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Research Article

Impact of Irrigation Systems Use in Agriculture Farming in Rwanda: A Case Study of Kagitumba, Nasho and Muyanza Schemes.

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ABSTRACT
Agriculture remains an important economic sector in many developing countries. It is a source of growth and a potential source of investment opportunities for the private sector. Irrigation, therefore, currently plays a less significant role in African agriculture compared to other regions, as Africa's irrigated cultivated land is much lower than the world average. This research study investigated the impact of irrigation system use in agriculture farming in Rwanda. A multi-stage sampling method was employed, whereby the Nyagatare, Kirehe and Rulindo districts, and three irrigation schemes such as Kagitumba, Nasho and Muyanza were first purposely selected. Finally, a simple random sampling was used to obtain a total sample size of 240 maize farming households, within these three irrigation schemes. The findings indicated that land size was significantly and positively associated with the water pump use. The water pump and sprinkler irrigation system use and farm income were significantly and positively correlated. The water user's association's membership and the water pumper drip and sprinkler irrigation systems were significantly and positively correlated. The findings of this research revealed that factors namely family size, education level, fertilizers, irrigation system, farming experience are statistically significant to influence productivity of maize crops at these irrigation schemes. In addition, the results of cost benefit and margin analysis indicated that the Net Farm Income (NFI) per ha at Nasho schme site was largest followed by Kagitumba and Muyanza scheme site was the lowest. However, the benefit cost ratio was the highest (2.3) at Kagitumba site, suggesting that one-dollar of investment at Kagitumba irrigation scheme generates 2.3 dollars of revenue. Some factors in this study were statistically and significant to influence the farmers' willingness to pay for irrigation water in study areas. After the findings, the researcher suggested that farmers should be encouraged to better use agricultural inputs, high attention should be made on infrastructures in order to sustain and maintain them in long run, farmers should be encouraged to pay for irrigation water, public and private sector should increase investment and expand the drip and sprinkler irrigation system where possible in country.
Keywords: Economic Analysis, Impact, Irrigation System, Agriculture Farming, Scheme.

INTRODUCTION
Agriculture remains an important economic sector in many developing countries. It is a source of growth and a potential source of investment opportunities for the private sector. Two-thirds of the world's agricultural value added is estimated to be created in developing countries (World Bank, 2008).
In Sub-Saharan Africa, it still provides a relatively large share of the gross domestic product (GDP) in many countries but productivity in the sector lags considerably behind that of other continents, as well as the region's potential. On average, about 65% of Africa's labour force is employed in agriculture activities, yet the sector accounts for only about 32% of GDP, reflecting relatively low productivity and subsistence farming. In Africa, most agricultural land is rain-fed and subject to erratic rainfall and recurrent droughts, leading to low agricultural sector performance. This includes low resilience of rural people to climatic effects, irregular

production and low productivity, low intensification and crop diversification, and weak value chain and market development (Fethi Lebdi, 2016).

Rwanda is a hilly country where most of the cultivation area is on hillside with an incline of more than 60% slope (MINAGRI, 2010). Given that, 90% of domestic cropland is on slopes, more efforts deployed in land management to improving land productivity and stability (MINAGRI, 2019). The agriculture sector is the main economic activity in Rwanda where 64% of the working population are employed in Agriculture. Agriculture GDP represents around a third of the National GDP and currently stands at 24% (MINAGRI, 2010). Smallholder agriculture is argued to remain important for economic development and poverty reduction in developing countries, but its development is challenged by the need for institutional innovations to overcome market failures (World Bank, 2008).

Given the predominance of agricultural livelihoods among poor rural households, this agenda will often have a strong agricultural orientation, with a focus on improving sustainability and resilience in agricultural practices. However, the agenda also needs to be relevant to different types of livelihoods that sometimes exist within a single household (MINAGRI, 2011). Modernizing and increasing productivity of Agriculture and livestock is one of the priority areas of the Government strategy for transformation (2018-2024) (MINAGRI, 2019).

Despite the importance of agriculture sector and the Government strategy for transformation (2018-2024), there is a huge low productivity of lands resulting from excessive use of land and low application of inputs including fertilizers, improved seeds pesticides; lack of stable irrigation system, difficulties to get access to agricultural credit, conservation of water and soil not integrated in agriculture and livestock, shallow knowledge about water management by the farmers, agricultural mechanization nearly absent and less operational, and marshlands badly and less exploited (MINAGRI.,2004) and (Tetteh Anang, B,2015).

Therefore, this require an effort of introducing new varieties, disease mitigation strategies as well as improving farmers' knowledge and skills to support specialization, intensification, diversification, and value addition is critical. In addition, reinforcing advanced technology will trigger increased production as well as facilitating in copping up with climate risk mitigation strategies (MINAGRI, 2004).

