	16.5	3.11
August	13.8	24.4	72	1	4.6	16.4	3.05
September	13.0	25.8	65	1	6.9	19.7	3.47
October	12.7	27.5	54	1	8.4	21.0	3.51
November	10.2	27.5	46	1	9.3	20.8	3.17
December	7.7	28.8	42	1	9.8	20.7	2.97
Average	**11.9**	**28.0**	**50**	**1**	**8.1**	**20.6**	**3.41**

Appendixes Table 2 Average monthly effective rainfall of the scheme

Monthly rain - C:\ProgramData\CROPWAT\data\rain\BDR Rain.CRM

Station: Bahirdar (Airport)   Eff. rain method: USDA S.C. Method

	Rain	Eff rain
	mm	mm
January	0.7	0.7
February	1.3	1.3
March	23.3	22.4
April	36.4	34.3
May	59.5	53.8
June	219.2	142.3
July	438.1	168.8
August	374.0	162.4
September	196.6	134.8
October	87.4	75.2
November	11.5	11.3
December	3.7	3.7
Total	**1451.7**	**811.0**

Appendixes Table 3 Soil data of the scheme

Soil - C:\ProgramData\CROPWAT\data\soils\FAO\HEAVY.SOI

Soil name: Heavy (clay)

General soil data

Total available soil moisture (FC - WP)	200.0	mm/meter
Maximum rain infiltration rate	40	mm/day
Maximum rooting depth	90	centimeters
Initial soil moisture depletion (as % TAM)	0	%
Initial available soil moisture	200.0	mm/meter

Appendixes -A1 Crop water requirement of each crop in the scheme

Appendixes Table 4 Crop water requirement of Barley

Crop Water Requirements

ETo station: Bahirdar (Airport) | Crop: Barley
Rain station: Bahirdar (Airport) | Planting date: 01/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.30	0.90	9.0	0.5	8.5
Jan	2	Deve	0.35	1.05	10.5	0.1	10.4
Jan	3	Deve	0.67	2.08	22.9	0.2	22.7
Feb	1	Mid	1.02	3.27	32.7	0.1	32.6
Feb	2	Mid	1.14	3.78	37.8	0.0	37.8
Feb	3	Mid	1.14	3.91	31.3	1.4	30.0
Mar	1	Mid	1.14	4.05	40.5	5.4	35.1
Mar	2	Mid	1.14	4.18	41.8	7.9	33.9
Mar	3	Mid	1.14	4.29	47.2	9.1	38.1
Apr	1	Late	0.97	3.77	37.7	9.9	27.9
Apr	2	Late	0.68	2.70	27.0	11.1	15.9
Apr	3	Late	0.38	1.52	15.2	13.4	1.8
					353.5	**58.8**	**294.7**

Appendixes Table 5 Crop water requirement of Beans

Crop Water Requirements

ETo station: Bahirdar (Airport) | Crop: Dry beans
Rain station: Bahirdar (Airport) | Planting date: 01/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.40	1.20	12.0	0.5	11.5
Jan	2	Init	0.40	1.20	12.0	0.1	11.9
Jan	3	Deve	0.55	1.71	18.8	0.2	18.6
Feb	1	Deve	0.81	2.60	26.0	0.1	25.9
Feb	2	Mid	1.05	3.49	34.9	0.0	34.9
Feb	3	Mid	1.14	3.92	31.4	1.4	30.0
Mar	1	Mid	1.14	4.05	40.5	5.4	35.1
Mar	2	Mid	1.14	4.19	41.9	7.9	34.0
Mar	3	Mid	1.14	4.30	47.3	9.1	38.2
Apr	1	Late	0.92	3.57	35.7	9.9	25.8
Apr	2	Late	0.53	2.10	21.0	11.1	9.9
					321.4	**45.4**	**275.9**

Appendixes Table 6 Crop water requirement of Maize

Crop Water Requirements

ETo station: Bahirdar (Airport) | Crop: MAIZE (Grain)

Rain station: Bahirdar (Airport) | Planting date: 01/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.30	0.90	9.0	0.5	8.5
Jan	2	Init	0.30	0.90	9.0	0.1	8.9
Jan	3	Deve	0.45	1.40	15.4	0.2	15.2
Feb	1	Deve	0.71	2.30	23.0	0.1	22.9
Feb	2	Deve	0.96	3.21	32.1	0.0	32.1
Feb	3	Mid	1.16	3.99	31.9	1.4	30.6
Mar	1	Mid	1.18	4.19	41.9	5.4	36.5
Mar	2	Mid	1.18	4.33	43.3	7.9	35.4
Mar	3	Mid	1.18	4.45	48.9	9.1	39.9
Apr	1	Late	1.14	4.40	44.0	9.9	34.2
Apr	2	Late	0.89	3.53	35.3	11.1	24.2
Apr	3	Late	0.61	2.43	24.3	13.4	10.9
May	1	Late	0.41	1.61	8.0	6.8	1.2
					366.3	**65.6**	**300.7**

Appendixes Table 7 Crop water requirement of Pepper

Crop Water Requirements

ETo station: Bahirdar (Airport) | Crop: Sweet Peppers

Rain station: Bahirdar (Airport) | Planting date: 01/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.60	1.80	18.0	0.5	17.5
Jan	2	Init	0.60	1.80	18.0	0.1	18.0
Jan	3	Deve	0.60	1.87	20.6	0.2	20.4
Feb	1	Deve	0.68	2.19	21.9	0.1	21.8
Feb	2	Deve	0.80	2.67	26.7	0.0	26.7
Feb	3	Deve	0.91	3.15	25.2	1.4	23.8
Mar	1	Mid	1.01	3.60	36.0	5.4	30.7
Mar	2	Mid	1.03	3.79	37.9	7.9	30.0
Mar	3	Mid	1.03	3.89	42.8	9.1	33.8
Apr	1	Mid	1.03	3.99	39.9	9.9	30.1
Apr	2	Late	1.02	4.05	40.5	11.1	29.4
Apr	3	Late	0.95	3.76	37.6	13.4	24.3
May	1	Late	0.89	3.52	17.6	6.8	10.8
					382.8	**65.6**	**317.2**

