PERFORMANCE EVALUATION OF DAKAWA IRRIGATION SCHEME MOROGORO TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN IRRIGATION ENGINEERING AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2020

ABSTRACT

Many irrigation schemes which have been built in Tanzania are performing below standard. This situation has resulted in low scheme production. Major causes for poor performance may vary between different schemes. However, a comprehensive performance evaluation of these schemes may bring a common understanding on the way to improve the performance and enhance crop productivity in the irrigation schemes. This Study was conducted to evaluate the overall irrigation performance of a cooperate irrigation scheme in Dakawa Irrigation Schemes. In this scheme, water abstraction weir was designed and constructed along Wami river to deliver water to a main canal in a typical cooperate irrigation schemes. Flows to each of the secondary canals were measured using calibrated staff gauges. The discharge data along with climatic data was used in computing overall irrigation performance, irrigation water supply, distribution performance, productivity of land and water, equity of irrigation water supply, relative water supply, relative irrigation supply, water delivery capacity and irrigation ratio. Moreover, social economic survey was also conducted to assess financial self-sufficiency, fee collection, relative water costs, technical knowledge of staff and sustainability of irrigable area. Irrigation performance indicators were also used to compare performance among different cultivated areas. Review of documents, key informant interviews, focus group discussions and field measurements was administered to collect information on irrigation and land use practiced by farmers. The results show that the main canal supplied 4160 l/s of water for irrigation to all secondary canals which uses 4003 l/s during the cropping season to meet crop demand for the entire irrigation scheme. However, the farmers at the head and middle reaches abstracted more water than they required and consequently caused a shortage of water supply to farmers at the tail-end reach. The result also shows that the overall coefficient of variation in the discharge of water to all

secondary canals was within the acceptable range which is 67%. This adequate coefficient of variation was due to improvements done in the whole scheme area including the pump house. The seasonal equity of water distribution in secondary canals in Dakawa was considered fair because all eight secondary canals equity values were above 62.5 percent. The productivity of land and output per command area in the Dakawa scheme is 8 198 346 US$. High productivity could be attributed to use of high–level inputs including sub-optimal cropping intensities. The relatively high values of output per irrigation supply suggest that the efficiency with which water is being used in the scheme is high. From the focus group discussion, it was found out that farmers still have limited understanding of irrigation scheduling and irrigation water management, as a result, some areas were over-irrigated while others faced water shortage. This situation calls for more farmers training to be conducted in the Dakawa Irrigation Scheme. Same actions may be considered to other existing irrigation schemes in Tanzania.

DECLARATION

I, Florian Pius Makaka, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor concurrently being submitted in any other institution.

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ACKNOWLEDGEMENTS

I wish first to express my sincere gratitude to my supervisors Prof. A.K.P.R. Tarimo, and Prof. N. I. Kihupi for their untiring guidance and time adjustment they made in my research work and above all the knowledge I have acquired from them during the whole period of the study.

My special appreciation to the Head of Department Prof. Boniface Mbilinyi, Prof. Mahoo and Dr. Salim Banda who assisted me during the period of my study at the Department and for coordinating our programme well. Again a lot of thanks go to Eng. Dr. Festo R. Silungwe and Dr. Proches Hironimo who assisted in many technical issues in this Study. I also wish to extend my appreciation to farmers from Dakawa Irrigation Scheme for having their time during data collection period. My special thanks go to Abel Francis-Scheme Agricultural Officer who was always there for me whenever I took the flow measurements. I am grateful to the farm manager for UWAWAKUDA for allowing me to stay in the hostels and provide me basic information of Mvomero area and my Study area-Dakawa.

I would also like to thank Eng. Towa, Irrigation Engineer from National Irrigation Commission responsible of Dakawa for having assisted me in collecting data. Sincere thanks should go to the farmers in Dakawa Irrigation Scheme for sparing their time and accepting to be interviewed and above all to use their fields for my research. Lastly, but not least, my heartfelt thanks are due to all staff of Department of Engineering Sciences and Technology.

DEDICATION

To my parents, my late wife and my children

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LIST OF ABBREVIATIONS AND ACRONYMS

AIWS	Adequacy of Irrigation Water Supply
AU	Area Uniformity
CV_R	Spatial Coefficient of Variation
D_{AVE}	Average Water Depth Supplied to the Whole System
DIS	Dakawa Irrigation Scheme
DPR	Delivery Performance Ratio
D_W	Water Depth for the Worst Supplied Area in the System
EMA	Environment Management Act
ET_C	Crop Water Requirement
ET_O	Reference Crop Evapo-Transpiration
FAO	Food Agriculture Organization
H	Gauge Height
IG	Gross Irrigation Requirement
IO	Irrigator Organization
IWMI	International Water Management Institute
IWR	Irrigation Water Requirement
K_C	Crop Factor or Crop Coefficient
MALC	Medicare Advantage Learning Collaborative
MW	The Ministry for Water
P_A	Adequacy
PE	Effective Rainfall
P_E	Equity
Q	Canal Discharge
Q_D	Amount of Water Delivered
Q_R	Amount of Water Required
R	Region or Sub-region Served by the System over a Period T
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SC	Secondary Canal
SGVP	Standardised Gross Value of Production
SIMIS	Scheme Irrigation Management Information System
SSA	Sub-Saharan Africa
T	One Irrigation Season (Days)
URT	United Republic of Tanzania
WASSA	Water Supply and Sanitation Act
WRMA	Water Resources Management Act
ZIO	Zonal Irrigation Office

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Irrigation is an important agricultural technology with strong impact on crop productivity. On average, irrigated crop yields tend to be higher than those from un-irrigated land (Lascano and Sojka, 2007), but there can also be unintended negative consequences of irrigation if it is not well managed such as salinization, water logging and environmental problems (Bart *et al.*, 2002). Developing countries have made huge investments in infrastructure for irrigation in the form of irrigation schemes over the last half century after realizing its importance for food production to feed the growing population (Faures, *et al.*, 2007). A study by (Hussain *et al*., 2004) confirms that access to reliable irrigation water can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, and greater returns from farming.

Consequently, the investment together with improved crop production technologies such as use of fertilizers, improved seeds, and plant protection techniques has enabled many countries to move towards achieving food self-sufficiency in food production (Rasul, 2016). Nevertheless, there are clear evidence that many irrigation schemes in Africa do not perform up to expectations leading to low productivity (Yokwe, 2009). This is evidenced by findings from sub Saharan Africa (SSA) where many irrigation schemes produce crops below their capacity for many reasons such as system's low efficiencies, and lack of maintenance attributed by weak irrigators' organization (Shady, 1999). This is partly due to inability of engineers, planners and managers to adequately quantify the effects of irrigation and drainage projects on water resource systems and to use facts generated from diverse studies as basis for improving technology, design and management (World Bank, 1989; van der Aalst, 1993; Kuroda, 1995).

Therefore, improving agriculture and enhancing crop productivity through improved farmer-managed irrigation systems is one of the key strategies for alleviating poverty and improving livelihood of rural communities where the majority of the poor households are directly or indirectly depending on agriculture (Mutiro and Lautze, 2015). Despite that, limited information is available on performance evaluation of irrigation schemes in Tanzania which may partly explain the persistent poor performance of many irrigation schemes.

Evidence from Tanzania indicate that the performance of most of the irrigation schemes which received financial support improved gradually for a short period of 5 years but later deteriorated (URT, 2016). The reasons are inappropriate system design, ineffective management, low irrigation efficiencies and poor operation and maintenance, resulting in their abandonment (URT, 2013). Literature indicate that irrigation performance is the result of a large number and variety of activities such as planning, design, construction, operation of facilities, maintenance, application of water to the land and strong water users' organization (Small and Svendsen, 1990; Nijman, 1992). However, the performance is judged by several indicators such as land and water productivity, reliable water supply, adequacy, and equity in water distribution within a canal command. Additionally, large irrigation command areas mostly suffer from inequitable water distribution and mismanagement in canal operation (Gaur *et al*., 2008). Also, factors such as soil, climate, system design, institutional capacity, operation, and maintenance may affect the irrigation performance (Bolaños *et al.*, 2011).

So far, numerous authors have attempted to evaluate the degree of equity and reliability of irrigation schemes so as to develop some guidelines to improve the performance of the irrigation system especially for equitable distribution of water (Chambers, 1988; Murray-Rust and Halsema, 1998; Samakande *et al.,* 2000). The challenge remains to the facts that many problems in irrigation schemes are not general, therefore, they require specific approach resulting from performance evaluations. Challenges such poor irrigation water management is usually due to lack of technical know-how (Chambers, 1988), of which some schemes may not have such limitations. Typical causes of poor hydraulic performance of canals are wear and tear, lack of maintenance, illegal intervention, and inappropriate or improper operation of water control structures (Murray-Rust and Halsema, 1998). Still, these may appear to be a challenge to few schemes and not to all (Murray-Rust and Halsema, 1998). Inequity in many irrigation schemes may also arise from deliberate action by unruly farmers to poach water or from poor design of water proportioning division devices (Tiffen, 1990).

The situation in Tanzania is that farmers in most of irrigation schemes contribute to poor hydraulic performance of canal by making cuts in the side of the canal, inserting stones and mud from the canal bank into the cut (Mchelle, 2011). This leads to a considerable waste of water that in turn causes scarcity in the tail end reaches and as a result, brings about inequity. Although, water distribution inequity among farmers is a function of both technical and social factors (Layton *et al*., 1993; Murray-Rust and Halsema, 1998), limited numbers of irrigation schemes in Tanzania have documented these factors as descriptors of their performance. Thus, inequalities of irrigation water supply resulting from design limitation causes farmers to not appreciate even the modern constructed structures (Samakande *et al.,* 2000).

Many irrigation systems indicate failures with respect to their anticipated benefits. However, improvement of these schemes can be brought about through their evaluation of their performance and implementation of the recommendations. Nevertheless, to obtain information on the extent to which irrigation systems are achieving the required performance, a set of performance indicators must be agreed upon. The most used performance indicators are efficiency of the scheme, dependability of the scheme, sustainability, adequacy of water supplied, equity, productivity of the scheme, and the availability of institutional and support services. These performance indicators help to evaluate the irrigation system. It is well established that without agreed standards of performance, there is no basis for saying whether the system is performing better or worse (Abernethy, 1986). Thus, evaluating performance of irrigation schemes by measuring the agreed standard performance indicators remains the key to success of implementation of operation and maintenance for an irrigation scheme.

Tanzania has a total irrigated area in of about 694 000 hectares out of an estimated potential area of 29.4 million hectares (URT, 2016). Still, this small portion of irrigated land is characterized by low productivity (Mkojera, 2008). The main causes of the low crop productivity are generally reported as scarcity of irrigation water and poor irrigation infrastructure due to poor design, construction, operation, and maintenance (URT, 2010; Rosegrant *et al.*, 2002). However, there is lack of specific details of actual causes of low performance to most of the irrigation schemes in Tanzania. Among the poor performing scheme is Dakawa irrigation scheme (DIS). With a potential irrigable area of 1991.7 ha and 919 farmers depending on it, DIS features among few large irrigation schemes in Morogoro region that have high potential of reducing poverty to many smallholder farmers. The scheme has been performing poorly for decades since its construction in 1980’s. To our knowledge, there is no documentation on performance evaluation of the scheme that can guide any improvements programs. This study aims to evaluate and document reasons of poor performance in all aspects ranging from design, construction and management, the administrative and behavioral reasons.

1.2 Problem Statement and Justification of the study

The shortfalls in performance of irrigation scheme can be cited at almost every level of the irrigation sector. Those who are concerned with major lending programs for irrigation, notably the Government, banks, and certain bilateral funding agencies, have begun to feel that the return on investment is not really justified. Good example is Dakawa Irrigation Scheme where greater emphasis has been placed on other sectors at the expense of new investment in irrigation, and in the rehabilitation or modernization of existing systems. Similarly, at scheme level, there is a disappointment in levels of cropping intensity, irrigation intensity and yields. The economics of irrigated agriculture are such that many farmers have not been able to achieve a more prosperous and healthy life. At the level of water distribution there are innumerable references to inequity of water distribution leading to major disparities between head and tail areas, to deficit water supplies and loss of production in some locations, or to excess water delivery and development of water logging and salinity in others. Water supplies at any given location are often poorly matched to crop needs, highly variable in both timing and discharge, and are, sometimes of increasingly poor quality.

Good performance is not only a matter of high output, but also one of efficient use of available resources. This evaluation looks at ways in which, through the introduction of more performance-oriented management processes, it should be possible to increase both output and sustain these increases into the future.

1.3 Objectives

1.3.1 Overall Objectives

The overall objective of this Study is to evaluate the performance of Dakawa Cooperative Irrigation Scheme to assess the productivity of land and water after rehabilitation.

1.3.2 Specific objectives

The specific objectives include to:

i. Evaluate performance of structures of Dakawa Irrigation Scheme in Morogoro region.
ii. Evaluate the water distribution system performance for Dakawa Irrigation Scheme.
iii. Assess social-economic status of Dakawa Irrigation Schemes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Trends of traditional Irrigation System in Tanzania

Improvement of traditional irrigation schemes in the country started prior to independence and was extended during the post-independence period (URT, 2010). In the 1960s to the 1980s the performance of the irrigation sector in the developmental and operational context was reported as being less positive (URT, 2012). This was due to absence of irrigation policy, poor management and planning, lack of national coordination, and inadequate resources. This was evidence by some of the modernized irrigation schemes totally collapsing mainly due to lack of proper maintenance while others are functioning far below their capacity. On the contrary, traditional small-scale irrigation systems are long established and are of economic significance (Alamirew *et al*., 2008).

