ASSESSMENT OF IRRIGATION SYSTEMS' PERFORMANCE AND SUSTAINABILITY IN BURUNDI

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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.

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EXTENDED ABSTRACT

Irrigated agriculture has a crucial role to play in enhancing food security; hence, irrigation expansion would significantly increase agricultural production, improving household income and reduce food insecurity and poverty levels among smallholder farmers. However, majority of irrigation schemes developed in Burundi have performed below their potential. Evaluation of the performance of an irrigation schemes is essential in knowing whether water availability meets or exceeds demand. In Burundi, these evaluations are limited. This study aimed to assess the irrigation systems' performance and sustainability in Burundi with a case study of Kidwebezi Irrigation Scheme. Specifically, this study intended (i) to evaluate the performance of the irrigation structures, (ii) to assess the water delivery performance using technical indicators and (iii) framers' knowledge and to assess the effect of Irrigators' Association on the performance of Kidwebezi Irrigation scheme with the target of evaluating the existing operation rules and proposing alternative options for further improvement.

In this study, a float method was used for determining the flow rate. The CROPWAT Penman-Monteith method was used to determine the reference crop evapotranspiration, the combination of Food and Agriculture Organization (FAO) CROPWAT 8.0 simulation software and the CLIMWAT 2.0 tool was used to calculate the crop water requirement (CWR) of the paddy.

Field observations (state of a structure) and physical work were used to evaluate the performance of the irrigation structures. Based on the technical performance indicators such as efficiency, adequacy, dependability, equity and water productivity, the performance of water delivery was assessed. A social economic survey (farmer interviews, focus group discussions and key informants) was undertaken to assess financial self-sufficiency, fee collection and relative water costs of the scheme.

Results for the performance evaluation of irrigation structures showed that 84.15%were still functioning. On the physical condition part, the findings showed that the intake was working at 80%; canals network was operational at 80% while command area development was functioning at 88%.

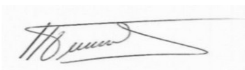
For the conveyance efficiency, the results indicate that 82.48%, 80.40% and 66.38% of water conveyed reached the destined farm for lined main canal, lined secondary canal and unlined secondary canal, respectively. The total net irrigation and total gross irrigation were 342.2 mm and 760.4 mm. The study results showed that the irrigation system was good in terms of adequacy and poor in terms of efficiency while it was fair to both dependability and equity.

Moreover, the results for the assessment of effect of Irrigators' Association with regard to financial viability and sustainability of the scheme were found to be encouraging. The results showed that the effectiveness of fee collection (EFC) was 87.77%, the financial self-sufficiency (FSS) was 3.11 with an average relative water cost of 0.05 and 97.75% of the scheme were still irrigated.

The results from farmer interviews, focus group discussions and key informant showed that the uncontrolled paddy farming expansion, lack of updated irrigation knowledge and technologies and low efficiency on water use are the main causes of low yields of paddy in the Kidwebezi Irrigation Scheme.

DECLARATION

I, Prosper MANIRAKIZA, 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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DEDICATION

To Almighty God,

My parents, my brothers and sisters,

My late wife Estella NZOYIHAYA,

My lovely children MANIRAKIZA Don Divin and MANIRAKIZA Don Précieuse.

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LIST OF ABREVIATIONS

BIF	Burundian franc
CEC	Cation Exchange Capacity
CV_R	Spatial coefficient of variation
CV_T	Temporal coefficient of variation
DPR	Delivery performance ratio
Ece	Electrical conductivity of the soil
Ecw	Electrical conductivity of water
EFC	Effectiveness of fees collection
ESP	Exchangeable sodium percentage
ET_C	Crop water requirement
ET_O	Reference crop evapotranspiration
FAO	Food Agriculture Organization
FGD	Focus group discussion
FSS	Financial self-sufficiency
IA	Irrigators’ Association
In	Net irrigation
Ig	Gross irrigation
IRRI	International Rice Research Institute
ISTEEBU	Institut des Statistiques et d’Etudes Economiques du Burundi (Institute of Statistics and Economic Studies of Burundi)
IWMI	International Water Management Institute
IWR	Irrigation water requirement
K_C	Crop factor or crop coefficient

KIS	Kidwebezi Irrigation Scheme
MINAGRIE	The Ministry of Agriculture and Livestock
O & M	Operation and maintenance
P_A	Adequacy
P_D	Dependability
P_E	Equity
P_F	Efficiency
pH	Potential of Hydrogen
Q	Discharge
Q_D	Amount of water delivered
Q_R	Amount of water required
RWC	Relative Water Cost
RWS	Relative Water Supply
SC	Secondary Canal
SCI	Structure Condition Index
SRDI	Société pour le Développement de la Région de l'Imbo (Imbo Regional Development Society)
SRI	System of Rice Intensification
SSA	Sub-Saharan Africa
T	One Irrigation Season (Days)
TC	Tertiary canal
UN	United Nations Organisation
USA	United States of America
WDP	Water delivery performance

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Irrigated agriculture is known for its contribution to food production and food security across the globe and has contributed to the impressive growth in the agricultural productivity over the past five decades (Masya, 2016; Bjornlund and Rooyen, 2020). At a global scale, irrigation accounts only 20% of the cultivated land, but contributes about 40% of the total production (FAO, 2016). However, in Sub Saharan Africa, despite the investment in irrigation schemes, countries still suffer from low crop productivity, with many schemes producing below their potential. For example, paddy production in Burundi is reported to be around 3.5 t/ha compared to the global average yield of 6 t/ha (Gahiro, 2013). Low crop productivity is a result of many factors including low efficiency in the irrigation systems, weak governance (irrigator's associations) and lack of repair and maintenance (FAO, 2016). It is important to note that, despite the low productivity, presence of irrigation schemes has delivered a vast socio-economic benefits including growth of business centres, improvement of rural infrastructure, with extended benefits in the agricultural value chain including agro-processing and jobs. It is critical that irrigation schemes are operated and maintained sustainably to realize benefits in the local social setting and should contribute to increased food production (FAO, 2014).

The efforts to increase food production in Sub-Saharan Africa requires not only deployment of new technologies, but also expansion of irrigated agriculture (Cai *et al*., (2009). Similarly, expansion of the irrigation area alone would likely not be sufficient to fulfil the future food demand due to the limitation in the surface water stock and land (IWMI and NBI, 2000). This calls for investment in technologies that ensure and increase food production to meet the growing demand without so much dependence on land expansion (Foley *et al.*, 2011). However, the evaluation of how well these innovations are performing is rarely conducted. In literature, two major approaches to performance evaluation have been considered. These include how well the service is delivered and the outcomes of irrigation in terms of efficiency and productivity of resource use (Molden, 2010).

Different parameters have been used to describe water delivery performance. These include: volume, discharge, frequency and duration (Molden and Clemmens, 2007). The overall performance of an irrigation water delivery system can be broken down into two components. These are (i) the delivery schedule and (ii) operations. The level to which irrigation systems attain the aims of water distribution is a need (Mateos *et al.*,2018; Yercan *et al*., 2009). Evaluation of performance and sustainability of irrigation systems has been approved for several reasons. Small and Svendsen (1990) and Molden and Clemmens (2007) used performance evaluation to improve system management (Cai *et al*. (2009); Bhadra *et al*. (2009) and Pereira (2002) determined overall system state and (Abdullaev and Rakhmatullaev, 2016) compared performance of systems over time and space.

The effectiveness of operation decisions to deliver water from a water source and the physical system can be described by irrigation system performance indicators (Kranz and Eisenhauer, 2011). The primary concerns for irrigation managers are the irrigation performance criteria of adequacy and equity (Nassah *et al*., 2018). Molden and Gates (1990) have suggested water delivery performance indicators for assessing water delivery in large-scale; Molden and Gates (1990); Marinus, 1997; Molden *et al*., 1998 and Dejen (2015) extended some performance indicators to evaluate water delivery performance at irrigation delivery points or structures. Major statistical indicators, adequacy, efficiency, equity and dependability have been defined by Molden and Gates (1990), as objectives of water delivery performance. These performance indicators have been widely used over the world (Unal *et al*., 2004; Vandersypen *et al.*,2006; Kazbekov *et al*., 2019 and Nam *et al*., 2019).

Performance evaluation needs to focus critically into the sustainability of the irrigation systems. While increasing production to meet the growing demands, it remains a critical focus in many irrigation systems. For sustainability to be achieved, the system needs to ensure that natural resources such as water resources are not reversibly replenished (Borsato *et al.*, 2020).

Studies by Kijne and Barker (2003) and Masya (2016), refer that an improvement in irrigation efficiency and increase in agriculture water productivity are crucial in the mitigation of competition for water resources, environment protection and sustainable food provision. Therefore, coordinated efforts are needed from diverse stakeholders in order to make sure a sustainable production and protect the threatened natural resources (Molden *et al*., 1998). With the view to minimize the water losses and increase productivity in Kidwebezi irrigation systems, a performance evaluation was carried out to assess the state of health of the systems and also the usage of water efficiently.

1.2 Problem Statement and Justification

1.2.1 Problem statement

In Burundi, like in many countries in Sub-Saharan Africa, crop production is mainly rainfed, which is susceptible to climate variability and climate change. Furthermore, irrigated agriculture is less than 5% of the cropland (FAO, 2016). As a result, incidences of households' food insecurity and low incomes have been reported, since over 90% of the population depend on agriculture for their livelihoods (Zabala, 2018; Borsato *et al.*,2020).

In addition, large numbers of irrigation structures are constructed without considering how their operation, maintenance and management can be sustained after the intervention (FAO, 2016) hence, the need to evaluate the performance and sustainability of the irrigation systems in Burundi. In addition, lack of knowledge and inadequacy of water resources management is one of the major reasons for the lower performance of most irrigation systems in Burundi (Fan *et al.*, 2018). There are also several references to inequality in water distribution leading to significant disparities between head and tail areas, deficiency water supplies and loss of productivity in some locations, or excess water delivery and development of water logging and salinity in others. Water supplies at any given location is often poorly matched to crop needs and is, highly variable in both timing and discharge which may result in low water application efficiency (Molden, 2010).

1.2.2 Justification

This study was designed to evaluate the performance and sustainability of irrigation systems in Burundi with a case study of Kidwebezi Irrigation Scheme in order to reduce competition for scarce water resources, to avoid water losses and to provide solutions to environmental degradation. In addition, the study aims to check the effectiveness of infrastructures, water use efficiency and water productivity and to evaluate the role of irrigators' associations (IAs) in the performance of irrigation schemes in order to identify potential approaches for its improvement and to identify key constraints that the sector should overcome. It is therefore anticipated that the results of this evaluation will assist in improving the performance of IAs in maintaining equitable irrigation water distribution, which is directly linked to sustained irrigated agriculture of poor farmers in Burundi. Moreover, policy makers can take this opportunity to use the results of the study to help other farmers who are not part of this study area.

1.3 Objectives

1.3.1 Main objective

The main objective of this study was to assess the performance and sustainability of irrigation systems in Burundi.

1.3.2 Specific objectives

More specifically this study intended to:

i. Evaluate the performance of the irrigation structures for Kidwebezi Irrigation scheme;
ii. Evaluate the irrigation system using technical performance indicators and farmers' knowledge; and
iii. Assess the effect of irrigators' association on the performance of Kidwebezi Irrigation Scheme.

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CHAPTER TWO

2.0 PERFORMANCE EVALUATION OF IRRIGATION STRUCTURES KIDWEBEZI IRRIGATION SCHEME IN BURUNDI

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ABSTRACT

Water conveyance structures have been the most important part of any irrigation system in the world. However, their function is affected by several factors, including deep percolation, cracks, seepage and physical damage to the canals. This is mainly due to poor operation and maintenance of infrastructure, thus enhancing low crop productivity. Therefore, a study was conducted to evaluate the performance of the irrigation structures align Kidwebezi Irrigation Scheme in Burundi. Field observations and field measurements were used to evaluate the irrigation structures. The data collected from the survey were analysed using Statistical Package for Social Sciences (SPSS) (IBM SPSS version 21). Results of the study revealed that 84.16% of structures were working properly, the intake was functioning at 80%, the canal network was operational at 80% and the command area development was functioning at 88%. From the current study, it is concluded that the irrigation structures at Kidwebezi were operating satisfactorily. Therefore, it is recommended to the government agency responsible of the scheme to make more efforts in water management, including maintenance of canals network and structures to improve the efficiency of water supply.

***Key words**: Irrigation Structures, Physical Condition Assessment, Field Measurements*

2.1 Introduction

Global demand for food is increasing, escalating pressure on scarce water resources and challenging its availability for food production while jeopardizing food security (Rosegrant *et al.*, 2002). The world is facing an enormous challenge to produce food to meet the growing needs of its ever-increasing population. According to the United Nations Department of Economic and Social affairs (UN, 2019) the world population is expected to reach 9.7 billion by 2050 and 11.2 billion people in 2100. The population of Sub-Saharan Africa (SSA) is expected to be almost 2.5 billion in 2050 (Ezeh *et al.,* 2020; UN, 2019), signifying an increasing challenge to produce adequate food by narrowing yield gap between the actual farm yields and potential yields (Van Ittersum *et al*., 2016). Irrigated agriculture is known for its contribution to food production and food security across the globe and has contributed to the impressive growth in the agricultural productivity over the past five decades (Masya, 2016; Bjornlund *et al*., 2020). At a global scale, irrigation accounts for only 20% of the cultivated land, but contributes about 40% of the total production (FAO, 2016).

However, in Sub Saharan Africa (SSA), despite investment in irrigation schemes, countries still suffer from low schemes productivity, with many schemes producing below their potential (FAO, 2009) and the trend has been on the decline since the 1960s, despite short period of growth in the mid-1970s and 1980s. As a result, food insecurity has been a recurrent phenomenon in almost 30% of the Sub-Saharan Africa population (Bjornlund *et al.*, 2020). Numerous studies have highlighted factors contributing to low efficiency of irrigation schemes and hence low crop productivity, including poor management, lack or inadequate rural financing mechanisms, high prices of inputs including fertilizer, lack of infrastructure, uncertainty in land tenure and lack of farmer organizations (Abdulai, 2006; Bjornlund *et al*., 2020; Inocencio, 2007; Mercoiret *et al*., 2007; Molle and Renwick, 2005). According to Bjornlund *et al*. (2020), irrigation schemes are generally complicated to manage and understand and can be considered a success if they are operated within the constraints of the water resource (Lankford, 2010) and connected to markets, transportation as well as advancement in information systems.

The reliability of irrigation scheme in increasing irrigation efficiency and sustainability of water resources depends partly on the improvement of irrigation structures. Irrigation efficiency contributes to reduced losses and hence better on-farm water application (Playán and Mateos, 2006) and improved water productivity. However, despite significant investments in the construction of new infrastructure, many irrigation schemes, even the public owned ones, suffer from lack of repair and maintenance (FAO, 2016), resulting in operation below their expected potential. High dependency on rainfed agriculture, coupled with low investment in water storage and maintenance of irrigation schemes as well as uncertainty in weather and climate due to climate change are likely to cause significant impacts on food security in many countries in SSA (FAO, 2016).

It is important to note that, despite the low production, the presence of irrigation schemes have delivered immense socio-economic profit including growth of business centres and jobs. In addition, irrigation schemes which are well operated and maintained sustainably realize benefits in the local social settings and should contribute to increased food production (FAO, 2014). However, poor management and maintenance of assets, inadequate crop management and other socio-economic factors are the causes of degradation or abandonment of many irrigation schemes (Dejen, 2015).

Agriculture in Burundi greatly depends on rainfall, but due to climate change, rainfall has become unpredictable and irregular. Drought is being experienced more frequently during what would normally be the rainy season (Minagrie, 2012). According to data from AQUASTAT (FAO, 2022), Burundi has a potential area suitable for irrigation of about 215 000 ha and currently only about 23 000 ha are equipped with irrigation infrastructure, and the number has remained almost the same for the past three decades. Rice is the main crop grown in the irrigated areas, including the 5000 ha in the Imbo plains, but despite the general increase in rice production, productivity remains low. Only about ten percent of areas identified as suitable for irrigation are equipped with irrigation technologies and mainly utilizing surface water. As the majority of the population depends on agriculture, shortage of water for crop production affects food availability, income and livelihoods (Okonya *et al.*, 2019). To mitigate the shortage of water, the Government of Burundi, is rolling out small-scale irrigation infrastructure to help farmers adapt to climate change. This inventiveness aims at enabling farmers to grow crops during the dry season, something that would otherwise be almost impracticable (Minagrie, 2012).

Water conveyance structures have been the most important part of any irrigation system in the world. However, the system is affected by several factors including deep percolation, cracks, seepage and physical damages of the canals (Sen *et al.*, 2018) and lack of operations and maintenance thus contributing to low crop productivity (FAO, 2016). The effectiveness of operation decisions to deliver water from a water source and the physical system can be assessed based on the irrigation system performance indicators (Klaartje and Jamin, 2006; Kranz and Eisenhauer, 2011). The commonly expressed problems leading to low water use efficiency and low yields are head-tail problems, leaky canals and malfunctioning structures due to the delayed maintenance (Cakmak *et al*., 2010). However, the challenge remains that each irrigation scheme has its own unique problems and consequently, requiring specific approach resulting from performance evaluations. Typical causes of poor hydraulic performance of canals are destruction of irrigation infrastructure due to lack of maintenance and/or inappropriate use of water control structures (Murray-Rust and Halsema, 1998).

The physical infrastructure is the most costly item in the irrigation development and in rehabilitation of old systems (Bos *et al.,* 1993). In the process of conveying water into the agriculture land through open canals, problems associated with free water movement in canals which include (i) bank collapse (BC), sediment deposition and scouring of beds; (ii) water pools (WP), (iii) seepage across the embankment and (iv) weeds growth (WG) (Kudzai, 2011) are contributing to the malfunctioning of the irrigation structures. Evaluating irrigation structures contribute to the detection of performance gaps for the need of improvements of agricultural productivity (Hakuzimana and Masasi, 2020).

As suggested by Amarasinghe *et al*. (1998), structures are considered to be in poor condition when there is limitation or enlargement of the canal cross section, observable siltation, visible seepage or other defects in the banks, cracks or other damage to the canal, grass and algae covering the canals and mud piling up on the channel blocking the flow of water. Different performance indicators and evaluation perspectives have been proposed or used to evaluate various irrigation schemes in recent decades (Ndayizigiye, 2009; Nsengiyumva, 2019). However, very little is known in the Burundian landscape in terms of operation and maintenance of irrigation schemes. To fill this gap, the current study was undertaken with the objective of assessing the effectiveness of existing water infrastructures in Burundi using a case study of Kidwebezi Irrigation Scheme. It is expected that the results of the study will be useful to the stakeholders in the agriculture sector in planning for the future improvement of water supply which may lead to sustainability of the Irrigation Schemes.