Appendixes Table 8 Crop water requirement of Vegetable

Crop Water Requirements

ETo station: Bahirdar (Airport) | Crop: Small Vegetables

Rain station: Bahirdar (Airport) | Planting date: 01/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.70	2.10	21.0	0.5	20.5
Jan	2	Init	0.70	2.10	21.0	0.1	21.0
Jan	3	Deve	0.77	2.39	26.3	0.2	26.1
Feb	1	Deve	0.89	2.86	28.6	0.1	28.5
Feb	2	Mid	1.00	3.32	33.2	0.0	33.2
Feb	3	Mid	1.04	3.58	28.7	1.4	27.3
Mar	1	Mid	1.04	3.70	37.0	5.4	31.6
Mar	2	Mid	1.04	3.82	38.2	7.9	30.4
Mar	3	Late	1.00	3.80	41.7	9.1	32.7
Apr	1	Late	0.95	3.68	18.4	4.9	13.5
					294.2	**29.4**	**264.7**

Appendixes Table 9 Crop water requirement of Wheat

Crop Water Requirements

ETo station: Bahirdar (Airport) | Crop: Spring Wheat

Rain station: Bahirdar (Airport) | Planting date: 01/01

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Jan	1	Init	0.30	0.90	9.0	0.5	8.5
Jan	2	Init	0.30	0.90	9.0	0.1	8.9
Jan	3	Deve	0.30	0.94	10.4	0.2	10.2
Feb	1	Deve	0.48	1.55	15.5	0.1	15.4
Feb	2	Deve	0.76	2.52	25.2	0.0	25.2
Feb	3	Deve	1.01	3.46	27.7	1.4	26.4
Mar	1	Mid	1.13	4.02	40.2	5.4	34.8
Mar	2	Mid	1.13	4.16	41.6	7.9	33.7
Mar	3	Mid	1.13	4.27	46.9	9.1	37.9
Apr	1	Mid	1.13	4.38	43.8	9.9	33.9
Apr	2	Late	0.98	3.88	38.8	11.1	27.8
Apr	3	Late	0.70	2.78	27.8	13.4	14.5
May	1	Late	0.42	1.68	16.8	13.6	3.2
					352.7	**72.4**	**280.3**

Appendixes -A2 Irrigation water requirements of each irrigation block

Appendixes Table 10 Irrigation water requirement of Adberamariam block

Scheme Supply

ETo station: Bahirdar (Airport)
Rain station: Bahirdar (Airport)
Cropping pattern: Adberamariam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.8	101.1	108.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	90.3	109.3	76.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2
3. Sweet Peppers	76.1	95.2	92.1	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.5	95.4	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	72.5	104.6	83.3	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
6. Dry beans	42.1	91.3	108.1	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net scheme irr.req.												
in mm/day	2.3	3.5	2.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
in mm/month	70.3	98.2	89.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7
in l/s/h	0.26	0.41	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.0
(% of total area)												
Irr.req. for actual area	0.26	0.41	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 11 Irrigation water requirement of Amarit block

Scheme Supply

ETo station: Bahirdar (Airport)
Rain station: Bahirdar (Airport)
Cropping pattern: Amarit

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.3	3.6	2.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
in mm/month	71.1	101.3	85.8	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.8
in l/s/h	0.27	0.42	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.0
(% of total area)												
Irr.req. for actual area	0.27	0.42	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
(l/s/h)												

Appendixes Table 12 Irrigation water requirement of Ambomesk block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Ambomek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. Spring Wheat	27.6	66.9	106.4	76.1	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. MAIZE (Grain)	32.7	85.6	111.9	69.3	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Sweet Peppers	55.8	72.4	94.4	83.7	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. Dry beans	42.0	90.8	107.4	35.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net scheme irr.req.												
in mm/day	1.4	2.8	3.3	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
in mm/month	44.6	78.4	102.0	49.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
in l/s/h	0.17	0.32	0.38	0.19	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Irrigated area	100.0	100.0	100.0	100.0	55.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(% of total area)												
Irr.req. for actual area	0.17	0.32	0.38	0.19	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(l/s/h)												

Appendixes Table 13 Irrigation water requirement of Andnet block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Andnet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.5	3.6	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
in mm/month	77.3	101.7	83.1	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3
in l/s/h	0.29	0.42	0.31	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
(% of total area)												
Irr.req. for actual area	0.29	0.42	0.31	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
(l/s/h)												

Appendixes Table 14 Irrigation water requirement of Bered block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Bered

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.3	3.5	2.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
in mm/month	70.8	97.9	88.3	10.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4
in l/s/h	0.26	0.40	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.0
(% of total area)												
Irr.req. for actual area	0.26	0.40	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
(l/s/h)												

Appendixes Table 15 Irrigation water requirement of Chihona block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Chihona

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.2	3.4	2.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
in mm/month	69.2	94.8	90.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8
in l/s/h	0.26	0.39	0.34	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.0
(% of total area)												
Irr.req. for actual area	0.26	0.39	0.34	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 16 Irrigation water requirement of Enguti block

Scheme Supply

ETo station: Bahirdar (Airport)
Rain station: Bahirdar (Airport)
Cropping pattern: Enguti

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.3	3.4	2.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
in mm/month	69.8	95.9	89.3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7
in l/s/h	0.26	0.40	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0
(% of total area)												
Irr.req. for actual area	0.26	0.40	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
(l/s/h)												