2.1.1 Evolution of irrigation development

Irrigation in the form of traditional irrigation schemes goes back hundreds of years in the country. Traditionally, irrigation was practiced on slopes but never in the wetlands. Only flood retention cultivation was carried out in the floodplains. In the early 20th century in the Mbeya region some families introduced stream diversion for rice production, a practice that was rapidly adopted locally (MALC, 2005). Modern irrigation was introduced in the 1930s by private companies and the Department of Agriculture. In the 1950s, additional traditional irrigation schemes were established by smallholders with the support of the government for infrastructures and extension provision, but irrigation development funds were mostly allocated to state farms.

In the 1960s, unrealistic targets of irrigation development of 10 000 ha/year were never achieved because of low level of Government commitment and funds until the 1974 - 75 drought that resulted in a major food crisis. In the 1970s, private commercial irrigated farms growing coffee, tea and sugarcane and performing well were nationalized. In the 1980s, priority was given to rehabilitation of traditional irrigation schemes and construction of new modern schemes for parastatal (rice, tea, and sugarcane) and smallholders, but both were mostly unsuccessful. External support from 1985 onwards increased the irrigation development rate, but performance remained low. The Government launched a major irrigation development plan in 1994 to address constraints to the sector. In the late 1990s, the horticultural and floricultural industry developed private irrigated estates with high efficiencies.

The main regulatory framework for irrigation in the United Republic of Tanzania is the 2009 Water Resource Management Act (WRMA) No. 11, which repealed the previous 1974 Water Utilization (Control and Regulation) Act. No. 42 as amended by the 1997 Water Laws (Control and Regulation) Act, but not the 1999 Water Laws (Miscellaneous amendments) Act. The 2009 WRMA Act stipulates that all water in mainland Tanzania is vested in the United Republic of Tanzania and introduces more participatory management through the five levels of water management in the country. It was completed by the 2013 National Irrigation Act establishing a National Irrigation Commission. Finally, the 2009 Water Supply and Sanitation Act (WASSA) organize the water provision services and establishes the National Water Investment Fund (MW, 2014). More generally, the 2004 Environmental Management Act (EMA) requires irrigated agriculture to protect the land, surface water and groundwater resources, as well as the community.

2.2 Irrigation Canals and Regulatory Structures

Many structures in irrigation systems have been designed to suit different types of conditions whereby each structure has a defined proportion of the total flow and allocating water in different areas (Murray-Rust *et al.,* 1998). Irrigation structures can be defined according to their functions namely water conveyance, flow regulation, flow division and flow measurement (Manzungu, 1999). Other important functions performed by the structural elements of a surface irrigation system, drip and above ground systems include: (1) turning the flow to a field on and off; (2) sediment and debris removal; (3) water level stabilization; (4) distributing water onto the field; and (5) allocating the flow among fields (Arar, 1988).

Water allocation refers to assigning of water quantities to each member of the irrigation community as per design; the allocation policy being based on the need to provide equity in water permits to the users, often depending on the size of their lands to be irrigated (Bandaragoda, 1998). Water distribution on the other hand refers to the act of providing water quantities to the system members according to the actual available water in an irrigation system. Irrigation distribution activity is intended to deliver the water in compliance with the allocation rules (Yoder, 1995). Equity of water allocation among cultivators is seen as essential for effective use of irrigation facilities.

Therefore, all cultivators should always receive their fair share of water irrespective of location within the system (Murray-Rust *et al*., 2000). Allocation rules of an irrigation plan generally identify who will get water and where the water can be used. In some cases, they outline the quantity and timing of water delivery together with defining the decisions made about entitlement to water (Yoder, 1995). To accomplish this very demanding policy, two overriding principles are common: proportional division of water in the water delivery system at secondary level, and rigid turn system between water users at the tertiary level (Murray-Rust *et al*., 2000).

2.3 Performance Indicators for Regulatory Structure

Some authors have suggested other indicators which can be useful when assessing the performance of irrigators associations. Nelson (2001) suggested the use The Poor Structure Ratio (PSR) indicators when evaluating structures in schemes managed by associations or cooperate such as water users association or irrigators cooperative. These indicators can usually be applied within the limited time and financial resources available to the typical manager or association. The indicators are mostly oriented toward aspects that affect water deliveries, rather than indicators like crop yields that are also affected by other factors. The PSR is the number of structures in poor condition divided by the total number of structures. Ideally, this ratio should be zero indicating that the system is working adequately.

Ijir and Burton (1998) used the Structure Condition Index (SCI) (Equation 1) which is the number of structures working normally divided by the total number of structures.

$$Structure\ of\ I = \frac{Number\ of\ Structures\ Working\ Normally}{Total\ Number\ of\ Structures} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Bos (1997) used the same indicator but called it *"Effectivity of Infrastructure"* as shown in equation 2).

$$Structure\ of\ Infrastructure = \frac{Number\ of\ Functioning\ Structures}{Total\ Number\ of\ Structures} \ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Generally, The PSR and SCI are similar, but PSR emphasizes on structures that are not functioning adequately; while SCI emphasizes structures that are functioning adequately.

For example, if PSR is 0.05 then 5% of the structures are in poor condition whereas SCI of 0.05 means 95% of the structures are in good condition.

2.4 Performance Indicators

Most existing literature on performance evaluation in irrigation whether it will be on agricultural productivity, water delivery, efficiency or otherwise, embrace one or more outputs of the irrigation system and therefore can be used in evaluating overall system performance (Nijman, 1992). Over the past two decades, there has been considerable interest in the development of indicators, which could describe different internal processes and outputs of irrigation systems. FAO (1999) cited some researchers such as (Jurriens and Bottral, 1984) as the early advocates of improved techniques to assess irrigation projects and (Small and Svendsen, 1990) who described a framework for assessing irrigation performance, but did not provide specific examples of performance indicators which might be used.

Nevertheless (Bos *et al.,* 1993) presented a framework of using performance indicators, with the latter being grouped as follows:

a. Water supply performance

   This deals with the primary task of irrigation managers in the capture, allocation, and conveyance of water from source to field by management of irrigation facilities. Performance Indicators address several aspects of irrigation efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery such as predictability and equity.

b. Agricultural performance

   This addresses the direct impact of operational inputs in terms of aspects as actual irrigated area and crop production, over which an irrigation manager may have some but not full responsibility. Agricultural performance is a direct outcome of water delivery performance (Small and Svendsen, 1990).

c. Economic, social, and environmental performance

   This deals with the impact of both operational and agricultural inputs on the viability and sustainability of irrigated agriculture; these impacts include both physical and socio-economic sustainability of irrigated agriculture (Small and Svendsen, 1990).

Although this framework has a specific set of indicators which are practical, useful, and generally applicable for assessing performance of irrigation, the authors in conclusion point out that these indicators have limited capacity to diagnose the long term implications of improving operational performance, and virtually no capacity to improve on management strategies, cost-effectiveness or responsiveness in a strategic sense.

Murray-Rust and Snellen (1993) introduced another framework of using performance indicators in the system assessment and noted two approaches to use performance indicators in the field of irrigation.

a. Attempts to develop indicators which allow the performance of one system to be compared to similar systems elsewhere.
b. The use of indicators to compare actual results to what was planned.

But according to Burt and Styles (1999), a major contribution of Murray-Rust and Snellens' work was a comparison of performance found in several countries and irrigation projects. They presented detailed and enlightening field data, which showed large discrepancies between assumed water delivery service and actual water delivery service, primarily in systems of Sri Lanka, Indonesia, India and Pakistan. However, these projects did not have significant modernization components.

2.5 Performance Indicators as per International Water Management Institute (IWMI)

Performance indicators can help to see how well irrigated agriculture is performing at the system, basin or national scale, (IWMI, 2000) described performance indicators as a tool for measuring the relative performance of irrigation systems or tracking the performance of individual systems. Although performance indicators would be difficult to apply for similar systems, but in different settings or countries with less well-maintained secondary data, they are oriented towards items that directly or indirectly affect water deliveries. This section provides definitions and discussions of the International Water Management Institute (IWMI) indicators as defined and presented by different authors (Molden *et al*., 1998 (a); Kloezen and Garces-Restrepo, 1998; FAO, 1999; Sakthivadivel *et al*., 1999; Degirmenci *et al*., 2001). Previous studies such as (Kloezen and Garces-Restrepo, 1998; Nelson, 2001; Malono and Burton, 2001; Degirmenci *et al*., 2003) advocate the use of IWMI comparative indicators in assessing performance of irrigation systems, since the indicators can be applied within the limited time, money, and information resources available to the typical manager or water users associations. IWMI performance indicators are also oriented towards the existing system, aspects that do not require major modification of the infrastructure (Kloezen and Garces-Restrepo, 1998).

2.5.1 Indicators of irrigated agriculture output

The Standard Gross Value of Production (SGVP) (Equation 3) makes it possible to compare the performance of systems, no matter where they are or what kind of crops are being grown. The SGVP captures both local preferences for example, specialized crops that may have a low international price, but a high local value of non-traded crops (Sakthivadivel *et al*., 1999; IWMI, 2000).

$$\text{SGVP} = \left[\sum_{crops} A_i Y_i \frac{P_i}{P_b} \right] P_{world} \qquad \ldots\ldots (3)$$

Where: A_i is the area cropped with crop i ,

Y_i is the yield of crop i ,

P_i is the local price of crop i ,

P_b is the local price of the base crop (predominant locally grown, Internationally traded crop), and

Pworld is the value of the base crop traded at the world prices.

2.5.2 Productivity of land and water

The four indicators below relate the monetary value of the system's final output, agricultural production, to the inputs of land and water. By standardizing the value of agricultural production, these indicators can try to compare the performance of radically different systems.(Sakhivadivel *et al.*, 1999)

(i) Output per cropped area $= \dfrac{SGVP}{Irrigated\ cropped\ area}$ ……………………... (4)

(ii) Output per unit command $= \dfrac{SGVP}{Command\ area}$ ……………………..…..…… (5)

(iii) Output per unit irrigation supply $= \dfrac{SGVP}{Diverted\ irrigation\ supply}$ ……….. (6)

(iv) Output per unit water consumed $= \dfrac{SGVP}{Volume\ water\ consumed\ by\ ET}$ ………(7)

2.5.3 Indicators of water supply

Bos *et al.* (1993) presented a framework of using performance indicators such as; (1) Water supply performance, (2) Agricultural performance and (3) Economic, social and environmental performance. They indicated that performance measures provide a quantitative assessment not only of overall system performance, but also of contributions to performance from the structural and management components of the system. These measures can be incorporated in an irrigation system monitoring program and can provide a framework for assessing system improvement alternatives.

2.5.3.1 Delivery Performance Ratio (DPR)

Delivery performance ratio (Equation 8) is defined as the ratio of actual measured discharge to the design discharge. It is calculated by using a relation given by (Murray-Rust *et al*., 2000).

$$DPR = \frac{Actual\ discharge\ in\ Cumecs}{Design\ discharge\ in\ Cumecs} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

Where,

DPR = Delivery performance ratio

Also DPR can be associated with CV in order to have a clean or good performance in the scheme.

2.5.3.2 Temporal Coefficient of Variation (CV)

Temporal coefficient of variation (CV) is an indicator to determine the variation in discharge in secondary canals. It indicates the degree to which variation reaches. The coefficient of variation (CV) is calculated using equation 9:

$$CV = \frac{Standard\ Deviation\ of\ Discharge}{Average\ Discharge} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

2.5.3.3 Equity

Equity of irrigation water supply is defined as the delivery of fair share of water to users or to all irrigators throughout the system (Molden and Gates, 1990). Several other researchers have also defined equity (Chamber, 1988); (Bos *et al.,* 1994); (Goussard, 1996). All the definitions reflect that equity is the achieving of a fair (but not necessarily equal) distribution of water. All the performance criteria guide the equity in supplying water to the respective area. A share of water represents a right to use a specified amount. The fair share of water may be based on a legal right for water or may be set as a fixed proportion of water supply, as done in many rotational delivery schemes (Molden *et al.,* 1998)(b).

Equity in the distribution of irrigation water has long been an operational objective and is still a primary objective for irrigation managers and managers of canal systems since plans for water allocation among users do not use equality as an allocation principle (Bos *et al*., 1994). Unfortunately, this objective is usually not achieved in the field. Field measurements confirm that distribution of surface irrigation water among outlets of distributions is substantially inequitable (Bhutta and Van der Velde, 1992). The cause of this inequity is the interaction between several or all the following conditions:

(i) Markedly changed channel physical condition resulting from low levels of maintenance, inputs, and/or deferred maintenance.

(ii) Changes in outlets from tampering.

(iii) Frequent distributary's operations at low head discharges.

(iv) Installation of physical interventions to appropriate water, especially in head and middle reach locations.

(v) Permanently installed pipe and flume outlets in head reach locations.

(Chari *et al*., 1994) used the Chritiansen's uniformity coefficient to quantify equity in water distribution. Although this is yet another simple indicator to compute equity, Christiansen's uniformity describes evenness of the depth of water applied or infiltrated throughout the field and is typically used for individual farm fields or for a particular irrigation method such as a sprinkler (Zoldoske and Solomon, 1988; Pereira, 1999; Nelson, 2001). (Jahrom and Feyen, 2001), interpreted equity (P_E) as spatial uniformity of the relative amount of water delivered and calculated it as the relative spatial variability of the ratio of the mount delivered to the amount required over the time period of interest (Molden and Gates, 1990) presented this measure by using equation 10:

$$P_E = \frac{1}{T}\sum CV_R\left(\frac{Q_D}{Q_R}\right) \quad \ldots\ldots (10)$$

Where: P_E = equity of irrigation water supply.

CV_R = spatial coefficient of variation over the region R.

Q_D = amount of water delivered.