2.2 Methodology

2.2.1 Description of the study area

i. Topography

The study was conducted at Kidwebezi Irrigation Scheme located in Mpanda District, Bubanza Province in the western part of Burundi. The scheme is located approximately 25 km from Bujumbura capital city. The scheme covers an area of about 83 ha and lies at Latitude of 3º 11' 60" South and Longitude 29° 23' 59" East (Figure 2.1). Kidwebezi is situated in the Imbo Plain, one of the eleven natural regions of Burundi. Imbo Plain is a lowland area with a mean altitude of 1000 m above the sea level.

ii. Climate

The rainfall regime in this zone is bimodal, with a short rainy season between October and January and a long rainy season between March and May. The annual rainfall in this zone ranges between 700 and 1000 mm and the temperature ranges from 24°C to 28°C and has a dry season of about five to six months.

iii. Agriculture activities

The major activities of the people of Kidwebezi include farming and livestock keeping. Major food and cash crops grown include paddy, maize, beans, watermelon, sweet potatoes and vegetables. Livestock production includes beef and dairy cattle, small ruminants and poultry, which are kept mainly for income generation (Ndayizigiye, 2009). Kidwebezi irrigation scheme is jointly managed by State and Farmers where the main and secondary canals are under the responsibility of the Government Agency (SRDI: Society for the Development of Imbo Region), while tertiary canals are under the farmers through the Irrigators' Association management.

2.2.2 Scheme layout

From Gifurwe River diversion (through an intake), water is conveyed by gravity to the Kidwebezi irrigation scheme by a main lined canal which is about 5 km long. The main canal distributes water into two secondary canals (SC) at 500 m before reaching the scheme (SC1 and SC2). Each secondary canal distributes water to 15 tertiary canals (TC). The tertiary canals supply water by gravity to the field or plots in the scheme. Also, the scheme comprises field drains, two collector drains and a main drain to remove excess water from the field (Figure 2.2).

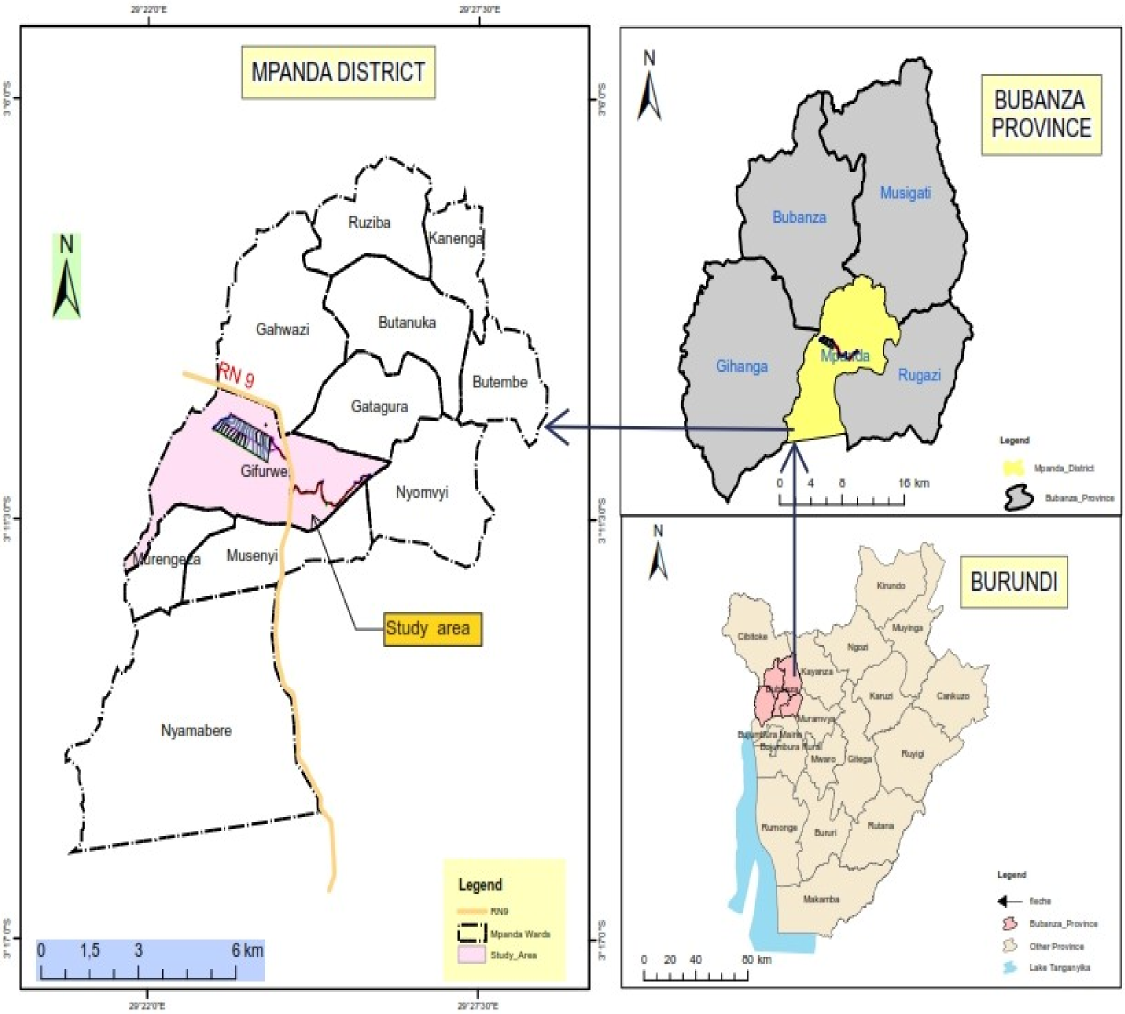
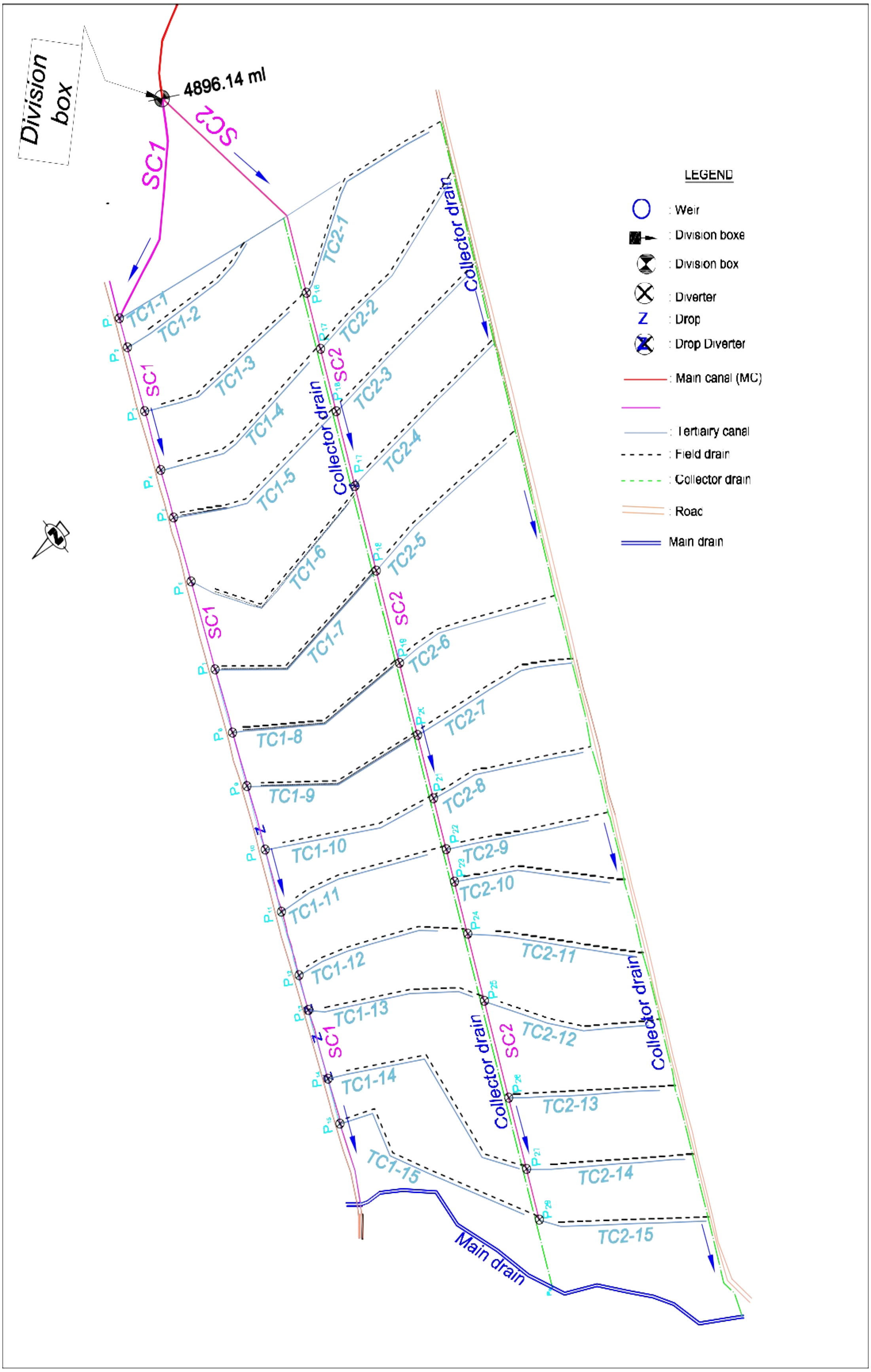


Figure 2.1: Location of the study area of Kidwebezi irrigation scheme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TC2-9
TC2-10
TC2-11
TC2-12
TC2-13
TC2-14
TC2-15
LEGEND
: Weir
: Division boxe
: Division box
: Diverter
: Drop
: Drop Diverter
: Main canal (MC)
: Tertiary canal
: Field drain
: Collector drain
: Road
Main drain

Figure 2.2: Layout of Kidwebezi Irrigation Scheme

2.2.3 Methods

2.2.3.1 Performance indicators for irrigation structures

To assess the temporal variations of water conveyance systems and their efficiencies, it is recommended to set criteria that would show whether canals (i.e., main, secondary and tertiary) and drains require maintenance or replacement (Bos *et al*., 1993). However, in several irrigation systems, the performance evaluation is conducted subjectively on appearance instead of sophisticated analytical methods (Zende and Nagarajan, 2013). Consequently, in this study, observation and field measurements were used to evaluate the performance of irrigation structures. Irrigation infrastructure was evaluated based on his functional potential (physical condition), his effectiveness (storage or conveyance losses) and benefits in decision-making processes (existing system improvement) using the four multi-criteria approaches described by Zende and Nagarajan (2013). As mentioned by Bos (1997), maintenance of structures is needed to keep the system in good operation conditions as intended.

i) Effectiveness of infrastructure

The study used the method developed by Ijir (1994) namely the Structure Condition Index (SCI) to measure the performance of irrigation structures and Bos *et al*. (1993) used the same indicator but called it “Effectiveness of Infrastructure which is the number of structures working normally, divided by the total number of structures (Equation 1).

$$Effectiveness\ of\ \inf rastructure = \frac{Number\ of\ functioning\ structures}{Total\ number\ of\ structures} \qquad (1)$$

However, a structure is functional if it can be operated or utilized to perform its intended function within an accepted level of correctness. For the analysis to be effective, however, the structures were divided into their hierarchical importance (main, secondary or tertiary level) and the analysis was done at each level.

ii) Intake Efficiency

Intake Efficiency (IE) was assessed by observing Sedimentation Level (SL), Condition of its Embankments (CE) and sluice Gate Operation (SG). These were grouped into five classes where maximum value (5) indicates the intensity of the difficulty in operation and minimum value (1) reflects the easiness according to Zende and Nagarajan (2013) (Appendix 1.1).

$$IE = [(SL\ rank\ x\ weightage) + (CE\ rank\ x\ weightage)\ (SGL\ rank\ x\ weightage) \quad ..(2)$$

Where:

IE= Intake Efficiency; SL= Sedimentation level, showing the quantity of sediments deposited in the intake. It was determined by measuring the water level compared to the initial level of the intake using a tape meter; CE= Condition of intake's embankments, indicating the potential water leakage of the intake determined after observing the intake status such as physical damage and seepage; SGL= Sluice Gate operation level, the intake water release capacity determined after inspection of the structure's state of being such as lubrication gates, anti-corrosion treatment, maintenance, etc.; Rank = the intensity of the difficulty (maximum) in operation and easiness (minimum) which was measured using class proposed by Zende and Nagarajan (2013) and; Weightage = the value/contribution/portion of each criterion to the sustainable operation of the structure (Appendix 1). After determining the value (percentage) of each parameter, the rank which is corresponding with the value was multiplied by the weightage of the parameter to find the intake efficient. The weightage value of each structure was proposed by Zende and Nagarajan (2013).

iii) Canal Condition

Canal condition (CC) was assessed by means of bank collapse (BC), water pools (WP) (mainly attributed to sediment deposition), seepage across the embankment and weed growth (WG) within the canal and conveyance losses (CL). The information collected was used in ranking and weighting the individual parameters referred to Zende and Nagarajan (2013) (Appendix 2).

$$IE = ¿\left[\left(BC\ rank\ x\ weightage\right) + \left(WP\ rank\ x\ weightage\right) + \left(WG\ rank\ x\ weightage\right) ¿\right] ¿ ¿ ¿ \quad .(3)$$

Where:

CC= Canal condition; BC= Bank collapse: the evaluation of bank was done using identification and measuring the damage or concretes slabs, erosion of banks, joints, etc.

WP = water pools, it was determined by evaluation the variation of movement of water (water stagnation) due to the sediment deposition; WG = Weed growth, it was determined by measuring the length of canal within weed infestation divided by the total length of the considered canal and; CL = Conveyance losses, a direct measurement technique using inflow- outflow was used to estimate magnitude of losses in the main and secondary canals. After determining the value (percentage) of each parameter, the rank which is corresponding with the value was multiplied by the weightage of the parameter to find the canal condition.

iv) Command Area Development

Command area development (CAD) of water infrastructure project was evaluated by the cropped area (CA), regulatory constraints (RC) and water sharing issues (WSI). The observed conditions were grouped into class, ranked and assigned weightage (Zende and Nagarajan, 2013) (Appendix 3).

$$CAD = \left[\left(CA\ rank\ x\ weightage \right) + \left(RC\ rank\ x\ weightage \right) \left(WSI\ rank\ x\ weightage \right) \right] \quad \ldots.$$

(4)

Where:

CAD = Command area development; CA= cropped area. It is a ratio obtained by dividing the current area cultivated by the total area of the scheme; RC= regulatory constraints, it was determined by identifying the main constraints that include water shortages, lack of agricultural inputs (fertilizers, soil credits and low yield; WSI= water sharing issues were determined by identifying how well the water is shared within the head-tail farmers during water scarcity using a questionnaire survey, focus group discussion and key informants data. After determining the value (percentage) of each parameter, the rank that corresponds with the value was multiplied by the weightage of the parameter to find the command area development.

2.2.3.2 Root causes and effects of performance of irrigation structures

To determine the causes and effects of performance of irrigation structures, data collected from respondents using questionnaires, focus group discussion and key informants were descriptively analysed using SPSS (Statistical Package for Social Sciences) (IBM SPSS version 21).

2.2.4 Sampling methodology and data collection

Personal visits and field work were conducted to identify the number of working and non-working structures during the study period. The main, secondary and tertiary canals were inspected and evaluated to determine the structure condition, cleanliness, operation and maintenance. Different data sets such as Structure Condition Index (SCI), Intake Efficiency (RSE), Canal Condition (CC) and Command Area Developments (CAD) were determined to evaluate the performance indicators of water infrastructures. Moreover, a household survey, Focus Group Discussion and key informants interviews were conducted to identify the root causes and effects of the performance of irrigation structures. To obtain a representative sample according to Bailey (1994), the sampling frame was stratified into three strata (head, middle and tail); from each stratum a simple random sampling technique was used to select 30 respondents among the farmers, making 90 respondents in total. The key informants included two (2) Irrigators' Association leaders, one (1) Kidwebezi Water Officer, one (1) Cooperative Officer, two (2) experienced paddy farmers for many years and (2) SRDI Staff Managers. Ten (10) participants (5men and 5 women) for Focus Group Discussion and 8 key informants were selected, making a total of 108 respondents. Key informant interviews were conducted using a prepared checklist.

2.3 Results and Discussion

2.3.1 Performance indicators of irrigation structures

2.3.1.1 Effectiveness of infrastructure

Table 2.1 presents results on the effectiveness of the irrigation infrastructure. A total of 101 structures were identified at the Kidwebezi Irrigation Scheme, including 16 drop structures, 30 turnouts, 6 diversion boxes, 30 check structures, 6 culverts, 8 cross regulators, 2 aqueducts and 3 level crossings. Results show that 14 out of the 16 drop structures functioned well, providing a structure condition index or effectiveness of infrastructure of 87.5%. The results further show that nearly all the infrastructure, except for culverts and level crossings, did not function at their best level, with the structure condition index ranging between 50% for aqueducts and 87.5% for drop structures.

Overall, the effectiveness of infrastructures was 84.16%. The good operational condition or status of this structure is likely due to the fact that, first, the scheme is small and has no sophisticated structures and secondly, the simplicity of the mode of operation. Results indicate that non-operational structures represent about 15.84 percent of the total identified structures. For non-operational structures, farmers have to make some modifications in conveying farm water into their plots using the grasses or other means to divert them to the canals.

Table 2.1: Evaluation of functioning and none functioning structures

Structure type	Number of structures	Number of working structures	Number of poor structures	Effectiveness of infrastructure (%)
Drop structures	16	14	2	87.5
Turnouts	30	24	6	80.0
Division boxes	6	5	1	83.3
Cross regulators	8	6	2	75.0
Check structures	30	26	4	86.7
Culverts	6	6	0	100
Aqueducts	2	1	1	50.0
Level Crossings	3	3	0	100
Total	101	85	16	84.16

The results are in agreement with others findings: Nelson (2002), had found a structure condition index (SCI) or effectiveness of infrastructure of 89% in Nigeria and Mchelle (2011) in Tanzania, reported the effectiveness of infrastructures of 0.9, or 90% of the structures were in good working condition in her study area of rehabilitated irrigation systems in the Igomelo irrigation scheme in Tanzania. Nonetheless, the high SCI observed in the Kidwebezi irrigation scheme does not mean that there is no problem with operation and maintenance. Results indicate that some portions along the canals had concrete slabs and linings removed along with the non-operational structures. Consequently, there is a certain amount of water that did not reach the farmers fields and was lost in the canals without reaching the plots.

2.3.1.2 Intake efficiency

Results on the physical condition assessment of the intake are presented in Table 2.2. It is shown that about 20% of the intake water systems were not effective. This was caused by sedimentation level (10%), weak embankments leading to leakage (7%) and the condition of the sluice gate operations (3%). When the water from a river arrives at the intake, a certain quantity of water accumulates up to a certain level before going towards the main canal. Over time, alluvium settles on the bottom and silt deposition reduce the amount of water that leads into the canal. After a certain time, the banks also deteriorate, leading to leakage, not forgetting the functioning of the valves, which deteriorated over time.