Appendixes Table 17 Irrigation water requirement of Kudmi block

Scheme Supply

ETo station: Bahirdar (Airport)
Rain station: Bahirdar (Airport)
Cropping pattern: Kudmi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.2	3.4	2.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
in mm/month	69.6	95.1	89.8	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.1
in l/s/h	0.26	0.39	0.34	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0
(% of total area)												
Irr.req. for actual area	0.26	0.39	0.34	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 18 Irrigation water requirement of Lasi block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Lasi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.1	97.5	103.3	43.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	86.7	104.4	72.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.9
3. Sweet Peppers	74.1	91.2	86.9	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.4	87.4	92.1	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	70.1	100.5	79.5	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.1	3.2	2.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
in mm/month	65.6	88.7	82.1	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6
in l/s/h	0.24	0.37	0.31	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Irrigated area	95.0	95.0	95.0	95.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.0
(% of total area)												
Irr.req. for actual area	0.26	0.39	0.32	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 19 Irrigation water requirement of Tagelwedefit block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Tagelwedefit

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.8	101.1	108.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	90.3	109.3	76.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2
3. Sweet Peppers	76.1	95.2	92.1	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.5	95.4	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	72.5	104.6	83.3	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.3	3.5	2.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
in mm/month	71.5	98.8	88.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.9
in l/s/h	0.27	0.41	0.33	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.0
(% of total area)												
Irr.req. for actual area	0.27	0.41	0.33	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 20 Irrigation water requirement of Tekledib1 block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Tekledib 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.8	101.1	108.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Dry beans	42.1	91.3	108.1	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. MAIZE (Grain)	90.3	109.3	76.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2
4. Sweet Peppers	76.1	95.2	92.1	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
5. Small Vegetables	67.6	89.5	95.4	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. Spring Wheat	72.5	104.6	83.3	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.3	3.7	2.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
in mm/month	72.4	102.5	85.5	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4
in l/s/h	0.27	0.42	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Irrigated area	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.0
(% of total area)												
Irr.req. for actual area	0.27	0.42	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 21 Irrigation water requirement of Tekledib2 block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Tekle Dib- 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.8	101.1	108.0	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Dry beans	42.1	91.3	108.1	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. MAIZE (Grain)	90.3	109.3	76.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2
4. Sweet Peppers	76.1	95.2	92.1	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
5. Small Vegetables	67.6	89.5	95.4	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. Spring Wheat	72.5	104.6	83.3	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.0	3.1	2.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
in mm/month	62.5	87.8	73.5	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4
in l/s/h	0.23	0.36	0.27	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Irrigated area	86.0	86.0	86.0	86.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.0
(% of total area)												
Irr.req. for actual area	0.27	0.42	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendixes Table 22 Irrigation water requirement of Teleta block

Scheme Supply

ETo station: Bahirdar (Airport)

Rain station: Bahirdar (Airport)

Cropping pattern: Teleta

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. Barley	41.6	100.4	107.1	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. MAIZE (Grain)	89.5	108.2	75.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
3. Sweet Peppers	75.7	94.4	91.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.1
4. Small Vegetables	67.6	89.0	94.7	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Spring Wheat	71.9	103.7	82.4	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.2
Net scheme irr.req.												
in mm/day	2.1	3.3	2.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
in mm/month	65.4	92.6	78.9	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.1
in l/s/h	0.24	0.38	0.29	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Irrigated area	92.0	92.0	92.0	92.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.0
(% of total area)												
Irr.req. for actual area	0.27	0.42	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
(l/s/h)												

Appendix -B Release amount from the main dam outlet starting from October 25/02/2010E.C

Number	Release day	Release time	Amount (l/s)	Elevation
1	25/02/2010	10:27	400	2015.48
2	02/03/2010	9:58	800	2015.42
3	11/03/2010	3:10	1280	2015.35
4	13/03/2010	5:00	2000	2015.32
5	18/03/2010	3:00	3700	2015.3
6	24/03/2010	10:10	4500	2015.2
7	30/03/2010	8:30	5100	2015.08
8	09/04/2010	2:42	5600	2014.85
9	16/04/2010	4:30	6000	2014.6
10	01/05/2010	5:05	6500	2014.01
11	01/07/2010	6:00	5000	Not recorded
12	01/08/2010	8:00	1900	2010.2
13				
14				
15				
16				
17				
18				
19				

Appendixes -C Average monthly temperature, precipitation, sunshine, humidity and wind speed data from (1993 to 2003) Bahrdar Airport station.

(Source Addis Ababa metrological station)

Appendixes Table 23 Average monthly precipitation data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	7.2	0.7	3.7	43.5	101.8	203.4	445.0	315.8	195.4	78.5	8.4	0.0
1994	0.0	0.2	0.0	62.6	133.7	252.7	424.9	358.3	243.1	10.0	6.5	6.3
1995	0.0	1.1	7.3	24.3	69.8	154.1	465.0	273.2	147.7	26.7	10.2	21.7
1996	0.5	0.8	38.2	68.9	101.9	275.8	443.8	361.9	220.8	36.7	35.3	0.0
1997	0.0	0.0	111.3	35.8	85.9	120.1	422.5	376.5	209.6	155.2	20.1	0.0
1998	0.0	0.0	31.9	2.6	59.0	278.3	357.4	391.1	187.5	145.3	0.0	0.0
1999	0.0	6.9	0.0	5.4	32.1	164.6	419.1	351.9	163.0	191.6	11.7	0.0
2000	0.0	0.0	0.4	90.5	31.3	133.9	419.4	566.8	174.9	181.6	23.3	0.0
2001	0.0	3.7	1.3	52.5	32.8	269.2	387.6	445.0	176.0	57.2	1.8	11.1
2002	0.0	1.0	2.5	14.4	4.7	339.5	460.4	291.2	186.0	33.6	0.0	1.5
2003	0.3	0.0	59.8	0.0	0.9	219.7	574.4	381.9	258.2	45.1	9.2	0.0
Average	0.73	1.31	23.31	36.4	59.45	219	438.1	374	196.6	87.41	11.5	3.7