Q_R = amount of water required.

T = one irrigation season (days).

CV_R (Q_D/Q_R) is spatial coefficient of variation of the ratio Q_D/Q_R over the region R. This measure is more comprehensive because it does not only relate the delivered flows to the required flows but also describes the degree of variability in relative water delivery from point to point over the region, which the other methods presented earlier do not address. The closer the value of P_E is to Zero, the greater the degree of equity (spatial uniformity) in delivery.

2.5.3.4 Relative Water Supply (RWS)

The two most crucial factors in irrigation planning, design and operation are the available water supply and the water demand. The ratio of supply to demand constitutes an important concept called Relative Water Supply (RWS), as originally described by Small *et al*. (1974) and Levine and Coward (1986). The comprehensive measure of adequacy, recommended by (IWMI, 2000) and by (Bos *et al*., 1994) is RWS. The RWS relates the water made available for crops, including surface supply, groundwater pumped and rainfall, to the amount crops need. This indicator provides information about the relative abundance or scarcity of water. RWS is calculated using the equation 11 as provided by (IWMI, 2000):

$$\text{RWS} = \frac{Total\ water\ \sup ply}{Total\ crop\ demand} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (11)$$

2.5.3.5 The Relative Irrigation Supply (RIS)

The relative irrigation supply (RIS) indicates how well irrigation supply and demand is matched. A value over one would suggest too much water is being supplied, possibly causing water logging and negatively impacting yields, whereas a value less than one indicates that crops are not getting enough water. Relative irrigation supply focuses on supply of irrigation water alone, in contrast to RWS, which also includes rainfall (IWMI, 2000). It can be calculated using equation 12 (Dejen *et al.*, 2012).

$$RIS = \frac{Supplied\ \ Irrigation\ Water}{Crop\ \ According\ \ to\ Design\ Specifications} \quad \ldots\ldots\ldots\ldots.....\ldots\ldots\ldots\ldots\ldots\ldots...(12)$$

2.5.3.6 Water delivery capacity and irrigation ratio

The water delivery capacity (Equation 13) and irrigation ratio (Equation 14) are two important indicators, which can tell whether irrigation system design and other factors of production are constraining agricultural production (IWMI, 2000).

$$\text{Water delivery capacity (\%)} = \frac{Canal\ capacity\ to\ deliver\ at\ system\ head}{Peak\ consumptive\ demand} \times 100 \ldots$$

(13)

$$\text{Irrigation Ratio} = \frac{\textit{Irrigated cropped area}}{\textit{Command area}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(14)}$$

The water delivery capacity can suggest changes in irrigation infrastructure or cropping patterns needed to maximize cropping intensity (IWMI, 2000). The irrigation ratio is one of the main indicators of farmers' willingness or unwillingness to engage in irrigation. A decrease in the irrigation ratio depends mostly upon factors such as national agricultural policy, increases in input prices, the landownership situation, poor farmer training, irrigation water fees and insufficient water resources (Degirmenci, 2001).

2.6 Social Economic Indicators

The term "social economics' may refer broadly to the "use of economics in the study of society" (John *et al.,* 1987). It studies the relation of economics to social values. In communities operating irrigation schemes, social economic surveys help to depict the socio-economic status, ownership pattern, use of modern equipment's and loan distribution etc., of the concerned villages. Each of the primary participants in the irrigation sector, i.e., planners, and policy makers, agency personnel and famers, has different perspectives on what is meant by economic performance (Chambouleyron, 1994). Each therefore, requires a separate set of indicators that reflects these different objectives.

Economic viability:

(a) Financial viability of irrigation scheme

Financial Self Sufficiency (Equation 15) indicates by how far the organization have enough capacity to run the system on their own while *Fee Collection Performance* (Equation 16) indicate the organizations ability to raise revenue from irrigator's organization. In many irrigated areas, water charges (irrigation fees) are being collected from farmers. The fraction of the annual fees (charges) due to be paid to the Irrigators Organization is an important indicator for level of acceptance of irrigation water delivery as a service to farmers. (Bos *et al*., 1974)

$$Financial\ Self\ Sufficiency = \frac{Actual\ Income}{Total\ MO + M\ requirements} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$Fee\ Collection\ Performance = \frac{Irrigation\ Fees\ Collected}{Irrigation\ Fees\ Due} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

From perspective of the farmer the social-economic of the irrigation can also be quantified by the relative cost of irrigation water.

$$Relative\ Water\ Cost = \frac{Total\ Cost\ of\ Irrigation\ Water}{Total\ Production\ Cost\ of\ Major\ Crop} \quad \ldots\ldots\ldots\ldots\ldots \quad (18)$$

Social viability

In the Irrigators Organization the Technical Knowledge Staff (Equation 18) involved in managing the organization need to be assessed for their level of expertise to manage this organization (Vos *et al*., 1997).

$$Technical\ Knowledge\ Staff = \frac{Knowledge\ Needed\ for\ Job}{Actual\ Technical\ Knowledge\ of\ Job} \quad \ldots\ldots\ldots \quad (19)$$

This ratio simply refers to the social capacity of the people and organization for managing and sustaining the irrigation scheme.

Sustainability of the physical environment for irrigation

According to (Till and Bos, 1985), aspect of physical sustainability that can be influenced by irrigation managers relate primarily over or under- supply of irrigation water leading to water logging or salinity. A simple measure of sustainability therefore can be expressed by equation 20; (Marre *et al*., 1997).

$$Sustainability\ of\ Irrigable\ Area = \frac{Current\ Irrigable\ Area}{Initial\ Total\ Irrigable\ Area} \quad \text{…………….. (20)}$$

The initial area refers to the total irrigable area in the design of the system or in the latest rehabilitation. Where it is appropriate, this ratio can be modified to specially refer to waterlogged or saline areas as a percentage of the total irrigable area (Marre *et al*., 1997).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted at Dakawa Irrigation Scheme which is located in Mvomero District, Morogoro, Tanzania. The scheme covers an area of 2000 ha and lies at Latitude 6° 24’S and Longitude 37° 33’E with mean altitude of 361m a.m.s.l. It is located 45 km from Morogoro town, 7 km north east of Wami - Dakawa village and north - west of Wami River on an extensive flat plain.

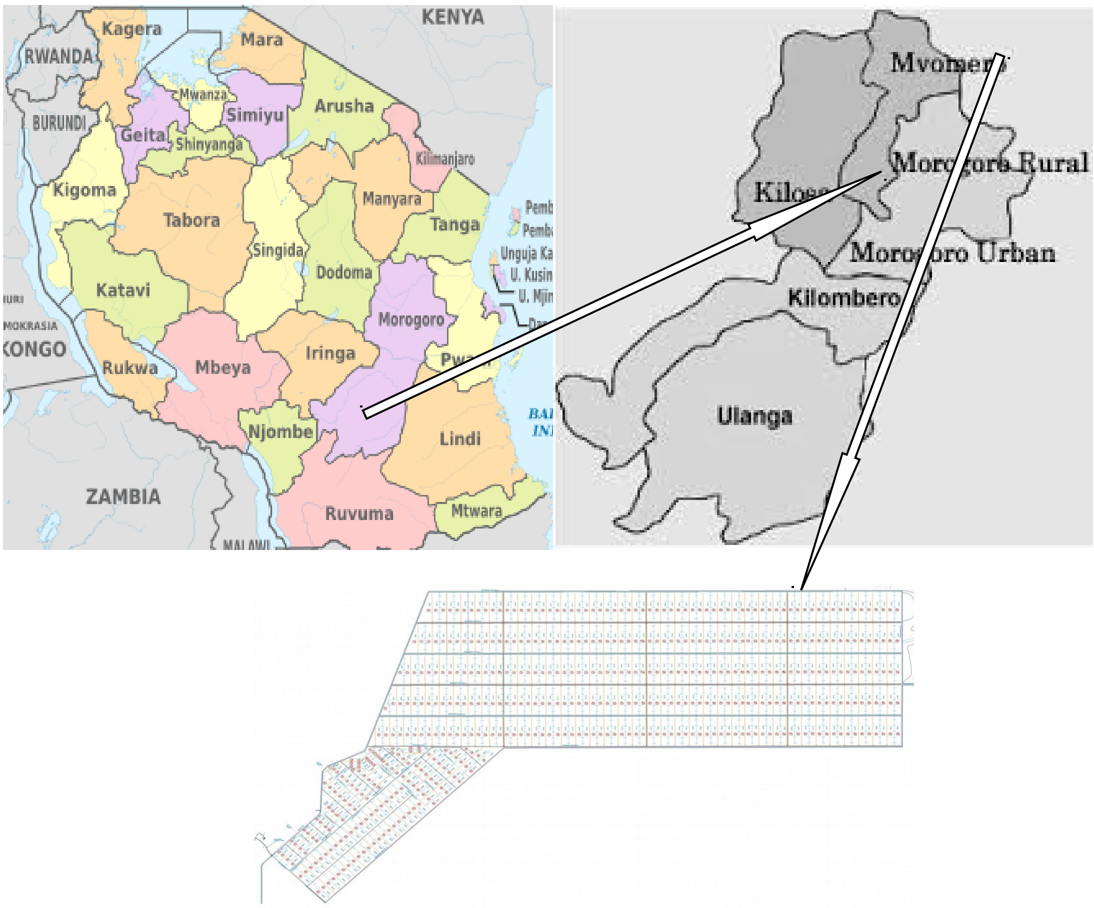

Figure 1: Location of the study area

3.1.2 Topography

Dakawa Irrigation Scheme is located within the *Lowland Agro-ecological Zone* (river valley and basin) (URT, 2014). This zone is comprised of Mgeta, Kafa, Ruvu, Wami, Msongozi, Mbulumi and Ngerengere river valleys in Morogoro and Mvomero Districts; Wami-Mkata plains and Mkondoa valley in Kilosa District and Luhombero Plains in Ulanga District (URT, 2014). The zone is densely populated in the upper parts of the valleys, and sparsely populated in the inner parts of the valleys due to occurrence of floods during the rainy season. The inner parts of the valleys are commonly used for rice cultivation.

3.1. 3 Climate

Climate data collected from Cholima weather station 5 km from Mvomero Distrct Headquarter indicate that annual rainfall ranges between 580 mm and 1191 mm. Rainfall distribution is bimodal with the short rains in October to January and the long rains in March to May (Figure 2). The long rains ranging between 74 mm to 410 mm are the most reliable for crop production compared to the short rains (50 mm to 387 mm).

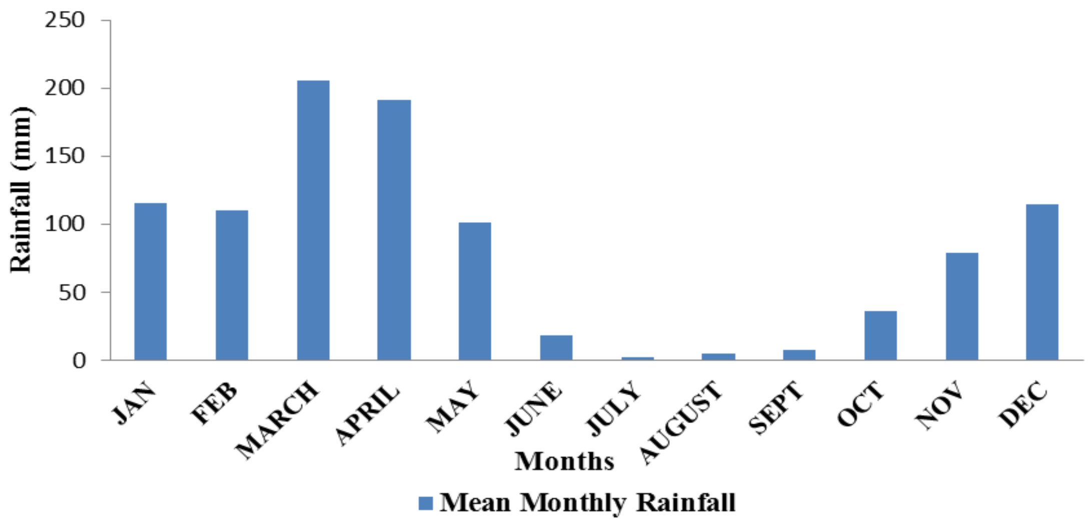

Figure 2: Mean monthly rainfall at Dakawa Irrigation Scheme, Morogoro, Tanzania (2004-2014).

Seasonal variations in temperature at Dakawa are minimal with an average monthly maximum ranging between 22°C in February to 32°C in July and mean monthly minimum temperature ranges from 15°C to 22°C for February and July, respectively (Figure 3).

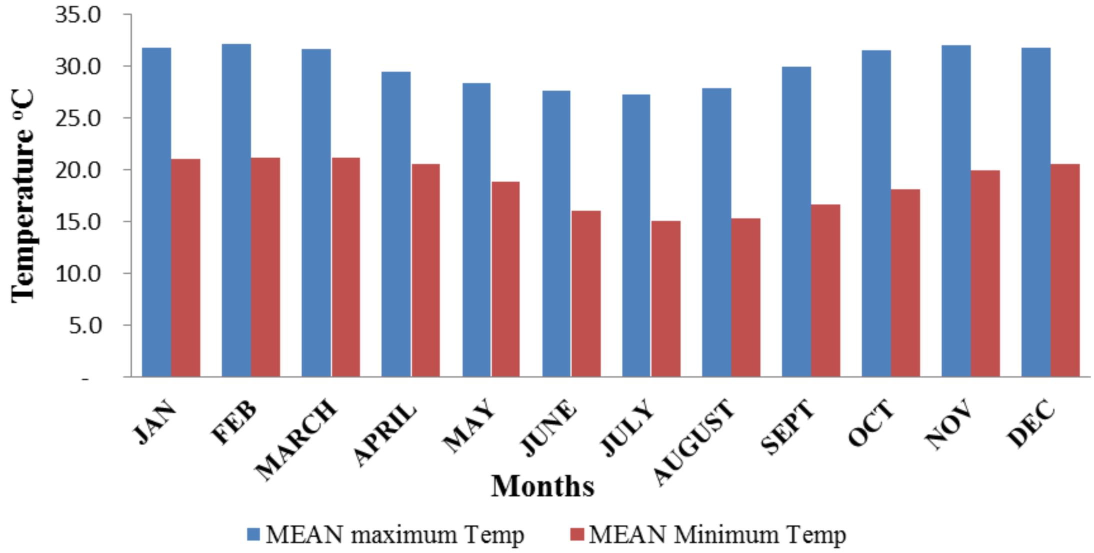

Figure 3: Mean monthly maximum and minimum temperatures at Dakawa Irrigation Scheme, Morogoro, Tanzania (2005-2014).