A physical examination of the intake reveals that it was operating at 80% efficiency. According to Vermillion *et al.* (1999), a deviation of more than 5% of structure defectiveness would signal the need for maintenance or rehabilitation of flow control structures. The intake efficiency at the Kidwebezi Irrigation Scheme can be considered not well maintained and is an alarm worth noting. That could be due to the fact that the structure is among the important ones that need the special fund from the Agency.

Table 2.2: Physical condition assessment of intake at Kidwebezi irrigation system

Parameter	Difficulty class in terms of operation (%)	Rank	Weight age (%)	Difficult value in operation (%)	IE (%)
Sediment level (SL)	11-30	4	50	10	40
Embankment level (El)	11-30	4	35	7	28
Sluice gate (SGL)	Close to gate	5	15	3	12
Total	-		100	20	80

2.3.1.3 Canal condition

The results in Table 2.3 reveal that the difficulty in operating canal conditions was found to be 20 per cent due to bank collapse, 6%, water pools in the canal, 4%, weed growth, (2%) and conveyance losses of 8%. This means that 80 per cent of the canal condition was found to be working well as a networking system.

Table 2.3: Physical condition assessment of canals

Parameter	Difficulty class (%) in terms of operation	Rank	Weightage (%)	Difficult value in operation (%)	CC (%)
Bank Collapse (BC)	11-20	4	30	6	24
Water pooling (WP)	21-30	4	20	4	16
Weed growth (WG)	11-30	4	10	2	8
Conveyance loss (CL)	11-20	4	40	8	32
Total	-		100	20	80

The evaluation of physical condition at Kidwebezi Irrigation Scheme indicates that the canal was maintained at a level of 80 per cent. In general, the findings for canal condition are poor when compared to the standard value of 15% of defectiveness proposed by Vermillion *et al.* (1999). However, the findings are different from those reported by Zende and Nagarajan (2013), who reported the canal condition to vary between 42% and 76.5% due to weak or damaged embankments. The difference in value of findings can be due to the difference in the region where the study was conducted and also to the type of structures evaluated. The systematic measurement of different canal samples as shown in Figure 2.3 revealed that 143m out of 4896 m (2.93%) of the lined main canal were damaged or poorly maintained, 120 m out of 3580 m (3.69%) of the lined secondary canals were poorly maintained and 192m out of 1280 m (15%) of the unlined secondary canals were found to be poorly maintained. The results further show that the poor maintenance of the sampled three tertiary canals was 33.33%, 27.59% and 29.42% at the head, the middle and the tail, respectively.

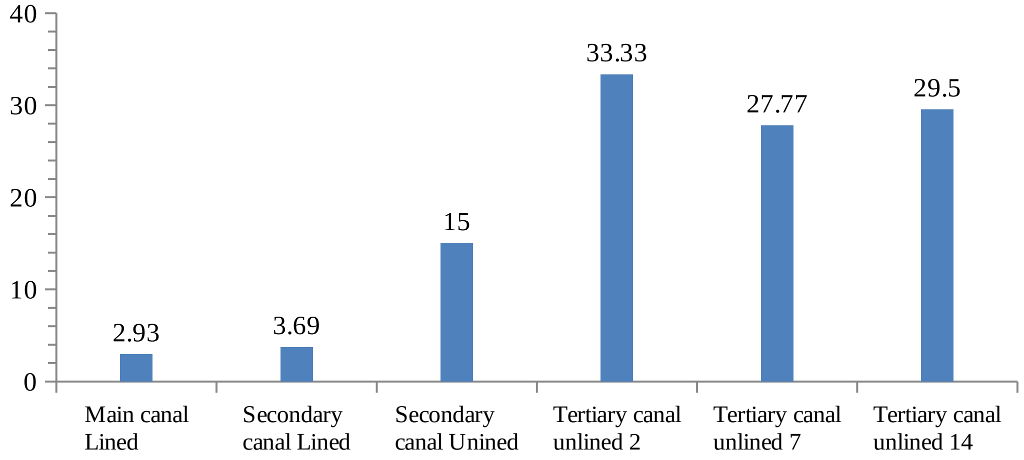

Figure 2.3: Percentage of poor maintenances on canals

Based on characterization of the condition of structures proposed by Vermillion *et al*. (1999), a deviation of more than 5% would signal the need for maintenance or rehabilitation for flow control structures while an average of 15% of the canals length which is defective is considered relatively high. It means that the lined main and secondary canals are in good condition due to its value being below 5%.

During the study, it was observed in the lined canals that there were some portions that were seriously damaged by farmers' regularly by illegally abstracting water at the upstream. However, in unlined secondary and tertiary canals, only a few canals were maintained. Normally, the tertiary canals get cleaned before the beginning of the season and in the middle of the season to allow the water to reach the plots easily, but according to what was observed during the study period, they were poorly maintained. The high percentage of poor maintenance observed in unlined canals classified them as significantly very poor because it was above the 15 per cent proposed by Vermillion *et al.* (1999). Lack of maintenance was identified as the major cause of the poor effectiveness of structures. This has a significant impact on paddy production and results in lower farm income.

2.3.1.4 Command area development

The command area development, as shown in Table 2.4, indicates that 12 per cent of the area was not functioning due to several reasons, including water flow constraints of 4% and water sharing issues of 8%. This means that 88 per cent of command area development was found to be in good working condition.

Table 2.4: Command area development assessment

Parameter	**Difficulty class in terms of operation (%)**	**Rank**	**Weight age (%)**	**Difficult value in operation (%)**	**CAD (%)**
Cropped Area (CC)	<10	5	60	0	60
Regulatory Constraints (RC)	20	4	20	4	16
Water Sharing Issues (WSI)	40	3	20	8	12
Total	-		100	12	88

For the command area development, the evaluation of the physical condition of the scheme has revealed that the scheme is at 88 per cent in terms of good management issues, which is acceptable. Zende and Nagarajan (2013) reported similar results, with 85 percent of the command area development reported. From our observations, we have also seen that even where the maintenance and cleaning of earth tertiary canals were done, the specific standards were not reached because some of their sections had already lost their original size. For example, the top width currently ranges from 1.5 m to 3.0 m, while the design specification was 1 to 2 m.

2.3.2 Factors that influence the performance of irrigation structures

2.3.2.1 Household heads characteristics

The main socio-economic characteristics of the survey sample are summarized in Table 2.5. The different variables used are age, gender, education level, land size and land tenure and years of irrigation experience of the household heads. The age of household heads ranged from 23 to 85 years, with an average of 48 years.

The age of farmers is taken as farming experience and has had a positive influence on the understanding of the importance or necessity of keeping structures in good working order. The results also show that 83.3% and 16.7% of the respondents were males and females, respectively. The dominance of men is a reflection of traditional African values where the man is recognized as the head of the household and is often in charge of technical and capital-demanding innovations (Urassa, 2015). Very few women are landholders due to the culture of Burundi, like many countries in Africa. However, the lack of women in the household heads farmers is a loss because the women are by nature workers in the field which could contribute to maintain the infrastructures especially the tertiary canal network.

Table 2.5: Age, gender and education level of the respondents (N=90)

Parameter	Frequency	Percentage
Age		
15-34	12	13.3
35-54	37	41.1
>55	41	45.6
Gender		
Male	75	83.3
Female	15	16.7

Education level		
Informal	36	40.0
Primary education	39	43.3
Secondary education	15	16.7
University education	0	0.00
Total	90	100

The findings show further that 43.3% of the farmers had primary education, while 33.3% of the respondents did not attend any formal education; the remaining 16.7% of the respondents had completed secondary education while none of the farmers has reached the university education level. The educational background of farmers influences the degree to which they can access innovative technical solutions that may lead to the best understanding, especially in the maintenance of irrigation structures. The results show that the low education level of majority of farmers in KIS has negatively influenced the performance of irrigation structures; the farmers have not been able to take ownership the maintenance works of the scheme as their own.

The findings in Table 2.6 show also that 47.8% of the respondents had a plot size of 0.5 ha, 38.9% had 0.25 ha and 13.3% had a plot size of 0.75 ha. The results further results show that 41.1% of the land household was purchased, 27.8% was given by government agency (SRDI), 27.8% were inherited from parents and 3.3% was rented. Land is very important to small farmers. The present land ownership influenced the participation of the farmers especially in planning stage of activities, operation and maintenance because the majority of farmers have purchased the land and lives far from their scheme.

Table 2.6: Land size and tenure of household head

Size of plot (ha)	Frequency	Percentage (%)
0.25	35	38.9
0.50	43	47,8
0.75	12	13.3

Total	90	100
Land tenure		
Purchase	37	41.1
Given by Government	25	27.8
Inherited	25	27.8
Rented	3	3.3
Total	90	100

2.3.2.2 Farmers opinion on maintenance of structures

During focus group discussion, the findings have shown that the farmers of Kidwebezi Irrigation Scheme had no interest for participating in maintenance works. They consider that the water fees they paid are enough to cover every activity of operation and maintenance of structures. 85% of participant said that they were not happy of the water fees payment system. Farmers attributed the unhappiness of paying water fees to the lack of transparency.

2.3.2.3 Causes of poor maintenance of structures

In terms of poor maintenance structures, results in Table 2.7 show that 46.7% of the respondents attributed poor performance to the poor leadership or poor organization of the work, 40% to the inequity of water allocation and distribution, 10% due to the lack of interest by the farmers in participating in maintenance work and 3.3% to the insufficient funds made available to the management.

Table 2.7: Factors causing poor maintenance of structures

Factors causing poor maintenance of structures	Frequency	Percentage
Lack of interest by the farmers in maintenance works	9	10.0
Insufficient funds made available to the management	3	3.3
Poor leadership and poor organization of the work	42	46.7
Inequity in water allocation and distribution	36	40.0
Total	90	100

During the focus group discussion, the majority of the participants pointed out that the increasing uncontrolled paddy farming is the source of the destruction of canals and has a negative impact on the paddy production of the Kidwebezi Irrigation Scheme. Normally, the existing infrastructure, designed by Government, were planned to irrigate only 85 ha at Kidwebezi, Irrigation Scheme in 1985, with a flow rate of 699 l/s. But, the pressure due to the increasing of population was leading to the expansion of paddy farming where more than 200 ha of paddy field have been initiated and cultivated near the scheme demanding more water which was not planned. According to key informants, the irrigation infrastructures are destroyed both at the farm level and at the collective shared infrastructures, as reported by more than 80% of the respondents. They argued that the increasing illegal (developed around the scheme) paddy farming located upstream diverted irrigation water directly into the head channel. The current water irrigation regulations do not have clear punishment to those water thieves, which is why the phenomenon of stealing water continues to be reported along the canal network among the head and tail farmers, leading to the overuse of water for some, while others are suffering from water shortage.

2.3.2.4 Agreeable status regarding transparency of the irrigator 'association in governance structures

Findings in Table 2.8 present the degree of Irrigator' Association (IA) in terms of governing water structures in the Kidwebezi Irrigation Scheme. The columns of disagree and strongly disagree suggest that the Irrigator' Association is not transparent in terms of selecting IA members for a position (37.7%), in term of contractors for infrastructure construction or maintenance (53.3%) and is not strong enough to resolve conflicts related to the problems of irrigation structures (40%). However, the results indicate that the specific criteria exist for the selection of a member in Irrigator' Association posts (7.8%) and for the information on sluice gate operation and maintenance of infrastructures are transparent (6.7%).

Table 2.8: Respondents ‘responses on effectiveness of IA (n=90)

Topics for discussion	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
Existence of criteria for selection of post in IA	3.3	7.8	20.0	57. 8	10.0
Transparent selection occurs for position of IA	17.7	30	8.9	33.3	10.0
Information on sluice gate operation is transparent.	0.0	7.8	22.2	60.0	10.0
Information on maintenances of infrastructures is transparent.	0.00	6.7	8.9	70.0	14.4
IA takes legally entitled advantages transparency from contractors	13.3	40.0	13.3	30.0	3.3
Ability of IA to resolve conflicts related to the problems	8.9	31.1	14.4	40.0	5.6
Average	7.2	21.0	14.6	48.3	8.9

Looking at the column for agree and strongly agree, the Table 2.8 shows that the Irrigator’ Association was effective in terms of transparency in delivering information on sluice gate operation (70%) and maintenance of infrastructure to all farmers (84.4%). Nevertheless, the overall results on the agreeable status of the Irrigators' Association regarding transparency in governance structures show that 28.2% denied the existence of transparency, 57.2% recognized it while 14.5% were neutral.

In addition, good maintenance depends on the effort provided by farmers and the quality of canals depends on how active and devoted various canal committees are. Sometimes, the problems of responsibilities and tasks are often observed, but they are defined only in general terms and not sufficiently detailed to be practicable. In other cases, farmers' responsibilities are clearly spelt out, but there is no mechanism for control or sanctions/penalties. Farmers and the government sometimes blame each other, waiting for the other party to take action. During the focus group discussion, 80% of the participants confirmed that maintenance and repairs are only carried out when someone reports a problem. Once reported, the IA notifies the representative of a government agency if it concerns the main system, which is managed by the government but has no power over it. An urgent meeting of IA is called to take action in case of problems concerning the tertiary canals. Maintenance issues have been reported as sources of conflicts among farmers. For example, if two neighbours have to clean their portion along the canal and there are others who refuse to clean their part within the same canal, the water will not reach the other side and the maintenance will not be effective. In that case, it is the responsibility of the IA to take a decision to maintain a controlling network in the canal.

However, reports from focus group discussions and key informants illustrated that majority of the farmers pointed out the existence of weaknesses by IA in water decision making, especially in control, collective actions and conflict resolution mechanisms. For instance, the farmers claimed that the increasing fields developed at the upstream of their scheme are the origin of the lack of water observed, but the IA does not do anything to rectify that situation. The findings correspond well with those of Ndayizigiye (2009) who reported that the increasing uncontrolled paddy farming reduces the performance of infrastructure.

2.4 Conclusion and Recommendations

2.4.1 Conclusion

In this study, the performance of structures for the Kidwebezi Irrigation Scheme was assessed through the identification of factors that limit its efficiency. Our inspection and evaluation of the entire irrigation scheme to identify the number of working and non-working structures and based on the responses from the survey, focus group discussion, and key informants, results of this study showed that effectiveness of the infrastructure at Kidwebezi Irrigation Scheme is performing at 84.16 percent. However, the poor performance of irrigation structures observed is attributed to:

i. Poor leadership and poor organization of the work, improper canal operation and maintenance;
ii. Over-increasing and uncontrolled expansion of paddy cultivation fields;
iii. Lack of operation and maintenance of the hydraulic structures on time; and
iv. Finally, the lack of transparency of IA in their routine activities.

2.4.2 Recommendations

i. The Government Agency (SRDI) should put more effort into irrigation water management aspects, including the maintenance of canals and drains, which are sources of lower water supply efficiency.
ii. The Irrigators Association Committee should improve their organization and transparency in their daily activities of operation and maintenance of the structures.
iii. The Government and IA should have an adequate legislative arrangement on responsibilities. It is very important to define the role of the farmers, the degree of Government involvement, in financing as well as the responsibilities for execution and control of irrigation infrastructure at all levels.

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CHAPTER THREE

3.0 EVALUATION OF IRRIGATION SYSTEMS USING TECHNICAL PERFORMANCE INDICATORS AND FARMERS' KNOWLEDGE IN BURUNDI

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ABSTRACT

Many irrigation schemes developed in Burundi indicate to perform below their potential. Major causes of poor performance are mainly due to the inequitable water distribution and mismanagement. This study aimed to evaluate the irrigation system using performance indicators and farmers' knowledge. The task involved the determination of irrigation water allocation and distribution at main, secondary and tertiary canals. Based on the climatic data and discharge data, the conveyance efficiency, the adequacy, the efficiency, the dependability, the equity of water supply and the water productivity were determined. Results of conveyance efficiency indicate that 82.48%, 80.40% and 66.38% of water conveyed by the system in lined main canal, lined secondary canal and unlined secondary canal, respectively reach the destined farms. The results show further more that the system of water distribution was good and poor in terms adequacy and efficiency and fair to both dependability and equity. The water productivity was 0.97, 1.36 and 1.41 kgm^{-3} and water

productivity performance was 1.06, 1.64 and 1.85 at the head, middle and tail, respectively. The study suggests adding more efforts for improving efficiency, temporal uniformity and equity in water allocation.

Key words: *Conveyance Efficiency, Delivery Performance, Water Productivity*

3.1 Introduction

Irrigated agriculture has played a significant role in increasing global food production and food security (Masya, 2016). In Africa, agriculture is one of the most important social and economic sectors where more than two thirds of people's livelihoods depend on farming and two thirds of poor people's household budgets are used for food (FAO, 2016). As a consequence, improving the wellbeing of people depends for a major part on the performance of the agriculture sector in Africa. Moreover, the performance of agricultural sector is low and hunger continues to be risky in Sub-Saharan Africa. Agricultural transformation is needed to address these challenges and irrigation is one pillar to contribute to such transformations (Feltz, 2016). Nevertheless, the achievement of irrigation system in agricultural management depends on the amount of water supply, demand and rational allocation of water in meeting the demand or in reducing the gap between supply and demands. The achievement of an irrigation water delivery system can be assessed by how well it meets the objectives of delivering the right amount of water at the right time and place (Dobriyal *et al*., 2017).

Moreover, different indicators of measuring irrigation system performance have been developed by several authors: (Abernethy, 1990; Bos and Nugteren, 1990; Molden and Gates, 1990 and Amarasinghe *et al.*,1998. The indicators are based on efficiency, dependability and equity of irrigation water supply. These indicators can be classified into two categories: (i) water allocation (Bos and Nugteren, 1990) such as of adequacy, efficiency, dependability and equity internally and (ii) water allocation outcomes (in the form of economic revenue, environmental effect and agricultural production externally (Molden *et al.*, 1998; Sanaee-jahromi and Feyen, 2016). In addition, other indicators have been used to monitor performance, in terms of land and water productivity, water availability, sufficiency and fairness in water allocation (Borsato *et al.*, 2020).

Water use in Burundi is mutually shared by three sectors: (i) agriculture (79.26%), (ii) domestic (15.39%) and (iii) industry (5.35%). Irrigation has become the most important factor in the agricultural sector in Burundi due to climate change and weather variability. Irrigation, on the other hand, is limited to surface irrigation (ponds, ditches, and furrows) and is in poor condition (FAO, 2020). Burundi has significant potential for irrigable land both in wetlands and plains (83 000 ha) but only 2430 ha (20.6%) of agricultural area are equipped for irrigation. The expansion of area equipped for irrigation could increase crop intensification, increase yields and reduce losses caused by irregularities in rainfall (Gahiro, 2013).

Additionally, the introduction of the system of rice intensification (SRI) has shown that yields of paddy could go from 2 to 7 tons per hectare under average condition of implementation of the technique and if water control was ensured as well as quality seeds and fertilizers (Ndayizigiye, 2009). However, for the vast majority of farmers, irrigation control necessitates a conceptual shift and the acquisition of new technical skills (Gahiro, 2013).