Appendixes Table 24 Average monthly relative humidity data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	43	40	38	44	46	59	71	66	66	57	45	39
1994	35	35	29	33	51	66	77	76	65	43	47	42
1995	33	32	31	33	42	57	74	73	64	45	43	43
1996	37	34	38	38	55	67	71	74	68	50	47	40
1997	38	34	36	41	57	67	74	70	65	62	53	46
1998	44	39	40	33	48	61	78	79	68	58	43	36
1999	38	28	30	32	46	55	76	72	64	59	46	46
2000	43	32	33	47	43	55	67	69	60	58	53	51
2001	41	34	33	34	43	60	68	72	65	58	46	45
2002	41	34	33	33	34	59	69	71	65	50	41	38
2003	35	35	32	28	28	55	74	74	67	50	41	37
Average	39	34.3	33.91	36	44.8	60.1	72.64	72.4	65.2	53.6	46	42.1

Appendixes Table 25 Average monthly sunshine data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	9.9	8.3	9.2	9.4	8.2	6.9	5.1	5.8	6.2	7.8	9.5	10.0
1994	9.7	9.5	10.1	9.7	8.5	6.3	3.6	4.1	7.1	9.1	9.3	10.3
1995	10.2	9.1	9.7	9.1	7.8	7.4	4.5	4.3	7.1	9.5	9.6	9.1
1996	9.7	10.1	8.8	8.9	6.8	6.6	5.1	4.5	6.8	9.4	8.6	9.6
1997	9.3	10.1	7.9	7.8	7.5	5.7	4.7	4.9	8.2	7.4	8.9	9.7
1998	9.6	9.4	8.5	9.4	8.2	7.8	2.8	3.4	6.3	8.3	9.7	10.1
1999	9.4	10.6	10.3	9.4	8.0	6.7	4.1	4.5	6.5	7.5	9.7	9.7
2000	10.1	9.9	10.0	7.1	8.3	7.2	4.8	4.0	6.4	7.9	9.1	9.7
2001	10.3	9.7	7.5	8.7	9.2	7.2	5.7	4.7	6.8	8.3	9.1	9.8
2002	10.2	9.6	9.1	10.2	10.0	7.2	6.5	5.5	7.1	8.6	9.1	9.8
2003	10.1	9.5	8.3	9.5	9.6	7.2	6.1	5.1	7.0	8.5	9.1	9.8
Average	9.9	9.62	9.04	9	8.4	7	4.8	4.6	6.86	8.4	9.25	9.8

Appendixes Table 26 Average monthly maximum temperature data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	28.2	29.1	30.1	31.2	29.4	27.0	23.7	24.3	24.6	25.7	26.9	27.3
1994	28.2	29.2	30.0	31.4	28.9	25.7	23.1	23.3	25.2	27.4	27.8	27.7
1995	28.1	28.9	30.2	30.9	29.9	28.3	24.2	24.1	25.9	27.4	27.2	27.5
1996	27.7	30.1	30.3	30.3	27.2	25.3	24.9	23.9	25.8	27.4	26.9	27.2
1997	28.0	30.3	31.2	30.5	28.7	26.4	24.6	25.2	26.8	26.9	27.2	28.0
1998	28.7	29.7	32.2	33.5	30.9	28.3	23.0	23.4	25.7	26.9	27.7	27.7
1999	28.1	31.5	30.6	32.1	30.2	28.3	23.6	24.2	26.0	26.8	27.5	27.8
2000	27.2	29.0	30.6	29.3	30.9	28.8	25.7	24.8	26.3	26.6	27.2	27.8
2001	27.4	30.3	30.2	31.9	31.1	26.6	24.9	24.9	26.0	27.3	27.1	28.4
2002	28.6	30.6	31.3	32.4	32.1	28.6	26.1	25.2	26.1	28.1	28.4	28.2
2003	28.9	31.1	32.1	32.3	32.8	28.5	24.4	24.6	25.7	27.5	28.2	28.5
Average	28.1	30	30.8	31.44	30.2	27.44	24.4	24.4	25.83	27.5	27.5	28.8

Appendixes Table 27 Average monthly minimum temperature data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	7.9	9.8	12.4	15.2	15.0	14.6	14.4	13.9	13.3	13.6	12.3	9.7
1994	8.9	11.3	11.2	15.8	15.2	14.9	14.6	14.3	13.8	13.0	12.3	9.3
1995	8.9	10.8	11.7	15.8	16.4	15.0	14.8	13.9	13.2	12.8	11.0	10.7
1996	9.7	11.5	13.5	15.7	14.9	14.2	13.8	13.5	12.9	11.3	9.5	7.2
1997	6.3	7.9	12.5	13.4	14.4	13.4	13.8	13.8	12.3	12.6	11.5	7.8
1998	6.3	6.4	11.0	12.6	14.5	13.8	14.1	14.2	13.0	13.1	8.6	5.4
1999	5.9	7.8	7.0	13.1	13.6	12.4	13.6	13.5	12.9	13.2	8.8	5.9
2000	9.4	10.7	13.3	12.9	13.8	13.2	13.8	13.2	12.7	13.3	9.0	6.3
2001	4.5	8.3	11.8	13.2	14.3	14.2	14.4	13.8	12.8	13.0	9.6	9.3
2002	7.6	9.6	12.0	13.5	14.8	14.6	13.9	13.9	12.4	11.8	9.7	6.7
2003	5.6	9.8	14.2	13.2	16.2	14.8	14.2	14.3	13.1	12.2	10.0	6.3
Average	7.4	9.45	11.9	14	14.8	14.1	14.1	13.85	13	12.7	10.2	7.7