3.1.4 Soils

According to land suitability evaluation and soil characterization done by (Msanya *et al*., 2003), showed that the soils of the area are of mixed clay mineralogy comprising kaolinite, illite and clay loam.

3.1. 5 Agricultural activities

The major activities of the people of Dakawa Ward include farming and livestock production. Major food and cash crops ´grown include maize, beans, sunflower rice, finger millet, sorghum, groundnuts, sweet potatoes, and vegetables. Livestock production includes beef and dairy cattle, small ruminants, and poultry, which are kept mainly for income generation (Tarimo *et al*., 2002).

3.1.6 Scheme extent and layout

Dakawa irrigation scheme diverts water from Wami River through an intake by three operated water pumps. A scheme layout (Figure 4) is comprised of an intake which has a main canal with a length of 7.5 km that distributes water to eight secondary canals. Among them, secondary canal number 1 to 5 have been lined and some part of secondary canals number 6 to 8.

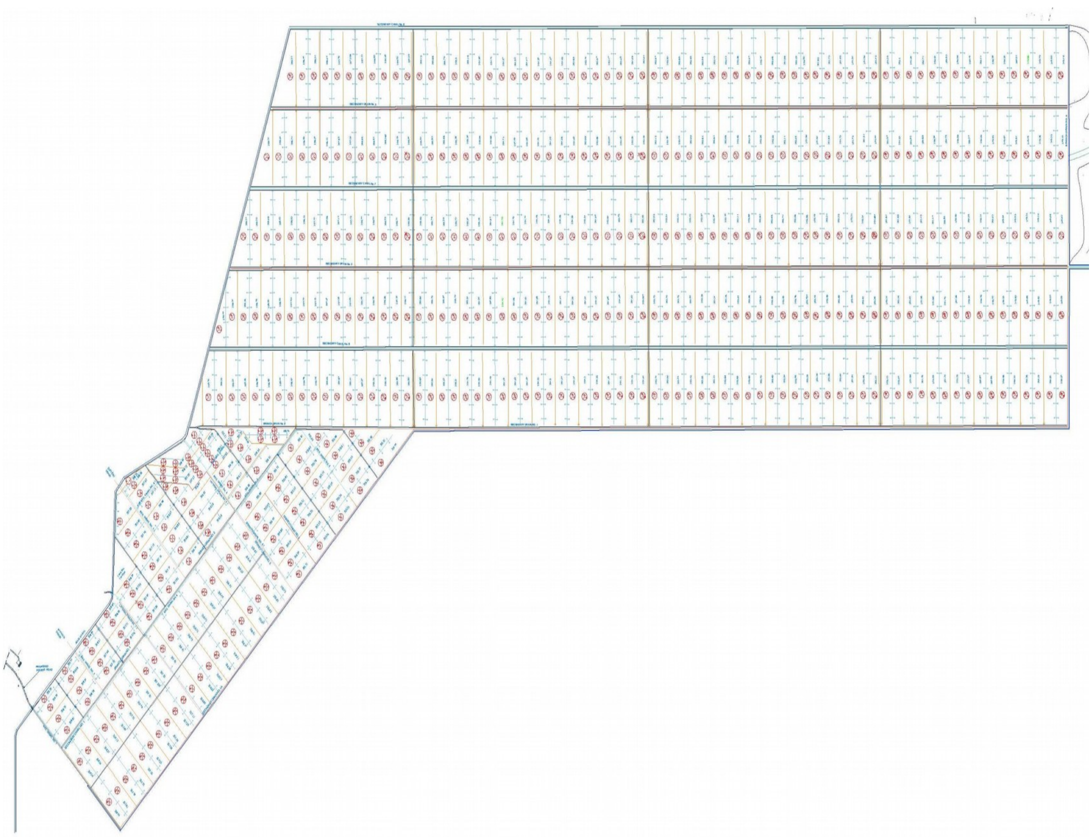

Figure 4: Dakawa irrigation scheme layout plan

3.2 Data Collection

Data were collected through different methods and activities as follows: 1) review of documents and site confirmations; 2) key informant interviews, 3) focus group discussions; 4) on-field measurements/ inspections/ observations. Field visits were made to identify the number of working and non-working structures. The main, secondary, and tertiary canals were sampled for the structure condition inspections and cleanliness and conveyance efficiency determination. Field data were measured and collected to quantify and test performance indicators. These indicators covered water delivery, water use efficiency, maintenance, sustainability of irrigation, environmental aspects, social economics, and management.

3.2.1 Interview survey

Interviews were conducted to obtain data using different indicators like, degree of farmer's involvement in system management, effectiveness of farmers organization, ratio of level of knowledge, access to resources, gender relations, quality of housing, nutritional and healthy status.

3.2.2 Poor structure index

Poor structure index (PSI) describes the percentage of the total number of conveyance, regulatory and flow measuring structures installed within the scheme that are in a poor state, thus not functioning properly or at the risk of failure.(Nelson, 2001). A field visit was made to identify the number of working and non-working structures. All structures in Dakawa Irrigation Scheme were checked and operated to see if they work properly. These structures in the system included gates in the division boxes at main and secondary canals. Other structures examined included canals culverts, drop structures and flumes. The main canal and eighty secondary canals were checked for structure condition inspections and cleanliness, and conveyance efficiency. All canals were selected and inspected at the head, middle and tail respectively if they were operating at the time of the Study.

$$PSI\% = \frac{Number\ of\ working\ structures}{Number\ of\ poor\ structures} \times 100 \qquad (21)$$

3.2.3 Discharge measurements

Flows at each supply branch in main canal to all secondary canals were measured using installed gauges at the head of each secondary canal. To facilitate water level reading, staff gauges were installed along main canal and all secondary canals at each head of secondary canals and in the branch canals. To avoid the possibility of being swept off by water waves, the gauges were tightly fixed with cement motor in the canal wall.

3.2.4 Calibration of head regulators of secondary canals

The aim of good irrigation management is to obtain a correct flow division within the canal network and over the fields. This means that discharges in canals should meet the demand for water from the farms. A poor flow division may result in discharges being too high in some canals and too low in others and could lead to water disputes between farmers. To achieve sufficient and equitable delivery of water to the fields it is useful to know the discharge in the canal. The discharge in a canal can be measured with or without a discharge measurement structure.

The method consists of estimating the average flow velocity (V), and measuring the area of the cross-section, called the ‘wetted cross-section’ (A). The discharge (Q) (Equation 22) can be used in calculation calculated by the following formula:

$Q = V \,.\, A$ ……………………………………………………………………………. (22)

where: Q is the Discharge in m^3/s;

V is the Average Flow Velocity in m/s; and

A is the area in m^2 of the Wetted Cross-section.

Thus, measuring gauges were constructed on the permanent structure of the head regulators of each distributary. Then, the opening of sluice gate and water depths at upstream and downstream of the channel was recorded using marked gauge (Plate 1).

Plate 1: Marked Gauge Secondary Canal No. 2

The data was then used to develop calibration equations. Gauges for gate opening were marked at the top of gates whereas, the gauges on wing walls of head regulators were fixed for upstream and downstream water depths with respect to crest level (Plate 2).

Plate 2: Calibrated gauge secondary canal no. 3

Normally, the water discharging from the sluice gate attains two types of flow i.e. free flow or submerged flow. Under free flow condition, the head loss is greater, that reflects the higher water level difference between upstream and downstream of the structure whereas, under submerged flow condition, this difference is small. Under submerged flow condition, effect of downstream water level on upstream water levels is quite visible and in certain cases; water touches the lower tip of sluice gate. While, under free flow condition, the downstream water level is independent and it does not touch the lower tip of sluice gate (Khan *et al*., 2012). Both conditions were taken into consideration during the calibration process.

3.2.5 Weekly data for secondary canal discharges

The discharges at head regulators of secondary canals were collected on a weekly basis between 11th March 2019 to 09th June 2019. Staff from Regional Irrigation Office (RIO) and Mvomero District assisted in data collection. The discharge related parameters such as gate opening, upstream and downstream water depths were taken with the coordination of the gate operator of Umoja wa Wakulima Wa Kilimo cha Umwagiliaji Dakawa (UWAWAKUDA). The gate operator was trained to collect the parameters on discharge related parameters using data collection sheet (Plate 3).

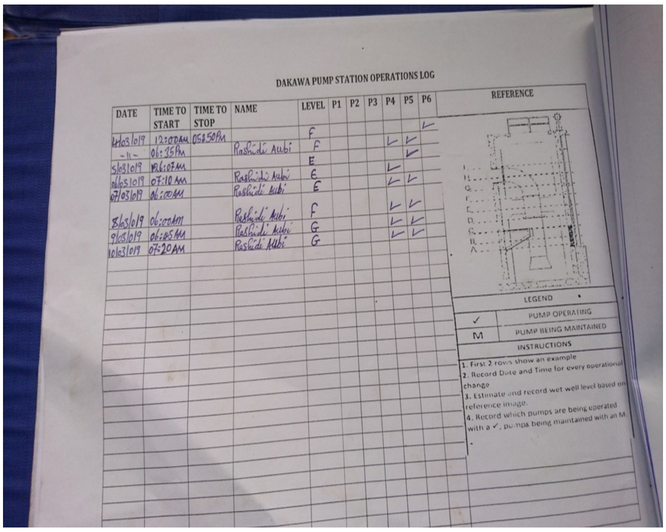

Plate 3: Data collection sheet

These parameters were then used in calibrated equations to calculate the actual discharge to be delivered using Equation 22. The weekly data was converted into average monthly discharges to set the seasonal discharges.

3.2.6 Daily stage height records and discharge computations

The daily stage levels for every secondary canal were read and recorded for a period of eleven, (11) consecutive weeks. Using the Equations 22, discharge values for each station were calculated as shown in Appendix 1. The discharges at the heads of secondary canals were measured and then hydraulic structures were calibrated at their respective heads. The discharge of secondary canals was measured on a weekly basis and then converted into an average monthly rate.

3.2.7 Variation in discharges of secondary canals

Variations in discharges of secondary canals were measured using the Coefficient of variation (CV). The CV is the measure of variability, which is independent of actual average values. It is the measure that suggests the variability in spatial and temporal coefficient of variation, to check how variability changes at a single location. It is difficult to set the ranges of CV values in order to set the variation limits, as there are no specified rules set by area water boards for accepted variation in discharge.

3.3 Assessment of Irrigation System Performance

3.3.1 Reliability and equity analysis

Reliability of water supply at the head of distributaries and equity in water distribution was calculated using Equation 8, and Equation 9. The values of CV were used to evaluate the performance in terms of discharge variation. The criteria was set by combining (Molden and Gates, 1990) and (Murray-Rust *et al*., 2000), keeping in view that the minimum discharge at secondary canals should not be less than 70% or more than 30% of design discharge value.

Good performance: $CV < 0.10$

Fair performance: $CV < 0.30$

Poor Performance: CV > 0.30 (Molden and Gates, 1990) and (Murray-Rust *et al*., 2000). The variations in secondary canals discharges during the time for two months were analyzed to determine the equity in water distribution between secondary canals, along the main canals.

3. 3.2 Computation of net irrigation requirement

INSTAT computer software was used to estimate the reference crop evapotranspiration, ET_O using climatic data, (Equation 25). Daily crop water requirements (ET_C) during the study period were computed by multiplying the reference crop evapotranspiration by the crop coefficient (K_C) as suggested by (Abdulmumin and Bastiaansen, 1990).

$$ET_c = K_c ET_o \quad \text{.......} \quad (23)$$

3.3.3 Equity of irrigation water supply

The equity of irrigation water supply for the scheme was determined on a weekly basis as proposed by (Molden and Gates, 1990) and (Gates and Ahmed, 1994). The equity for the whole season was evaluated as spatial uniformity of the relative amount of water delivered using Equation 11 presented in Section 2.5.2.1 and by using the RWS concept. The data for water delivered (Q_D) was obtained from the discharge records computed in Section 3.4.2 and amount required (Q_R) from the net irrigation requirement. Microsoft EXCEL was used in computing and plotting the graphs of equity for a period of 11 weeks.

3.3.4 Productivity of land and water

The data regarding cultivated area, yields and prices during the season were obtained through interviewing the farmers using interview survey as mentioned in Section 3.2. And some secondary data were obtained from existing records kept by branch secretaries and the Ward Irrigation Extension Officer. A set of comparative performance indicators related to agricultural and water use efficiency developed by the International Water Management Institute (IWMI, 2000) were used for the assessment of the irrigation system performance in terms of land and water productivity. The indicators used allow a comparison of the performance by standardizing the gross value of agricultural production (SGVP). These are: Output per unit cropped area, output per unit command, output per unit irrigation supply and output per unit water consumed (Equations 11 - 14).