Several researches (Ndayizigiye, 2009; Gahiro, 2013) have been done to evaluate the performance of irrigation schemes in Burundi. However, little is known about the performance of the water delivery system in the Burundian agricultural sector. Thus, there is a need to assess the irrigation water delivery and consumption patterns in order to identify and propose the improvement in the irrigation water management. The specific objective of this study was to evaluate how well water delivery indicators performed in terms of adequacy, efficiency, dependability and water productivity at Kidwebezi Irrigation Scheme.

3.2 Materials and Methods

3.2.1 Description of study area

The study was conducted at Kidwebezi Irrigation Scheme located in Mpanda District, Bubanza Province in Burundi's western region (Figure 3.1). The scheme is about 25 km from Bujumbura capital city. The scheme covers an area of about 83 ha and lies at Latitude of 3º 11' 60" South and Longitude 29º 23' 59" East. Kidwebezi is situated in the Imbo plain, one of the eleven regions of Burundi. The Imbo plain is a lowland area with an average elevation of 1000 m above the sea level. The rainfall regime in this zone is bimodal, with a short rainy season from October to January and a long wet rainy season between March and May. The annual rainfall in this zone ranges between 700 and 1000 mm and the temperature ranges from 24°C to 28°C and has a dry season of about five to six months. The major activities of the people of Kidwebezi include farming and livestock keeping.

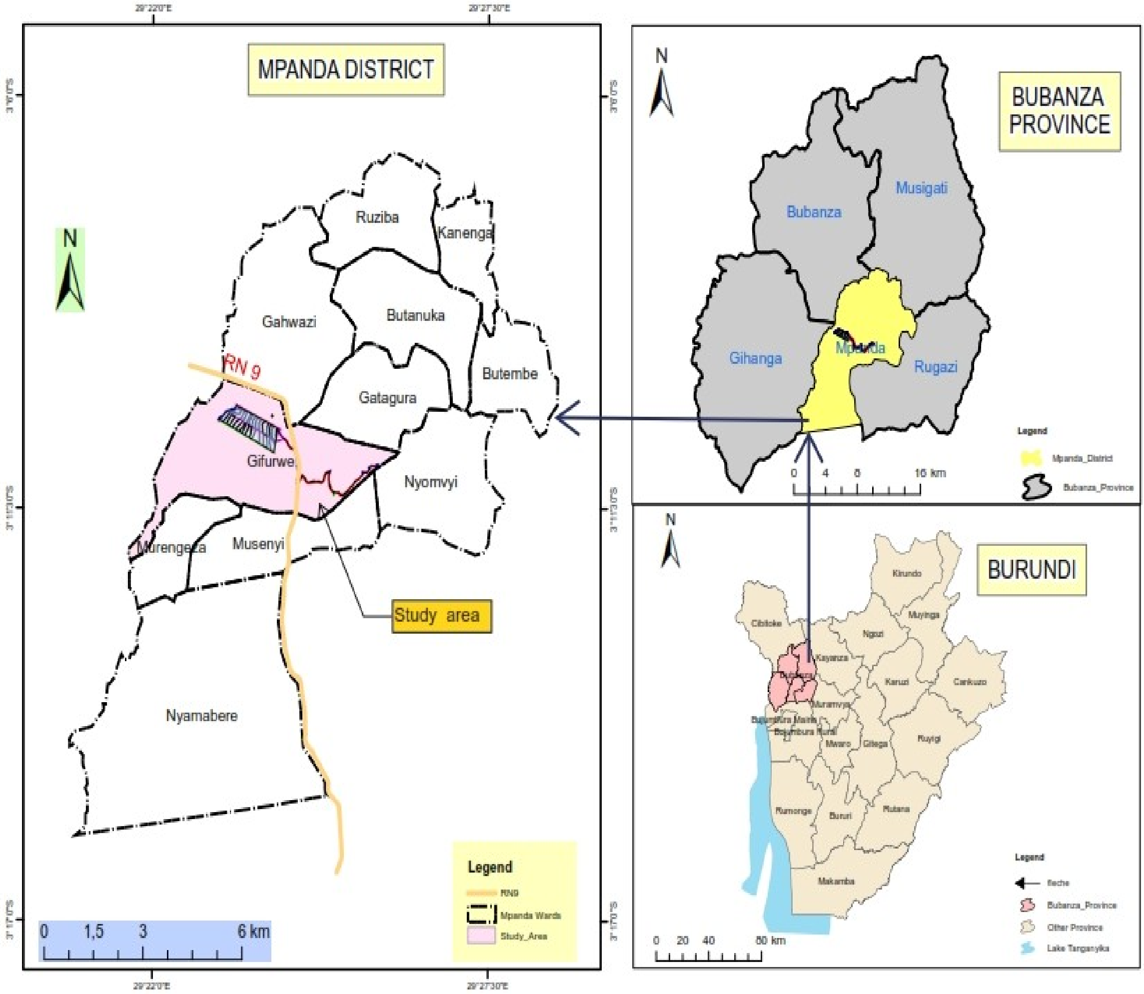

Figure 3.1: Sketch Map showing location of the study area

3.2.2 Scheme layout

From Gifurwe River diversion, water is conveyed by gravity to the Kidwebezi irrigation scheme by a lined main canal which runs for about 4.9 km from the intake to secondary canals. The main canal is divided into two secondary canals just before reaching the fields. Then, through the two secondary canals, one on the right (SC1) another on the left (SC2), divert water from the main canal and distribute it into the tertiary canals. The secondary canals are both divided into 15 tertiary canals which irrigate from plots of different size designed in way that facilitate their management and easiness of water distribution. Also, the scheme comprises field drains, two collector drains and the main drain to remove the excess water from the field (Figure 3.2).

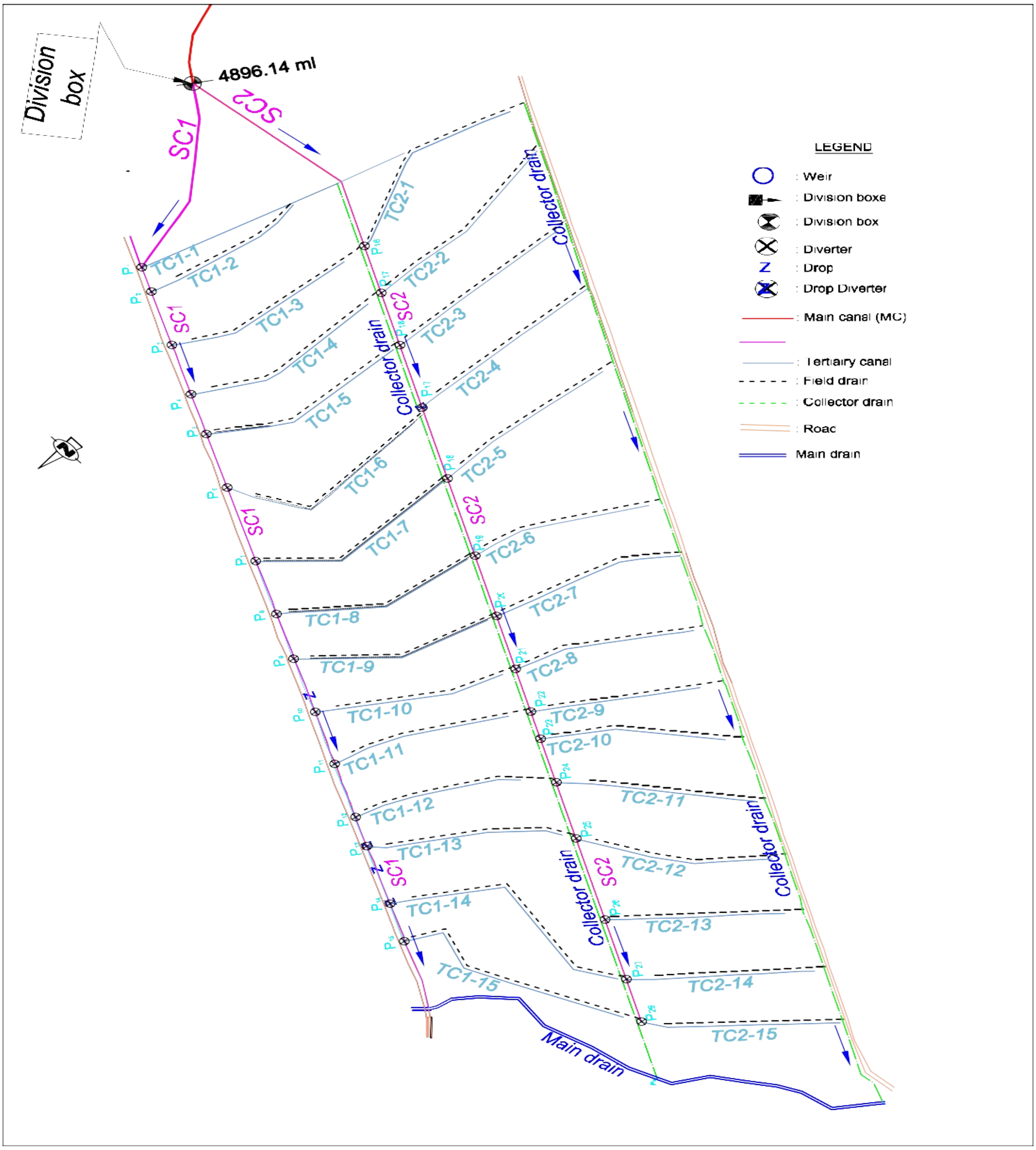

Figure 3.2: Layout of Kidwebezi Irrigation Scheme

3.2.3 Methods

3.2.3.1 Estimation of crop water requirement

Climatic data used were collected at Gihanga meteorological station. Mean daily weather conditions data for 20 years (2001-2020) such as relative humidity, temperature (min and max), wind speed and radiation were used to determine (ET_O) using INSTANT computer program. The FAO Penman-Montheith methodology through the CROPWAT 8.0 windows program was used to determine reference evapotranspiration (Allen *et al.*, 1998). Crop coefficient for cultivated crops was obtained from FAO guidelines for crop water requirements (Allen *et al.*, 1998). Crop evapotranspiration was calculated as a product of crop coefficient (K_C) and reference evapotranspiration (ETo), as given in Equation 1.

$$ETc = Kc \ x \ \ ETo \qquad \text{……………………………………………………………….} (1)$$

Where:

ETc = Crop Water Requirements (mm/day); Kc= Crop Coefficient; and

ETo = Reference Evapotranspiration (mm/day)

The estimation of net irrigation requirement (In) does not include losses that are occurring in the process of applying the water. It is delivered from the field balance Equation 2.

$$In = ETc - Pe \qquad \text{……………………………………………………………….……..} (2)$$

Where:

In= Net irrigation requirement; ETc = Crop water requirements (mm/day); and

Pe = effective dependable rainfall (mm); Pe = 0.8P- 25 if P> 75 mm/ month and Pe =0.6P-10 if P < 75 mm/ month (FAO, 1994).

The gross irrigation requirement accounts for losses of water incurred during conveyance and application to the field. When calculated from net irrigation requirement, it is expressed in terms of efficiency, as shown in Equation 3.

$$Ig = \frac{In}{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

Ig = the Gross irrigation requirement (mm); In = the Net irrigation requirement (mm); and E = the overall project efficiency, E = 45% for surface irrigation (FAO, 2018).

3.2.3.2 Technical performance evaluation

Technical performance indicators used in this study included the measurement of conveyance efficiency and water delivery performance in the main canal and secondary canals.

a) Conveyance efficiency

Conveyance efficiency was estimated by measuring inflowing and out flowing water along the selected canal lengths. The efficiency is affected by different factors including canal lining, evaporation of water from the canal, technical and managerial management facilities of water control (Burt, 2001). It is expressed by Boss *et al*. (1993) in Equation 4.

$$Ec = \frac{Wf}{Wd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:

Ec = conveyance Efficiency; Wf = water delivered and Wd = water diverted

b) **Water delivery performance**

The most basic and short-term performance indicators compare the actual discharge to the expected or target discharge at any given time of the season (Bos *et al*. (1993). The most important hydraulic performance indicators are delivery performance ratio (DPR) and water delivery performance (Molden and Gates, 1990 and Molden *et al.*,1998). According to Clemmens and Bos (1990) and Bos *et al*. (1993) the delivery performance ratio and water delivery performance are calculated using the Equations 5 and 6.

$$\text{Delivery Performance Ratio} = \frac{\text{Actual Discharge}}{\text{Target Discharge}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

$$\text{Water Delivery Performance} = \frac{\text{Actual Volume}}{\text{Target Volume}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...$$

(6)

3.2.3.3 Irrigation efficiency indicators

Irrigation efficiency is an evaluation of hydraulic conditions in a spatial context over a specific time period. Irrigation efficiency is usually measured in terms of volume delivered over a period of time rather than instantaneous discharge. Bos and Nugteren (1990) have discussed in detail the indicators of efficiency, the most important ones are efficiency, adequacy, dependability and equity.

i. Efficiency

Efficiency embodies the potential to conserve water by comparing water delivery with water requirement. The determination of water efficiency is calculated using the Equation 7 as proposed by Molden and Gates (1990).

$$P_F = \frac{1}{T}\sum_T\left(\frac{1}{R}\sum_R \frac{Q_R}{Q_D}\right)$$

Where:

PF= efficiency of irrigation water supply; Q_D = amount of water delivered;

Q_R =amount of water required; T = one irrigation season (days); R=one region R

ii. Adequacy

The two most important aspects in irrigation planning, design, and operation are the available water supply and the water demands (Sakthivadivel *et al*., 1993). The ratio of supply to demand constitutes an important concept named Relative Water Supply (RWS), as firstly described by Levine (1982) and Abernethy (1990). This indicator provides information about the relative abundance or scarcity of water. The determination of adequacy is calculated using the Equation 8.

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Total crop water requirement}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The total water supply is the summation of actual irrigation water supply by system via irrigation canals and the total rainfall; and the term crop water requirement is defined as the amount of water needed to compensate the evapotranspiration loss from the cropped field for a specific time. Crop water requirement is estimated by CROPWAT model simulation (Allen *et al.*, 1998). When the volume delivered exceeds the volume necessary, the amount delivered is accepted as adequate; a value of less than 0.80 is considered insufficient water supply (Molden and Gates, 1990). However, in paddy field the required relative water supply is 2.5.

iii. Dependability of water supply

Dependability refers to the system's ability to provide water at the desired time and in the desired location The predictability of water deliveries is concerned with the time of water delivery compared to the planned time (Bos *et al.*,1993). This indicator has been presented by Molden and Gates, (1990) as:

$$P_D = \frac{1}{R}\sum_R CV_T\left(\frac{Q_D}{Q_R}\right) \qquad \text{..................} \quad (9)$$

Where:

P_D = Dependability of irrigation water supply; CV_T = Temporal coefficient of variation; Q_D = Amount of water delivered; Q_R = Amount of water required; R = the region R; T= one irrigation season. CV_T (Q_D/Q_R) = temporal coefficient of variation of the ratio Q_D/Q_R over the region R. Dependability in water is greater when P_D approaches zero in delivery.

iv. Equity

According to Molden and Gates (1990), Equity of irrigation water supply is defined as the delivery of fair share of water to all irrigators' rights through the system. However, equity does not mean automatically equal but equity is the achieving of a fair distribution of water. Equity express the degree of variability in relation to water delivery from point to point over the irrigated area (Nam *et al.*, 2019). Equity is calculated using Equation 10.

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

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; and T= one irrigation season (days). CV_R (Q_D/Q_R) = Spatial coefficient of variation of the ratio Q_D/Q_R over the region R. Equity in water is shown to be greater when P_E approaches zero (spatial uniformity) in water delivery (Molden and Gates, 1990).

3.2.3.4 Determination of water productivity (WP)

Kijne and Barker (2003) defined water productivity (WP) as a reliable indicator of an agricultural system's ability to turn water into food. The ratio of crop output to irrigation water applied by the irrigation system during crop growth is known as irrigation water productivity (Kazbekov *et al.*, 2009, Molden, 2010). Water productivity can be expressed in physical or economic terms as factor of productivity. It is expressed in terms of weight (kg) or even in monetary terms ($) to comparison different crops (Molden *et al*.,1998). The determination of water productivity is calculated using the Equations 11 and 12 (Molden, 2010).

$$Water\ Productivity = \frac{Output\ delivered\ from\ water\ use}{Total\ water\ input} \qquad \text{......................(11)}$$

.(12)

$$Water\ Productivity\ Performance = \frac{Actual\ water\ productivity}{Target\ water\ productivity}$$

3.2.4 Data collection

In this Study, different methods and activities were used to collect data such as field measurements. Field measurements were conducted to evaluate the performance of irrigation system at the main, secondary and at the sampled tertiary canal. The field data were collected to evaluate performance indicators using performance indicators proposed by Molden and Gates (1990). These indicators include water delivery, water use efficiency, water productivity and environment aspect. Moreover, in order to collect important information related to irrigation water management, the degree of farmers' knowledge in crop water requirement, irrigation water use practices and their impact on paddy productivity, the Questionnaire, Focus Group Discussion and Key informants interviews were conducted.

i) Determination of the discharge

The amount of water flow passing in the main, secondary and tertiary canals was measured and collected using floating method. This 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) is determined by multiplying the cross sectional area of water by average velocity of the water. It is expressed by the following formula (FAO, 1994):

$$Q = AV \qquad (13)$$

Where:

Q = stream discharge (m^3/s); A = cross-sectional area in m^2 and V = surface flow velocity in m/s. To estimate the surface flow velocity, a floating object is placed in the centre of the canal (20 metres along the canal) and time measurement was repeated five times to avoid mistakes of the velocity estimation. In order, to obtain the average velocity, the surface velocity was reduced by using a correction factor k of 0.85 which is a commonly used value (Pariva and Syed, 2016).

The flows were monitored weekly at the main and secondary canals and at 6 turnouts on tertiary canals sampled randomly (two at the head, two at the middle and two at the tail) during growing season from January to April 2021.

ii) Determination of volume of water delivered, target and required per season

Based on CROPWAT calculations, irrigation water deliveries were determined during the growing season (from January to April). Hence, Q_D and Q_R values were determined monthly. Farmers using water from the downstream farmers claimed that they get less water than upstream farmers. To study this claim, Q_D and Q_R were determined for the head, middle and tail of the secondary and sampled tertiary canals.

The amount of water delivery (Q_D in m^3) was determined using the product of actual discharge (m^3/s), the duration of irrigation per day (sec) and number of irrigation days for each stage. Total target volume (m^3) was determined by multiplying the scheme area by irrigation interval, irrigation duration (24 hours divided by number of hours per day) and target discharge (m^3/day). The amount of water required was determined by multiplying the gross irrigation (mm/day), irrigation interval (day), duration of irrigation (24h per irrigation time in h) and area to be irrigated (FAO, 1989) (see Appendix 2.4).

iii) Coefficient of variation (CV)

Coefficient of variation (CV) is an indicator to determine the variation discharge in secondary canals. The CV is the measure of variability which suggests the variability of discharge and checking how it changes at a single location. The Coefficient of variation is the ratio of standard deviation to the mean. It was calculated using the Equation 14 (Clemmens and Molden, 2007).

$$CV = \frac{Standard\ Deviation\ of\ Discharge}{Average\ Discharge} \tag{14}$$

3.2.5 Data analysis

The data collected from respondents using questionnaires, focus group discussion and key informants were descriptively analysed using SPSS (Statistical package for social sciences) (IBM SPSS version 21). Descriptive statistics was employed for the analysis of the data collected from field measurements. Spatial and temporal distribution of required, scheduled and delivered water was used to evaluate the water delivery performance.