Agriculture has tremendous potential to reduce poverty and create employment for the rural poor since most are employed in it. However, this cannot be achieved without improving the agriculture water resources use. Given that agriculture is largely rain-fed, irrigation water has become a very crucial resource in agricultural production, and poverty reduction. Poverty reducing impact of irrigation is substantial as evidenced in many Asian countries. For example, about 35-40% of cropland in Asia is irrigated and poverty reduction in the 1970s was substantial (Hussain & Hanjra.,2003).

Despite rapid economic growth in Africa over the past years, the performance of agricultural sector is low and hunger continues to be a risk, in particular in the Horn of Africa and Sahel region. Rural vulnerability, low resilience to climatic effects and poverty are still deep in rural areas and nutrition is poor. Agricultural transformation is needed in Africa to address these challenges and irrigation is one pillar to contribute to such transformation (Fethi Lebdi, 2016).

Rwanda is very rich in surface water, yet crop yield and crop productivity consistently suffer from a lack of irrigation water specifically eastern region during the growing season. The factors considered in using irrigation as a production strategy in Rwanda has been different from many countries mainly because of geographical diversity, water availability and financial constraint. Irrigation schemes has allowed farmers to move from rain-fed agriculture to diversified high value crops hence resulting to increased cropping intensity and land productivity. The country has registered 63,742 ha under irrigation - including 37,273 ha of marshlands, 8,780 ha of hillsides and 17,689 ha of small-scale irrigation (MINAGRI, 2020).

In Rwanda, agriculture provides rural employment, guarantees food security, and drives economic growth. Therefore, successive governments have attached importance to agricultural and rural development through a series of development programs and agricultural reforms. Water is a vital economic resource especially in agriculture, as it plays a crucial role in the fertility of agricultural lands (Davivongs, V *et al*, 2012). In addition, accessibility to water resources contributes to improving the livelihoods of small-scale farm households (Kitchaicharoen *et al*, 2008).

Water scarcity has become a major issue for both policy makers and water users. In fact, agriculture sector is more prone to water scarcity. Adoption of modern irrigation technology can be an appropriate strategy to overcome the effects of water scarcity (Koundouri *et al*, 2006). In developing country including Rwanda, irrigation can be considered as a strategy of poverty reduction through intensive agriculture (Smith, 2004). Nevertheless; for proper management and development of irrigation system, there must be a sound coordination between local institution and government agency (Ostrom, E, 1992).

The traditional system of irrigation comprises of the use of either rope and buckets to lift and distribute water from shallow open wells or watering cans to lift water from streams. Although the low capital requirement of these traditional technologies makes them advantageous and affordable, their low delivery capacity and labor-intensive nature make them highly unfavorable to African production conditions (Kamara, 2004).

Such traditional methods of irrigation like flood, level border, and furrow requires more water in short amount of time. Since those technologies are based in the gravity that results in non-uniform distribution of water. Whereas, for some modern technologies, such as drip and sprinkler irrigation, comparatively less amount of water is required over long time and the distribution of water is uniform by maintaining a level of pressure in water delivery system (Green,1996).

An irrigation scheme is a systematic approach to managing water in the farmland whereby the water is provided to and channelled away from the farmland, and includes the conservation of water for dry seasons and ecological maintenance. The ultimate goal of an irrigation scheme is to enhance the economic performance with minimal water and energy consumption (Samian *et al.*, 2014; Pandy., *et al;* 2000, and Panda *et al*., 2004).

Irrigation water is applied to ensure that soil moisture is sufficient to meet crop water needs and thus reduce water deficit as a limiting factor in plant growth (Van-Averbeke, *et al.*, 2011). Irrigation technology allows for the control and distribution of water to meet varying needs within a water system, such as agricultural, industrial, and household needs (Gregg, N. S.; 2008, Lenton, R.; Muller, M. 15). Irrigation is generally defined as the application of water to the land for the purpose of supplying moisture essential to plant growth. Irrigation is intended to augment the water supply from rainfall Mutsvangwa, T., & Doranalli, K., (2006) defined irrigation as the cultivation of land through the artificial application of water to ensure double cropping as well as steady supply of water in areas where rainfall is unreliable. There are wide variations in the proportion of irrigated agricultural land in the developing world, with 37% in Asia, 15% in Latin America, 6% in Africa and 4% in Sub-Saharan Africa (FAOSTAT, 2012). Irrigation, therefore, currently plays a less significant role in African agriculture compared to other regions, as Africa's irrigated cultivated land is much lower than the world average.

Low levels of irrigation in Africa are as a result of high irrigation investment costs, perceived failures of past irrigation projects, limited government commitment, and poor rural infrastructure, and fragmented farmers, and crops with low water requirements (You *et al.,* 2010). Irrigation schemes have proven to be a viable and attractive option for rural farmers in developing countries. He further asserted that returns from irrigated farming even on tiny plots could greatly exceed returns from rain-fed production. In many developing countries, irrigation schemes were counted on to increase production, reduce unpredictable rainfall and provide food security and employment to poor farmers (Burrow, 1987). It enables farmers to earn an income, which enables them to meet some of their basic needs.

