

# Economic Valuation of Irrigation Water in Smallholder Farming System in Rwanda: The Case of Kibaya-Cyunuzi Scheme

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**Abstract** – This study has been carried out in one irrigation scheme of the Eastern Province, Rwanda. The study determined the economic value of irrigation water of a smallholder irrigation scheme (Kibaya-Cyunuzi Scheme). The specific objectives were to estimate the economic value of water for irrigation, investigate the willingness to pay among smallholder farmers for irrigation water in Kibaya-Cyunuzi scheme and to identify the impact of Irrigation Management Transfer using water users' association on water allocation and management in the scheme. The study worked on the data collected from 110 respondents from two villages which are Kibaya and Cyunuzi. The data were analyzed using descriptive and quantitative methods. The Residual Computation Method was used to compute the economic values of irrigation water for paddy as a main crop found in the scheme. This is because the government of Rwanda has given the production of paddy in the country's marshlands a priority, because the marshlands are the areas where paddy has a great potential for increased production. The Contingent Valuation Method was employed to elicit the farmers' willingness to pay for irrigation water and its related infrastructures; while the socio-technical analysis helped us to capture the process of water control and management through Water users association. The findings show that the economic value of water for irrigation for paddy was 5.33 Frw/m<sup>3</sup>. The economic value for paddy is low in that scheme due to the fact that some parts of that scheme do not receive sufficient water and paddy needs much water. The results from CVM indicate that the respondents were willing to pay an average of 8000 Frw per Ha per annum for irrigation water. The study also shows that the WUAs are becoming the realms of interaction for different interest groups involved in water management. The study revealed some of the problems faced by farmers in the scheme, and whose solutions require joint effort among stakeholders in order to improve farming in that scheme. The decision making process related to water sector investments, allocation and management could be properly guided if key dimensions of water that are related to water availability and use in the face of increased scarcity are properly accounted for in valuation.

**Keywords** – Contingent Valuation Method, Economic Valuation, Irrigation water, Willingness to Pay.

## I. INTRODUCTION

Water has unique characteristics that determine both its allocation and use as a resource in agriculture. Over the years, many researchers have examined the valuation of water as an instrument for improving water allocation, reducing water consumption and management of the irrigation systems (Maetsu, 2001). This is because

irrigation is a vital component of agricultural production in many developing countries

The Fourth Principle of the 1992 Dublin statements defines water as an economic good. Such a definition is aimed at achieving efficient and equitable use, and encourages conservation and protection of water sources. The Fourth Dublin Principle denotes a landmark shift in emphasis to the economic dimensions of water use in general, and irrigation in particular (WMO, 2007).

As Kadigi (2006) argues, irrigated agriculture, which consumes about 50% to 70 % of global water resources, constitutes a driving force of both food productivity and agricultural income. As an immediate consequence of the climate and the socio-economic structure, water is not only an essential input for a profit-making agriculture, but also, for the economic viability and the social coherence of various rural areas.

The value of water has been varying across time and space, and the value which stakeholders at various scales (farmer, system manager, basin planner and national policy maker) attaches to water could be quite different (Hussain *et al.*, 2007).

Thus, the need to develop flexible institutions to maximize water's beneficial use in the face of growing demands for scarce and variable water supplies is the most compelling issue for economic development for the people who live in dry places. In principle, more water, better timed water, water at a more suitable place, and better quality water for a particular use are usually available at higher prices. Thus, sufficient time is required for building storage, conveyance and or treatment capacity (ward *et al.*2002).

Over 80% of the population in Rwanda lives in rural areas and engage in agriculture as their main economic activity. Agriculture production contributes about 40% of the national GDP (Ministry of Finance and Economic Planning, 2007).

The agricultural sector in the country is dominated by smallholder farmers with average farm size of less than one ha. However, smallholder farmers have been performing poorly mainly due to overdependence on rain fed agriculture which is often at the mercy of highly unreliable rainfalls (Ministry of Agriculture and Animal Resources, 2007).