Appendixes Table 28 Average monthly wind speed data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	1.2	1.5	1.7	1.8	1.6	1.5	1.2	1.2	1.2	1.2	1.2	1.3
1994	1.4	1.5	1.7	1.8	1.5	1.5	1.0	1.0	1.0	1.3	1.2	1.2
1995	1.2	1.3	1.6	1.7	1.6	1.5	1.1	1.0	1.0	1.0	1.2	0.8
1996	1.2	1.4	1.5	1.7	1.3	1.2	1.0	0.8	0.7	0.6	0.8	0.5
1997	0.8	0.9	1.2	1.2	1.1	0.8	0.7	0.6	0.5	0.5	0.5	0.9
1998	0.7	0.7	0.8	0.9	0.9	1.0	0.6	0.5	0.4	0.5	0.7	0.7
1999	0.7	1.1	1.3	1.4	1.2	0.9	0.7	0.5	0.4	0.5	0.6	0.5
2000	0.7	1.0	1.0	0.9	0.8	0.7	0.4	0.4	0.4	0.4	0.5	0.7
2001	0.7	0.9	1.1	1.2	1.2	0.9	0.6	0.6	0.5	0.5	0.7	0.7
2002	0.7	1.1	1.2	1.5	1.4	1.0	0.7	0.6	0.5	0.6	0.6	0.4
2003	0.7	1.0	1.2	1.4	1.3	1.0	0.7	0.6	0.5	0.6	0.7	0.1
Average	0.7	1.13	1.3	1.41	1.3	1.1	0.8	0.71	0.65	0.7	0.8	0.71

Appendix –D Measured discharge data from the main canal for the three consecutive months

Appendixes Table 29 Measured discharge data of the main canal (February week -1)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharg (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	7.2	3.2	1.3	S0.2=8.85	9.11	0.915	0.923	0.929	6.72	6.24
						S0.8=9.82	10.11	0.906	0.985			
						M0.2=8.152	8.994	0.872	0.881			
						M0.8=8.251	9.012	0.915	0.931			
						E0.2=9.125	10.1	0.956	0.968			
						E0.8=8.823	8.91	0.815	0.886			
4KM	2003	E=0295691 N=1256762	7.1	2.8	1.2	S0.2=8.93	9.16	0.927	0.977	0.980	5.94	5.82
						S0.8=9.91	10.17	0.941	0.992			
						M0.2=8.21	8.89	0.871	0.948			
						M0.8=8.35	8.98	0.874	0.957			
						E0.2=9.17	9.73	0.961	0.999			
						E0.8=8.88	8.98	0.827	0.983			
10KM	2002	E=0295152 N=1261718	6.3	2.8	1.1	S0.2=6.52	7.56	0.919	0.934	1.04	5.01	5.21
						S0.8=9.83	10.01	1.06	1.275			
						M0.2=8.35	9.17	0.904	0.927			
						M0.8=9.63	9.34	0.956	0.998			

						E0.2=10.25 E0.8=10.31	10.37 10.73	0.985 0.923	1.122 0.975			
18KM	1922	E=0294996 N=1268972	2.3	1	0.45	S=11.15 M=10.2 E=10.12	11.45 11.14 10.41	0.925 0.911 0.915	0.936 0.964 0.926	0.942	0.751	0.71
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	2.1	1	0.36	S=11.53 M=10.23 E=13.05	12.01 11.55 14.21	1.12 1.05 1.26	1.21 1.17 1.35	1.24	0.558	0.69

Appendixes Table 30 Measured discharge data of the main canal (February week -2)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	7.2	3.2	1.3	S0.2=9.92 S0.8=8.89 M0.2=8.352 M0.8=8.451 E0.2=9.625 E0.8=8.883	10.11 9.21 8.994 9.012 10.1 8.99	0.916 0.954 0.888 0.925 0.936 0.805	0.983 0.968 0.971 0.941 0.948 0.846	0.943	6.72	6.33

4KM	2003	E=0295691 N=1256762	7.0	2.8	1.2	S0.2=9.42 S0.8=9.15 M0.2=8.79 M0.8=9.81 E0.2=9.72 E0.8=9.85	9.75 9.45 9.09 10.12 10.09 10.14	0.954 0.925 0.911 1.051 0.995 1.073	0.978 0.951 0.941 1.091 1.019 1.098	1.01	5.88	5.94
10KM	2002	E=0295152 N=1261718	6.3	2.8	1.1	S0.2=8.52 S0.8=9.73 M0.2=8.55 M0.8=9.63 E0.2=10.15 E0.8=10.36	7.56 10.01 9.17 9.98 10.38 10.73	0.821 1.16 0.904 0.956 0.915 0.923	0.904 1.381 0.932 0.995 1.050 1.101	1.05	5	5.25
18KM	1922	E=0294996 N=1268972	2.1	1	0.46	S=11.23 M=10.2 E=10.12	12.25 10.85 11.48	0.915 0.876 0.986	0.936 0.904 1.061	0.967	0.713	0.69
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	2.0	1	0.36	S=10.92 M=12.24 E=10.23	11.56 13.29 11.11	1.14 1.28 1.08	1.21 1.39 1.16	1.25	0.54	0.67

Appendixes Table 31 Measured discharge data of the main canal (February week -3)

Chainage (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	7.2	3.2	1.3	S0.2=9.82	10.15	0.926	0.985	0.937	6.72	6.3
						S0.8=8.79	9.17	0.944	0.968			
						M0.2=8.352	8.99	0.888	0.951			
						M0.8=8.451	9.012	0.915	0.931			
						E0.2=9.625	10.1	0.935	0.953			
						E0.8=8.883	8.99	0.815	0.836			
4KM	2003	E=0295691 N=1256762	7.1	2.8	1.2	S0.2=9.36	9.78	0.987	1.061	0.999	5.94	5.93
						S0.8=9.53	9.88	0.998	1.101			
						M0.2=8.91	9.27	0.935	0.948			
						M0.8=9.18	9.38	0.951	0.969			
						E0.2=7.93	8.12	0.822	0.836			
						E0.8=9.58	9.87	0.989	1.079			
10KM	2002	E=0295152 N=1261718	6.4	2.8	1.1	S0.2=8.62	8.86	0.851	0.877	1.06	5.06	5.36
						S0.8=9.73	10.01	1.16	1.261			
						M0.2=8.55	9.17	0.914	0.982			
						M0.8=9.63	9.98	0.956	0.998			
						E0.2=10.15	10.38	0.995	1.111			