The SGVP was used as a basis for comparing the different cultivated areas of Dakawa irrigation scheme. Rice was chosen as the base crop due to its relatively high cropping intensity in the study area and its importance both at the local market and in international markets. The SGVP was calculated using Equation 3 as explained in Section 2.5.1. Microsoft EXCEL was used to compute the indicators as per above stated equations.

3.3.5 Relative water supply

Discharge data were obtained for each secondary canal selected that abstracted water from the main canal. Also, total rainfall in the area and the design water requirement for crop grown in the area were obtained for relative water supply calculations and hence the measure for adequacy (Equation 11).

3.3.6 Relative irrigation supply (RIS)

The supplied irrigation water from the main canal to the secondary canals was calculated and results compared with crop water use as per design specifications. This useful indicator assesses the degree of irrigation water deficit or abundance in relation to demand. Equation 12 is used to calculate the RIS. It tells how well irrigation water supply and demand are matched.

3.3.7 Water delivery capacity irrigation ratio

The canal capacity to deliver irrigation water at the system head and peak consumptive demand were calculated to assess the water delivery capacity using Equation 13. Again, cropped irrigated area and irrigable command area also were calculated. The two important indicators tell whether irrigation system design and other factors of production are constraining agricultural production. Irrigation ratio (IR) tells the degree of utilization of the available irrigable area at a time. While there are several factors contributing to the variation in IR, availability of irrigation water is the major one, but even under sufficient water supply low figures can be caused because of misuse. The IR is one of the main indicators of farmers' willingness or unwillingness to engage in irrigation. A decrease in the IR depends mostly upon factors such as national agricultural policy, increases in input prices, the landownership situation, poor farmer training, irrigation water fees and insufficient water resources.

3.4 Social economic Assessment

3.4.1 Economic viability of irrigation scheme

Financial Self Sufficiency and Fee Collection Performance were calculated using Equations 16 and 17 respectively to indicate the capacity of the organization to run the system on their own and the organizations ability to raise revenue from irrigators. In many irrigated areas, water charges are being collected from farmers. The fraction of the annual fees paid to the Irrigators Organization is an important indicator for level of acceptance of irrigation water delivery as a service to farmers. The Relative water costs were calculate using Equation 18.

3.5.2 Social viability

Social viability was evaluated by comparing between the knowledge needed for a job and actual number of technical staff engaged for the job. In the irrigators organization the technical knowledge staff involved in managing the organization were counted and assessed their level of expertise to manage this organization using Equation 19.

3.5.3 Sustainability of physical environment for irrigation

Sustainability of irrigable area was assessed by looking between the current irrigable area and initial total irrigable area. The initial area refers to the total irrigable area in the design of the system or in the latest rehabilitation. Where it is appropriate, this ratio can be modified to specially refer to waterlogged or saline areas as a percentage of the total irrigable area (Equation 20).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Dakawa Irrigation Schemes Structures

This Chapter presents the results of performance evaluation of irrigation of Dakawa scheme under a cooperative irrigation scheme in Dakawa as shown by salient features Table 1.

Table 1: Salient features of Dakawa secondary canals

Off taking Canal	Global Position		Off taking RD	Design Qm^3/s	CCA (ha)	Number of Outlets
	Easting	Northing				
SC1	338 211.7	9 290 114.6	359.1	0.2	80.0	6.0
SC2	338 564.7	9 290 468.8	359.1	0.1	16.0	5.0
SC3	338 895.4	9 290 837.9	359.3	0.2	94.5	11.0
SC4	338 950.5	9 291 514.2	359.0	0.1	37.2	16.0
SC5	339 504.7	9 291 820.0	359.0	0.1	89.0	13.0
SC6	339 698.1	9 292 356.9	359.0	1.4	683.0	12.0
SC7	340 050.7	9 293 371.0	359.0	1.3	670.0	4.0
SC8	340 402.6	9 294 377.0	358.5	0.6	322.0	3.0

Table 1 shows that secondary canal 4 (SC4) had the highest number of outlets with 16 outlets followed by SC5 (13), SC6 (12) while SC8 had the lowest number of outlets. On contrary, SC4 had the lowest design discharge Q (0.1 m^3/s). The lowest Q in SC4 was due to smallest area which the canal commands (37.2 ha) as compared to other canals.

4.2 Land Tenure and Area Under Irrigation for Dakawa Irrigation Scheme

From the historical background, Dakawa farms were owned by the Government for many years. The Government then leased the area to UWAWAKUDA and then the cooperative society allocated plots to different people. Some farmers who rent the plots from people had to go through the cooperative society for approval before given an ownership of the plot. The total numbers of farmers are 919, with the Dakawa farm size of 1991.7 ha, the size of farms owned by farmers' ranges from 1 ha to 5 ha.

4.3 Irrigator's Organization (IO)

The scheme is operating under the governing body which has a mandate of everything with a General Manager who execute daily activities via his officials in the UWAWAKUDA as per organisation chart shown in Figure 6. The type of irrigator's organization used at Dakawa Irrigation Scheme is a cooperate type of organization.

ORGANIZATION CHART FOR UWAWAKUDA

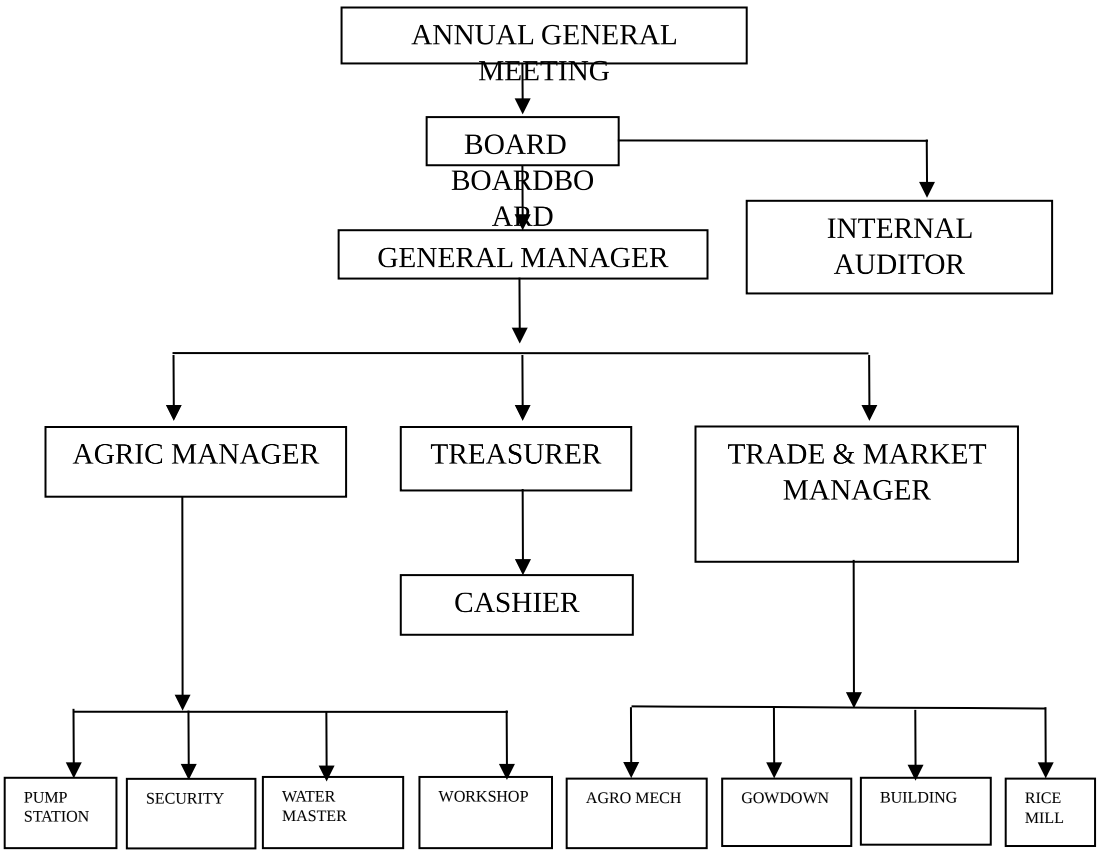

Figure 5: Organization Structure

4.2.4 Irrigation practice

In Dakawa scheme not all the secondary canals are being used for irrigation at the same time following shortage of water in Wami River. Only secondary canal number 1, 2, 3, 4 and 5 can irrigate together while canal number 6, 7 and 8 are scheduled to operate at the same time.

4.2.5 Farmers challenges and opinions

Table 2 shows that farmers had problems of water shortage, lack of inputs and frequently experienced occurrence of diseases and pests. Among these three problems water shortage was the main constraint (59 %) followed by lack of inputs (22 %). According to the respondents the most probable solutions to the problems could be fair sharing of water (42 %) and provision of input such as fertilizer and pesticides (21 %).

Table 2: Problems Faced by Farmers and Suggested Solutions

Problems	**Most probable solution to the problems**							**Scores**
	Sharing fairly	**No solution**	**Provision of Loan**	**Application of manure**	**Reducing irrigated area**	**Construction of Dam**	**Water Conservation**	**Total (%)**
Shortage of water	42					12	5	59
Lack of inputs			9	13				22
Diseases and pests			12					12
No constraints		7						7
Total (%)	**42**	**7**	**21**	**13**		**12**	**5**	**100**

The problem of water shortage could have been caused by seasonal fluctuation of Wami river and this is the main problem of the area. At the upstream of Wami River there are lots of activities underway which can be the cause of their problem. Among the farmers interviewed, it was found that 12 % of the respondents, proposed a dam construction at the upstream due to climate change issues. They also pointed out that water in the Wami River water will have a low level hence proposing dam before their intake to solve the problem of water shortage once it happens. After installation of proportioning weirs at the head of secondary canals, the farmers later on agreed to have the water supply in rotation such that outlets could be closed for an agreed period of time to supply water to each reach. However, some dishonest farmers in the head reach took advantage of this arrangement and blocked part of the water going downstream so that they could irrigate their field although it is not their turn to irrigate.

4.3 Cropping Pattern and Calendar

Cropping pattern is defined as the arrangement of crops in sequence on a land in a given growing season, whereas the cropping calendar provides information on the sequence of the crops grown and on the timing of their cultivation.

The cropping pattern in Dakawa Irrigation Scheme is found to be inadequate. Individual farmers are free to plant any type of crop according to their preference. The major crops grown in the Dakawa irrigation scheme is found to paddy, which is cultivated for two seasons. The crop is normally transplanted in February while harvesting is done usually from May to June. Paddy fields are usually sub-divided into smaller plot of different sizes to facilitate levelling the fields. These fields are in a form of check basins to prevent runoff and to allow infiltration after irrigation water is cut-off. Many farmers are not growing paddy during the dry season due to shortage of water in Wami river.

4.4 Performance of Irrigation Structures

The data collected were used to evaluate the performance indicators of irrigation structures at Dakawa such as PSI, RWS, RIS, equity, water delivery performance ratio, CV, irrigation ratio, productivity of land and water and social economic indicators.

4.4.1 Poor structure index (PSI)

Poor structure index (PSI) describes the percentage of the total number of conveyance, regulatory and flow measuring structures installed within the scheme that are in a poor state, thus not functioning, not functioning properly or at the risk of failure (Bos, 1997).The structure indices of the scheme are presented in (Table 3).

Table 3: PERFORMANCE INDICATORS FOR STRUCTURES

Name of canal	Total Number of Structures	Number of Working Structures	Number of Poor Structures	PSI %
SC1	39	31	28	72
SC2	45	33	39	87
SC3	48	28	41	85
SC4	54	44	37	69
SC5	53	43	35	66
SC6	87	66	61	70

The scheme recorded PSI ranging between 66-87 % which reveals that the conditions of the structures of the scheme are in average working condition when compared to the recommended value (0 %) as given by (Bos, 1997). The conveyance structures are in an extremely poor condition for the first 200 m of SC 6, SC 7, and SC 8. In this portion, all the concrete slabs and linings were removed (Plate 4a-g) due to construction weakness, flooding, cleanliness etc. The regulatory structures that are in poor working condition are the lateral gates. Out of a total of 93 lateral gates which were installed on the left bank canals 15 are not functioning due to detached stem from plates and worn out angle-iron (Plate 4 a-g).

	Plate 4a: Farmers Improvising Check structure on a Canal Using Sandbags
	Plate 4b: Improved Lateral Check Structure and Stones from Stones and Grass

	**Plate 4c:** 1. The 7.4 km long canals are in good working condition from chainage 0 + 000 to 4 + 000 2. No many breaches, sediments and weeds were found in the canals 3. The canals were rehabilitated in 2015 by USAID
	**Plate 4d:** 1. The 7.4 km long canals are in good working condition from 4 + 000 m to 7 + 400 m 2. No many breaches, sediments and weeds were found in the canals 3. The canals were rehabilitated in 2016 by USAID

	**Plate 4e:** 1. The 8 SC's are in fair working condition 2. Each SC's has breached at several sections despite the rehabilitation in 2014 to 2017 3. Two (2) of the SCs 6,7,8 at the tail-end are presently not lined to the end 4. The present condition results in seepage and water logging in the scheme
	**Plate 4f:** 1. The SC 1, 2, 3, 4 and 5 are in good working condition 2. There are no breaches and they are free of sediments and weeds 3. They were rehabilitated in 2014 – 2017 by USAID 4. The check structures are working properly
	**Plate4 g:** 1. All the first 2km of SC 6, 7 and 8 are lined and in good working condition. 2. No cracks, sediments and weeds. 3. They were rehabilitated in 2014 – 2017 by USAID 4. Some lateral and check structure gates are absent

Plate 4 a-g: Shows different parts of Dakawa Irrigation Canals working conditions despite of being rehabilitated by funds from USAID between 2013-2017. This stipulates the structural working conditions.