In Rwanda, small-scale irrigation is seen as an important rural development factor that creates employment opportunities, generates income and enhances food security. In this respect, huge investments are made in the sector, and this includes rehabilitating the existing

irrigation schemes. In the realization of this fact, the Government of Rwanda has initiated a reform programme which aims at revitalizing smallholder irrigation schemes from the Government to smallholder farmers, since irrigation contributes to a sustainable use of water.

The reform, which referred to here, requires that an Irrigation Management Transfer Agreement (IMTA), which involves a cost recovery and institutional change, be adopted (KWAMP, 2008). The Rwandan government has decided to introduce institutional reforms in the water sector and transferred the responsibility for operation and maintenance (O&M) of irrigation systems to water users. Thus, the creation of Water Users Associations (WUAs) became a key element of irrigation management transfer (IMT).

## II. PROBLEM STATEMENT

Despite that water is needed for meeting basic human needs and for ecological reserve, it is no longer a free commodity and therefore every user is expected to pay for water use so that the rule of efficiency can be applied. In fact, irrigation water is an asset and its availability increases or reduces household capacity to produce income in combination with other assets. Since, the smallholder irrigation sector is no exception to this rule there is therefore the need for the estimation of water productivity and value in the sector (Yokwe, 2004).

Rwanda has about 9000 hectares which is potential for irrigation. Such areas of land for irrigation would require 13,000 cubic metres of water per hectare per year from the Congo Basin drainage system and 12,500 cubic metres per hectare per year from the Nile Basin. Currently, only 2000 ha are under some form of irrigation and water inflows into these is 0.11 cubic kilometers from the Congo Basin and 0.46 cubic kilometers from the Nile Basin (REMA, 2007). However given the terrain of Rwanda, the overall significance of irrigation as a way of improving use of water to support better livelihoods is limited. The costs and benefits of irrigation in a country like Rwanda is undoubtedly an aspect that has not been adequately researched and which may expectedly raise more questions than answers. Irrigations systems that would suit Rwanda are probably very expensive to implement. There is however, a need of establishing a mechanism which looks into the manner in which poor households can water their gardens up-hill and irrigate small plots in the valleys without facing challenges of water scarcity as there is a lot of water flowing out of the basins (REMA, 2007).

In finding ways to allay irrigation water problems, the government of Rwanda is initiating a reform program aimed at revitalizing small holder irrigation schemes and reducing the pecuniary load of its maintenance and operational costs. Smallholder irrigation farmers and the government are now involved in the process of Irrigation Management Transfer Agreement (IMTA), which includes cost recovery and institutional change principle in Rwanda (KWAMP, 2008). This arrangement is made on the assumption that irrigation water is to be priced, and farmers will have to pay for the cost of water supply and

related services by forming Water Users Associations (WUA).

The IMTA through WUA concept and its generic requirements for farmers to pay for irrigation water and O&M in Rwanda require an understanding of the value of irrigation water; as Vermillion and Sagardoy (1999) note, the public investment in irrigation is still high since it also includes the massive rehabilitation works that are usually carried out prior to the irrigation management transfer (IMT). This is particularly important if irrigation fees paid by smallholders are to reflect the marginal value of irrigation water.

However, water resources management in Rwanda needs to be informed by research data. The current study therefore makes the first step in this direction; it does so by examining the value of irrigation water in smallholder farming system and potential implications of changes in water management on these water uses. Currently, this knowledge is lacking, at least in the context of smallholder irrigation schemes in Rwanda.

One study has focused on the analysis of social factors that need to be considered in the management of irrigation water (Murengerantwari *et al.*, 2008). Considerable work has also been done on technical issues related to irrigation water requirement based on climatic, soil and crop characteristics (Ngoga, 2008).

However, according to some scholars (e.g. Hellegers and Perry, 2006; Ward and Michelsen, 2002) conceptually correct and empirically accurate estimates of the economic value of water are essential for making rational water management and allocation decisions.

Knowledge of this value is necessary when making, for instance, investment decisions concerning water resources development, policy decisions on sustainable water use and water allocations, or when determining the socio-economic impacts of water management decisions (Hussain *et al.*, 2007). Specifically for the agricultural sector, this knowledge is important to design fair, informed and rational pricing systems, providing incentives to irrigators upon using water sparingly and efficiently and allowing recovering operation and maintenance costs (Lange, 2007; Perret & Geysler, 2007). Equally important is the evaluation of smallholder farmers' willingness to pay for water in the scheme and its determinants.