There are some interrelated mechanisms by which irrigated agriculture can increase particularly increasing production and income, and reduced food price, that helps poor households meet the basic needs and improve welfare, protecting against the risks of crop loss due to erratic, unreliable or insufficient rain fall, promoting greater use of yield enhancing farm inputs which creates additional employment, which together enables people to move out of the poverty cycle.

Compared to furrow systems, drip irrigation can substantially improve water use efficiency (WUE) by minimizing evaporative loss of water and maximizing capture of in-season rainfall by the soil profile (Dandedjrohoun, 2012). The main disadvantage of drip irrigation systems is the cost of installation and maintenance. Historically, irrigation scheduling in drip irrigation systems has proved to be slightly more difficult than for other irrigation delivery methods nevertheless, drip irrigation can help satisfy the demands associated with increased pressures of growers to increase WUE and maximize production (Oladeji *et al.*, 2015).

However, there are a number of studies in different countries that show evidence that irrigation schemes have served as the key driver behind growth in agricultural productivity and increasing household income and poverty alleviation (Lipton, 2003).

There is a need to prioritize irrigation development in Rwanda not only because of the existence of agricultural water resources, but also because of the high value of irrigated agriculture in the country and the large number of rural poor that could benefit from high productivity as a result of irrigation investment. These schemes helped in reducing rural-urban migration by offering rural population an alternative source of employment and income. Food security is likely to increase in households practicing irrigation farming. This study was mainly focused on analysis of the impact of small-scale irrigation system use in agriculture farming in Rwanda.

MATERIALS AND METHODS

Description of the Study

This study focuses on the three districts namely Kirehe, Nyagatare and Rulindo of Eastern and Northern Province respectively. Kirehe District is one of the seven districts making up the Eastern Province. It is made up of 12 administrative sectors, 60 cells and 612 administrative villages. Kirehe District extends over a total area of 1,118.5 Km^2 with about 164,012 male and 176,971 female inhabitants equalling to 340,983 of its total population according to the newly provisional results released by the National Institute of Statistics of Rwanda (NISR, 2014). The Economy of Kirehe district is based on agriculture and livestock, which is at least 90% of the population. It is characterized by a low altitude plain of more or less than 1,350 m of altitude. The District of Kirehe is characterized, in general, by lowly undulating hills separated by valleys some of which are swampy and boggy. This kind of topographical layout constitutes an important potentiality for modern irrigation system and mechanized agriculture.

The study area covered three irrigation schemes such as Kagitumba, Nasho and Muyanza locsted in the said above districts. Due to their mechanization and irrigation system, the annual crops cultivation was possible for all seasons. Umuvumba, Akagera Rivers and Muyanza

Dam are being the main source of irrigated water of those commend areas. In the eastern province, the water from the Umuvumba, Akagera Rivers basin were principally used for agriculture and household consumption purposes.

Sampling Technique and Sample Size

A field survey was carried out using a structured questionnaire to gather the quantitative data from the participating crops farming households in this study sites. In addition, observations, in-depth interview sessions, focus-group discussions, and key informant interviews were undertaken for the background and qualitative data. The population of interest constituted by farmers growing crops in thess three irrigation water schemes. A multi-stage sampling was used, whereby the Nyagatare, Kirehe and Rulindo districts, and three irrigation schemes such as Kagitumba, Nasho and Muyanza were first purposely selected. Following this, stratified sampling was applied to categorize the farming households by the irrigation system: the water pump, drip and sprinkler. Finally, simple random sampling was used to obtain a total sample of 240 crops farming households, within which there are 106 farmers for water pump irrigation system, 40 farmers for drip irrigation system, and 94 farmers for sprinkler irrigation system farmers.

Data collected were analysed using descriptive statistics, cost benefit, gross margin, budgetary technique analysis and quantitative methods. Descriptive statistics such as percentage and frequency were used to analyse farmer's socio-economic characteristics to maize production. Multiple regression analysis was employed to identify the factors influencing irrigation system use and productivity of crops grown in area; cost benefit, gross margin and budgetary technique analysis were used to evaluate the profitability of using irrigation system in agriculture farming improved seeds, while difference in difference method was employed to compare the impact of three irrigation system on productivity of crops grown in those schemes. The gross margin technique is specified below:

GM = TR - TVC

Where:

GM = Gross margin, TR = Total Revenue from maize

TVC = Total Variable Cost utilized

Data Analysis

A process of cleaning, transforming, and modeling data to discover useful information for business decision-making. The purpose of Data Analysis is to extract useful information from data and taking the decision based upon the data analysis.