Normally, if “*Poor Structure Ratio*” (PSR) is 0.05 then 5 % of the structures are in poor condition whereas “*Structure Condition Index*” (SCI) of 0.05 means 95 % of the structures is in good condition (Site inspection 2019). Figure 6 indicates that during the Study 60% of all structures were performing correctly.

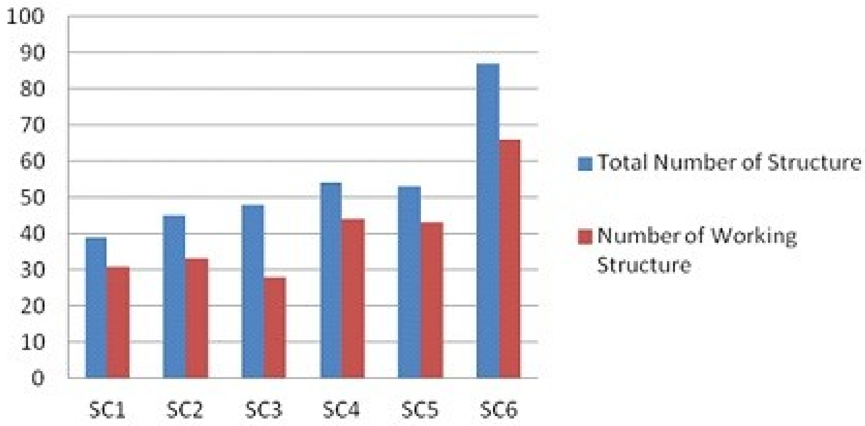

Figure 6: Structure working condition

4.4.2 Relative water supply and relative irrigation supply

Both RWS and RIS (Table 4) relate the supply to demand and, they give some indication to water abundance or scarcity, and how tightly supply and demand are matched. There was a wide range of variations in the values of RWS (0.7-5.9) between the head reach and the tail-end reach implying that there was inequity of water supply between farmers in the head reach and tail-end reach (Table 4). This inequity in water supply is because of farmers in the head reach blocking the water going downstream with stones to abstract more water.

Table 4: Relative Irrigation Supply (RIS) and Relative Water Supply (RWS)

Name of canal	Irrigated cropped area (ha)	Designed Q (mm)	Supplied Water m^3/s	RIS	RWS	Supplied Water in (mm)
SC1	80	390	0.13	0.9	1.2	369
SC2	16	130	0.02	0.9	5.9	117
SC3	94.5	410	0.14	1.0	1.8	393
SC4	37.2	390	0.07	0.9	2.0	352
SC5	89	430	0.16	1.0	1.8	410
SC6	683	430	1.23	0.9	1.8	405
SC7	670	410	1.20	1.0	2.1	393
SC8	322	520	0.51	1.0	0.7	497

The term relative irrigation supply (RIS) was presented to be consistent with the term relative water supply (RWS) and to avoid any confusing value judgments inherent in the word efficiency (Table 4). Both RWS and RIS relate supply to demand and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. Values for RWS vary between 0.70 and 5.9, while values for RIS ranged between 0.9-1. Half of the systems have RWS values greater than 2 showing an adequate supply relative to demand (Table 4) and (Figure 7). The adequacy of irrigation water supply in Dakawa irrigation scheme during the season is presented by comparing relative water supply to relative irrigation supply. Relative irrigation supply is the inverse of the irrigation efficiency presented by (Bos and Nugteren, 1974).

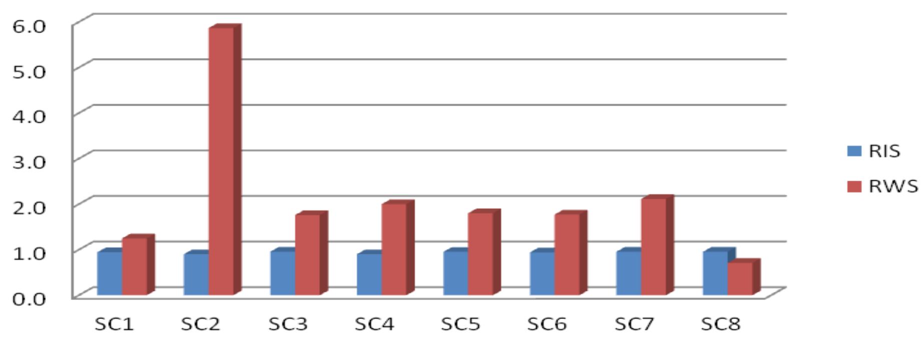

Figure 7: Relative irrigation supply (RIS) and relative water supply (RWs) values for Dakawa irrigation scheme

Care must be taken in the interpretation of results as an irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate appropriate use of available water, and a lower RWS would be less desirable. Likewise, 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. Thus, calibration of head regulators is of paramount importance to measure the actual discharges. It was found that the decrease in discharge through structures occurred due to side contractions, mismatch between sluice gate and frame and crest surface roughness. These factors caused some leakage of water from sides and beneath the sluice gate.

4.4.3 The seasonal equity of water distribution in secondary canals

The equity was found to be fair at the start of the growing season and was good towards the end of the season by having an equity <0.1. The same explanation advances for adequacy which would seem to hold for the fair equity at the start of season. In addition, farmers in the head and middle reach were blocking the water flows going downstream so that they can get more water during that time. However, towards the end of the season around October/November, flows get quite low and farmers fight for their share of water. This is due to low level of water at Wami river. This is the time when strict guidance of sharing water among users is required to ensure equitable share of water.

4.4.4 Water Delivery Performance Ratio (DPR)

Measurement of the discharge was done on weekly basis and the data were taken and analyzed to have different parameters to assess the water delivery performance. The water delivery performance ratio indicates whether the system design is in anyway a constraint to meet the maximum crop water requirement. It was revealed that the discharge performance in all secondary canals shows that they are all above 0.65 which is within acceptable performance (Table 5). Values much greater than 1.0 indicate that their capacity is not a constraint to meeting crop water demands (Abernethy, 1986).

Table 5: AVERAGE DISCHARGE MEASURED AT THE HEAD OF SECONDARY CANALS

Subdivision	Design Qm^3/s	Delivery Performance Ratio	Total weekly discharge	Area (ha)
SC1	0.16	0.84	0.13	80
SC2	0.03	0.65	0.02	16
SC3	0.18	0.79	0.14	94.5
SC4	0.09	0.74	0.07	37.2
SC5	0.18	0.87	0.16	89
SC6	1.40	0.88	1.23	683
SC7	1.33	0.90	1.20	670
SC8	0.63	0.82	0.51	322

However, all canals in Dakawa irrigation scheme have values less than 1 (Table 6), which indicate that there may be difficulties meeting short-term peak demands. Often times, additional capacity is designed (at additional cost) to allow for more flexible water deliveries, or to ease management.

The reliability of irrigation water supply at the heads of channels can be indicated by calculating the DPR. The DPR values have been calculated for each secondary canal located in Dakawa irrigation canals (Table 6). Figure 8 shows the DPR values of each secondary canal during the season. The pattern of DPR values is quite dispersive during the Study period. Only few values are close with the line of equity which indicates the reliable supply to the off-taking secondary canals.

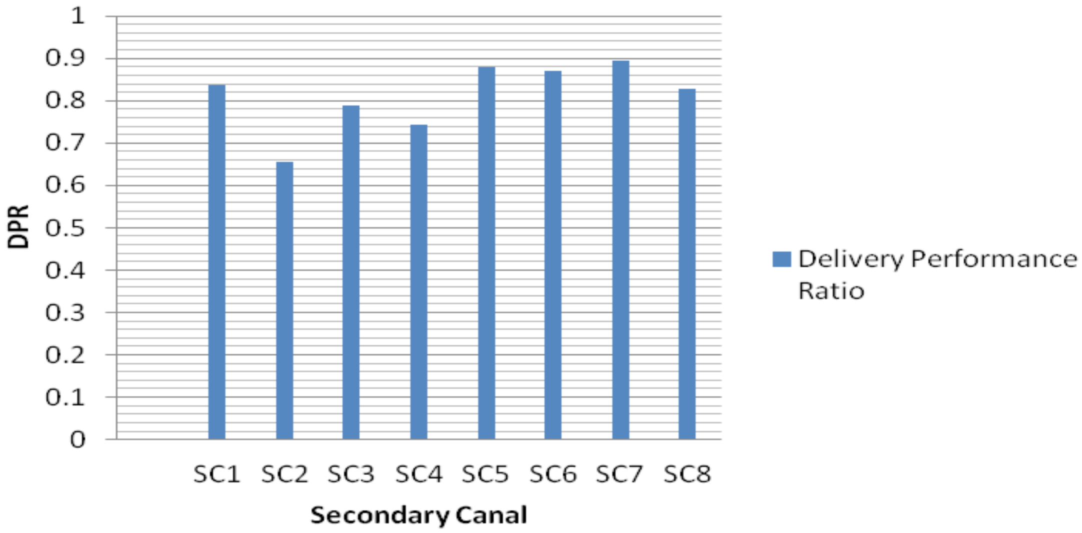

Figure 8: Delivery performance ratio Vs Secondary canals

The DPR values during the season show the reliability to some extent among secondary canals, the fluctuation in DPR values is exceptionally low. Comparison of the individual channel reveals that, secondary canal seven (SC 7) has got maximum discharge of about 90% and secondary canal two (SC 2) has lower discharge of 65 %. Almost all secondary canals have received higher discharge as per design share. This analysis has been made according to the guidance of the National Irrigation Commission of Tanzania, which suggests that the channels should at least get 70% but not greater than the design discharge.

Therefore, the DPR values less than 0.7 shows the unreliable supply at heads of secondary canals. Table 6 shows DPR values for all secondary canals in the Study area. During the season, the 70 % values of DPR were rated under poor performance category. The average reliable supply to the channels remained only 81% during the period of Study. This reliability value is treated as satisfactory as evaluated by (Murray-Rust *et al*., 2000) for the same area. Table 6 shows interesting results for a maximum period during season time and supply at heads of secondary canals remained reliable. Considering the sensitivity of performance under this scenario, (Murray-Rust *et al*., 2000) suggested that the deliveries to secondary canals could be adjusted to keep DPR values at 0.7 and 1.3 on alternate days. This modification is the result of combining the rules given by (Molden and Gates, 1990). The delivery performance measured in the Study area is very good as compared to other African countries, analysis in different location suggested that a DPR value equal to unity observed implies water delivery service at this level is rated from fair to good as indicated by (Kerkvliet, 2009).

4.4.5 Coefficient of variation in discharges of Secondary canals

Using the RWS concept of inequity of water supply (Abernethy *et al*., 1986), the variation of irrigation water supply in Dakawa irrigation scheme was deduced. Molden and Gates (1990) developed three categories of variability, which they termed as reliability if CV were less than 0.1 is good, if it ranges between 0.10 and 0.20 it is fair, when is more than 0.3, is poor (Table 6).

Table 6: Coefficient of variation in discharges of Secondary canals (Molden and Gates, 1990)

Ranges of CV values		**˂0.1**	**˂0.3**	**˃0.3**	**Good**	**Fair**	**Poor**
March, 2019	Week 1 Week 2 Week 3	6	1	1	75	12.5	12.5
April, 2019	Week 4 Week 5 Week 6 Week 7	5	3	0	62.5	37.5	0
May, 2019	Week 8 Week 9 Week 10 Week 11	5	2	1	62.5	25	12.5

The average seasonal coefficient of variation in individual secondary canals for different months is illustrated in Figure 9. It shows that during Study period all secondary canals attained remarkably high variability.

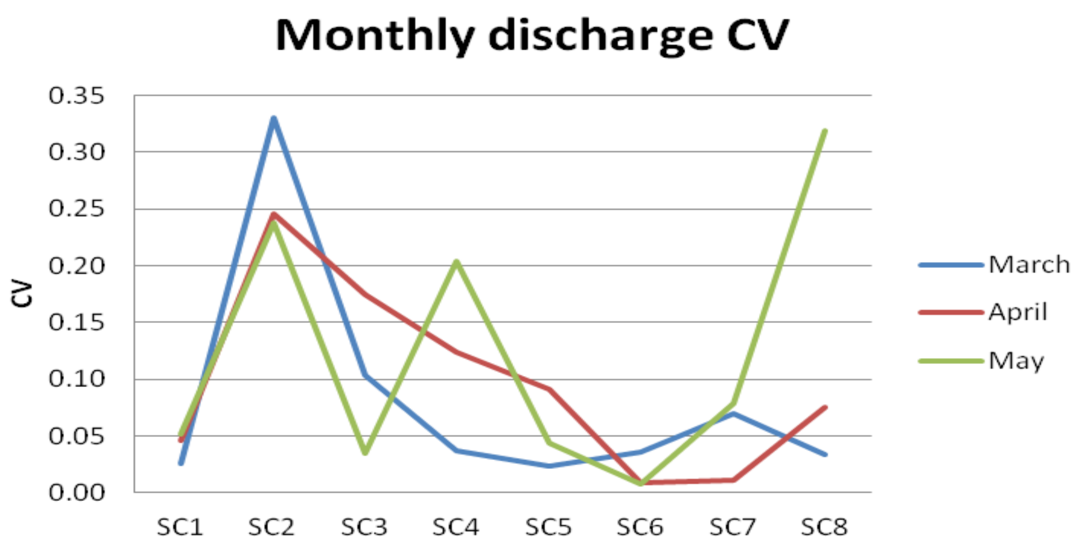

Figure 9: Discharge variation in secondary canals

The SC 2 and SC 8 distributaries had the highest variation in discharges. In general, the seasonal or annual performance in terms of reliability was particularly good. Discharge variations in secondary canals were calculated and results are shown in Table 7. The results reveal that discharge variations recorded for eleven weeks were significantly high. Maximum variation in discharges was observed at two secondary canals (SC 2 and SC 8) which is 0.33 during the months of March for SC 2 and May for SC 8 which is 0.32 as compared to other six secondary canals.