The proposed study is therefore an attempt to inform the economic value of irrigation water in Rwanda and therefore fill the existing knowledge gap in this area. The study has used the case of Kibaya-Cyunuzi Scheme.

## III. RESEARCH OBJECTIVES

### *Main Objective*

The general objective of this study was to determine the economic value and management of water in smallholder irrigation system of Kibaya-Cyunuzi scheme in Rwanda.

### *Specific objectives*

1. To estimate the economic value of water in smallholder irrigation system in Kibaya-Cyunuzi scheme,

2. To investigate smallholder farmers' willingness to pay for irrigation water in Kibaya-Cyunuzi scheme
3. To identify the impact of Irrigation Management Transfer through water users associations with regards to water allocation and management in the scheme.

#### IV. LITERATURE REVIEW

Water has unique characteristics that determine both its allocation and use as a resource in agriculture; water is a vital component in production especially in the Irrigation sector. Over the years, many researchers have examined the valuation of water as an instrument for improving water allocation in irrigation systems (Karthikeyan *et al.*, 2009).

Renwick (2001) has valued water in irrigated paddy cultivation and reservoir fisheries in Sri Lanka. The author used a Residual Imputation Method (RIM) and found the estimated total annual value of water in irrigated paddy production to be US\$ 3.1 million; also the study demonstrated significant potential financial and economic gains to irrigated agriculture from improvement of water management practices.

Kadigi *et al.* (2004) assessed the value of water in irrigated paddy and hydroelectric power (HEP) generation in the Great Ruaha (GR) Catchment in Tanzania using the Change in Net Income method. The average values of water for irrigated paddy were estimated at USD 0.01 and 0.04 per m<sup>3</sup> for abstracted and consumed water respectively. For HEP, the values were relatively higher USD 0.06-0.21 per m<sup>3</sup> for gross and consumed water respectively.

Speelman *et al.* (2008) applied RIM to calculate water value for small-scale irrigation schemes in the North West Province of South Africa. The study found an average water value of US\$ 188/m<sup>3</sup>, in line with the expectations for vegetable crops. Furthermore, the crop choice and the irrigation scheme design and institutional setting were shown to significantly influence the water value, whilst individual characteristics of farmers proved to be less important.

On the side of agricultural water management, Abdullaev and Mollinga (2010) examined water management by applying a framework for socio-technical analysis in some selected Water Users' Associations (WUAs) in northwest Uzbekistan's Khorezm region. The study showed that the WUAs are becoming arenas of interaction for different interest groups involved in water management. The socio-technical analysis of Khorezm's water management highlights growing social differences at grass root level in the study of WUAs. The process of social differentiation is in its early phases, but is still able to express itself fully due to the strict state control of agriculture and social life in general.

In Rwanda, few studies have been undertaken to value irrigation water. Mati *et al.* (2008), identified Agricultural Water Management Interventions with Proven Returns to Investment to smallholder farmers by using different technologies, that is, gravity fed-irrigation found in low land. In the study by Mati *et al.* (2008), household variables have been considered to influence those technologies. One of their findings shows that rice production on gravity fed-irrigation increased by 39% and 13 % in utilization of valley bottoms.