For this study, both quantitative and qualitative data analyses were applied. Descriptive statistics were used to describe the characteristics of the households by frequency, percentage, and standard deviations. Economic returns associated with the three irrigation technologies were analysed using the cost and benefit method where the F-test was employed to determine the statistical differences of the revenue and cost items among the variable irrigation schemes.

The functional form of the stochastic frontier production (or cost) model employed for this study is the Cobb-Douglas (C-D) functional form. This is because it is self-dual and therefore it allows for the estimation of both the production and cost functions. The efficiency estimates obtained by the methods described above are regressed on some farm and household specific attributes by use of the Tobit model.

RESULTS AND DISCUSSION

Demographic and Socioeconomics of the Respondent's Farmers

Table 1 shows the demographic and socioeconomic characteristics of the maize farmers involved in irrigation system (water pump, drip, and sprinkler) at Kagitumba, Naho, and Muyanza schemes.

The findings in table 1 indicated that (50.8%) of the respondent farmers (240 farmers) were male and 41.9% were female. The respondents' ages were classified into four age groups (table 1): less than 30; 31–40; 41–50, and above 51. Overall, the 46–51 age group constituted the largest proportion (35.4%), followed by the 31-45-plus (33. 8%), less than 30 (18.8%), and above 61 (12%) age groups. The findings showed that younger generations are currently abandoning agriculture farming due to the lack of initial capital and other support to enter the sector properly which in turn cause a huge lack of labor force and high urban migration. The respondents' years of maize farming experience were classified into five lengths of time. The findings of this study indicated that the overall, the 11–15 group had the largest number of respondents (30%), followed by the 6–10 (29.2%), 16–20 (16.6%), >5 (14.2%), and above 20 years (10%) groups.

The land sizes were categorized into five classes as shown in table above. The findings revealed that the majority of farmers have farm less than 1 ha represented by (43.3%) followed by the class ranging between 1.1-2 ha with (21. 7%), 2.1-3 with (14. 2%). The results indicated farmers with small land are concentrated in Muyanza site in Rulindo diatrict with less than 1 ha. While big farmers with big farm are highly located in Nasho, and Kagitumba sites in Kirehe and Nyagatare districts respectively. This implies that irrigation system is more utilized in eastern region rather than northern due to the lack of regular run fall. The study indicated that an increase in the land size influenced an increased probability of the water pump, dip, and sprinkler irrigation system used in maize farming in study areas.

The Factors Influencing Farmers to Use (Water Pump, Drip and Sprinkler) Irrigation System

A probit regression model was fitted using the binary dependent variable. The results of the model showed that the data fitted well (R-square equal to 0.7768; 0.7920, and 0.8587 respectively for Water pump irrigation system, Drip irrigation system, and Sprinkler irrigation system all of them with a p-value < 0.0001) as presented in table 2.

The water pump and drip irrigation system and age had a significant negative correlation with each other (β = -0.0735, $p < 0.05$), while this association was significantly positive between the sprinkler use and age (β = 0.207, $p < 0.05$). The findings showed that the young farmers were more receptive to the sprinkler irrigation system due to its ease of use, while their old farmers preferred the WP technology probably due to their familiarity with the motorized machinery and pumps as well as their great distance from the water source. Our support in-depth interviews indicated that the discontinuity of traditional irrigation system could lead a new generation of farmers shifting to using new technology especially drip and sprinkler due to its easier use and easily facilities from government.

Land size was significantly positively associated with the water pump use (β = 0.621, $p < 0.01$). Thus, an increase in the land size contributed to an increased probability of the use of drip and water pump irrigation system use in maize cultivation of the study area. The water pump and sprinkler irrigation system use and farm income were significantly positively correlated (β = 0.000, $p < 0.01$), which suggested that the increased income from the sales of maize contributed to the greater likelihood of the two-system utilization. On the other hand, the drip irrigation system was significantly negatively associated with farming income (β = -0.007, $p < 0.01$). Supported by, one study Gebregziabhe *et al*., (2014) noted that farming households with alternative sources of income exhibited a greater tendency to adopt modern irrigation technologies (e.g., the motor pumps). It was also supported by farmers revealed that farmers using water pump many times face some challenges especially expenses in terms of equipment, maintenance, and fuel.

The sprinkler and water pump use were significantly positively correlated with an upstream farmland location (β = 4.042, $p < 0.01$). On the other hand, the upstream location of farmlands was significantly negatively associated with the drip irrigation use (β = -0.387, $p < 0.01$). The findings revealed that despite the advantageous farmland location, the upstream maize farmers still deployed the sprinkler and water pump system to significantly irrigate their maize farms, giving rise to the downstream farmers' perceived unfairness of the water allocation. The farmers who are encourage away from the water resource may experience water shortages for agriculture farming, which in turn affect maize production.