						E0.8=10.36	10.73	1.013	1.141			
18KM	1922	E=0294996 N=1268972	2.1	1	0.45	S=11.03 M=10.12 E=10.32	12.15 10.75 11.38	0.925 0.915 0.978	0.941 0.934 1.11	0.995	0.697	0.69
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	2.0	1	0.37	S=9.19 M=11.12 E=12.23	9.67 11.55 13.57	0.987 1.12 1.37	0.998 1.21 1.43	1.21	0.56	0.68

Appendixes Table 32 Measured discharge data of the main canal (February week -4)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	7.2	3.2	1.3	S0.2=9.78 S0.8=9.15 M0.2=8.452 M0.8=8.651 E0.2=9.625 E0.8=8.341	10.21 9. 75 8.99 9.012 10.1 8.78	0.936 0.914 0.864 0.935 0.905 0.895	0.995 0.958 0.941 0.951 0.923 0.936	0.95	6.72	6.38

4KM	2003	E=0295691 N=1256762	7.1	2.8	1.2	S0.2=9.71 S0.8=10.07 M0.2=8.69 M0.8=8.98 E0.2=9.63 E0.8=9.85	9.98 10.23 8.89 9.12 9.92 10.05	1.011 1.108 0.878 0.907 0.996 1.018	1.032 1.116 0.903 0.922 1.001 1.012	1.01	5.94	6.00
10KM	2002	E=0295152 N=1261718	6.3	2.8	1.1	S0.2=9.02 S0.8=9.87 M0.2=8.75 M0.8=9.53 E0.2=9.31 E0.8=10.16	9.51 10.01 9.27 9.97 9.88 10.74	0.981 1.062 0.944 0.986 0.978 1.167	0.983 1.187 0.985 0.998 0.993 1.291	1.07	5	5.35
18KM	1922	E=0294996 N=1268972	2.1	1	0.45	S=10.23 M=9.71 E=10.12	10.85 9.85 10.38	1.015 0.968 0.995	1.105 0.973 1.011	1.02	0.697	0.71
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	2.0	1	0.36	S=8.91 M=14.01 E=10.72	9.71 14.57 11.09	0.973 1.44 1.08	0.991 1.61 1.22	1.27	0.54	0.69

Appendixes Table 33 Measured discharge data of the main canal (March week -1)

Chain age (Km)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	6.1	3.2	1.1	S0.2=8.87 S0.8=9.98 M0.2=8.58 M0.8=9.03 E0.2=5.73 E0.8=7.2	10.11 10.19 7.23 8.15 5.97 7.91	0.989 1.108 0.915 1.006 0.653 0.812	1.121 1.131 0.814 0.912 0.678 0.886	0.924	5.115	4.73
4KM	2003	E=0295691 N=1256762	6.0	2.8	1.1	S0.2=7.54 S0.8=9.47 M0.2=8.71 M0.8=9.65 E0.2=7.98 E0.8=9.12	7.42 10.27 8.92 10.31 8.11 9.27	0.745 0.998 0.872 1.018 0.823 0.912	0.750 1.121 0.881 1.127 0.831 0.923	0.934	4.84	4.52
10KM	2002	E=0295152 N=1261718	5.3	2.8	0.9	S0.2=5.42 S0.8=9.53 M0.2=9.35 M0.810.43 E0.2=10.05	5.46 9.91 10.07 10.54 9.17	0.619 1.06 1.04 1.156 1.115	0.240 1.110 1.117 1.681 1.022	1.175	3.65	4.28

						E0.8=11.33	10.73	1.253	1.890			
18KM	1922	E=0294996 N=1268972	1.8	1	0.35	S=11.38 M=12.15 E=9.120	11.4 13.4 11.4	1.05 1.14 1.015	1.09 1.17 1.05	1.10	0.49	0.54
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	1.7	1	0.31	S=12.39 M=10.09 E=12.98	12.96 11.67 13.19	1.17 1.06 1.19	1.25 1.18 1.22	1.52	0.42	0.50

Appendixes Table 34 Measured discharge data of the main canal (March week- 2)

Chain age (Km)	Elevn (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real, V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	6.1	3.2	1.1	S0.2=9.87 S0.8=9.95 M0.2=8.58 M0.8=9.03 E0.2=5.63 E0.8=7.12	10.11 10.09 7.23 8.15 5.98 7.71	0.991 0.998 0.815 1.006 0.751 0.801	1.02 1.05 0.914 0.912 0.871 0.856	0.937	5.115	4.79

4KM	2003	E=0295691 N=1256762	6.0	2.8	1.1	S0.2=9.58 S0.8=9.87 M0.2=8.95 M0.8=9.15 E0.2=6.65 E0.8=7.21	10.23 10.11 7.09 8.27 6.97 7.53	0.998 0.992 0.811 1.05 0.777 0.866	1.031 1.011 0.912 0.915 0.879 0.858	0.936	4.84	4.53
10KM	2002	E=0295152 N=1261718	5.3	2.8	0.9	S0.2=5.57 S0.8=9.73 M0.2=9.85 M0.810.33 E0.2=10.05 E0.8=11.33	5.76 9.91 10.01 10.44 9.17 10.73	0.619 1.05 1.01 1.151 1.115 1.23	0.524 1.15 1.12 1.48 1.02 1.49	1.13	3.65	4.13
18KM	1922	E=0294996 N=1268972	1.8	1	0.35	S=11.38 M=11.75 E=9.22	11.46 12.41 10.43	1.03 1.17 0.93	1.06 1.18 0.97	1.07	0.49	0.52
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	1.7	1	0.32	S=10.97 M=13.14 E=9.98	11.55 13.97 10.27	1.07 1.18 0.91	1.11 1.23 1.08	1.14	0.43	0.49

