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RESEARCH ARTICLE

PERFORMANCE EVALUATION OF IRRIGATION SCHEMES IN RUGERAMIGOZI MARSHLAND, RWANDA

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ABSTRACT

Evaluating irrigation schemes contributes to the identification of performance gaps and this may lead to implementation of necessary improvements for enhancing agricultural productivity. In Rwanda, despite significant investments in irrigated agriculture, most of the irrigation schemes are performing far below their planned capacity. This study aimed at benchmarking the performance of Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes located in Rugeramigozi marshland, Rwanda using irrigation indicators developed by the International Water Management Institute (IWMI). The study showed that land productivity for both the two irrigation schemes was generally low. Rugeramigozi 2 irrigation scheme had superior performance than Rugeramigozi 1 in terms of water productivity due to adoption of deficit irrigation strategies that promoted water conservation. The performance indicators for water service delivery showed that water use was more sufficient in Rugeramigozi 1 compared to Rugeramigozi 2 irrigation scheme. The water delivery capacity performance for both schemes revealed that the existing irrigation canals were sufficient to meet the irrigation water requirements at peak demand. The analysis of financial performance in both schemes indicated that the collected irrigation fees were inadequate to cover the operation and maintenance costs. Similarly, the gross returns on investment were low in both irrigation schemes due to low crop yields that generated low revenue for farmers. Overall, the performance indicators showed that both Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes were in need of intensive management and infrastructural improvements in order to increase productivity and enhance sustainability of the schemes.

KEYWORDS

irrigation, irrigation performance indicators, marshland development, Rugeramigozi marshland.

1. INTRODUCTION

Agriculture contributes significantly to the economy of Rwanda (Bayisenge et al., 2019). According to Hashim (2014), agriculture accounts for about 33% of Rwanda's gross domestic product (GDP) and more than 70% of employment creation. However, the current agricultural production has remained insufficient to meet food demand for the country's population. The World Food Programme (2012) reported that about 21% of households in Rwanda were food insecure. In addition, food insufficiency in Rwanda has been exacerbated by the rapidly increasing population, which has intensified the pressure on land and water resources. Population growth in Rwanda was reported to be among the highest in Africa, increasing at about 3.5% per annum. This phenomenon has resulted in scarcity of arable land resources since many areas in Rwanda are generally hilly (Diao et al., 2010). In many cases, farmers in the country are left with no option but to cultivate these non-productive hilly areas and this has contributed to environmental degradation. All these challenges forced the government of Rwanda to increase investments in the agricultural sector in order to increase productivity and ensure the country's food self-sufficiency. The major focus by the government was to develop small and medium scale irrigation schemes in marshlands across the country to boost crop production and reduce dependence on unpredictable rainfall. As a result, considerable investments have been continuously channelled towards irrigation development (Giertz et al., 2015; Urujeni et al., 2015). Currently around 60,000 hectares are under irrigation and the government is targeting 102,000 hectares by 2024 (Mwai, 2019).

Despite the considerable investments, most of the irrigation schemes are operating below the planned capacity and resultantly, the overall performance of Rwanda's agricultural sector has remained poor over the years. The land productivity of many irrigation schemes has remained low, and there has been evidence of decline of farm sizes and this has caused reduction of incomes for farmers (Diao et al., 2010). The irrigation schemes in Rwanda are also facing irrigation efficiency challenges because of underutilization of water distribution infrastructure including reservoirs/dams and irrigation canal networks (MINAGRI, 2013; Nabahungu, 2012). Dusabimana (2012) reported that underperformance of most irrigation schemes in Rwanda emanate from poor management and operation and maintenance (O&M) of the irrigation systems. Additionally, the 2013 Rwanda Irrigation Policy and Action Plan highlighted the irrigation challenges to be a result of lack of monitoring,

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evaluation and improvement of existing irrigation infrastructure (MINAGRI, 2013). In addition to water quantity challenges, Uwiragiye (2015) indicated the threat to irrigation schemes to originate from water quality issues due to presence of heavy metals in irrigation water.