The water pump utilization and the distance from the water source were significantly negatively correlated (β = -1.056, $p < 0.01$). This implies that a greater distance from the irrigation system meant a greater a lower chance of getting desired amount of water for irrigation due high requirement of materials. Moreover, a previous study of Aseyehegu *et al*, (2012) reported that distance had no influence on the water pump use in Ethiopia. Meanwhile, the relationships of the proximity to the water source with the drip and sprinkler system use were more and positively correlated. The water users' associations membership and the water pumper, drip and sprinkler irrigation systems were significantly positively correlated (β = 2.3745, $p < 0.01$).

Therefore, the registration of farmers into the water user associations plays an important role in terms of increasing the awareness of the issues of the lack of water and best exploitation of water resources and to allocate adequate water to members in the group, which influence positively water allocation efficiently and effectively. According to previous studies of Buyukcangaz, (2007) and Smith (2002), the establishment of water user associations and the transfer of responsibility for operation and maintenance of irrigation systems to the farmers plays an important role in encouraging users to adopt technologies for more efficient water use and increased crop production.

Factors Influencing Productivity of Irrigation System in Study Area

The factors influencing productivity of irrigation water were determined through OLS using STATA software with version 13.0. The results of OLS regression are presented in Table 3. The results in table 3 shows the model fits the data reasonably well (p-value < 0.0001 and R^2 of 0.83). This means that 83% of the variation in the dependent variable is explained by the explanatory variables.

Productivity of irrigation water is influenced by several factors in study area. In the study, social economic variables such as family size, education level, fertilizers, irrigation system, farming experience, volume of water, extension service, off farm income, gender, and cooperative membership have positively influenced productivity. Factors namely family size, education level, fertilizers, irrigation system, farming experience are statistically significant at 1% level to influence productivity while volume of water, extension service, off farm income were positively influenced at 5% level. Hence gender, cooperative membership was positively influenced at 10% level. Five factors such as labour source, age, price of produce, distance to market, agricultural credit, negatively influenced productivity in study area. One factor namely land size/plot did not influenced productivity.

The results show that among the variables, factors namely family size, education level, fertilizers, irrigation system, farming experience have high positive significant influence on productivity (p values <0.01) while the as labour source, age, price of produce, distance to market, agricultural credit have high negative significant influence on the productivity under irrigation water (p <0.01). It is expected that a unit increase in family size would contribute 1.3-unit increment in the productivity in study area under irrigation system, while holding other factors constant. A 1% increase in extension should increase productivity by 1.4%. This is because more contact with these organizations technicians enhances sharing of information regarding the technology and accessibility of water for irrigation. In the other word service contact is enhanced by attendance to group meetings from where the farmers are met by extension agents. Farmers who fail to participate in such meetings/trainings often get little information and thus lower usage of agricultural inputs properly.

A 1-year increase in farming experience should increase productivity by 0.32%. This is because the longer being in farming, the better to know different agricultural practices hence, high reduction of challenges example irrigation system and pests and diseases control. Factors such as age, price of produce, distance to market, agricultural credit, negatively influenced productivity. This implies that 1-kilometer increase to the market should reduce productivity by 1.2%. This shows that accessibility to market is a key factor in the level of irrigation system use and agricultural productivity. For a unit increase in reduction of price of produce, there is a 0.3% increase in the reduction of agricultural productivity in study area under, holding other factors constant.

Economic (Cost-Benefit) of Using Irrigation System at Kagitumba, Nasho and Muyanza Schemes

The economic analysis of profitability of maize farming associated with this three-irrigation system (water pump, drip, and sprinkler) at three sites such as Kgitumba, Nasho, and Muyanza of the participating farming households were analysed and compared using the economical method of conventional cost benefit. Economically, the measures of farmers' economic conditions encompass the adoption cost, operational cost, productivity, profitability, and farm efficiency.

Table 1. Demographic and Socioeconomics of the Respondent's Farmers.

	Kagitumba		Nasho		Muyanza		Total	
	F	%	F	%	F		F	%
Gender								
Male	44	55	41	51.25	37	46.25	122	50.8
Female	36	45	39	48.75	43	53.75	118	49.2
Age								
Less than 30	16	20	20	25	9	11.25	45	18.8
31-45	24	30	33	41.25	24	30	81	33.8
46-60	33	41.25	17	21.25	35	43.75	85	35.4
61and above	7	8.75	10	12.5	12	15	29	12
Marital Status								
Single	16	20	21	26.25	16	20	53	22.1
Married	37	46.25	34	42.5	40	50	111	46.3
Divorced	18	22.5	15	18.75	11	13.75	44	18.3
Widower	9	11.25	10	12.5	13	16.25	32	13.3
Education level								
None	31	38.75	22	27.5	25	31.25	78	32.5
Primary	20	25	27	33.75	18	22.5	65	27.1
Secondary school	15	18.75	10	12.5	16	20	41	17.1
Vocation	10	12.5	18	22.5	14	17.5	42	17.5
University	4	5	3	3.75	7	8.75	14	5.8
Farming Experience								
Less than 5	11	13.75	17	21.25	6	7.5	34	14.2
6-10	23	28.75	21	26.25	26	32.5	70	29.2
11-15	22	27.5	20	25	30	37.5	72	30
16-20	17	21.25	13	16.25	10	12.5	40	16.6
Above 21	7	8.75	9	11.25	8	10	24	10
Land Size (ha)								
Less than 1	17	21.25	12	15	75	93.75	104	43.3
1.1-2	25	31.25	23	28.75	4	5	52	21.7
2.1-3	16	20	17	21.25	1	1.25	34	14.2
3.1-4	12	15	15	18.75	0	0	27	11.2
Above 4.1	10	12.5	13	16.25	0	0	23	9.6