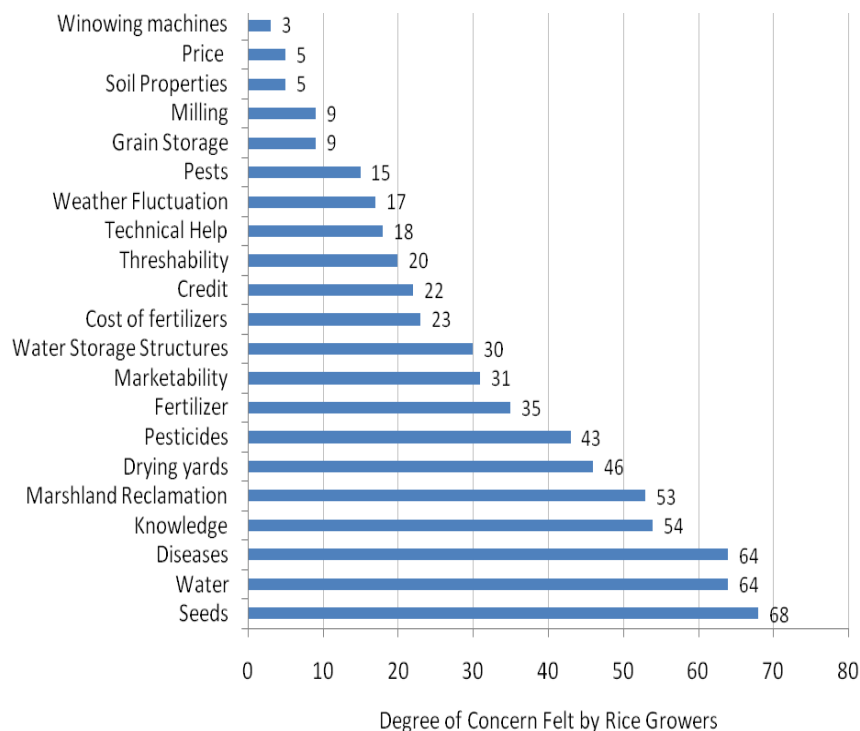


Fig.1. Farmers' constraints in raising productivity levels of rice crop in marshlands of Rwanda (Source: Rural Sector Support Project, 2009)

Murengerantwali *et al.*(2008) studied social aspect of irrigation management in Migina marshland, the outcome of this study shows that the stakeholders must not be ignored when designing new infrastructures and choosing irrigation technologies.

However, economic valuation of irrigation water in Rwanda is very important as long as farmers still consider water problem as a major hindrance to their rice productivity ( Rural Sector Support Project, 2009).

## V. METHODOLOGY

Empirical estimates of the value of irrigation water provide important evidence on the farmers' ability to pay and effective management in implementing cost recovery programs for development projects, and for long-term sustainability purposes.

Kibaya-Cyunuzi is a small scale Irrigation Scheme located in Kirehe district in the western province in Rwanda. It is a swamp that forms a Kibaya-Cyunuzi marshland complex, as cited in Organic Law N° 04/2005 of 08/04/2005 determining the modalities of marshlands Protection as fragile ecosystems in Rwanda. The swamp has permanent water source (Kabilizi river), where water abstraction is by gravity. The scheme command area is 196.5 ha. The farmers in the area practice two overlapping seasons per year and the main crop grown is Paddy rice and vegetables in season C. The scheme has one source of water, Kabilizi River.

The swamp rice scheme has been selected because it has got a chance of being developed by Rural Sector Support Project of the Ministry of Agriculture and Animal Resources (MINAGRI); and the WUA model, which has been initiated, plays an important role in increasing efficiency in the use of water.

This study adopted a cross-sectional data which allowed data to be collected at a single point in time without repetition from the target population.

The primary data for this study were collected from farm households selected from two zones (Kibaya and Cyunuzi) under Kibaya-Cyunuzi Irrigation Scheme. The study targeted farmers farming in the scheme seasons A and B 2010. It also interviewed leaders, technical personnel in the scheme, leaders of WUA, personnel responsible from the district as well as from development projects in that area. Given the diversity and nature of the sampled population, the data obtained from all these stakeholders were assumed to be reliable and consistent. Farmers in that scheme are grouped in a farmers' Cooperative (COOPROKI) from each zone. They constituted a sampling frame from which, 110 farming households were randomly selected.

### Determination of water value

Neoclassical economic theory predicts that in a competitive market, the economic value of a good corresponds to its market price, which reflects individuals' willingness to pay for that good. For water, however, due to the limited role played by markets, valuation techniques must be used Young (1996), cited by Speelman *et al.* (2008).

Several methods for estimating the value of water have been developed. They can be

grouped according to whether they rely on observed market behavior and data to infer economic value "indirect techniques", or alternatively use survey methods to obtain valuation information directly from water users "direct techniques" (Agudelo, 2001). In general, the most scientifically accepted methods are those based on actual market behaviour and information (Hussain *et al.*, 2007).