In light of the highlighted irrigation challenges in Rwanda, Burt and Styles (1998) argued that sustainable agricultural production can be achieved by either developing new irrigation projects or by evaluating and improving the performance of the already existing operational and/or dysfunctional irrigation schemes. In countries like Rwanda that are characterized by land and water scarcity, it is inevitable to evaluate the performance of existing irrigation schemes and to propose measures that enhance crop productivity, and ultimately the economy and food self-sufficiency of the country.

Rugeramigozi 1 and Rugeramigozi 1 located in Rugeramigozi marshland are two examples of existing irrigation schemes in Rwanda that are experiencing performance and productivity challenges. To the authors' best knowledge, there is no published research that investigated the performance of these two irrigation schemes since their inception. Therefore, the overall objective of this study was to benchmark the performance of two important irrigation schemes located in Rugeramigozi marshland in Rwanda using widely accepted irrigation indicators developed by the International Water Management Institute (IWMI) and recommend strategies that may improve their performance.

2. Materials and Methods

2.1 Study area

The study was conducted at Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes located in the Rugeramigozi marshland in Muhanga district of the southern province, Rwanda (02°07′40″ S, 29°45′20″E). Rugeramigozi marshland covers an area of 250 ha on the plateau agro-ecological zone of Rwanda at an altitude of 1650 m (Hakuzimana, 2015; Umugwaneza, 2014). The average annual rainfall in Rugeramigozi is 1200 mm and the temperature ranges between 18-20 °C. The most dominant soil series in the marshland are black clay and sandy loam. The marshland initially consisted of three adjacent irrigation schemes including the upstream Rugeramigozi 2 covering an area of 121 ha and irrigated by Misizi reservoir, Rugeramigozi 1 covering 66 ha in the middle and Biringanya in the downstream occupying 64 ha. Currently, Rugeramigozi 1 and Biringanya are managed as one irrigation scheme called Rugeramigozi 1, with a total of 130 ha of land utilized for agricultural production.

Rugeramigozi 1 irrigation scheme is managed by 1,200 farmers registered in Koperative Imparaniramusaruro y'Abahinzi-Boroziba Rugeramigozi (KIABR) cooperative. In this cooperative, farmers have a water users' association which is in charge of water supply and collection of irrigation fees that are used for management of the scheme including operation and maintenance of the irrigation infrastructure. Irrigation water is supplied from the Rugeramigozi impounding reservoir, which has a storage capacity is 270,000 m^3. The reservoir's source of water is mainly rainfall and runoff from its catchment as well as the outflows from the Misizi reservoir located in the upstream. The major crops grown in Rugeramigozi 1 irrigation scheme include maize, beans and vegetables.

Rugeramigozi 2 gets irrigation water from the Misizi impounding reservoir which has a total storage capacity of 320,000 m^3. Misizi reservoir has no permanent river inflows except for a few available springs and the runoff from the neighbouring hills. Drainage water from Rugeramigozi 2 irrigation scheme in the upstream is also a major source of water for Rugeramigozi 1 which is in the downstream. The major crops grown in Rugeramigozi 2 irrigation scheme are maize, beans and sorghum. Figure 1 shows Muhanga district in Rwanda where Rugeramigozi marshland is located.

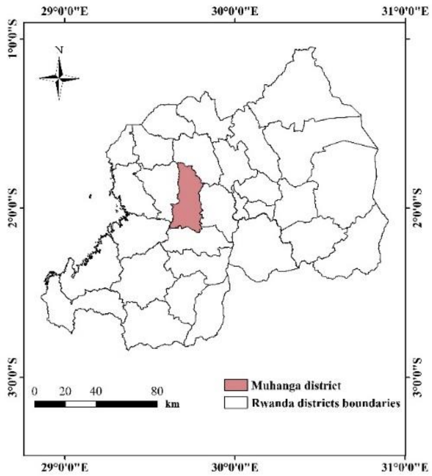

Figure 1: Location of Muhanga district, Rwanda

2.2 Data collection

This study utilized primary data collected through field measurements, semi-structured interviews with farmers and government officers, and secondary data gathered from historical records of the two irrigation schemes. The data included climate data, flow measurements, agronomic and crop yields. Data on crop production, irrigation water supplies, O&M costs and water fees were collected for the period between 2011 and 2014 in each scheme. Table 1 presents the irrigated area, water requirements, crop yields and production values aggregated over the study period for the two irrigation schemes.