3.3 Results and Discussion

3.3.1 Degree of farmers' awareness crop water requirement

Results in Table 3.1 show that 100 per cent of the respondents do not keep recording irrigation water applied in their farm plots throughout the growing season. Farmers do not have enough knowledge to compute the quantity of water applied. This can be attributed to the degree of weakness of the extension service and lack of training on crop water requirement. None of the farmers has the awareness of water applied throughout the season.

As for the factors influencing farmers' decisions on when to irrigate, results show that about 50% of the respondents reported that they decide when to irrigate by using a fixed number of days between irrigations fixed by the water committees, 3.3% just use the available moisture content by observations, 10% use crop appearance while 36. 7%tdoes not consider any factor on deciding when to irrigate just follow the schedule (Table 3.1). It was further observed that, most of the farmers lack understanding of when a crop requires different amount of water at different stages. Lack of knowledge on crop water requirement is a common problem to many irrigation schemes in Burundi. That has a consequence in using water, especially when there are shortages or abundances of water, where they tend to either over or under use water instead of using it efficiently. For the farmers who decide to irrigate by observation of crop appearance or soil moisture content, it is an easy method but, not easy to use because it requires the irrigators to have supplementary experience (Tarimo *et al*., 2004, Kihupi, 2008). Thus, more training on water management and water requirement can help to improve the use of water efficiently leading to increase productivity and sustainability.

Table 3.1: Farmers who kept records of irrigation water applied throughout the season and factors that were considered for deciding when to irrigate

Farmers recorder water applied throughout the season	**Frequency**	**Percentage (%)**
Yes	0	0.0
No	90	100
Total	90	100
Factors that were considered to decide when to irrigate		
Fixed number of days between irrigation	45	50.0
Available moisture content	3	3.3
Crop appearance	9	10.0
Others (do not know)	33	36.7
Total		100

3.3.2 Physical and chemical properties of the water

The result from laboratory has shown that electrical conductivity of water (EC_w) was 0.101 dS/m at the upstream and 0.157 dS/m at the downstream. According to the irrigation water quality criteria as revised by the Colorado University State in 2007 (Clay *et al*., 2007), the quality of water in Kidwebezi irrigation scheme was found to be excellent because it was in rank of good for irrigation purposes (Appendix 2.2). As suggested by Shahinasi and Kashuta (2008) the normal ranking in irrigation water should be in range of between 0 and 3 dS/m for EC_w, 0-20, 0-5, 0-40 mg/l for Ca_2^+, Mg^{2+}, K^+ and Na^+ respectively (Appendix 2.3.4). The exchangeable bases such as Ca^{2+}, Mg^{2+}, K^+ and Na^+ were found to be 1.6 mg/l, 1.0 mg/l, 2.7 mg/l and 11 mg/l for upstream 3.1 mg/l, 1.3 mg/l, 2.9 mg/l and 22.8 mg/l for downstream respectively. These results reveal that the values of EC_W and exchangeable bases at the downstream are higher than upstream. This condition can be explained by the fact that the water samples were taken after being drained from the field contained the residual of some inputs such as fertilizers or pesticides. However, the values from the analysis show that both upstream and downstream ranged in acceptable water properties for growing paddy.

Table 3.2: Chemical properties of irrigation water at the experimental site

Parameters	H_2O	ECw	Ca^2+	Mg^{2+}	K^+	Na^+	SO_4^{2-}	NO_3^-	NO^-_2
Units	pH	Ds/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Upstream	7.52	0.101	1.6	1.0	2.7	11.0	27	2.6	5.54
Downstream	7.1	0.157	3.1	1.3	2.9	2.8	43	4.9	3.9

3.3.3 Physical and chemical properties of the soil

From the soil analysis, the results were found to be 29%, 13.8% and 56.9% for clay, silt and sand, respectively which classify the soil among the sand-clay soil. The average pH of water was found to be 5.8. The pH values were generally classified as medium acid. The ECe values were 0.29 dS/m at head, 0.32dS/m at the middle and 0.34 dS/m at the tail. These values show the electrical conductivity to be excellent at head, good at the middle and at the tail (Appendix 2.2). According to (FAO, 1989), it implies that the ECe cannot cause any yield reduction or any salinity effect. The average exchangeable bases in the Study area for Calcium, Magnesium and Sodium were classed in the medium range of exchangeable capacity with values 7.4, 0.93 and 0.19cmolkg^{-1}, respectively while the exchangeable Potassium was classed it into very low with a value of 0.05cmolkg^{-1} (Appendix 2.3.4). The values of exchangeable bases were found to be very low for K and Na and medium for Mg and very high for Ca (Appendix 2.3.4). This type of soil is ranged in soil with good properties for growing crops (FAO, 2009).

Table 3.3: Physical properties of the soil at Kidwebezi Irrigation Scheme

Reaches	Area (ha)	Particle Size (%)			Textural class	Organic Matter (%)		
		Clay	Silt	Sand		OC (%)	N (%)	P(mg/kg)
Head	21.5	24.0	13.9	62.1	SCL	0.62	0.16	0.9
Middle	30.0	28.1	13.7	58.2	SCL	0.61	0.19	2.8
Tail	31.5	35.7	13.8	50.5	SC	0.67	0.18	1.2
Average		29.2	13.8	56.9	SCL	0.63	0.18	1.6

The results in Table 3.4 show that the soil has a low total nitrogen (TN) of about 0.17% and 0.63% organic carbon (OC), which can be classified among the soil with low available organic matter and total nitrogen (Appendix 2.3.2). The Cation and Exchange Capacity (CEC) was 6.26 mg/kg (Table 3.4) which was classified as medium (Appendix 2.3.4).

Table 3.4: Characterisation of chemical soil properties of KIS

Parameters Units	pH H_2O	ECe Ds/m	Ca	Mg	Na	K	CEC	ESP (%)
			mg/kg					
Head	5.88	0.29	6.95	0.76	0.18	0.04	4.30	4.16
Middle	5.84	0.31	6.82	0.77	0.19	0.04	4.10	4.56
Tail	5.92	0.34	8.60	1.28	0.21	0.08	10.40	2.00
Average	5.88	0.31	7.45	0.94	0.19	0.05	6.26	3.57

3.3.4 Crop water requirement

Results in Table 3.5 show that for different parameters during growth stages of paddy were20, 42, 30 and 28 days, Kc were 0.76, 1.05, 1.2 and 0.9 and daily ETc of 4.45, 6.99, 8.19 and 5.46 mm/day for the initial, development, mid- season and late season stages, respectively.

Table 3.5: Determination of ETo and ETc in the Study area

Growth stages	Initial stage	Development stage	Mid season stage	Late stage	Total
Stage duration	1/1-20/1	21/1-3/3	4/3-2/4	3/4-30/4	
Periods (days)	20	42	30	28	120
ETo (mm/day)	5.855	6.657	6.825	4.955	
Kc	0.76	1.05	1.20	0.90	
ETc (mm/day)	4.45	6.99	8.19	5.46	
RAM (mm)	42	42	42	42	
Interval (days)	9	6	5	7	
Total ETc (mm)	89	293.58	245.7	152.88	781.53

Results in Table 3.6 show the total water applied during the growing season to be 42.2 mm for net water requirements and 760.6 mm for gross water requirements.

Table 3.6: Determination of crop water requirement

Growth stage	ETc (mm/day)	ETc (mm/stage)	Pe (mm/month)	Pe (mm/stage)	In (mm)	Ig (mm)
Initial stage	4.45	89.0	112.7	72.7	16.3	36.2
Development stage	6.99	293.6	106.3	159.5	134.2	298.1
Mid- season stage	8.19	245.7	95.7	92.6	153.1	340.2
Late season stage	5.46	152.9	122.4	114.2	38.7	85.9
Total (mm)		**781.2**	**437.1**	**439.0**	**342.2**	**760.4**

Where
Pe = effective dependable rainfall (mm), Ig = the Gross irrigation requirement (mm); In = the Net irrigation requirement (mm)

3.3.5 Water allocation at Kidwebezi Irrigation Scheme

Due to the shortage of water, water allocation is by rotation to canals or to blocks. The approved irrigation interval for Kidwebezi is 7 days; means that each farm plot is irrigated once per week for duration of 8 hours per day. The major factors which influenced the water distribution schedule were mainly availability of water and reduction of conflicts among farmers. However, the duration which was planned to fulfil the requirement was 12 hours per day, but the provided 8 hours per day was just a decision from the Government agency (SRDI) to reduce the conflicts between legal (planned for irrigation) and illegal farmers (developed after). The information from the key informants indicates that there were repetitive conflicts between legal and illegal famers before adjustment of the schedule. The problems of inequity in water distribution were also expressed by many farmers during focus group discussion; they said that the inequity is caused by the deliberate action of unruly farmers poaching water or by poor design of structures at the scheme. As consequence, downstream farmers complained to suffer the low distribution of water while the upstream farmers are over distributed leading to low production.

Table 3.7: Actual water allocation schedule for Kidwebezi Irrigation Scheme

Day	Location	Type of canal	Area irrigated (ha)	Irrigation schedule
Monday	Head	SC1	10.0	TC 1-1 to TC1-5
Tuesday	Middle	SC1	16.0	TC 1-6 to TC1-10
Wednesday	Tail	SC1	14.0	TC 1-11 to TC1-15
Thursday	Head	SC2	11.5	TC 2-1 to TC2-5
Friday	Middle	SC2	16.0	TC 2-6 to TC2-10
Saturday	Tail	SC2	15.5	TC2-11 to TC2-15

Source: Kidwebezi irrigators' Association office

3.3.6 Comparison of performance of secondary canals

Results in Table 3.8 show that only upstream farmers have water delivery exceeding the water required and this applies to the two secondary canals while farmers of the middle and tail have less amount of water than the targeted and required in all the secondary canals. The results imply that there was a mismatch between the delivered, the intended and the required over canal reaches. This mismatch in water supply is a result of shortage of water resulting from increasing sizes of paddy fields which were not planned for. Similar findings are reported by Ndayizigiye (2009) who found that the mismatching of water in Imbo region was caused by the uncontrolled rice farmers demanding more water than the available amount.

Table 3.8: Discharge and volume delivered, target and required

Reach	Canal name	Actual Del (l/s)	Target (l/s)	Volume delivered (m^3)	Target volume (m^3)	Volume Required (m^3)
Head	SC1	143.2	144.9	69981.1	50077.4	48 963.5
	SC2	151.8	166.6	78028.4	57589.1	56308.0
Middle	SC1	129.6	231.8	63008.6	80123.9	78341.6
	SC2	136.6	202.8	67343.0	70108.4	68548.9
Tail	SC1	97.1	231.8	57425.7	80 123.9	78341.6
	SC2	102.3	224.6	63184.0	77620.0	75 893.5
Total				398970.4	415642.7	406397.1

3.3.7 Delivery performance ratio and water delivery performance

Results in Table 3.9 show that the average delivery performance ratio (DPR) was 0.95, 0.61 and 0.54 at the head, the middle and at the tail, respectively. That means that distributaries received only 95%, 61% and 54% of the target discharge at the head, middle and tail end, respectively. According to Murray-rust and Halsema (1998) classification the delivery performance ratio ranging from 0.9 to 1.1 is taken as good while the values outside this range were considered as poor. Based on that classification, the results show that the delivery performance ratio was good at the head and poor at both the middle and tail.

The Table 3.9 shows also that Water delivery performance (WDP) was found to be 1.37, 0.82 and 0.67 at the head, the middle and the tail respectively. It can be assumed that, if the water delivery performance is close to unity, then the management inputs are effective. It is evident that the water delivery performance was not effective; the upstream farmers got more water than the targeted amount while those in the middle and the downstream farms got less than the targeted amount of water.

Table 3.9: Delivery Performance Ratio and water delivery performance

Location	Head			Middle			Tail		
	SC1	**SC2**	**Mean**	**SC1**	**SC2**	**Mean**	**SC1**	**SC2**	**Mean**
DPR	0.98	0.91	0.95	0.56	0.67	0.61	0.51	0.57	0.54
WDP	1.40	1.35	1.37	0.56	0.67	0.62	0.71	0.81	0.76

A value of water delivery ratio equal to unity means that, the system is able to deliver the intended amount. The values less than one reveal inadequate portion of the intended water for the direct users. But a value greater than one means that there is extra water than scheduled being delivered to the area under assessment. (Clemmens and Bos, 1990; Bos *et al*., 1993).

3.3.8 Coefficient of variation in discharges of secondary canals

The temporal coefficient of variation (CV_T) at the secondary canal (SC1) was found to be 0.06, 0.13 and 0.08 for the head, the middle and the tail respectively while those of SC2 was found to be 0.23, 0.25 and 0.19 for the head, the middle and the tail respectively (Figure 3.3). Similarly, Figure 3.3 shows the spatial coefficient of variation (CV_R) of the secondary canal1 (SC1) to be 0.20, 0.21 and 0.22 for the head, the middle and the tail respectively while CV_R of SC2 was 0.17, 0.14 and 0.18 for the head, the middle and the tail, respectively. According to Molden and Gates (1990), three categories of variability were developed, which were termed as dependability if CV was less than 0.1 to be good and between 0.10 and 0.20 was fair and poor when it was more than 0.3. From that classification, Figure 3.3 shows that the temporal variability of discharge was good at the head and the tail and fair at the middle for the SC1while it was fair at all reaches for the SC2. Furthermore, the spatial variability in discharges was fair for all the two secondary canals at all reaches. It is remarkable that during the Study period all secondary canals were characterized by medium variability where average seasonal coefficient of variation was found to be 0.16, 0.18 and 0.13 for the head, the middle and the tail, respectively. However, these findings are different with those reported by Makaka (2020) who found the discharge variations recorded during his study to be significantly high. That difference can be due to the fact that the amount of water from the supply source is different.

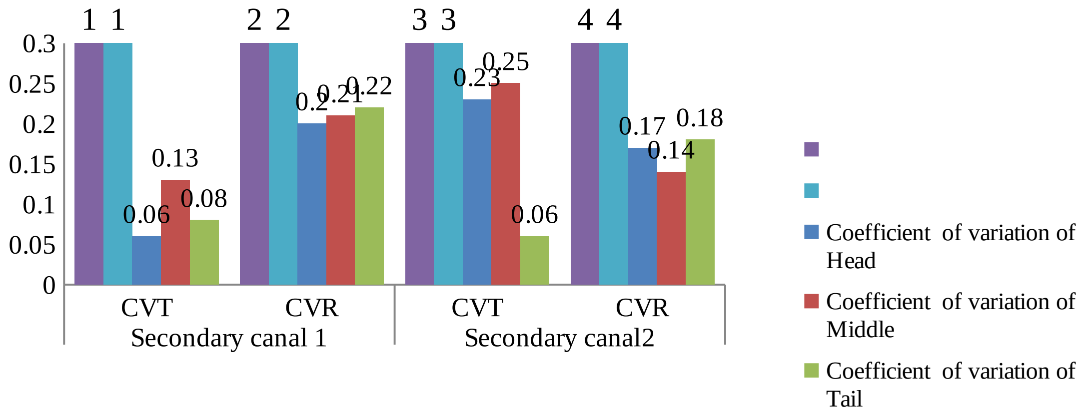

Figure 3.3: Coefficient of variation of discharge in secondary canal

3.3.9 Conveyance efficiency for the lined main and secondary canals

The result in Table 3.10 shows the average conveyance efficiency of 82.48%, 80.40% and 66.38% for the lined main canal, lined secondary and unlined secondary canal respectively. According to FAO, the standard value of conveyance efficiency for the canal adequately maintained are 95% for lined and 75% for unlined canals (FAO, 2008). Our results of conveyance efficiency for both lined and unlined canal are below the standards. The low conveyance efficiency observed for the unlined secondary canal is explained by the poor maintenance of the canal and the nature of the soil. Inefficiency could be due to weeds in some locations and seepage losses. The same finding was reported by van Halsema *et al*. (2011) where the conveyance efficiencies in the main, secondary and tertiary canals of the Haleku Irrigation Scheme ranged from 70.2% to 82 %.

Table 3.10: Average conveyance efficiency for main and secondary canals

Month	Lined main canal	Lined secondary canal	Lined secondary canal
January	82.39	80.90	67.90
February	82.35	80.60	64.09
March	83.79	79.24	67.97
April	81.39	80.84	53.95
Average	82.48	80.40.	66.38

3.3.10 Performance measure of irrigation system

The calculated measures of adequacy (P_A), efficiency (P_F,) water required compared to the delivered; dependability (P_D) and equity (P_E) provide combined summaries of system performance. The values determined for the secondary and tertiary canals are presented in Tables 3.11 and 3.12.

Table 3.11: Summary of performance values for secondary canals

Parameters	Head	Middle	Tail	Average
P_F	0.71	1.13	1.28	1.04
P_A	1.39	1.25	0.90	1.18
P_D	0.20	0.18	0.06	0.14
P_E	0.26	0.16	0.15	0.19

Table 3.12: Summary of performance values for tertiary canal

Parameters	Head	Middle	Tail	Average
P_F	0.63	0.99	0.98	0.96
P_A	1.47	1.06	0.71	1.10
P_D	0.25	0.18	0.12	0.17
P_E	0.17	0.12	0.09	0.12

i. Irrigation Efficiency

Results in Table 3.11 show that the irrigation efficiencies of the secondary canals was found to be 0.71 at the head, 1.13 at the middle and 1.28 at the tail with an overall average of 1.04. The results in Table 3.12 show that the efficiency of the tertiary canals was 0.63 at the head, 0.99 at the middle and 0.98 at the tail with an average of 0.96. According to the standard values of efficiency proposed by Molden and Gates (1990), the findings further indicate that irrigation efficiency in all the reaches both on secondary and tertiary canals are poor because the upstream farmers get more than they need while the farmers of middle and downstream farmers get less than they need. Poor efficiency can be attributed to water scarcity due to uncontrolled field developed in that area. Lack of operation and maintenance of water infrastructures has also been reported by farmers during focus group discussions to increase water losses along the canal water supply systems. The results align with the findings of other researchers (i.e. Sibale *et al*., 2021) who reported that the water delivery efficiency was 0.70 and 0.82 for 2018 and 2019 and emphasized the need of scheme rehabilitation in order to improve water supply, allocation and application.

ii. Adequacy of irrigation water supply

At the secondary canals, Table 3.11 shows that the average values of relative water supply (RWS) were 1.39 at the head, 1.25 at the middle and 0.90 at the tail while at the tertiary canals sampled the RWS was 1.47 at the head, 1.06 at the middle and 0.71 at the tail (Table 3.12). According to Molden and Gates (1990) classification and performance standards, the RWS ranging from 0.90 to 1 is taken as good while the values of less than 0.8 are taken as inadequate water delivery and all value above one are accepted as adequate regardless of the amount of excess (Appendix 2.4). Based on this classification, the adequacy of irrigation water supply is good.