Table 2. The Probit Regression Analysis of the Factors Influencing Farmers to Use Irrigation system.

Factors	Water pump irrigation system		Drip irrigation system		Sprinkler irrigation system	
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Gender	0.649	0.319	0.324	0.159	0.973	0.478
Age	-0.447	0.305	-0.073	0.152	0.207	0.002
Education level	1.295	0.211	-0.647	0.105	1.942	0.316
Farming experience	0.008	0.000	-0.089	0.005	0.267	0.002
Land Size	0.621	0.176	0.310	0.088	-0.535	0.264
Family income	0.001	0.000	-0.007	0.116	0.000	0.000
Labor	-0.191	0.077	0.095	0.038	0.286	0.115
Location	2.774	0.267	-0.387	0.133	4.042	0.400
Proximity to water	-1.056	0.090	0.499	0.045	1.498	0.135
WUA membership	0.749	0.361	2.374	0.185	1.123	0.542
Constant	3.37	5.24 1	0.407	0.286	0.785	0.551
Log likelihood	-34.755		-41.548		33.634	
LR (likelihood ratio) test Chi2	145.43		239.13		207.57	
Prob > Chi2	0.0000		0.0000		0.0000	
Pseudo R-squared	0.7768		0.7920		0.8587	

Table 3. The Factors Influencing Productivity of Irrigation System Use in Study Areas.

Variables	Coefficient	Standard Errors	P-value
Land size/plot	0.649	0.319	0.684
Labour source	-0.447	0.305	0.057
Family size	1.295	0.211	0.000
Gender	0.178	0.055	0.086
Age	-0.621	0.176	0.073
Education level	0.162	0.232	0.005
Fertilizers	0.191	0.077	0.001
Irrigation system	0.774	0.267	0.000
Volume of water	0.999	0.09	0.013
Off farm income	0.749	0.361	0.052
Price of produce	-0.298	0.583	0.000
Distance to Market	-0.138	0.137	0.077
Agricultural credit	-0.697	0.213	0.000
Farming experience	0.319	0.304	0.000
Extension Service	1.421	0.113	0.035
Cooperative membership	0.224	0.306	0.081
Constant	0,774	1,402	0.000
Number of obs = 240, R-squared = 0.8307			
F(16, 223) = 44.22, Adj R-squared = 0.8365			

Table 4. Economic (Cost-Benefit) Analysis of Using Irrigation System at Kagitumba, Nasho and Muyanza Schemes.

Object	Kagitumba	Nasho	Muyanza	Overall Average	F-Test (Sig)
Farm revenue	970 140.5	1 025 100	629 080	874 773.5	0.001
Total variable cost	356500.5	385300	326450	356083.5	0.000
Fixed cost (Depreciation)	64451.7	86559	58500	69836.9	0.000
Total cost = (2) + (3)	420952.2	471859	384950	425920.4	0.003
Yield (kg/ha)	4850.7	5125.5	3145.4	4373.867	0.000
Gross margin = (1) -(2)	613 640	639 800	302 630	518 690	0.000
Net farm income (crop value per ha) = (1) - (4)	549 188.3	553 241	244 130	448 853.1	0.000
Operating expense ratio = (2)/(1)* 100	36.7	37.6	51.9	42.1	

Depreciation expense ratio = (3)/(1)*100	6.64	8.4	9.3	8.1
Net farm income ratio = (7)/(1)*100	56.6	53.9	38.8	49.8
Benefit-to-cost ratio = (1)/(4)	2.3	2.2	1.6	2

The findings in table 4 by comparison indicated the investment costs and economic returns per unit area of maize farming (ha) of the participating maize farmers under the three irrigation schemes (Kgitumba, Nasho, and Muyanza). By comparison, the Net farm income per ha at Nasho schme site was largest with (553 241 Rwf), followed by the (549 188.3 Rwf) at Kagitumba scheme site and (244 130 Rwf) at Muyanza scheme site farmers. This indicates that the greatest maize yields per unit area of cultivation occurred under the sprinkler irrigation system particularly at Nasho and Kagitumba where these two types of irrigation are modern developed. Meanwhile, water pump farmers main concentrated at Muyanza scheme incurred the smallest total cost per ha of (384950 Rwf) which is less than the average cost of the three schemes (425920.4 Rwf). This should due to some good agricultural practices that are not taken into consideration which in turn cause a high reduction of productivity of maize per unit area. In addition, the low economic return at Muyanza scheme was largely attributable to the fuel costs to operate the pumps and labour paid daily for this pump. The findings also pointed out that the farm revenue, total cost, and net farm income were statistically different among the three-irrigation system at these three schemes ($p < 0.01$).