Table 7: Discharge variation in secondary canals

Subdivision	Coefficient of Variation of Discharge			Average
	March	**April**	**May**	
SC1	0.03	0.05	0.05	0.04
SC2	0.33	0.25	0.24	0.27
SC3	0.10	0.18	0.03	0.10
SC4	0.04	0.12	0.20	0.12
SC5	0.02	0.09	0.04	0.05
SC6	0.04	0.01	0.01	0.02
SC7	0.07	0.01	0.08	0.05
SC8	0.03	0.07	0.32	0.14
Overall average	0.08	0.10	0.12	**0.10**

While in the months of April and May, the variation in discharges at four distributaries (SC 2, SC 3 and SC 4) remained within satisfactory limits which is 0.25 and 0.24 for SC 2 and 0.12 and 0.20 for SC 4 and 0.18 out of eight secondary canals. (Makongoro, 1997) The other remaining secondary canals remained, showed that they were in a good discharge variation operating below 0.1.

The discharge variation in secondary canals is categorized in Figure 10, which depicts that most of the CV values remained under the category of good performance. The degree of good performance was 67 %. The major portion of poor performance was observed during March in SC 2 and May in SC 8. During the month of April, it was observed that equity of water distribution was total poor due to river low level. It is postulated that discharge of water from Wami river to main canal was not good due to low level of water in the river.

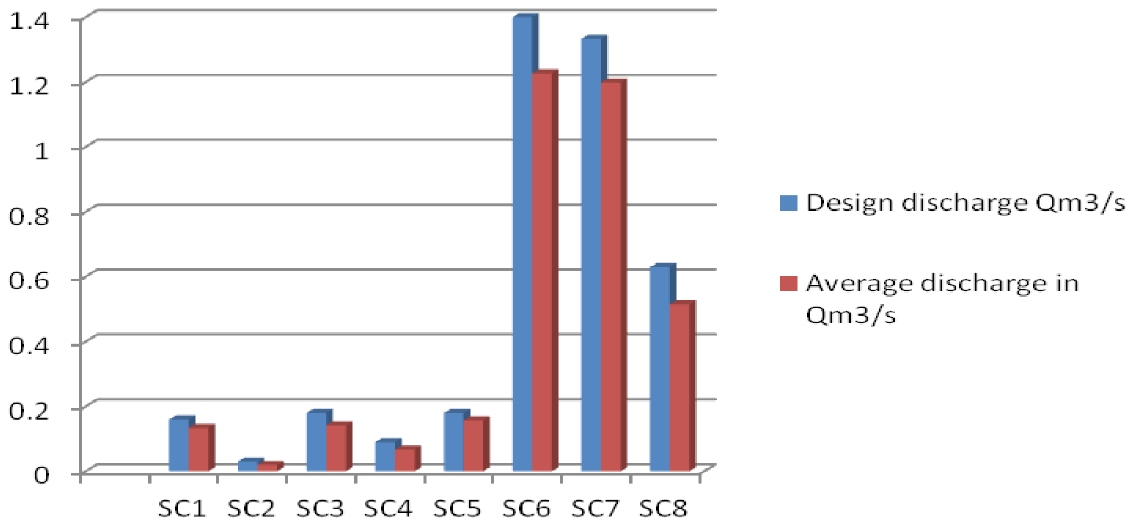

Figure 10: Design and actual discharges

4.4.6 Irrigation Ratio

Irrigation ratio indicator considers only the area irrigated in one cropping season and not the cropping area on the same plot of land in a year. The irrigation ratio value of Dakawa irrigation schemes shows that 98% of the irrigable land has been irrigated. These values indicates that the scheme have a better performance. Sustainability of irrigation is indicative of whether the area under irrigation is contracting or expanding with reference to the nominal area initially developed. A total of 1 991.7 ha was cropped in all the eight secondary canals in Dakawa scheme. The command area in any secondary canal was equal to cropped area. But another potential area is out of the current system under irrigation. The value of irrigation ratio obtained in this Study is due to the proportioning weirs because the low flows are distributed fairly.

4.5 Productivity of Land and Water

4.5.1 Output per unit cropped area and output per unit command

In this Study, along with the other performance indicators, four comparative indicators developed by IWMI (2000) corresponding to unit area and water were used as performance indicators. The output per unit cropped area and output per unit command over the entire season for the eight secondary canals are presented in Figure 11 and Table 8. The output per unit cropped area varied between 33 and 1 412 $ha^{-1} while the output per unit command varied between 24 and 1 007 $ha^{-1}. The highest and the lowest values of the output per unit cropped area were observed at SC6 and SC2, respectively.

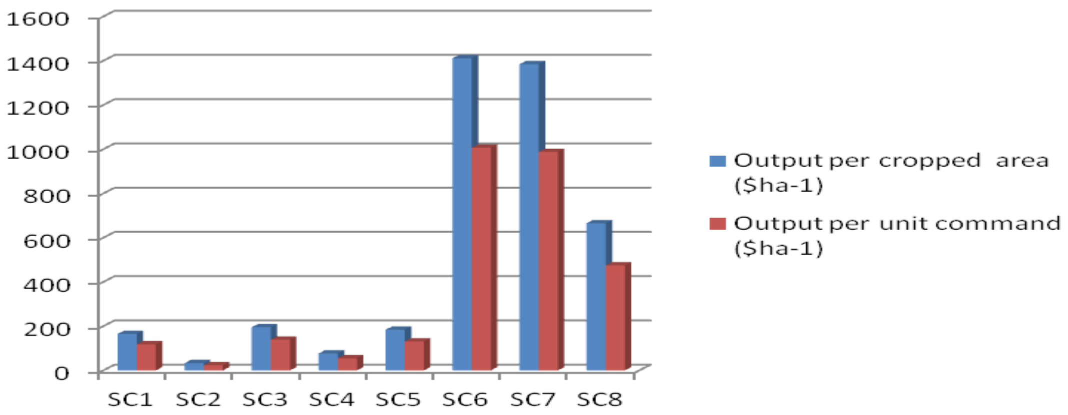

Figure 11: Output per unit cropped area and output per unit command

The output per unit cropped area varied from one cultivated area to another mainly due to fluctuations in the cropping pattern. Farmers supplied by SC6, SC7 and SC8 canals took advantage of the abundant water and increased the output per unit cropped area by cultivating more crops per unit area unlike SC2 and SC4 who received inadequate water. The Output per unit command is consistently lower than the Output per unit cropped area due to the fact that most of the lands under command was not cultivated during the season and this could be due to water shortage as pointed out by the farmers especially for those at the tail end. The fluctuations of output per unit command was less compared to the output per cropped area which varied between 24 and 1 007 $ha^{-1}. The highest and lowest values of the output per unit command were for SC 2 and SC 6 respectively.

Table 8: AGRICULTURAL INDICATORS FOR DAKAWA IRRIGATION SCHEMES

Name of Canal	Area (ha)	SGVP US$	Output per cropped area ($\$ha^{-1}$)	Output per unit command ($\$ha^{-1}$)	Relative Water Supply	Relative Irrigation Supply
SC1	80	329 300	165	118	1.2	0.9
SC2	16	65 860	33	24	5.9	0.9
SC3	94.5	388 986	195	139	1.8	1.0
SC4	37.2	153 124	77	55	2.0	0.9
SC5	89	366 346	184	131	1.8	1.0
SC6	683	2 811 402	1412	1007	1.8	0.9
SC7	670	2 757 891	1385	988	2.1	1.0
SC8	322	1 325 434	665	475	0.7	1.0

Many researchers have studied the calculation of output per unit command in parallel studies carried out in different regions of the world. For example output per unit command values were calculated as 105 – 1 800 $ ha^{-1} in the Alto-Rio Lerma project in Mexico, and 308 – 5 771 $ ha^{-1} in the southeastern Anatolia Project in Turkey (Molden *et al.*, 1998)(a); (Kloezen and Garces-Restrepo, 1998); (Degirmenci *et al.*, 2003).

Comparing these results to results obtained from Dakawa irrigation scheme, the output per unit command from this study seems to be on the high side. This would appear to suggest high productivity in the scheme, which is indicative of high–level use of inputs including sub-optimal cropping intensities. This is also reflected in the land tenure system being practiced in the area where about farmers own their plots of which this factor is contributing to higher output per unit command and the cropping intensity and the type of crop grown.

4.5.2 Output per unit irrigation supply and output per unit water consumed

Consumed water is the actual evapo-transpiration from irrigated crops (ET_a). The gross value of output per unit water consumed is 0.32 $\$m^{-3}$. It is seen that purely rice-based systems with abundant water supply and rice-based system with cropping intensity less than 100 percent give a gross value of output per unit water consumed of about US$ 0.10 whereas water-short systems with orchard and industrial crops and those systems with private- well pumping give a gross value of output per unit water consumed between $ 0.20 to $ 0.60 (Table 9).

Table 9: TOTAL OUTPUT PER UNIT IRRIGATION SUPPLY AND OUTPUT PER UNIT WATER CONSUMED

Productivity, ton/ha	**SGVP (US$)**	**Output per cropped area ($/ha)**	**Output per unit command area ($/ha)**	**Output per unit irrigation supply ($/m^3)**	**Output per unit water consumed ($/m^3)**
7.125	8 198 346.1	4 116.26	2 936.69	0.032	0.17

The values of output per unit irrigation supply and water consumed are (0.032 and 0.17 $ m^{-3}) especially in the upper reaches of the secondary canal suggest that a lot of water is being diverted to those areas but much of it is wasted. On the other hand, tail-end users such as those along SC 6, appear to use water more efficiently as the output per unit water consumed is almost the same as that per unit irrigation supply. The efficiency with which water is being used in Dakawa irrigation scheme is still low when compared to the reported values of between 0.13 and 2.16 $ m^{-3} Hancagiz and Derk- Dumluca irrigation schemes in Turkey (Degirmenci *et al.*, 2003). The average value of output per unit water consumed obtained in this Study was 0.17 $m^{-3} for the whole farm. Similar range of values were obtained by (Degirmenci *et al.*, 2003) from 0.45 to 2.92 $m^{-3} for several schemes in the Southeastern Anatolia Project in Turkey.

4.5.3 Crop production per unit relative water supply

Table 10 shows values of the output per cropped area and relative water supply. Cultivated areas served by secondary canals with adequate supply relative to demand have higher output per cropped area, while areas short of water have low output per cropped area.

Table 10: OUTPUT PER CROPPED AREA AND RELATIVE WATER SUPPLY

Name of Canal	Area (ha)	SGVP US$	Output per cropped area ($\$ha^{-1}$)	Output per unit command ($\$ha^{-1}$)	Relative Water Supply (Ratio)	Relative Irrigation Supply (Ratio)
SC1	80	329 300	165	118	1.2	0.9
SC2	16	65 860	33	24	5.9	0.9
SC3	94.5	388 986	195	139	1.8	1.0
SC4	37.2	153 124	77	55	2.0	0.9
SC5	89	366 346	184	131	1.8	1.0
SC6	683	2 811 402	1412	1007	1.8	0.9
SC7	670	2 757 891	1385	988	2.1	1.0
SC8	322	1 325 434	665	475	0.7	1.0

However, SC6, SC7 and SC8 has higher output per cropped area for SC6 is 1 412 $\$m^{-3}$ compared to SC2 which is 33 $\$m^{-3}$ and others despite having a higher relative water supply Figure 12.

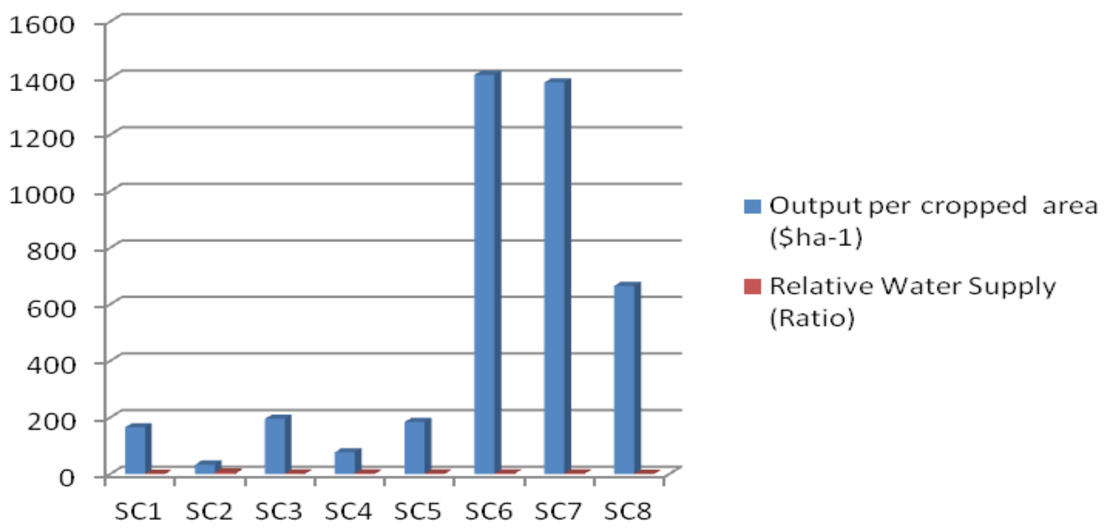

Figure 12: Output per cropped area and Relative water supply

The most obvious advantage of using tail-water is the increased uniformity and efficiencies Nutrient losses are reduced, due to higher uniformity and lower leaching. This leads to higher crop yields. The nutrients in the surface runoff are reused, thereby resulting in lower fertilizer costs (Broner, 2002). Hussain *et al.* (1999) conducted a study to understand the causes of differences in land and water productivity in wheat production across reaches of selected irrigation systems in India and Pakistan. They found that the farmers on the tail reach obtained higher yields as compared to farmers in the head and middle reaches.