Table 1: Annual irrigated area, water requirements, crop yields and production value for Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes

Irrigation scheme	Crop	Total irrigated area (ha)	*CWR (mm)	†NIR (mm)	Total Yield (Mg)	Production value (US$)
Rugeramigozi 1	Rice	124.2	1,524	1,315	309.0	108,000
	Maize	40.0	535	236	6.6	3,700
	Beans	40.0	381	66	6.1	3,400
	Vegetables	6.4	432	365	47.6	6,900
Rugeramigozi 2	Rice	59.1	1,527	1,306	91.8	34,200
	Maize	63.7	544	233	38.7	21,500
	Beans	55.7	386	65	64.1	35,700
	Vegetables	13.0	471	381	75.9	12,000

*CWR - Crop water requirements, †NIR - Net Irrigation Requirements

Cropping patterns were similar in the Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes and comprised of four crops including rice, maize, beans and vegetables. The CROPWAT 8.0 model developed by the Food and Agriculture Organization (FAO) was used to calculate the crop water requirements and irrigation requirements.

3. Results & Discussion

3.1 Land productivity

Land productivity gives an indication of the crop production or output per unit land area (Dharmasiri, 2012). The indicators that were used to evaluate land productivity in this study were: output per unit irrigated area (OIA) and output per unit command area (OCA). For standardization across crops in the two irrigation schemes, the land productivity indicators were expressed in monetary value per unit area based on local market prices. The results showed similarities in the land productivity performance for both Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes. The estimated OIAs for Rugeramigozi 1 and Rugeramigozi 2 were US$579/ha and US$540/ha, respectively. Additionally, the OCA values were US$1,017/ha and US$985/ha for Rugeramigozi 1 and Rugeramigozi 2, respectively (Figure 2). The land productivity indicators estimated for the two irrigation schemes in this study were significantly lower than those reported by Muema et al. (2018) for similar irrigation schemes in Kenya, which is also located in East Africa. Muema et al. (2018) found average OCA values ranging from US$1,921/ha to US$2,047/ha and OIAs ranging from US$981/ha to US$1,841/ha for the Kenya irrigation schemes and highlighted the high values to be a result of intensive irrigation in those schemes. This could mean that the Kenya irrigation schemes had sound operation and maintenance that allowed for better irrigation water adequacy than Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes evaluated in the current study.

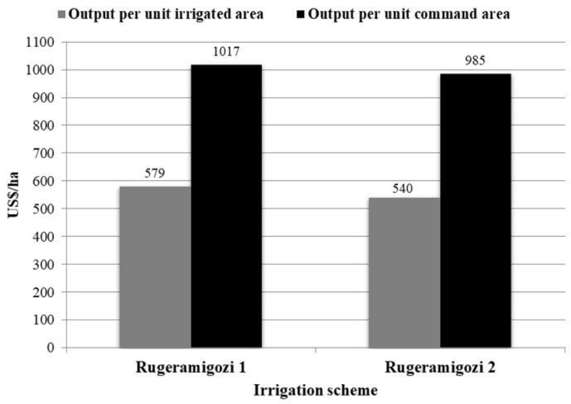

Figure 2: Land productivity indicators in Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes

Under rice cropping in Thailand, Bumbudsanpharoke and Prajamwong (2015) determined also high average OIA and OCA values ranging from US$1,300/ha to US$1,310/ha and US$1,570/ha to US$1,640/ha, respectively. The land productivity values reported in literature clearly shows that both Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes were performing below the expected levels, which appears to be caused mainly by low crop yields. In an irrigation benchmarking study by Ghazalli (2004), similar challenges identified in Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes were reported for irrigation schemes in Malaysia, which achieved OIA values ranging between US$100/ha to US$800/ha. Many smallholder irrigation schemes around the world have similar challenges of low crop yields which often result from water shortages (Ghazalli, 2004; Masasi, 2015; Masasi and Ng'ombe, 2019).