The research findings indicated that the lowest operating expense ratio which is a measure of what percentage of farm revenue is allocated to the variable operating expenditures was achieved at Kagitumba irrigation scheme (36.7%), followed by (37.6%) at Nasho irrigation scheme and (51.9%) at Muyanza irrigation scheme. In addition, the depreciation expense ratio was highest at Muyanza irrigation scheme (9.3%), followed by (8.4%) and (6.6%) at Nasho and Kagitumba schemes respectively. Further, the economic investigation and analysis revealed that despite some negative effect like the high depreciation cost and environmental pollution, the utilization of the water pump irrigation system was common in the study area due to its ease of deployment to the proximity of water sources, and easy support (subsidies) from government where a committed farmer pay 50% of the total cast of this pump and other 50% are paid by government.

As the highest net farm income ratio of (56.6%) was found at Kagitumba irrigation scheme compared to those of (53.9%) found at Nasho and (38.8%) found at Muyanza irrigation scheme. Similarly, the benefit cost ratio was the highest (2.3), suggesting that one-dollar of investment at Kagitumba irrigation scheme generates 2.3 dollars of revenue. The Nasho (2.2) and Muyanza (1.6) irrigation scheme followed this.

However, in order to improve and increase efficiency in terms of technique and crop yield, farmers should be encouraged to grow maize and irrigate as well as possible according to the crop water requirement. Likewise, government should increase the extension service that help agronomist to better provide knowledge and shills pertaining to the factors of production, especially the proper application of fertilizers and pesticides, improved seeds which in turn affect significantly maize production and productivity both in quality and quantity. Farmers should be followed and trained on GAP particularity at Muyanza scheme where yield per ha still too low compared to the other two sites and desired production per unit area. A proper application of GAP directly rise maize with an increase rate and decrease cost of production with a decreasing rate.

Factors Influencing Farmers' Willingness to Pay for Irrigation Water

The results of the regression are presented in Table 5. The results indicate that 76.42% of the variation in the dependent variable is explained by the explanatory variables. The overall significance and fitness of the model is indicated by the F-value, which in this case is 57.65 and is significant at 1% level, indicating that the explanatory variables reliably statistically predict the dependent variable.

Table 5. Factors Influencing Farmers' Willingness to Pay for Irrigation Water.

Variables	Coefficient	Standard Errors	P value
Age	-0.076	0.024	0.014
Gender	0.036	0.044	0.414
Household size	-0.013	0.009	0.066
Education level	0.056	0.037	0.009
Off farm income	0.119	0.082	0.002
Access to credit	0.074	0.043	0.000
Land size	-0.694	0.206	0.071
Rate of rain fall	-0.967	0.296	0.000
Money gained from harvest	0.391	0.676	0.067
Money payed per season	0.035	0.028	1.923
Inputs cost	-0.766	0.322	0.921
Constant	1.802	0.508	0.000
Number of observation = 240, Prob>F= 0.0000			
F (11,228) = 57.65, R2 =0.7642			

Out of the eleven explanatory variables, four such as education level, off farm income, credit was statistically and significant at 1% level to influence the farmers' willingness to pay for irrigation water in study area. This implies that 1% increase in credit access the farmers' willingness to pay for irrigation water should be increased by 0.074%. The results also indicated that the off-farm income was statistically and significant to influence farmers' willingness to pay for irrigation water at 1% level. This explains that households that earned off-farm income should willing to pay more compared to that not earning off-farm income.

Access to credit also positively and significantly influenced farmers' willingness to pay for irrigation water. This could be due to the possibility that part of the access to credit offered is used to pay for irrigation water, among other inputs increasing of agricultural production and productivity. Education level on best management of irrigation water and application system positively influenced farmers' willingness to pay for irrigation water. Farmers with high education level understand more agricultural best practices and better management of irrigation water system and use. This class of educated farmers were found to be more willing to pay more compared to those of low class who are not willing to pay for irrigation water.

Five factors such as age, household size, land size, rate of rain fall, and inputs cost were found to have a negative relationship with farmers' willingness to pay for irrigation water. For example, rate of rainfall was found to be negative and statistically and significant at 1% level to influence farmers' willingness to pay for irrigation water. This implies that 1% increase in rate of rainfall should reduce the farmers' willingness to pay for irrigation water by 0.97%. While a 1%, increase in household size should reduce the farmers' willingness to pay for irrigation water by 0.013%.