In the case of Rwanda, there are no water markets from which values for irrigation water can be derived. Furthermore, since subsistence farmers exploiting marshland in the study area are paying water fees in addition to other fees, the establishment of a relationship between price and demand from actual behaviour to generate demand function is not a straightforward matter. However, the study has used inductive methods to investigate the economic value attributed to water and its management in a Small Holder Irrigation Scheme.

Two approaches that were employed, these include the Residual Imputation Method (RIM) (see Lange, 2007), and WTP by means of Contingent Valuation Method (CVM) to estimate water values for the studied small irrigation scheme.

### Residual Imputation Method (RIM)

To evaluate water value by crop type, the Residual Imputation Method (RIM) was adapted to measure the return to water out of the gross margin obtained from all the production input employed. Before applying RIM, the analysis of the value of water in crop production started with modeling of crop water requirement using FAO's CROPWAT model (8.0 version). This is a computer programme used to calculate crop water requirement, irrigation water requirement, the irrigation scheduling, and yield reduction due to water shortage of a given region from climatic and crop data. The analysis in this study was limited to crop water requirement.

Considering the production function process in which the crop output  $Y$  is produced under irrigation by the following factors; Capital ( $K$ ), Labour ( $L$ ), water ( $W$ ) used and other non-water inputs ( $Z$ ).

Note that water is used as an intermediate good (input to produce another good) in irrigation.

The production function is:

$$Y = f(K, L, W, Z) \quad (1)$$

Assuming constant prices under competitive factor and product market;

$$TVP_Y = (VMP_K \times Q_K) + (VMP_L \times Q_L) + (VMP_W \times Q_W) + (VMP_Z \times Q_Z) \quad (2)$$

Where:  $TVP$  = Total value of product,  $Y$

$VMP$  = Value marginal product of resource  $K, L, W, Z$

$Q$  = the quantity of resource

Assuming  $VMP_i = P_i$ , that is, value marginal products equal the prices of resources and then by substitution and rearrangement of the equation, it follows that:

$$P_W = \left\{ TVP_Y - \left[ (P_K \times Q_K) + (P_L \times Q_L) + (P_Z \times Q_Z) \right] \right\} / Q_W \quad (3)$$

Note:  $QW$  was estimated from CROPWAT programme

This gives out the value of the shadow price of water ( $P_w$ ), which is basically the Economic Value of Water. The residual method has been widely used to derive economic values of water, especially in irrigated agriculture (Young, 1996; Renwick, 2001; Kadigi *et al.* 2004; Yokwe, 2005).

In fact, the assumptions of the RIM are not overly restrictive, but care is required to assure that conditions of production under study are reasonable approximations of the conceptual model. The main issues can be divided into two types (Young, 1996; Lange & Hassan, 2007): (1) those relating to the specification of the production function, and (2) those relating to the market and policy environment (i.e. the pricing of outputs and non-residual inputs). If inputs to production are omitted or underestimated or if there are inputs that are not priced or not competitively priced, then the RIM will generate inaccurate estimates.

To overcome the first problem, all relevant inputs should be included in the model. The second problem can be solved by determining shadow prices for the inputs that are not correctly priced. Because of this sensitivity to the specification of the production function and the assumptions about market and policy environment, the residual imputation method is only suitable when the residual input contributes a large fraction of the output value. However, this is the case for irrigated agriculture in water scarce regions (Speelman *et al.* 2008).

#### *Willingness to pay for irrigation water*

Willingness to Pay (WTP) is an economic concept, which aims at determining the amount of money a consumer is willing to pay for the supply of a given good. The consumers' WTP is becoming increasingly popular and is one of the standard approaches that is used by market researchers and economists to place a value on goods or services for which no market-based pricing mechanism exist (Khawaja *et al.* 2001). Experience shows that very high level of WTP for water is observed in developing countries (Briscoe *et al.* 1995).