3.2 Water productivity

Water productivity is defined as the amount of beneficial output per unit of water depleted (Molden, 1997). The most general indicators used to calculate water productivity in irrigated agriculture include the output per unit irrigation water supply (OIS) and output per unit water consumed (OWC). Despite the low water productivity values determined for both schemes, Rugeramigozi 2 irrigation scheme relatively utilized water slightly more efficient compared to Rugeramigozi 1 irrigation scheme. Field observations showed that farmers in Rugeramigozi 2 irrigation scheme generally utilized deficit irrigation to try to optimize crop production with less water supply. Figure 3 presents the results of the OIS and OWC determined for Rugeramigozi1 and Rugeramigozi 2 irrigation schemes.

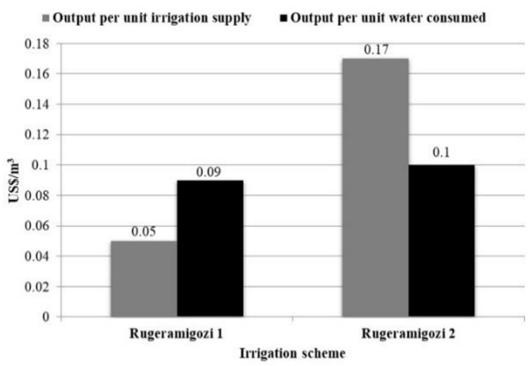

Figure 3: Water productivity indicators in Rugeramigozi 1&2 irrigation schemes

The OIS and OWC values determined for Rugeramigozi 2 irrigation scheme were within the range of values reported for West Kano and Bunyala irrigation schemes in Kenya (Muema et al., 2018). The OIS and OWC values ranged from US$0.11/m^3 to US$0.25/m^3 and US$0.07/m^3 to US$0.22/m^3 for the two Kenyan irrigation schemes. According to Muema et al. (2018), these low values indicate inefficient use of water resources for irrigation. From that same conclusion, it can be seen that both Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes did not get better returns of water used for irrigation. Similar to the findings of this study, low water productivity values were also reported for rice dominating irrigation schemes in Malaysia with OIS and OWC values in the range of US$0.01- US$0.28 and US$0.01- US$0.43, respectively (Ghazalli, 2004).

3.3 Service delivery performance

The Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) indicators were used to assess the adequacy of water supply to meet the crop water demand in the two irrigation schemes. Both RWS and RIS indicate whether water is abundant or is limited in a given irrigation scheme (Beshir and Awulachew, 2008; Molden et al., 1998). Optimal service delivery conditions occur if RWS and RIS values are equal to 1. Values less than or greater than one for either of these indictors would indicate under- or over- supply of available water for irrigation, respectively (Ayana and Awulachew, 2008). According to Molden et al. (1998), RWS values of at least 0.8 may represents no water challenges in an irrigation scheme. Table 2 presents the average annual RWS and RIS values determined for Rugeramigozi 1and Rugeramigozi 1 irrigation schemes.

Table 2: Annual Relative water supply (RWS) and Relative irrigation supply (RIS) indicators for Rugeramigozi 1and Rugeramigozi 1 irrigation schemes

Performance indicator	Rugeramigozi 1	Rugeramigozi 2
Relative water supply	2.61	1.28
Relative irrigation supply	2.69	0.98

Generally, the average values determined for annual RWS and RIS in Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes indicated that enough water is available to meet crop water demands according to the existing cropping patterns. However, field observations particularly in Rugeramigozi 2 irrigation scheme showed that more attention should be paid to maintaining existing water channels and irrigation schedules of the irrigation scheme in order to avoid over irrigation and other water losses. Figure 4 shows an example of breached field ditch in Rugeramigozi 2 irrigation scheme.

Figure 4: Broken field ditch in Rugeramigozi 2 irrigation scheme

In order to show the adequacy of the irrigation infrastructure to supply water in the two irrigation schemes, the water delivery capacity (WDC) was also estimated. This indicator answers the question of whether the existing water distribution system (irrigation channels) is able to meet the peak irrigation requirement in a particular season. Values greater than 1 indicate that the canal capacity is not a constraint to meet crop water demands (Molden et al., 1998). The discharge capacity of the main canals at the system head were 0.81 m^3/s and 0.66 m^3/s for Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes, respectively. The peak irrigation requirements expressed as a flow rate at the head of the irrigation systems were estimated using the CropWAT model and were determined as 0.26 m^3/s and 0.29 m^3/s for Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes, respectively. The peak irrigation requirement occurred in the month of July for both schemes, which is the dry season period in the study area. Overall, the average estimated WDC values were 3.1 and 2.3 for Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes, respectively, an indication that the existing water distribution systems in both irrigation schemes were adequate and not constraining for irrigation.