CONCLUSION

The current research investigated the impact of small-scale irrigation system use in agriculture farming in Rwanda. A case study of Kagitumba, Nasho and Muyanza schemes.

The findings of this research indicated that (50.8%) of the respondent farmers (240 farmers) were male and 41.9% were female. The respondents' ages were classified into four age groups. The findings showed that younger generations are currently abandoning agriculture farming due to the lack of initial capital and other support to enter the sector properly which in turn cause a huge lack of labour force and high urban migration. The respondents' years of maize farming experience were classified into five lengths of time and the findings of this study indicated that the overall, the 11–15 group had the largest number of respondents (30%). The land sizes were categorized into five classes as shown in table above. The findings revealed that the majority of farmers have farm less than 1ha represented by (43.3%). The results indicated farmers with small land are concentrated in Muyanza site in Rulindo district with less than 1 ha. While big farmers with big farm are highly located in Nasho, and Kagitumba sites in Kirehe and Nyagatare districts respectively where a farm should have even more than 5ha.

The water pump and drip irrigation system and age had a significant negative correlation with each other (β = -0, 0735, $p < 0.05$), while this association was significantly positive between the sprinkler use and age ($\beta = 0.207$, $p < 0.05$). Land size was significantly positively associated with the water pump use ($\beta = 0.621$, $p < 0.01$). The water pump and sprinkler irrigation system use and farm income were significantly positively correlated ($\beta = 0.000$, $p < 0.01$), which suggested that the increased income from the sales of maize contributed to the greater likelihood of the two-system utilization. The water users' associations membership and the water pumper, drip and sprinkler irrigation systems were significantly positively correlated ($\beta = 2.3745$, $p < 0.01$).

The findings of this research revealed that factors namely family size, education level, fertilizers, irrigation system, farming experience are statistically significant at 1% level to influence productivity of maize crops at these irrigation schemes. The results indicated that by comparison, the Net farm income per ha at Nasho schme site was largest with (553 241 Rwf), followed by the (549 188.3 Rwf) at Kagitumba scheme site and (244 130 Rwf) at Muyanza scheme site farmers. The research findings showed that the lowest operating expense ratio which is a measure of what percentage of farm revenue is allocated to the variable operating expenditures was achieved at Kagitumba irrigation scheme (36.7%), followed by (37.6%) at Nasho irrigation scheme and (51.9%) at Muyanza irrigation scheme. In addition, the depreciation expense ratio was highest at Muyanza irrigation scheme (9.3%), followed by (8.4%) and (6, 6%) at Nasho and Kagitumba schemes respectively. The highest net farm income ratio of (56, 6%) was found at Kagitumba irrigation scheme compared to those of (53.9%) found at Nasho and (38.8%) found at Muyanza irrigation scheme.

Similarly, the benefit cost ratio was the highest (2.3), suggesting that one-dollar of investment at Kagitumba irrigation scheme generates 2.3 dollars of revenue. The Nasho (2.2) and Muyanza (1.6) irrigation scheme followed this. Out of the eleven explanatory variables, four such as education level, off farm income, credit was statistically and significant at 1% level to influence the farmers' willingness to pay for irrigation water in study areas.

RECOMMENDATIONS

After the findings and conclusion provided above, the following recommendations were specified:

The results indicated that by comparison, the Net Farm Income per ha at Muyanza scheme site was too low compared to the desired yield per unit area and compared to those found at Kagitumba and Nasho irrigation schemes. Therefore, farmers should be encouraged to better use irrigation system, improved seeds, apply fertilizer and pesticides on time and apply all advised quantity of those inputs.

As the depreciation of fixed infrastructures is one of the most measures to main them, farmers should be encouraged to be registered in water user's associations and sensitized on having sprit of willingness to pay for irrigation water which in turn support/or help in to replace the destroyed and or old materials facilitating irrigation system on site.

The low productivity should be influenced by several factors like lack of water conservation, shallow knowledge about water management by the farmers, agricultural mechanization nearly absent and less operational, marshlands badly and less exploited. However, government should increase investment in marshlands management, water conservation, integration of erosion control and soil management in the technological package to extend to the farmer as well as to facilitate irrigation system in agriculture farming in long run.

The government should expand the drip and sprinkler irrigation system in the another agro climatic zones in order to reduce the dependence of farmers on rain fed agriculture which main disturbed by climate change especially in eastern province where actually rain is lower than other provinces of Rwanda (e.g. Western and Northern).

Drip and sprinkler irrigation systems are very cost and expensive infrastructures for installation and maintenance. Therefore, a high attention should be made by farmers and technicians during agricultural practices in order to sustain and maintain them in long run.

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