The CVM was used to elicit information on household willingness to pay for irrigation water. The contingent valuation method (CVM) is a direct method of assessing WTP. It is a survey-based stated preference valuation technique used to value non market environmental amenities. In the last two decades, Contingent valuation method has gained popularity and has become a major tool for valuing environmental amenities. According to Hassan and Lange (2004), this approach does not rely on market data, but asks individuals about the value they place on something, that is, by asking them how much they would be willing to pay for water. Questions can be asked in a variety of ways, using both open-ended and closed-ended formats. In the open-ended format, respondents are asked to state their maximum willingness to pay for the environmental improvement. With the closed-ended format, also referred to as discrete choice, respondents are asked whether or not they would be willing to pay for environmental improvement, or whether they would vote yes or no for a specific policy at a given cost.

Since the key advantage of CVM does not rely on market data, it is useful in estimating the marginal value of water in Smallholder Irrigation System (SHIS). Karthikeyan *et al.* (2009) applied this method to value the WTP for irrigation water in tank irrigation systems in South India. According to the survey results by Calatrava and Sayadi (2005), who studied the evaluation of water and willingness to pay analysis with respect to tropical fruit production in Southeastern Spain, growers paid an average price of €0.14 m<sup>-3</sup> for their water; the lowest price paid was €0.054 m<sup>-3</sup> and the highest was €0.192 m<sup>-3</sup>.

The current study has used open-ended format, where respondents were asked their maximum willingness to pay for irrigation water. Then after factors that affect that WTP have been analyzed.

#### *Factors affecting farmers' willingness to pay for irrigation water*

In analyzing factors influencing farmers' willingness to pay for irrigation water in the scheme, multiple regression model was adopted. The factors examined included: farmers' characteristics (age, education levels and gender), farm size, irrigation water availability, capital invested, access to credits, membership to water users association and contribution of supplementary crops. The multiple regression model is represented as follows:

$$Y_i = \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{EDU} + \beta_3 \text{GENDER} + \beta_4 \text{FS} + \beta_5 \text{IWA} + \beta_6 \text{CAP} + \beta_7 \text{AC} + \beta_8 \text{MWUA} + \beta_9 \text{SCr} + \epsilon_i$$

Where:

$Y_i$  = Average income of farmers

$\beta_0$  = Intercept

$\beta_1, \beta_2, \dots, \beta_9$  = Coefficients

AGE = Age of the respondents

EDU = Education level of the respondents

GENDER = Gender (sex of the respondents)

FS = The plot size cultivated by the household in the scheme for the seasons A and B 2010

IWA = Irrigation water availability

CAP = Capital

MWUA = Membership to WUA

AC = Access to credits

SCr = Contribution of supplementary crops

$\epsilon_i$  = Disturbance term

Regression equations generated by ordinary least square are associated with a number of problems depending on the type of the data used, the nature and form of the regression model employed in the analysis. The common problems encountered in the regression analyses include multicollinearity, heteroskedasticity and autocorrelation (Gujarati, 1998).

This study used cross-sectional data; such data are likely to have multicollinearity and heteroscedasticity. The problem with heteroscedasticity is that ordinary least squares estimators while still linear and unbiased can no longer provide minimum variance. This makes the least square estimators unreliable; that is, the variance will be large leading to small t-values. The small t-value associated with large variance leads to a situation whereby the explanatory variable's parameters are rejected more frequently than necessary. To contend with this situation in the study, a natural logarithm transformation of the

dependent variable data was adopted because changing the functional form of the model can treat heteroskedasticity problem (Gujarati, 1998).

Another problem associated with multiple regressions is the presence of the multicollinearity. This problem is caused by the existence of the linear relationships among the explanatory variables. The symptoms suggesting the existence of the multicollinearity include: the existence of a very high coefficient of determination ( $R^2$ ), illogical signs of the parameters included in the model, and F-ratios being highly significant whilst most of the individual t-ratios are insignificant. The data in this study show no serious sign of the existence of multicollinearity.