4.6 Social Economic Indicators from a Social Economic Survey of Dakawa Irrigation Schemes

4.6.1 Financial viability of irrigation scheme

The revenue from irrigation includes all income derived from water fees, water user association's fees, outstanding debt and interest on debt payments but excludes all kind of government subsidies or payments. For Dakawa irrigation scheme in 2019, the revenue amounted to TZS. 491 949 900.0 Tanzanian shillings. The exchange rate for 2019 was 2 298 TZS/dollar so the revenue from irrigation was US$ 214 077.4. Operation and maintenance (O&M) expenditures included all expenditures to operate and maintain the system. For Dakawa, in addition to O&M expenditure they also included the administration costs, totaling 424 580 000 TZS or US $ 184 760.7 for this year. Therefore, financial self-sufficiency for the scheme was found to be 116 % which implies that the scheme is operating with profit.

In Dakawa irrigation scheme UWAWAKUDA sets a fee amounting 100 000 TZS/ acre. A total 1991.7 ha equivalent to 4919.5 acres were given to farmers for planting this year of 2019. This implies that a total amount of TZS 491 950 000 were being collected annually. Total collection for Dakawa scheme in 2019 was found to be TZS. 391 500 900/= Tanzanian shillings. The exchange rate for 2019 was 2 298 TZS/dollar, therefore, the revenue from irrigation was US$ 214 077.4. During the year irrigation fees were TZS 100 449 100/= equivalent to US$ 43 711.5. Thus, the fee collection performance was found to be 4.9 which indicates that farmers in Dakawa are well involved in paying the required fees. In addition, the total cost of irrigation water was recorded to amount to TZS 266 000 000/= per year and total production cost of a major crop was 424 580 000 TZS. Therefore, the relative water cost = (266 000 000 / 424 580 000) = 0.63, the value which indicates that the cost for water is extremely high for more than a half of the whole production cost. There must be an alternative solution for another plan for water abstraction rather than using pump as this increase the cost for water.

4.6.2 Social viability

It was observed that the team for UWAWAKUDA meaning (Umoja wa Wakulima Wa Kilimo Cha Umwagiliaji Dakawa) is comprised of board members, General Manager, Internal Auditor, Treasure, Agriculture Manager, Commercial Manager and Cashier. Others are casual labourers. A group of seven educated personnel are employed to take day to day activities in the entire irrigation scheme. It is evident that the technical knowledge for employed staff was 100%.

4.6.3 Sustainability of the physical environment for irrigation

The data of sustainability in the current irrigated land was divided by the initial irrigated land when the system was first fully developed. There are no changes between initial and the current command area which implies that there are no losses in the study area due to different reasons such as use of irrigation area for other purposes. Other Study in Turkey (Bos, 1997) found that the ratio of average sustainable irrigated area is 97%. Dakawa irrigation scheme has a potential of 1991.7 hectares of which has been put under irrigation, and the area has been maintained.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this Study, the performance of Dakawa Irrigation Scheme was assessed using comparative indicators. These indicators used are useful to evaluate the degree of utilization of resources such as land and water in producing agricultural outputs. The comparative indicators used are agricultural, water use (supply) and financial. The results of performance with respect to both land and water productivity indicate that Dakawa it is performing well. Higher land productivity values at Dakawa are mainly due to the improved irrigation management in the scheme and cropping intensity. Although the amount of irrigation water supplied with respect to demand is higher at Dakawa, the water productivity values are still higher at this scheme. The differences in performance found among secondary canals are attributable to other agricultural factors such as soil fertility, land suitability and the cropping patterns rather than purely water management. RWS and RIS values were above 1 and some approaching 1 at Dakawa (except RWS at SC 8 (0.7)), excess water supply and irrigation supply is supplied at the scheme.

The RIS results indicated that excess irrigation water is supplied at Dakawa. Generally, the RWS and RIS values alone in this Study indicate that water demands for the crops in the schemes are satisfied. These values also imply that the relationship between the water supply and crop water demand was poor from the point of water distribution to the rest in the scheme. System manager should have a yearly water budget plan that includes total and seasonal water requirement according to the cropping pattern and farmer petition in the scheme area.

Irrigators at Dakawa irrigation scheme are responsible for the overall water management including maintenance of the main bulk water supply, secondary canals, secondary drains, and all structures. The main problem about fee collection is the delay of payments by the farmers. The collection of water fee will help for operation and maintenance and other managerial activities of the irrigation systems.

The results of the Study revealed that the Dakawa irrigation schemes have infrastructural deficiency with a bit good structure index. The main canal in the Dakawa irrigation scheme is in good working condition due to the rehabilitation but some small positions are still in poor working condition due to lack of maintenance and repairs. This has greatly affected efficiencies in conveyance of water downstream. The first 2000 m of SC 6, SC 7 and SC 8 are not lined and do not have structures at all. Farmers in the irrigation schemes responded to some of the constraints and problems by adaptation, improvisation, maintenance, or abandonment.

From the Study, the following conclusions were made.

i. The amount of water which is being diverted to the Dakawa irrigation scheme was more than adequate for irrigation water requirement. But a comparison of net irrigation water requirement and the cumulative water supplied to the fields together with relative water supply in all eight secondary canals showed that more water was used at the head and middle locations. However, farmers at the tail-end reach used tail water recovered from the head and middle reaches and therefore their crops did not suffer from water stress.

ii. Although farmers in the head and middle reaches got more water than farmers at the tail-end the overall equity of water supply in Dakawa irrigation scheme appears to be fair. This is an improvement due to intensive rehabilitation made by the Government of Tanzania.

iii. When considering productivity of land, the values of output per unit cropped area show that SC6, SC7 and SC8 were more productive than others. The output per unit command was consistently lower than the output per unit cropped area because not all land under command was cultivated due to water shortage especially in the tail end reach. Generally, productivity in the Dakawa irrigation scheme is high, which is indicative of high–level use of inputs including sub-optimal cropping intensities.

iv. The SGVP per cubic meter of irrigation in Dakawa scheme was low. The output per unit irrigation supply was much lower in the cultivated areas of the head reach compared to the tail-end reach areas. In contrast the SGVP per unit water consumed in all cultivated areas was higher than the SGVP per cubic meter of irrigation. The higher output per unit irrigation supply in the tail-end reach compared to the upper reaches was due to fact that besides the little water they received, the tail-end farmers were also using tail water recovered from the upper reaches to irrigate their crops. The relatively low values of output per irrigation supply suggest that the efficiency with which water is being used in the scheme is rather low as reflected by the wasteful use of water, especially in the upper reaches.

v. Results obtained from the interview survey reveal that farmers in Dakawa irrigation scheme understand irrigation scheduling and irrigation water management, which led to good water management.

vi. The information and data obtained from this Study was for only one season. To have well-informed decision as to what areas need improvement, several seasons should be considered. There is therefore need to extend the performance assessment in future in order to come up with a better representation of the performance of the scheme.

5.2 Recommendations

Despite of having some few shortfalls in Dakawa Irrigation Scheme still the system is running better in most part of the entire area in terms of different scenarios. These indicators are not meant to replace day-to-day monitoring techniques that allow for performance-based management. They are useful in answering the question “am I doing the right thing. They can be used to identify long-term trends in performance and to set and verify long-term strategic objectives. The next step is to proceed with gathering these indictors for a greater variety and number of irrigation systems. However, recommendations from this study are as follows.

i. Water distribution needs attention because the farmers at the tail end were short of water because some farmers in the head reach were blocking water with stones to abstract more water. It is therefore recommended that the water users association should formulate a team to regulate water balance in the area.

ii. Excess use of water by some farmers is a common problem not only in Dakawa irrigation scheme but also in most farmer managed irrigation schemes in developing countries. This may arise because some farmers do not know how much water to apply and when to irrigate. It is therefore inevitable to evaluate irrigation schedules practised by individual farmers with the view of developing simple irrigation scheduling techniques, which can easily be used by farmers. This would go a long way towards improving irrigation efficiencies among the farmers and hence lead to effective use of the existing limited water resources.

iii. Canal maintenance and rehabilitation should be part and parcel of the responsibilities of the irrigator association. The maintenance committee should be put in place to attended among other things problems related to canal capacity such sediment deposits, erosion and vegetation.

iv. To meet the technical requirements of some of the specialised committees of the water users associations such as the maintenance committee, training and extension should be enhanced. Training and extension including monitoring and evaluation would also ensure that farmers follow recommended irrigation scheduling and cropping patterns. This can result in improved irrigation water management.

v. There is need to find out farmers' opinions and preferences on utility of irrigation water supply. This may bring out a lot of issues considering the fact that it will be a demand driven performance assessment, which is most likely to directly address gaps and problems, faced by farmers in irrigation water supply rather than the traditional top- down approach of planning, designing and assessing irrigation systems.

vi. The information and data obtained in this Study was for only one season. To have well-informed decision as to what areas need improvements, several seasons should be considered. There is therefore need to extend the performance assessment in future in order to come up with a better representation of the performance of the scheme.

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APPENDICES

Appendix 1: Average weekly discharges m^3/s measured in 2019

Subdivision	Average Weekly Discharges m^3/s Measured in 2019										
	W1	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**
SC1	0.14	0.14	0.13	0.14	0.13	0.14	0.14	0.13	0.14	0.13	0.12
SC2	0.01	0.02	0.03	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02
SC3	0.15	0.15	0.13	0.17	0.12	0.13	0.14	0.15	0.14	0.15	0.15
SC4	0.07	0.06	0.06	0.07	0.08	0.07	0.07	0.07	0.06	0.06	0.08
SC5	0.17	0.17	0.17	0.15	0.17	0.15	0.15	0.16	0.16	0.15	0.15
SC6	1.11	1.11	1.18	1.25	1.25	1.26	1.27	1.27	1.28	1.26	1.26
SC7	1.05	1.19	1.19	1.21	1.22	1.23	1.20	1.30	1.30	1.10	1.20
SC8	0.57	0.59	0.61	0.59	0.60	0.61	0.52	0.52	0.42	0.42	0.22

11-17/03/2019	Week 1
18-24/03/2019	Week 2
25-28/03/2019	Week 3
01-07/04/2019	Week 4
08-14/04/2019	Week 5
15-21/04/2019	Week 6
22-28/04/2019	Week 7
29-05/05/2019	Week 8
06-12/05/2019	Week 9
13-19/05/2019	Week 10
20-27/05/2019	Week 11

Appendix 2: AVERAGE DISCHARGE MEASURED AT THE HEAD OF SECONDARY CANALS IN DAKAWA

Subdivision	Coefficient of Variation of Discharge		
	March	**April**	**May**
SC1	0.03	0.05	0.05
SC2	0.33	0.25	0.24
SC3	0.10	0.18	0.03
SC4	0.04	0.12	0.20
SC5	0.02	0.09	0.04
SC6	0.04	0.01	0.01
SC7	0.07	0.01	0.08
SC8	0.03	0.07	0.32

Appendix 3: Reference data/ flow rate according to the design

Canal	Capacity (l/s)	Block No.	Area (ha)
SC1		1	16
		6	64
Total SC1	**160**		**80**
SC2		2	16
Total SC2	**30**		**16**
SC3		3	25
		7	70.4
Total SC3	**180**		**95.4**
SC4		4	37.2
Total SC4	**90**		**37.2**
SC5		5	18.8
		8	33.6
		9	36.6
Total SC5	**180**		**89**
SC6		13	78.8
		14	85.6
		18	96
		19	96
		23	96
		24	76.8
		28	76.8
		29	76.8
Total SC6	**1400**		**682.8**
SC7		11	61.6
		12	70.4
		16	96
		17	96
		21	96
		22	96
		26	76.8
		27	76.8
Total SC7	**1333**		**669.6**
SC8		10	52.8
		15	96
		20	96
		25	76.8
Total SC8	**630**		**321.6**
Total all	**4003**		**1991.6**
Total sector 1			**1363**
Total sector 2			**629**

Appendix 4: Calculations of ET crop and net irrigation requirement for Dakawa irrigation scheme.

Month	ET_0	Perco-lation	Rainfall Average	k_c for HYV	ET_c	Net Field Req.'mnt	
	(mm/day)	(mm/day)	(mm)		(mm/day)	(mm/day)	(l/s per ha)
Jan 1	5.3	5.0	99				
2	5.3	5.0					
Febr 1	5.5	5.0	118	LP			
2	5.5	5.0		LP			
March 1	5.1	5.0	92	LP			
2	5.1	5.0		1.05	5.4	8.8	1.02
April 1	3.9	5.0	194	1.05	4.1	7.0	0.81
2	3.9	5.0		1.2	4.7	8.9	1.03
May 1	3.4	5.0	76	1.2	4.1	8.9	1.04
2	3.4	5.0		1.1	3.7	9.7	1.13
June 1	3.4	5.0	8	0.97	3.3	10.0	1.15
2	3.4	5.0		0.9	3.1	8.1	0.93
July 1	3.5	5.0	7	0.6	2.1	7.1	0.82
2	3.5	5.0		0.3	1.1	6.1	0.70
Legend:	WLR =	Water layer replacement (after fertilizer application on drained rice field)					k_c =
	ET_0 =	Reference crop evapotranspiration (MMD Feasibility Study, 1996)					NFR =
	ET_c =	Actual crop evapotranspiration, includes LP and WLR					THR =
	PR =	Pump requirement					SR =