Appendixes Table 35 Measured discharge data of the main canal (March week-3)

Chain Age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	6.1	3.2	1.1	S0.2=9.85	10.01	0.981	1.111	0.936	5.115	4.79
						S0.8=9.91	1.09	0.998	1.133			
						M0.2=8.18	8.23	0.615	0.725			
						M0.8=9.01	9.17	0.906	0.912			
						E0.2=5.73	6.98	0.661	0.781			
						E0.8=8.12	9.71	0.901	0.956			
4KM	2003	E=0295691 N=1256762	6	2.8	1.1	S0.2=8.72	9.35	0.945	0.954	0.934	4.84	4.52
						S0.8=9.76	10.02	1.010	1.031			
						M0.2=9.18	9.37	0.945	0.961			
						M0.8=9.83	10.11	1.021	1.072			
						E0.2=7.14	7.38	0.744	0.763			
						E0.8=8.19	8.28	0.821	0.827			
10KM	2002	E=0295152 N=1261718	5.3	2.8	0.9	S0.2=7.87	7.91	0.812	0.821	1.148	3.65	4.19
						S0.8=9.73	9.91	0.965	1.081			
						M0.2=9.65	9.91	0.932	1.118			
						M0.8=10.13	10.24	1.15	1.37			
						E0.2=10.05	10.17	1.11	1.29			

						E0.8=10.31	10.63	1.03	1.21			
18KM	1922	E=0294996 N=1268972	1.8	1	0.36	S=11.48 M=12.15 E=10.22	11.66 12.47 10.43	1.01 1.05 0.98	1.07 1.12 1.01	1.07	0.50	0.53
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	1.7	1	0.32	S=10.09 M=11.11 E=11.01	10.46 11.61 11.48	0.96 1.01 0.99	1.02 1.08 1.01	1.04	0.43	0.44

Appendixes Table 36 Measured discharge data of the main canal (March week-4)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	6.1	3.2	1.1	S0.2=9.65 S0.8=9.77 M0.2=8.18 M0.8=9.01 E0.2=7.73 E0.8=8.12	9.81 9.98 8.33 9.27 7.98 9.71	0.962 0.978 0.835 0.919 0.781 0.951	0.989 0.997 0.875 0.962 0.798 0.979	0.933	5.115	4.77

4KM	2003	E=0295691 N=1256762	6	2.8	1.1	S0.2=9.71 S0.8=9.89 M0.2=6.89 M0.8=8.27 E0.2=10.09 E0.8=10.29	9.84 9.98 7.12 8.74 10.27 10.43	0.965 0.986 0.576 0.823 1.007 1.093	0.982 0.998 0.602 0.854 1.102 1.112	0.941	4.84	4.55
10KM	2002	E=0295152 N=1261718	5.3	2.8	0.9	S0.2=8.47 S0.8=9.63 M0.2=9.65 M0.8=11.11 E0.2=10.15 E0.8=11.31	8.71 9.91 9.91 12.24 10.27 12.63	0.713 0.955 0.942 1.25 1.16 1.13	0.727 0.995 1.19 1.38 1.27 1.31	1.145	3.65	4.18
18KM	1922	E=0294996 N=1268972	1.8	1	0.36	S=12.18 M=10.15 E=12.32	12.46 10.41 12.53	1.11 0.97 1.13	1.17 1.01 1.19	1.1	0.50	0.55
Tail (Teleta)19KM	1905	E=0294745 N=1270501	1.7	1	0.33	S=12.08 M=10.76 E=10.85	12.67 11.45 11.27	1.08 1.09 1.04	1.11 1.12 1.08	1.1	0.45	0.49

Appendixes Table 37 Measured discharge data of the main canal (April week-1)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	3.3	3.2	0.45	S=10.215 M=10.08 E=10.19	11.85 10.71 10.23	1.25 1.12 1.05	1.36 1.25 1.21	1.27	1.46	1.85
4KM	2003	E=0295691 N=1256762	3.3	2.8	0.5	S=10.12 M=10.31 E=10.23	10.41 10.65 10.55	1.04 1.11 1.07	1.12 1.16 1.14	1.14	1.52	1.73
10KM	2002	E=0295152 N=1261718	3.0	2.8	0.4	S=11.4 M=11.16 E=11.19	11.61 11.25 11.31	1.26 1.16 1.18	1.38 1.26 1.27	1.30	1.16	1.51
18KM	1922	E=0294996 N=1268972	1.1	1	0.12	S=13.115 M=12.21 E=13.12	14.85 13.34 12.46	1.13 1.31 1.43	1.23 1.45 1.54	1.41	0.14	0.19
Tail (teleta) 19KM	1905	E=0294745 N=1270501	1	1	0.11	S=12.62 M=12.35 E=10.25	13.11 12.98 10.78	1.52 1.48 1.17	1.64 1.56 1.33	1.51	0.10	0.17

Appendixes Table 38 Measured discharge data of the main canal (April week-2)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	3.4	3.2	0.45	S=10.225 M=10.08 E=10.19	10.55 10.21 10.23	1.25 1.08 1.21	1.34 1.12 1.32	1.26	1.48	1.86
4KM	2003	E=0295691 N=1256762	3.3	2.8	0.5	S=11.21 M=10.03 E=9.83	11.36 10.11 10.01	1.21 0.995 0.981	1.32 1.07 0.998	1.13	1.52	1.72
10KM	2002	E=0295152 N=1261718	3	2.8	0.36	S=12.45 M=10.66 E=12.35	13.27 11.75 14.07	1.36 1.24 1.45	1.52 1.37 1.64	1.51	1.04	1.57
18KM	1922	E=0294996 N=1268972	1.1	1	0.13	S=11.56 M=9.62 E=10.32	13.58 10.14 12.52	1.37 1.08 1.31	1.58 1.22 1.52	1.44	0.14	0.20
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	1	1	0.11	S=12.83 M=10.34 E=11.78	13.61 10.98 11.78	1.51 1.12 1.33	1.72 1.35 1.57	1.55	0.11	0.17