However, adequacy seemed to decrease towards the downstream as the RWS values at the tail reach plots were low compared to the ones upstream and in the middle. This could be due to conveyance losses due to the lack of maintenance. The findings are low compared to those reported by Mchelle (2011) where she found 1.78 for the upstream, 1.65 for the middle and 1.25 at the tail.

iii. Dependability of irrigation water supply

Results in Tables 2.11 and 2.12 show that the average values of dependability (P_D) were 0.20, 0.18 and 0.06 at the head, at the middle at the tail, respectively, with an average of 0.14 for the Secondary canals and 0.25, 0.18 and 0.12at the head, the middle and the tail, respectively for the tertiary canals with an average of 0.17. According to Molden and Gates (1990) dependability's classification, the values ranged between 0-0.11 are good, 0.11-0.25 are fair and above 0.25 are poor; in this respect, the dependability in this study can be classified as fair for both the secondary and tertiary canals. However, high variability within location was observed where the upstream showed good dependability than the downstream farmers. Sibale *et al*. (2021) reported the values of dependability of 0.11and 0.21 classed as fair and poor for 2017. He argued that there were a lot of water losses in the conveyance and distribution systems. On the other hand, Mchelle (2011) showed the value of dependability ranged between 0.62 and 0.70 showing poor dependability, attributed it to poor water management practices caused by poor timeliness in water distribution by the water allocation and distribution committee.

The poor dependability observed at Kidwebezi is due to the shortage of water and poor share among farmers. That was confirmed by majority of farmers during focus group discussion where more than 90 per cent of the participants attribute it to the water scarcity caused by the uncontrolled paddy fields developed at the upstream.

iv. Equity of irrigation water supply

The results in Table 3.11 show that the average values of equity for secondary canals were 0.26, 0.16 and 0.15 at the head, the middle and the tail respectively with an average of 0.19. The results in Table 3.12 show that the equity of tertiary canals was 0.17, 0.12 and 0.09 at the head, the middle and the tail respectively. According to Molden and Gates (1990) classifications, the values between 0-0.1, 0.1-0.20 and above 0.20 are taken as good, fair and poor respectively. Taking consideration of that classification of equity, the average equity was fair for both the secondary and the tertiary canals. The low level of equity may have been caused by remarkable shortage of water due to an increasing number of fields demanding more water which was not planned before.

During focus group discussion, most participants (80%) have complained the inequalities of water share between farmers situated at the head reach and those situated at the tail-end arguing that the uncontrolled increasing paddy fields to be the main factor causing the inequity of allocation leading to low yield. This findings generally fall in the range given by Sibale *et al*. (2021) who showed the values of equity as 0.15 and 0.20 classed as fair and poor for the period of 2017 and 2018.

3.3.11 Physical and economic water productivity

The results in Table 3.13 show the average production per hectare as 6666, 5883 and 5380 kg at the head, the middle and the tail, respectively. That result show further that the upstream farmers have got higher yield than those in the middle and the downstream locations. The difference in yields can be attributed to the lack of fair share of water delivery. However, although high yield were observed at the upstream farmers, the highest water productivity was found at the tail with 1.41 kg per m^3 using 3828.88 m^3 as irrigation water per ha, followed by the middle with 1.35kg per m^3 per ha and finally the lowest average was 0.97 kg per m^3 found at the head of the scheme using 6888.4 m^3 per ha as irrigation water. The low values of output observed especially at the head suggest that a lot of water was being diverted to that area but most of it is wasted. The findings are in agreement with others findings by other scholars who reported water productivity variation of between 1.0 and 1.7 kgm^{-3}in China, in USA and Brazil and between 1.7 and 2.4 kg m^{-3} in Western European countries (Cai *et al*., 2009). The results in Table 3.13 show also that actual economic water productivity for the head, the middle and the tail were 0.45, 0.63 and 0.50 US$ per m^3, respectively.

These results showed that downstream farms had the highest income per unit of irrigation water diverted to the network with 0.65 US$ per m^3 and the lowest income was found to the upstream farmers with 0.45 US$ per m^3 indicating that the farmers need to know how to use water efficiently. The results is in agreement with the study finding of Degirmenci *et al.* (2003) who reported economic water productivity ranged from 0.13 to 2.16 US $ m^{-3} at Derk - Dumluca irrigation schemes in Turkey.

Table 3.13: Physical and economic water productivity at KIS

Reach	Head	Middle	Tail	Average
Actual water use per ha (m^3)	6884.4	4345.1	3828.8	5019.4
Target water use per ha (m^3)	5007.7	5007.7	5007.7	5007.7
Total Yield per ha (kg)	6 666	5883	5380	5976.3
Actual physical WP (kg/m^3)	0.97	1.35	1.41	1.19
Target physical WP (kg/m^3)	1.33	1.17	1.07	1.19
Total Yield cost per ha ($)	3076.6	2715.2	2483.1	2758.3
Actual economic WP ($m^{-3})	0.45	0.63	0.65	0.50
Target Economic WP ($m^{-3})	0.62	0.54	0.49	0.55

In addition, the findings from survey have shown that 68.89 % of the respondents were satisfied with the production of the last season. The findings show also that 73.3% of the respondents did not achieve their target yield. The reason for not achieving the target were the shortage of irrigation water (43.3%), lack of fertilisers (42.2%), low soil fertility (8.9%) and pest and or disease infestation (5.6%).

3.4 Conclusion and Recommendations

3.4.1 Conclusion

Conclusions drawn from this study are as follows:

i. The overall performance in terms of water allocation shows the head to perform well while poorly for both the middle and the tail.

ii. According to the performance indicators, the irrigation system was good for adequacy, fair with respect to dependability and equity, while it was poor in terms of irrigation efficiency.

iii. The amount of water diverted to the Kidwebezi Irrigation Scheme was more than adequate at the head but inadequate at the middle and at the tail.

iv. However, the scheme faces a problem of a fair share of water, which continues to decrease due to an increase in the number of paddy fields.

3.4.2 Recommendations

Due to the challenges of water deficit in the Kidwebezi Irrigation Scheme, the study recommends

i. To the Government to increase water supplies from the Mpanda River, which might assist to lessen the water shortage.

ii. To the government agency (SRDI) to provide education to farmers and committee members on equity of water supply and sustainability.

iii. The branch committees should be trained on water allocation and water distribution in order to avoid the inequity.

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CHAPTER FOUR

4.0 EFFECT OF IRRIGATORS'ASSOCIATION ON THE PERFORMANCE OF KIDWEBEZI IRRIGATION SCHEME IN BURUNDI

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ABSTRACT

Despite the important role played by irrigation schemes as a catalyst for economic prosperity, increased incomes and improved livelihoods to the majority of farmers, the irrigation schemes are still performing poorly. In many irrigation schemes, entrusting more responsibilities to farmers through establishment of Irrigator's Associations (IAs) has been considered as a viable path towards improving performance. However, while it is recognized that benefits accrued from the IAs are critical in enticing laggers and reluctant farmers to be active, diversity in implementation strategies have made the evaluation difficult. The objective of this study was to evaluate the impact of Irrigators' Association on performance of irrigation schemes in Burundi. In achieving that objective, social economic surveys were undertaken to assess the Irrigators 'Association impact on Kidwebezi Irrigation Scheme in: (i) fee collection performance, (ii) financial self-sufficiency, (iii) relative water costs and (iii) sustainability of irrigated area which are critical attributes for performance, the financial viability of the irrigation scheme, (2) the profitability, (3) the socio viability and (4) the sustainability of the physical environment for irrigation scheme. Results show that effectiveness of fee collection (EFC) was 87.77%, financial self-sufficiency (FSS) was 3.11 relative water cost of 0.05 and sustainability of irrigated area of 97.64%. The findings show that the IA of Kidwebezi Irrigation Scheme is financially able to sustain its scheme in operation and maintenance.

Key *words*: *Irrigation Scheme, Irrigator's Associations, Effectiveness of Fees Collection*

4.1 Introduction

Irrigated agriculture is one of the important components of world food production. It is reported to have significantly contributed to maintaining world food security and to the reduction of rural poverty (Nkhata, 2014; de Fraiture and Giordano, 2014; Hussain and Hanjra, 2004). Increased competition for land and water, the high future cost of irrigation schemes development and rehabilitation and environmental degradation are some of the changes that have had a significant impact on irrigated agriculture, necessitating increased labour productivity, water productivity and crop production (Checkol *et al*., 2008).

Lack of irrigators' participation in the planning and operation has been reported as one amongst the reasons leading to poor performance of irrigation schemes, mainly due to lack of sense of ownership (Gragasin *et al*., 2005). It is now widely accepted that participation of irrigators as water users in their management of irrigation systems is pre-requisite for sustaining the performance of irrigation systems (Gragasin *et al*., 2005).

In many irrigation schemes, entrusting more responsibilities to farmers through establishment of Irrigator's Associations (IAs) has become customary and is considered as a viable pathway towards improving performance (Fujiie *et al*., 2005). Governments and development agencies have promoted the formation of IAs as a new mechanism in implementing the Integrated Water Resources Management (IWRM) and for increasing production and productivity. Irrigators' Associations (IAs) are water management organizations that are user-driven and participative. IAs are designed to improve water resources, increase agricultural output and provide farmers with the information they need to engage in the irrigation management process (Hui *et al*., 2014). The Irrigators' Associations, on the other hand, are confronted with a number of challenges, including a lack of essential skills and commitments to fulfil reciprocal responsibilities, as well as a lack of organizational and administrative structure among local irrigation scheme managers. These issues have put irrigation systems' long-term viability in doubt, leading in food insecurity and poverty (Checkol *et al*., 2008).

Climate change has become such a frequent constraint that there is now an urgent need for agricultural policy to include a clear direction toward the mobilization and effective control of water resources in order to adjust for erratic rainfall patterns (Minagrie, 2012). To address the challenges of food insecurity and associated poverty, improving agricultural productivity is a key component of the present Burundian Government's National Agricultural Investment Plan (NAIP) strategy (Mineagrie, 2019). Burundi’s agricultural sector policy is laid down in the national agricultural strategy document adopted in 2019, which takes into account and follows the guidelines and priorities of the country’s basic strategic documents, particularly outlook of 2025 and the Strategic Framework for Poverty Alleviation (SFPA) (Minagrie, 2019).

The government set about drawing up a National Agricultural Investment Plan (NAIP) covering the period 2019 – 2024, with the participation and contribution of all the technical and financial partners. Irrigation development is one of the pursued strategic interventions in this regard. The government now recognizes that it is impossible to expect any great degree of agricultural production intensification under a rainfed dry land farming system. Hence, tremendous efforts are underway to promote large, medium and small-scale irrigation through huge financial and labour investment (Minagrie, 2019).

However, sustainability of water resources, the irrigation systems including infrastructure is in serious jeopardy if management is not taken into consideration, especially participation of communities and end-users. Governments and development agencies have promoted the formation of IAs as a new mechanism for increasing production and productivity.

Irrigators' Associations (IAs) are established to improve water resources, to increase crop production and help giving farmers with the knowledge they need and provide the farmers with the opportunity to be involved in the process of irrigation management. IAs are also established to conserve water from a source and which is used jointly by the members of the irrigators' association, resolve conflicts related to the joint use of water resource among members of the association and collect water use fees. These functions cannot be realized unless researches are done to assess their role in managing water use issues and catchment management (Hui *et al*., 2014). Hydro logically, Burundi is divided into two main river basins, the Nile Basin which empties in the North-East of the Mediterranean Sea and the Congo River basin which empties in the Atlantic Ocean. Despite, being endowed with abundant water resources, Burundi is facing increasing pressure on its water resources mainly due to increasing population, competing uses and uneven distribution (Nkurunziza and Sabushike, 2008). According to Food and Agriculture Organizations of the United Nations Aquastat data (FAO, 2022), renewable internal freshwater resources per capita in Burundi is approximately 930 cubic meters per annum per capita as of 2017, which is below the 1000 cubic meter per annum per capita, a threshold for water scarcity (Damkjaer and Taylor, 2017). Furthermore, the situation is expected to get worse with increasing population and increasing demands for water for various purposes including socio-economic activities and in particular agricultural activities. It is widely accepted that a significant amount of freshwater around the world is being used for irrigated agriculture and the case is not different in Burundi (Ndayizigiye, 2009). It is therefore critical that an integrated approach is institutionalized for sustainable management of water resources. Although policies and legal frameworks to support IWRM in Burundi exist, but the lack of coordination mechanisms of actions of institutions related to water is becoming a major obstacle in sustainable management. At the scheme level, water resources management is done through the Irrigators' Associations which are part of the executive commission. In order to ensure the effective operation and transparent financial affairs of the IA, there is a special board of supervisors to monitor the commission's routine work and financial affairs. Government agencies, IA member representatives, irrigation management groups and local farmers often make up the board of supervisors.

Several researchers on irrigated agriculture noted that agency-managed irrigation schemes show low performance compared to farmer-managed irrigation schemes (Pradhan,1989 and Materu *et al.*, 2018). In other words, irrigation management is not only about managing the transportation of water within an irrigation system, but various irrigation management options also includes the organization of human relationships between irrigators, organization officers, irrigation officials and other stakeholders (Narain, 2003). Studies by Kijne and Barker (2003) and Masya (2016) suggest that an improvement in irrigation efficiency and an increase in agricultural water productivity are crucial in the improvement of competition for water resources, environmental protection and sustainable food provision. Therefore, coordinated efforts are needed from diverse stakeholders in order to ensure sustainable production and protect the threatened natural resources (Molden *et al.*, 1997). Conflict resolution is a major difficulty for small-scale irrigation systems, especially when it comes to resource use between public and private irrigation, as well as upstream and down stream users (Bjornlund and Rooyen, 2017).

Although there are many theories concerning Irrigators' Association assessments, this evaluation concentrates on their influence in operation and management, with specific references to irrigation in Burundi. Certainly, assessing the role of Irrigation Association and its influence on the farmers as the main goal of this Study would bring constructive results for all stakeholders. Furthermore, the majority of IAs were only established in the last two decades and have yet to be evaluated. As a result, there is insufficient evidence/information to guide future IA expansion and it is also unknown whether such IAs is worthwhile. Hence, this Study aimed to assess the Irrigators 'Association impact on Kidwebezi Irrigation Scheme in: (i) fee collection performance, (ii) financial self-sufficiency, (iii) relative water costs and (iv) the sustainability of the physical environment for irrigation scheme.

4.2 Materials and Methods

4.2.1 Description of the study area

The Study was conducted at the Kidwebezi Irrigation Scheme, which is located in Mpanda District, Bubanza Province in the western part of Burundi, about 25 km from Bujumbura, the capital city. The scheme lies at Latitude of 3^{o}11' 60'' South and Longitude 29^{0} 23' 59'' East. Kidwebezi is situated in the Imbo plain, one of the eleven natural regions of Burundi. Imbo plain is a lowland area with a mean altitude of 1000 m above sea level. The rainfall regime in this zone is bimodal, with a short rainy season between October and January and a long rainy season between March and May. The annual rainfall in this zone ranges between 700 and 1000 mm and the temperature ranges from 24°C to 28°C.

The major activities of the people of Kidwebezi include farming and livestock keeping. Major food and cash crops grown include paddy, maize, beans, watermelon, sweet potatoes and vegetables. Livestock production includes beef and dairy cattle, small ruminants and poultry, which are kept mainly for income generation (Ndayizigiye, 2009). Kidwebezi Irrigation Scheme has a command area of 83 ha shared by 238 household farmers grouped within the Kidwebezi Producer Association. Farmers' land holdings ranged between 0.25 and 0.5 ha. The Kidwebezi Irrigation Scheme is supplied with irrigation water from an intake constructed in the Gifugwe River from which a main canal of about 4.9 km in length begins.

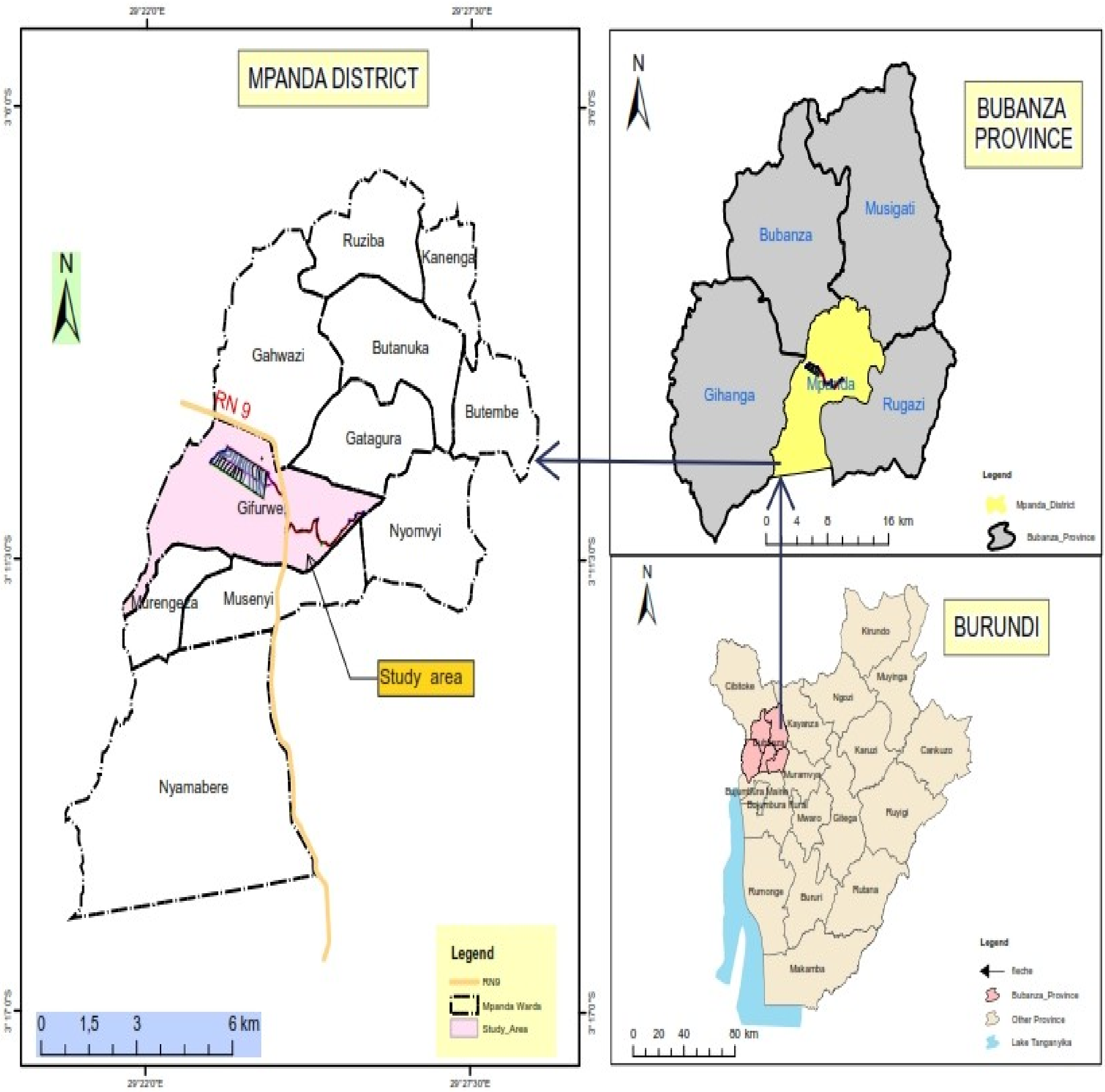

Figure 4.1: Location map of Mpanda district showing the study area

4.2.2 Methods

4.2.2.1 Research design and sampling methods

A descriptive research design was used in this study. To obtain a representative sample according to Bailey (1994), the sampling frame was stratified into three strata (head, middle and tail); from each stratum, a simple random sampling technique was used to select 30 respondents among the farmers. A sample size of 90 household heads selected out of 238 (38%) farmers of Kidwebezi was interviewed to get the information needed. Ten (10) participants for focus group discussion were identified. Eight (8) key informants included two (2) Irrigators' Association leaders, one Kidwebezi Water Officer, two (1) Cooperative Officers, two (2) experienced paddy farmers from many years and (2) government staff managers Ten (10) participants for focus group discussion and eight (8) key informants were selected, making a total of 108 respondents. Key informant interviews were conducted using a prepared checklist.