## VI. RESULTS AND DISCUSSION

### *Socio-economic Characteristics of Respondents*

#### *Sex of respondents*

Table 1: Distribution of respondents by sex in the study area

sex	Kibaya (n=55)	Cyunuzi (n=55)	Total
Male	40=36.3%	43=39.1%	75.4%
Female	15=13.7%	12=10.9%	24.6%
Total	55= 50%	55=50%	100

The socio-economic profile of the sample respondents shows that the participation of males in agriculture is higher than that of females. This trend is in contrast with the countrywide profile where agriculture provides work for 80% of the total economically active population where 60% of agricultural workers are female (EDPRS, 2008). It can be said therefore that female participation in irrigation farming is relatively low in the study area.

#### *Marital status of the household*

Table 2: Distributions of head of household by marital status

Marital Status	Kibaya(%)	Cyunuzi(%)	Total
Married	35= 31.8%	44=40%	71.8
Single	4=3.6%	0=0%	3.65%
Divorced	1=0.9%	2=1.9%	2.8
Widowed	15=13.7%	9=8.1%	21.8
Total	50	50	100

From the results in Table 4.2, majority (i.e. 71.8%) of the respondents were married while 3.65% were single and 21.8 % of the household heads were widows. This shows that young people are less involved in agricultural activities and managing water resources in the study area. Marital status influences decision making at the household level, including the use of water in irrigated agriculture and management of water sources and environmental resources. Understanding the distribution of marital status of household heads is important in assessing management and utilization of water for irrigation. Therefore it is important to have a good percentage of young people encouraged to join farming activities under the irrigation schemes.

### *Education level of household heads*

Table 3: Distribution of household heads by education level in the study area

	Kibaya	Cyunuzi
None	1=0.9%	4=3.7%
No completed primary	7= 6.4%	10= 9%
Primary	42= 38.1%	38=34.5
Post primary	4= 3.7%	3= 2.8%
No completed secondary	1= 0.9%	0
Total	55	55

From the results in Table 4.3, the majority of respondents 72.6% had attained primary education. The higher the education levels the higher the knowledge on wise use of irrigation water. In the study area, there are only a few people with no formal education (illiterate) and those with secondary percentages wise. The situation indicates that, the studied community of farmers has enough education to follow basic knowledge and farming skills if provided. However providing farmers with proper farming knowledge and techniques would still improve their economic status irrespective of their education level, this is because the farmers have requisite practical knowledge and skills which can be put to use.

### *Average farm size of household*

Table 4 : Land allocation to crops found in the scheme

Variable	Mean (are)	Minimum (are)	Maximum (are)
Paddy	10.0667	2.0	35.00
Vegetables	1.0889	0.00	13.00

Paddy is a major crop grown in Kibaya-Cyunuzi scheme. According to Integrated Rwanda rice commodity chain (2010), paddy production has been given high priority by the Government, especially in the valley bottom marshlands, where the crop has a high production potential. Here rice is potentially capable of yielding over seven metric tons per hectare for each of two crops per year, as long as water is available. This is far greater than the returns from any other crop that can be planted in the marshlands. Vegetables are often cultivated in the plots where water is insufficient and there are not prioritised in the valley bottom marshlands as paddy that's why its minimum value is 0.

### *Land ownership in the scheme*

Kibaya-cyunuzi irrigation zone officer and farmers, in responding to questions related to land ownership and transfer in the scheme, according to the draft law determining the use and management of marshlands in Rwanda (2009), there is a common rule and/or regulation that marshland resource, which means all biological resources within a specific marsh including vegetation, wildlife resources, marshland produce and associated ecosystems are under a registration of land lease agreement provided by the Ministry. For this reason in many cases, there is no land re-allocation, but individually owned plots do exist under the supervision of farmers' cooperatives. The present tenure arrangement does not provide much opportunity and incentive for uninterested

farmers to sell out and for interested and capable ones to expand their holdings. This may prevent the achievement of full productive potential of the irrigated land..

#### *Economic value of Irrigation Water*

The costs of production for paddy without the cost for irrigation were calculated. These costs of production were deducted from gross returns of the crop. These residual revenue were further divided by the amount of water applied ( $m^3$ ) to get the economic value of water for irrigation for a particular crop. The amount of water used was estimated from FAO's CROPWAT programme (8.0 version). This is a computer programme used to calculate crop water requirement. Therefore, the economic value of water for irrigation has been estimated for the crop cultivated in the study area according to their costs from the crop water requirement.