Appendixes Table 39 Measured discharge data of the main canal (April week-3)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	3.4	3.2	0.46	S=10.18 M=10.83 E=11.19	10.75 11.09 11.73	1.07 1.19 1.21	1.19 1.24 1.26	1.23	1.52	1.87
4KM	2003	E=0295691 N=1256762	3.3	2.8	0.5	S=10.02 M=10.13 E=10.39	10.21 10.31 10.51	1.01 1.08 1.11	1.07 1.12 1.15	1.11	1.52	1.69
10KM	2002	E=0295152 N=1261718	3	2.8	0.35	S=13.15 M=10.74 E=12.85	14.05 11.03 14.16	1.16 0.99 1.28	1.72 1.11 1.45	1.43	1.02	1.46
18KM	1922	E=0294996 N=1268972	1.1	1	0.12	S=14.56 M=11.62 E=13.32	16.58 13.14 14.52	1.47 1.28 1.33	1.68 1.31 1.48	1.49	0.126	0.19
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	1.1	1	0.11	S=12.34 M=13.84 E=12.45	13.12 14.27 13.32	1.32 1.48 1.42	1.41 1.59 1.55	1.52	0.116	0.18

Appendixes Table 40 Measured discharge data of the main canal (April week-4)

Chain age (KM)	Elevation (m)	coordinate	Top Width (m)	Bottom Width (m)	Water Depth (m)	Revolution (R/s)		Velocity (m/s)		Aver Real V(m/s)	Area (m^2)	Discharge (m^3/s)
						Average	Real	Average	Real			
Main (outlet)	2004	E=0297054 N=1254894	3.3	3.2	0.46	S=10.13 M=10.28 E=11.29	10.35 10.99 11.83	1.07 1.09 1.25	1.17 1.21 1.31	1.23	1.50	1.85
4KM	2003	E=0295691 N=1256762	3.2	2.8	0.5	S=9.93 M=10.12 E=11.11	10.01 10.21 11.23	0.995 1.03 1.14	1.01 1.12 1.22	1.12	1.50	1.68
10KM	2002	E=0295152 N=1261718	3	2.8	0.36	S=13.15 M=10.74 E=12.85	14.05 11.03 13.16	1.36 1.31 1.28	1.52 1.41 1.33	1.42	1.04	1.48
18KM	1922	E=0294996 N=1268972	1.1	1	0.13	S=14.16 M=11.22 E=13.42	15.08 12.87 14.67	1.49 1.18 1.37	1.63 1.31 1.45	1.46	0.136	0.20
Tail (Teleta) 19KM	1905	E=0294745 N=1270501	1.1	1	0.12	S=13.32 M=14.38 E=12.96	14.11 14.97 13.55	1.35 1.42 1.27	1.48 1.54 1.39	1.47	0.126	0.18

Appendixes –E Crop type, planed, irrigable and irrigated and implementation report in each command area

(Source Koga irrigation project office 2010E.C)

Appendixes Table 41 Koga irrigation project implementation report

List	unit	Name of blocks													
		KU	CH	AB	AD	TA	EN	LA	BE	AN	AM	TE	TD1	TD2	Total
plan	**ha**	**329**	**599**	**696**	**672**	**598**	**368**	**477**	**451**	**463**	**258**	**787**	**361**	**453**	**6512**
irrigable	”	**346**	**541**	**640**	**590**	**570**	**328**	**418**	**400**	**423**	**215**	**650**	**322**	**409**	**5850**
implementation	**%**	**105**	**90**	**92**	**88**	**95**	**89**	**88**	**89**	**91**	**83**	**83**	**89**	**90**	**90**
irrigated	”	332	541	533	580	570	328	418	400	423	210	640	322	409	5705
implementation	%	101	87	77	86	95	89	70	89	91	81	81	89	90	88
Crop type	”	332	541	533	580	570	328	418	400	423	210	640	322	409	5705
crop		**131**	**210**	**313**	**332**	**337**	**146**	**195**	**229**	**321**	**172**	**508**	**268**	**285**	**3446**
Wheat	”	121	198	260	275	289	128	154	137	153	126	437	224	247	2750
Barley	”	1.63	5	25.7	20	8.75	6	1.25	26.5	4	17	26.	9.50	5.800	157.5
Maize	”	8.5	7	27	37.0	39	12	40	66	163	28.6	45	33.5	32.6	538.7
Vegetable	**”**	**197**	**323**	**208**	**242**	**229**	**174**	**219**	**167**	**101**	**37**	**130**	**47**	**121**	**2196**
Potato	”	137	196	156	180	124	78	108	108	46	24	70	20	60	1305
Cabbage	”	1	3.5	13	20	17	8.0	4.5	3.0	0.5	0.5	2.0	0.50	0.63	73.0
Tomato	”	0.08	10.0	2.1	9	5.6	7.0	3.7	7.0	1.0	1.5	0.5	0.50	2.3	50.3
Onion	”	17	103	32.7	30.0	77	69	100	43	52	11	35	26.0	52.8	648

Garlic	”	41.8	10.0	4.3	3.0	6	12	2	5	1	0.23	23	0	5.39	114.6
Carrot			0.38	0.0											0.4
Onion seed	”	**0.20**	**1.00**				**0.375**	**0.13**	**0.75**	**1.50**					**4.0**
Ingredient		**2.68**	**8.00**	**7.63**	**5.00**	**3.88**	**7.50**	**3.75**	**3.75**	**0.75**	**1.25**	**2.00**	**4.50**	**2.72**	**53.4**
Pepper	”	2.68	8.00	7.6	5.0	3.875	7.50	3.75	3.75	0.750	1.25	2.00	4.50	2.7	**53.4**
Grain		**0.375**	**0**	**5.05**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**1**	**9.9**
Pea, Bean	”	0.375		**5.05**	1.0								3.00	0.50	**9.9**