Table 4.1: Distribution of all respondents in the study area

Types of respondent	Male	Female	Total
Farmers household heads	75	15	90
Focus group discussion	5	5	10
Key informants	4	4	8
Total	84	20	108

4.2.2.2 Data collection and procedures

Both primary and secondary data were collected. The primary data was collected through interviews with household heads using a questionnaire. A survey of a sample of 90 household heads was conducted using questionnaire of 33 questions using face-to-face interviews. The information from key informants was collected using a checklist. For key informants, face-to-face was used to get important and general information related to constraints or issues facing the schemes or farmers in running the system of water management. A focus group discussion (FGD) guidance was administered to FGD participants other than those participating in a questionnaire interview where a discussion on different irrigation challenges was discussed freely. In the focus group discussion, the government officers included locality executive officers, village executive officers and long-time resident farmers were involved. Also, the discussion involved old people with long experience and knowledge of the history of the scheme. A checklist of questions or issues of interest was used to guide the discussion.

Secondary data was gathered through personal communication with government agency (SRDI) staff, District Water Engineers, Kidwebezi Irrigation Scheme officers, Irrigators' association staff and water stakeholders. Others secondary data such as publications reports and varied researches in agricultural sector were sourced from stakeholders particularly in past research findings on rice sector.

4.2.3 Evaluation of economic, social and environmental performance

These indicators have been divided into three primary categories: (i) those relating to economic viability, (ii) those relating to social viability and (iii) those associated with sustainability of the physical environment for irrigation (Bjornlund and Rooyen, 2017).

a) Economic viability

Financial viability of irrigation systems*:* Financial Self-Sufficiency viability indicates how far the organization has a capacity to run the system while Fee Collection Performance indicates the organisation ability to raise revenue from irrigator's association. The first indicator, proposed by Bjornlund and Rooyen (2017) describes overall financial viability of the system as:

$$Financial\ Self\ Sufficiency = \frac{Irrigation\ Agency\ Income}{Total\ O \wedge M\ requirement} \qquad \text{……………………….…(19)}$$

$$Fees\ Collection\ Performance = \frac{Irrigation\ fees\ collection}{Irrigation\ fees\ due} \qquad \text{..(20)}$$

$$Relative\ water\ cost = \frac{Total\ cost\ of\ water}{Total\ production\ cost\ of\ major\ crop} \qquad \text{.(21)}$$

b) Sustainability of the physical environment for irrigation

Aspects of physical sustainability that managers can affect relate primarily to over- or under-supply of irrigation water that leads to water logging or salinity (Molden *et al*., 1998). The simplest measure of sustainability is therefore expressed as:

$$Sustainability\ of\ Irrigatied\ Area = \frac{Current\ Irrigable\ Area}{Area\ Initial\ Irrigable\ Area} \qquad \text{…………………….(22)}$$

4.2.4 Data analysis

The data collected from survey were verified, compiled, reorganised and summarised for statistical analysis such as frequencies, means and cross-tabulation tables for different variables were used to present the result. Data which were collected from FGD and Key informants using researcher's personal organizer and checklists were processed manually where a report synthesis of farmers' judgment was written after. Quantitative data were coded, processed and descriptively analysed using computer software known as Statistical Package for Social Science (SPSS) (IBM SPSS version 21) to obtain descriptive statistics of respondents.

4.3 Results and Discussion

4.3.1 Socio economic characteristics of household head

In this part, socio-economic characteristics such as age, sex, household size, educational level, land size, organization rules, water distribution and schedule, production, farm and off-farm income, access to credit and extension, years of farming experience and availability of water for irrigation are discussed.

4.3.1.1 Distribution of household heads by age and sex

Results in Table 4.2 show that the majority of the household heads (45.55%) in the Study area were older than 55 years, followed by 41.11%, which ranged between 35 and 54 years, while 13.33% were aged between 15 and 35 years. It means, most household heads in the study area are too old compared to the mean age of 48 years (Table 4.2). On the other hand, the age of farmers is taken as farming experience and had a positive influence on paddy production level. These results are similar to those of Nyanga *et al*. (2016), who found that when a farmer has good experience in irrigation farming, he/she is likely to produce more than the inexperienced ones.

Results also showed that most of the households in the study about 83.3% were males and 16.7% were females. The dominance of men is a possible reflection of traditional African values where the male is recognized as the head of the household and is often, in particular, in charge of technical and capital-demanding innovations. The findings are similar with those of Urassa (2015) and Nyanga *et al*. (2016) who pointed out that land ownership is mainly a male right as a result of the highly deep-rooted patriarchal system.

Table 4.2: Age and sex of the respondents

Age	**Frequency**	**Percentage**
15-34	12	13.3
34-54	37	41.1
>55	41	45.6
Total	90	100
Sex		
Male	75	83.3

Female	15	16.7
Total	90	100

4.3.1.2 Distribution of household heads by size and education level

The results in Table 4.3 show that the majority (61.1%) of respondents' household sizes ranged from 5 to 8 people, followed by 23.3% between 1 and 4 people, while 15.6% of the families have more than 9 people. The average household size was found to be 6 people per family, with a minimum family size of one and a maximum family size of 12 people. The findings have shown further that the education level of the majority of household heads (43.3%) have primary education, followed by 33.3% who have not attended any formal education and only 16.7% of household heads have reached secondary school.

Furthermore, the finding shows that there is no farmer with a university education level. According to the finding, the majority of respondents (83.3%) have not been able to go beyond elementary school. The absence of farmers of high education means that the agricultural sector is not attractive to the elite class, which can explain why the agricultural sector remains under developed.

Table 4.3: Household size of respondents

Household size	Frequency	Percentage
1-4	21	23.3
5-8	55	61.1
9-12	14	15.6
Total	90	100
Education level		
Not educated	30	33.3
Adult education	6	6.7
Primary	39	43.3
Secondary	15	16.7

Total	90	100

4.3.1.3 Distribution of household heads by land size and tenure

The results in Table 4.4 show that the majority of households (47.8%) remained with plot sizes of 0.50 ha followed by 38.9% with plot sizes of 0.25 ha and 13.3% of the households have plots with a size of 0.75 ha. In the aspect of land tenure, the findings in Table 4.5 show further that only 27.8% of the respondents remained with the land given by the government, 41.1% of the land cultivated was purchased, 27.8% owned land that was inherited from parents and 3.3% cultivated in land that was rented. It means that more than 72% of the respondents have changed their land tenure.

Table 4.4: Farmer's land size information

Size of plot (ha)	Frequency	Percentage
0.25	35	38.9
0.50	43	47.8
0.75	12	13.3
Total	90	100

Table 4.5: Actual land possession at Kidwebezi Irrigation scheme

Acquisition of land	Frequency	Percentage
Bought	37	38.9
Inherited	25	27.8
Given by Government agency	25	27.8
Rented	3	3.3
Total	90	100

4.3.1.4 Criteria for selection of posts in IA

Selecting people who have good leadership qualities in the irrigation association has an important impact on the irrigation water resources management of a scheme. There must be criteria for the selection of posts in IA. The result in Table 4.6 showed that 47.8% of the respondents agreed that criteria exist, but nobody cares, 25.5% said that there are criteria but selection is only done upon them without transparency, 18.89% said that there are no proper criteria, but some "socially accepted" characters and 7.8% denied the existence of criteria for being used to fill free posts in IA.

Table 4.6: Criteria for selection of posts in IA

Existence of criteria for selection of posts in IA	Frequency	Percentage
There are criteria agreed, but nobody cares	43	47.8
There are criteria but selection is only done upon them	23	25.5
No proper criteria, but are some “socially accepted”	17	18.9
Not Applicable	7	7.8
Total	90	100

4.3.1.5 Level of farmers’ knowledge of water management in the field

Table 4.7 shows that 100% of the respondents do not record or compute the amount of water applied to their farm plots throughout the season. That can be explained by the low education level of the farmers. They lack the necessary knowledge to calculate the amount of water used. None of them are aware of the water that is used throughout the season. Many irrigation schemes in Burundi face a lack of understanding about agricultural water requirements.

Table 4.7: Farmers who compute water applied throughout the season

Keep writing or recording water applied throughout the season	Frequency	Percentage
Yes	0	0
No	90	100
Total	90	100
Factors to consider for deciding when to irrigate		
Fixed number of days between irrigations	45	50.0
Available moisture content	3	3.3
Crop appearance	9	10.0

Others (Do not know)	33	36.7
Total	90	100

4.3.1.6 Farm's production

Findings in Table 4.8 show that 68.9% of respondents were satisfied with the production for the last season, while 31.1% were not satisfied. However, the findings also show that the majority of respondents (73.3%) have not achieved the target yield while only 26.67% have achieved the target yield. It shows furthermore that 51,1% of the respondents did not reach the yield target due to the lack of fertilisers, followed by 43.3% of the shortage of water for irrigation due to a lack of fertilisers, while 5.6% of farmers have not achieved the target yield because of pest or diseases.

Table 4.8: Factors affecting farmers' satisfaction by the production

Paddy rice harvested	Frequency	Percentage
Satisfied by yield	62	68.9
Not satisfied by yield	28	31.1
Total	90	100
Achieved the target yield		
Yes	24	26.7
No	66	73.3
Total	90	100
Factors affected to not reach the yield expected		
Pests and diseases	5	5.6
Shortage of water for irrigation	46	43.3
Lack of fertilisers	39	51.1
Total	90	100

4.3.1.7 Distribution of household heads by institutions and social inclusion

i) Access to extension service

Table 4.9 shows that 61.1% of the respondents have access to extension services, while 38.9% indicated that they lack access to extension services. The result is closely in line with the findings of Mkojera *et al*. (2008), which indicated that 54% of the interviewed paddy farmers had access to extension services.

ii) Access to credit facilities

The results in Table 4.9 show that 60% of respondents have access to credit facilities, while 40% of respondents have no access. The results are in agreement with those reported by Nyamweru (2017) where 72.6% of the interviewed paddy farmers had access to credit facilities in the Maramvya Irrigated Scheme (Burundi). Further findings show that 83.3% of the respondents who have access to credit had applied for credit previous season. According to the respondents, the majority of rice farmers use the credit money to execute their farming activities.

Table 4.9: Farmers access to extension services

Access to extension service	Frequency	Percentage
Yes	55	61.1
No	35	38.9
Total	90	100
Access to credit facilities		
With access to credit	54	60
No access to credit	36	40
Total	90	100

4.3.2 Irrigators' associations

Kidwebezi is designated as "Irrigation Schemes with Mixed Control". It is an irrigation scheme where the main canal, secondary canal, main drain and collector drains are managed by government officials while the tertiary canals and field drains are under the control of farmers. The government agency (SRDI) is in charge of the scheme's operation and management by providing founds for maintenance activities in the main canal, secondary canals, main drain and collector drains while farmers are in charge of the tertiary canals and field drains. The Irrigators’ Association has been initiated by the SRDI (in 2009: twenty years later) to facilitate some activities, including allotment of land, transport and distribution of water, maintenance of the system and the overall management of the use of the system.

The existing organizational structure of IA is as shown in Figure 4.2. The IA is composed of three committees, namely: finance; construction and water allocation and distribution. The finance committee is in charge of applying for water rights, registering water users, and collecting water fees from the members; plans mechanisms for generating income; and makes bylaws. The construction committee plans the repair and maintenance of the irrigation structures at the scheme.

The water allocation and distribution committee is responsible for managing the gate rider, whose operation is based on the farmers ‘agreed-upon water distribution schedule, as well as checking the condition of all canals and proposing action to be taken in case of any problems. In addition to these three committees, the scheme has a secretary and a chairman, who together are responsible for the general meeting. Farmers sell their produce on their own and they do face a serious problem in securing fair prices for their produce because there is no service responsible for marketing and the value chain of the produce so they need a marketing committee. The scheme has an agronomist and a permanent manager of SRDI who are in charge of managing and coordinating the program's daily activities.

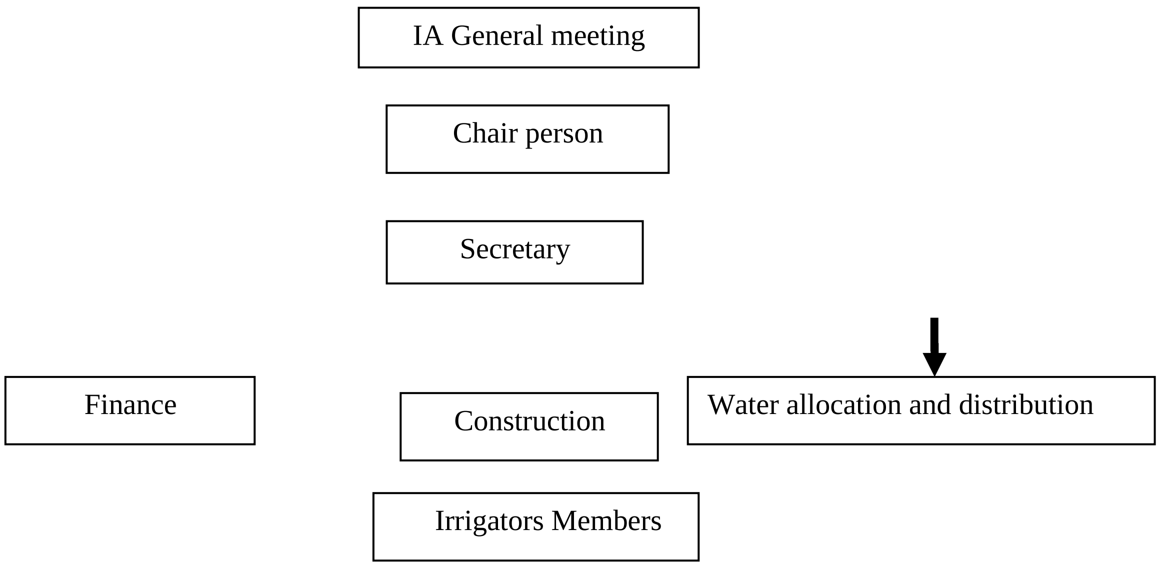

Figure 4.2: Diagram showing the organization structure of IA

4.3.3 Financial viability of irrigation scheme

In the Kidwebezi Irrigation Scheme, there is a contract between the Government and farmers with regard to water pricing based on land size (i.e., a hectare). The water fees are fixed at 300 kg of paddy per hectare per season. The water fees are charged without considering whether you have gotten a good yield or not and whether you have sufficient water or not. The only criteria are the plot area. Nevertheless, the effectiveness of fee collection (EFC) values has been at a satisfactory level for the period of 2017–2020 as shown in Table 4.10. The effectiveness of fee collection (EFC) is one of the most important indicators for Irrigators' Associations as it is their only source of income and contributes to the sustainability of the scheme.

According to Imbo Region Development Society (SRDI) annual reports, the effectiveness of fee collection (EFC) for Kidwebezi irrigation scheme was 92%, 82.16%, 89.29 and 87.62%, with an average EFC of 87.77%, collected for the last 4 years from 2017 to 2020 (Table 4.10). That EFC could be considered good according to Yercan *et al*. (2009), who suggests that an EFC of more than 70% is judged as satisfactory. However, these results are very high when compared to those found by Mchelle (2011) who blames the low EFC (66.8%) obtained to the weakness of IA. This difference might be explained by the scheme's status in the fees collection system, which is different. The high EFC found in the Kidwebezi irrigation scheme is motivated by the system of payment and rigorous control where non-payment for two consecutive seasons can lead to the seizure of the farm plot.

However, the ratio of fees collected is decreasing year by year (from 92.7% to 82.16%), that can explain how the farmers are unhappy about paying the water fees day after day. From the FGD, the farmers affirm their unhappiness regarding the price of water fees. The farmers argued that the price was fixed without their consultation and without a legal calculation basis, so they consider it is as another tax. They would like to know if the money they pay is more or less because it was fixed for a long time at 300 kg of rice paddy per hectare. In additional, from FGD, key informants and individual interviews, all explained their unhappiness and wished for more severe measures against informal irrigation water users who did not even pay for water fees they used.

Table 4.10: Fees collection performance

Year	Fees collected (US$)	Estimated fees due (US$)	EFC (%)
2017	7989.0	8683.1	92.00
2018	7134.0	8684.0	82.16
2019	8086.0	9055.2	85.29

2020	7980.4	9108.0	87.62
Average	7796.3	7989.0	87.77

Source: Imbo Region Development Society (SRDI) annual reports
The exchange rate for 2021 was 1950 BIF/ US$

The findings in Table 4.11 show that the Financial Self-Sufficient (FSS) varies between 2.78 and 3.51, with an average of 3.21 for the last four years (2017–2020). With these values of FSS, it appears that the Kidwebezi irrigation scheme is financially able to sustain its operation and maintenance. FSS is one of the factors that determine the financial capacity of a scheme in operation and maintenance expenditures. The average FSS of Kidwebezi could be judged to be good. Therefore, the average FSS of 3.21 collected is more than enough to cover management, operating, and maintenance budgets. Therefore, this Study has shown that farmers' willingness to pay irrigation fees may improve the financial self-sufficiency of irrigation scheme. This result is similar with those found by Yercan *et al*. (2009), who reported that FSS ranged from 1 to 2.6 for eight irrigation schemes evaluated in Gediz River Basin in Western Turkey. Nevertheless, the high FSS found at Kidwebezi may not necessarily indicate that this irrigation scheme is sustainable because the operation and maintenance expenditures reported appears to be lower than the total maintenance financial needs for the scheme, which means that some money are used in other activities than irrigation managements.