3.4 Financial performance

The gross return on investment (GRI) and financial self-sufficiency (FSS) indicators explain how an irrigated agricultural system perform financially (Molden et al., 1998). The investment cost on water distribution system in both irrigation schemes were obtained from the management of the schemes and were about US$496,000 and US$464,000 for Rugeramigozi 1 and Rugeramigozi 2, respectively. The GRI values obtained were 24.6% and 22.3%, respectively. The GRI values were low due to the low crop production in both schemes. On average, the annual revenues collected from water fees in Rugeramigozi 1 and Rugeramigozi 2 were US$9,548 and US$1,200. The total operation and maintenance expenditures were US$29,120 and US$1,365 for Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes, respectively. Overall, the FSS values were 32.8% and 87.9% for Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes, respectively. Rugeramigozi 2 had relatively better financial performance because farmers were more faithful in paying irrigation fees. However, as explained by Molden et al. (1998), the high FSS determined for Rugeramigozi 2 irrigation scheme in this study may not necessarily indicate that this irrigation scheme is sustainable as the O&M expenditures reported in the records appeared to be lower than the total maintenance financial needs of the scheme. Nevertheless, this study has showed that willingness to pay irrigation fees by farmers may improve the financial self-sufficiency of irrigation schemes. Rugeramigozi 1 irrigation scheme depends mainly on government subsidies and generally these funds are not enough to offset the O&M expenditures in the irrigation scheme, hence the low FSS. Similar to Rugeramigozi 1, farmers in irrigation schemes worldwide, particularly in developing countries have a general attitude that it is their governments' responsibility to perform the operation and maintenance of their irrigation schemes, and therefore are usually unwilling to pay irrigation fees (Ghazalli, 2004). In Thailand, Bumbudsanpharoke and Prajamwong (2015) found low FSS values ranging between 29.2 and 33.3% for the Great Chao Phraya Irrigation scheme which is similar to what was found for Rugeramigozi 1 irrigation scheme in the current study. Bumbudsanpharoke and Prajamwong (2015) recommended increasing fees paid by famers for irrigation water in order to raise the annual O&M expenditures in Great Chao Phraya Irrigation scheme. However, there is a need for finding strategies that enhance the willingness of farmers in the two irrigation schemes to pay irrigation fees. Motivating farmers to cover the O&M costs without external subsidies from the government usually creates a sense of ownership among farmers and hence, may improve the performance the two irrigation schemes.

4. Conclusion

This study conducted performance evaluations of Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes in Rwanda using irrigation performance indicators developed by the International Water Management Institute (IWMI). The IWMI indicators were used to assess the land and water productivity, service delivery and financial performance of the two irrigation schemes. The results showed that the two irrigation schemes were performing far below their expected capacity. The land productivity indicators estimated for the two irrigation schemes in this study were significantly lower than the reported values for similar irrigation schemes in the East Africa and other regions around the world. Similarly, water productivity indicators showed minimum financial returns due to inefficient use of irrigation water. Generally, water supply in both irrigation schemes was determined to be adequate for meeting water demands of the traditional crops in the study area, but poor operation and maintenance of irrigation infrastructure in the irrigation schemes led to significant water losses. The financial performance of both irrigation schemes in this study was lower than what is reported in literature for similar schemes. This study recommends motivating farmers to pay irrigation fees in order to cover the operation and maintenance costs, and encouraging farmers to adopt and cultivate cash crops that may lead to better gross margins and ultimately the sustainability of the irrigation schemes. Furthermore, it is recommended that farmers and management staff in Rugeramigozi 1 and Rugeramigozi 2 irrigation schemes be trained in aspects of water supply, irrigation schedules, fertilizer application and other agronomic practices to boost agricultural productivity.

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