Table 4.11: Financial self sufficiency

Year	**Income (US$)**	**Maintenance expenditure (US$)**	**Financial self-Sufficiency**
2017	7989	2482.1	3.21
2018	7134	2557.2	2.78
2019	8086	2307.0	3.51
2020	7980.4	2665.3	2.99
Average	7796.3	2502.5	3.11

4.3.4 Production and relative water cost

Results in Table 4.12 show that the average paddy production per farmer and per season was 5895 kg/ha. The results show also that there is a big difference in production according to the locality in the scheme, where the average yield was 6666, 5883 and 5380 kg/ha at the head, middle and tail end, respectively. This observation was due to the fact that, upstream farmers' access to irrigation water was better than middle and downstream farmers. This finding is within the estimation by ISTEEBU (2019), which reported that, the average paddy production per hectare to vary between 5 and 7 tones/ha for irrigated rice production and was confirmed by Imbo Region Development Society (SRDI) in its 2020 annual report (SRDI, 2020).

Table 4.12: Determination of relative water cost by location

Locality	Area (ha)	Yield (kg/ha)	Total yield (kg)	Price (US$/kg)	Yield cost (US$)	Water cost (US$)	RWC
Head	21.5	6666	143319	0.462	66213.3	2776.9	0.042
Middle	30	5883	176490	0.462	81538.3	4153.8	0.051
Tail	31.5	5380	169470	0.462	78295.1	4361.5	0.055
Average	83	5895	5895	0.462	2723.5	138.5	0.050

The Table 4.12 shows further that the values of relative water cost was 0.045, 0.051 and 0.055 at the head, middle and tail, respectively. The average relative water cost of the scheme was 0.05. However, that value is still high if compared to the value proposed by Bos *et al.* (2005) for surface irrigation. This ratio often ranges between 0.03 and 0.04. They argue that if the ratio becomes higher, farmers may abandon irrigation because of fear of the cost of water (Bos *et al*., 2005).

4.3.5 Sustainability of the physical performance environment

Physical performance indicators are related to the varying or loss of irrigated land in the command area for different reasons (Sener and Konukcu, 2007). After rehabilitation of the scheme, the current irrigated area was evaluated at 97.64%. The small losses are due to a second secondary canal being added in 2010 to facilitate the water to reach the entire scheme. The irrigation scheme is well sustained because all the command areas are cultivated.

Table 4.13: Environmental of sustainability of irrigation scheme

Scheme	Current Irrigated Area (ha)	Initial Irrigable area (ha)	Sustainability of irrigated area (%)
Kidwebezi	83	85	97.64

4.4 Conclusion and Recommendations

4.4.1 Conclusion

Conclusions drawn in this study are as follows:

i. Kidwebezi Irrigation Scheme is a source of paddy as their livelihood for the majority of respondents. It serves as both food for household and as a source of income;

ii. Kidwebezi Irrigation Scheme is performing well with respect to both EFC and FSS, meaning that it has enough capacity to maintain itself through the collection of water fees;

iii. However, there were differences in production between the head and tail-end which are attributable to the water shortage due to the poorly water management and poor leadership of Irrigators' Association;

iv. The increasing number of uncontrolled paddy field have been found to impact negatively on paddy production of the scheme hence, attention is needed to improve the way it is currently managed.

4.4.2 Recommendations

Recommendations drawn from the study include:

i. The government agency and to the Irrigators Association should make efforts to improve the water management in equitable distribution of water across the head, middle and tail-end plots which could potentially improve water productivity with minimum or no negative effects.

ii. The IA committee and farmers should be trained on irrigation water management aspects, including crop water requirements.

iii. The government agency should develop a mechanism of quantifying the water used at the field level to avoid inequity in water use.

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CHAPTER FIVE

5.0 EXTENDED CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Conclusions drawn from this study are addressed as follow:

i. The presence of the Kidwebezi Irrigation project has shown to contribute an increase in agricultural productivity and household income; it played a crucial role in the socio-economic development by acting like an engine of development for the area under consideration;

ii. The presence of the Kidwebezi Irrigation project has shown to contribute an increase in agricultural productivity and household income; it played a crucial role in the socio-economic development by acting likes an engine of development for the area under consideration;

iii. Kidwebezi Irrigation Scheme was performing at 84.16 per cent in terms of effectiveness of the infrastructure;

iv. The main causes of the poor performance of the irrigation structures were the over-increasing and uncontrolled expansion of paddy field, the lack of operation and maintenance of hydraulic structures on time, the poor leadership of IA and poor organization of the work and lack of transparency of IA in their routine activities;

v. In terms of water delivery performance indicators, the results show that the irrigation system performed fairly in terms of adequacy, dependability, and equity, but poorly in terms of irrigation efficiency;

vi. Kidwebezi Irrigation Scheme has the potential to improve small farmers' productivity and income and eliminating rural poverty if the challenges of the water shortage are resolved by increasing water supplies from other sources.

5.2 Recommendations

The followings are recommendations from the study:

i. The Ministry of Environment, Agriculture and Livestock should put efforts to come up with short and long term strategies to secure funds for irrigation infrastructure development;

ii. The Government agency (SRDI) should put more efforts to the overall water management including maintenance of canals and drains which are sources of lower efficiency of water supply;

iii. The SRDI and IA should have adequate legislation arrangements on responsibilities and rights, financing and control by defining the role of the farmers, degree of government involvement, in financing as well as in responsibilities for execution and control of maintenance of irrigation infrastructures at all level;

iv. The Irrigators 'Association committee and farmers must be trained especially in the area of water allocation and water distribution so that they can manage the shortage and scarcity of water in the Kidwebezi Irrigation Scheme.

APPENDICES

Appendix 1.1: Physical condition assessment of irrigation structures

Parameters	Class	Rank	Weightage
Sedimentation level	< 10%	5	50
(with reference total capacity) (S1)	11-30 %	4	
	31-50 %	3	
	50-70 %	2	
	> 70 %	1	
Embankment	< 10%	5	35
(damage in % of total length) (E1)	11-20 %	4	
	11-30 %	3	
	31-50 %	2	
	> 50 %	1	
Sluice gate operation:	Below	5	15
level of sedimentation with reference	Close to gate	4	
to gate opening (SG1)	Same level	3	
	Above the gate level	2	

Appendix 1.2: Physical condition assessment of canals

Parameters	Class	Rank	Weightage
Conveyance loss (CL)	<10%	5	40
(evaporation + Seepage)	11-30 %	4	
	31-50 %	3	
	50-70 %	2	
	> 70 %	1	
Bank collapse	<10%	5	30
(% of total canal length) (BC)	11-20 %	4	
	11-30 %	3	

	31-50 %	2	
	> 50 %	1	
Water pooling in canal (WP)	<10%	5	20
	11-30 %	4	
	31-50 %	3	
	50-70 %	2	
	> 70 %	1	
Weed growth (WG)	<10%	5	10
	11-30 %	4	
	31-50 %	3	
	50-70 %	2	
	> 70 %	1	

Appendix 1.3: Command area development assessment

Parameters	Class	Rank	Weightage
Cropped area) (CA) (reference to proposed)	<10%	5	60
	11-30%	4	
	31-50%	3	
	50-70%	2	
	> 70%	1	
Water flow Regulatory constraints (RC)	<10%	5	20
	11-20%	4	
	21-30%	3	
	31-50%	2	
	>50%	1	
Water sharing issues (WSI)	<10%	5	20
	11-30%	4	
	31-50%	3	
	50-70%	2	
	> 70%	1	

Source: Zende and Nagarajan (2013)

Appendix 2.1: Average Monthly discharges and their coefficient of variation in Secondary canals

Reach	Canal Name	January l/s	February l/s	March l/s	April l/s	Average l/s	CVT	CVR
Head	SC1	145.39	134.24	142. 47	139.83	140.48	0.06	0.20
	SC2	135.10	104.70	120.80	144.6	126.30	0.23	0.17
Middle	SC1	127.50	107.37	113.37	120.39	117.13	0.12	0.21
	SC2	126.00	87.36	108.56	115.40	109.34	0.25	0.14
Tail	SC1	108.24	102.06	97.56	97.41	103.57	0.08	0.22

Appendix 2.2: Suggested criteria for irrigation water base on conductivity

Class of water	Classification	Electrical conductivity (dS/m)
Class 1	Excellent	≤ 0.25
Class 2	Good	0.25-0.75
Class 3	Permissible	0.76-2.00
Class 4	Doubtful	2.01-3.00
Class 5	Unsuitable	≥3.00

Source: Bauder *et al*. (2007)

Appendix 2.3: Guide to general evaluation of some soil chemical and physical properties

Appendix 2.3.1: Soil pH classification

Extremely acid	pH<4.5	Neutral	pH 6.6 to 7.3
Very strong acid	pH 4.5 to 5.0	mildly alkaline	pH 7.4 to 7.8
Strongly acid	pH 5.1 to 5.5	moderate alkaline	pH 7.9 to 8.4
Medium acid	pH 5.6 to 6.0	strongly alkaline	pH 8.5 to 9.0
Slightly acid	pH 6.1 to 6.5	Very strongly alkaline	pH > 9.0

Appendix 2.3.2: Organic matter and total nitrogen

Parameters	very low	Low	Medium	High	Very high
Organic matter (%)	<1.0	1.0-2.0	2.1-4.2	4.3-6.0	>6.0
Organic C (%)	<0.6	0.60-1.25	1.26-2.50	2.51-3.50	>3.5
Total N (%)	< 0.1	0.10-o.20	0.21-0.50	>0.50	

Source: FAO, 1998

Appendix 2.3.3: Available phosphorus

Mg/kg	Low	Medium	High
Available (Bray-Kurtz I)	<7	7-20	>20
Available (Olsen)	<5	5-10	>10

Appendix 2.3.4: Exchangeable bases and Cation and exchangeable capacity (CEC)

Parameters	Very low	Low	Medium	High	Very high
CEC	< 6	6.0-12.0	12.1-25.0	25.0-40.0	>40.0
Ca (me/100g)	< 0.5	0.5-2.0	2.1-4.0	4.1-6.0	>6.0
Mg (me/100g)	< 0.25	0.25-0.75	0.75-2.0	2.1-4.0	>4.1
K (me/100g)	< 0.13	0.13-0.25	0.26-0.80	201-4.0	>4.1
Na (me/100g)	< 0.10	10-0.30	0.31-0.70	0.71-2.00	>4.1

Appendix 2.4: Evaluation standard for performance indicators

Parameters	Performance Classes		
	Good	Fair	Poor
P_F	85-100%		
PA	0.9 - 1.0	0.8 - 0.9	< 0.80
PD	0 - 0.100	0.1 - 0.25	> 0.25
PE	0 - 0.100	0.1 - 0.20	> 0.20

Source: Molden and Gates (1990)

Appendix 2.5: Conversion mm per day to litre per second

8.64 mm/day = 1l/s/ha

1 l/s/ha = 8.64mm/day = 86.4m^3/ha/day

In other words, an irrigation application of 8.64 mm per day corresponds to a continuous water flow of 1litre per second per hectare

For not continuous irrigation system (Rotation) which is our case we adjusted by multiplying interval schedule and 24 hours divided by duration of irrigation time of the day:

Target discharge = 0.69 l/s/ha x7 x 24/8 = 0.69*21= 14.49 l/s/ha

Target volume = 0.116l/s/ha x 6mm x area (ha)* 10 =144.9m^3/l/ha

Appendix 2.5.1: Actual and target discharge and total volume delivered and target

Reaches	Head		Middle		Tail		Total
	SC1	SC2	SC1	SC2	SC1	SC2	
Area (ha)	10	11.5	16	14	16	15.5	83
Actual discharge (l/s)	143.2	151.25	129.63	136.61	97.1	102.3	
Target discharge(l/s)	144.9	166.61	231.84	202.86	231.81	224.6	
Irrigation days (days)	7	7	7	7	7	7	7
Irrigation time per day (s)	2880	2880	2880	2880	2880	2880	2880
Total volume supply (m^3)	69981.1	78028.4	63008.6	67343.1	57425.7	63184	398970.4
Total target volume(m^3)	50077.4	57589.0	80123.9	70108.4	80123.9	77620	415642.7
DPR	0.98	0.91	0.56	0.67	0.51	0.57	
WDP	1.4	1.35	0.56	0.67	0.71	0.83	

(FAO Scheme Irrigation Supply Training Manual)
Volume of water required to be abstracted = 10 x area x gross

Appendix 3.1: Farmers' Survey questionnaire

Questionnaire number : ………… Date of interview : …………………

I. Farmer's household characteristics

1. Farmer's name: ………………Tel …………… Block…… Age: ……………
2. Gender: 1 = Male [ ] 2 = Female [ ]
3. Marital status

1= Single [ ] 2 = Married [ ] 3 = Separated [ ] 4 = Widow [ ]

4. Level of education

1 = No formal education [ ] 2 = Adult Education [ ] 3 = Primary [ ]

4 = Secondary [ ] 5 = University [ ]

5. **Household size and composition**

Age group (years)	Male		Female		Total
	Educated	Not educated	Educated	Not educated	
0-5					
6-15					
16-55					
> 55					
Total					

II. Land information's

8. How big is your land? 1= 0.25ha 2= 0.50 ha 3= 0.75 Aha 4= >0. 75 ha
9. For the piece of land owned, how was it obtained?

1 = Inherited [ ] 2 = purchased [ ] 3 = given by SRDI [ ] 5 = rented

III. Respondent affiliation with Irrigators Association (IA)

10. Are you a member of IA? 1 = Yes [ ] 2 = No [ ]
11. Are there any special steps you are taking to save water during water scarcity periods?

1= Yes [ ] 2 = No [ ]

If yes, what are they? ....

iv. Organizational Rules, Legitimacy and management of the field

A. IA by-laws are available and known to all members?

12. Are the relevant acts written and shared among farmers? 1= Yes [ ] 2 = No [ ]

13. If yes, are they known, accessed and understood by farmers?

1= Not applicable

2 = IA relevant documents are known but not accessed

3 = By-laws and statutes or relevant documents are available, shared, and understood by all IA members

14. Have you seen a hard copy of IA act or by laws with this respondent? 1=Yes 2= No

B. Selection criteria for IA posts are specific and known to the IA members

15. What are the criteria for selection of posts in IA?

1=Not Applicable 2=I don't know of such criteria

3= No proper criteria, but there are some "socially accepted" characters

4 =There are criteria agreed, but nobody cares

5=There are criteria, selection is only done upon them

16. What are the types and major causes of water use conflicts among the farmers?

Scarcity of water [ ] Use without water right [ ]

Unequal water distribution [ ] Poor water management [ ]

17. What are the roles of the management structure in place?

Collect water user fee [ ] Repair water supply systems when broken [ ]

Over see the water system [ ] others [ ]

C. Management of the Field

18. Do you know how much water was applied to the representative field last season?

1 = Yes [ ] 2 = No [ ]

If yes, how much irrigation water was applied? …………..mm

19. Did you keep written or computer based records of water applied throughout the season? 1 = Yes [ ] 2 = No [ ]

20. How much did you pay for the water? …………………BIF/hectare

21. Which method did you use to decide when to irrigate?

1= Fixed number of days between irrigations. How many days? .... days

2= Accumulated evapotranspiration (ET). How much ET? ………………mm

3= Available soil moisture. How determined? 4= Crop appearance

5= Crop consultant determines schedule   6 = other (specify)…

22. Who decides the irrigation interval?

D. Production and off farm income

23. What quantity of paddy rice have you harvested during the last season?
24. Given the size of land owned and input availability, do you set any target on yield to be achieved?   1 = Yes [ ] 2 = No [ ]
25. If yes, do you think that the targeted yield was achieved? 1 = Yes [ ] 2 = No [ ]
26. If no, what factors are attributed to the less than the optimal yield?

1 = Bad weather [ ] 2 = Pests and diseases [ ] 3 = Low soil fertility [ ]

4 = Lack of fertilizers (low input use)   5 = Shortage of water for irrigation [ ]

6 = Shortage of labour [ ]   7 = other reasons ……………………

27. Apart from crop farming activities, do you have other activities that bring income to your household?   1 = Yes [ ]   2 = No [ ]
28. If yes, what are your main activities and how much did you get from any activities during the last season?

E. Institutions and social inclusion

30. Do you have access to extension services?   1= Yes [ ] 2 = No [ ]
31. If yes, do you have access to credit facilities?   1 = Yes [ ] 2 = No [ ]
32. If yes, did you apply for credit for the last season?   1 = Yes [ ] 2 = No [ ]
33. If yes, what was the motive for applying for credit?

1= for fertiliser 2= for labour 3= for fertiliser and labour 4= others

Appendix 3.2: Checklist for key informants

1. Name of office……………………….………
2. Name of interviewed officer..........................
3. Designation …………………………………
4. Is your office responsible for managing irrigation water resources?

a) Yes [ ] b) No [ ]

5. If yes, what is the role of your office in management of the existing Irrigation Schemes?
6. Do you have water irrigators' associations (IA) in existing Irrigation Schemes?

a) Yes [ ] b) No [ ]

7. If yes, how they were established? What were the reasons for their establishment?
8. What are the roles played by IAs in managing water resources in Kidwebezi?
9. Are there any conflicts occurred in the irrigation areas? Yes [ ] No [ ]
10. How were these conflicts solved?
11. How much water fees paid by the farmers per hectare?
12. How scores of the fees were paid by the farmers for the last five years?
13. What were the total cost of operation and maintenance in Kidwebezi scheme for the last five years?
14. What constraints/challenges does IA face in Kidwebezi? ……………………
15. What do you recommend? ………………………………………………..

Appendix 3.3: Check list for Focus group discussion

1. What are the types and major causes of water use conflicts among the farmers?

Scarcity of water [ ] Use without water right [ ]

Unequal water distribution [ ] Poor water management [ ]

2. Did you keep written or computer based records of water applied throughout the season? 1 = Yes [ ] 2 = No [ ]

3. What quantity of paddy you usually harvested per hectare? ....

4. According what you have harvested, do you think that the targeted yield was achieved?

1 = Yes [ ] 2 = No [ ]

5. If no, what factors are attributed to the less than the optimal yield?

1 = Bad weather [ ] 2 = Pests and diseases [ ] 3 = Low soil fertility [ ]

4 = Lack of fertilizers (low input use) 5 = Shortage of water for irrigation [ ]

6. Did you keep written/computer based records of water applied throughout the season?

1 = Yes [ ] 2 = No [ ]

7. The farmers of KIS do they have access to extension services?

8. If yes, do you have access to credit facilities? 1 = Yes [ ] 2 = No [ ]

9. If yes, what are the principal motivations for applying for credit?

1= for fertiliser 2= for labour 3= for fertiliser and labour 4= others

10. What are the roles played by IAs in managing water resources in Kidwebezi?

11. What constraints/challenges do IA faced in Kidwebezi Irrigation Scheme?