The revenue earned by the farmers for each crop was calculated by multiplying the production by the market prices. On the input side, the costs of fertilizers and pesticides were taken into account. These were considered as relevant inputs in the production process. For these inputs and the outputs, market prices are thus considered to equal the shadow price. Price correction, as proposed by Lange & Hassan (2005), is necessary to fulfill the assumptions of the RIM.

Table 5: Irrigation water value in paddy within Kibaya-Cyunuzi scheme

Parameters	Value
Average revenue from irrigated paddy per Ha (Rwf)	1093792
Average cost for non water inputs in irrigated paddy per Ha (Rwf)	790380
Average residual revenue attributable to water (Rwf)	303412
Estimated water requirement ( $m^3$ )	58011.87
Estimated average value of irrigation water (Rwf/ $m^3$ )	5.23
Average paddy yield (Kg/ha)	5200
Estimated average water productivity $kg/m^3$	0.08

The government of Rwanda has given high priority to production of paddy in the country's marshlands (Integrated Rwanda rice commodity chain, 2009), it is because of this that paddy has become one of the main crops in Kibaya-Cyunuzi scheme.

However, the value of water was calculated for paddy crop only because this crop was identified as the main

crop in the scheme whereas vegetable crop is in the area which is not reached by water in the scheme. (According to the scheme officer; the scheme has one part whereby water doesn't reach; however the scheme's future plan is to cover the whole area under the scheme).

The calculations were based on the data gathered from the scheme and from agricultural officers. As shown in Table 4.6, the average value of irrigation water was calculated to 5.23 Rwf per  $m^3$  of water. One obvious reason identified was that Kibaya-Cyunuzi scheme experienced serious water shortage last season due to drought and thus, a big part of the area in the scheme is without sufficient water. The average productivity of irrigation water (paddy produced per drop) was very low in the scheme. According to the study results, the average water productivity is  $0.08 kg/m^3$ .

As it is not easy to specify the main causes of low water productivity; poor plot leveling, leading to poor water control, poor plot bunds and lack of water control structures in the canals, such as, water gates and proper water distribution boxes seem to be some of the major factors for low water productivity. Farmers feel that access to seed and water are the two most limiting factors in increasing productivity of their paddy crop.

When these results are compared with those obtained in the study by Kadigi *et al.* (2004) in Usangu basin in 2004, which is  $0.18kg/m^3$  and, when comparing with the average for the Sub Sahara African countries, which is about  $0.25 kg/m^3$ ; it is clear that the average water productivity from the studied irrigation scheme is very low. It is important therefore, that the Rwandan agriculture policy focuses much attention on valuating agriculture water especially in the irrigation aspect.

#### *Profit margins and returns to labor in paddy production*

Results in Table 8 show paddy as having a low profit margin in the scheme, and this does not match with the labor requirements neither does it match with the returns. Paddy in the case study has less attractive returns of 1035/man day. As it has been revealed in other studies in Rwanda, considering the complexity of rice value chain, the smallholder rice farming in Rwanda is constrained and characterized by unsustainable agricultural practices such as mono cropping, inefficient inputs, inferior seeds, improper control of pests and diseases, and inappropriate soil and water management. It is obvious in our case study that these problems are the prohibiting factors to farmers in raising the productivity of paddy.

Table 6: Profit margins and returns to labor in paddy production

Type crop	Yield T/ha	Average Price Rwf	Gross Income Rwf	Production costs Rwf	Profit Margin Rwf	Man days	Return to labour Rwf/mandays
Paddy	5.2	171.5	891800	790380	101420	98	1035

#### *Willingness to pay for irrigation water*

The WTP value in our study has been reviewed for irrigation water, operation and maintenance of irrigation infrastructure; since this value is perceived by farmers as combined, there is no value attributable to irrigation water only. The supporters in water provision even the scheme

management committee has decided to combine the payment of irrigation water and its related infrastructures in what they call *redevance*. All farmers in the scheme are aware of that contribution; they know very well its importance and they are willing to pay. The only issue for discussion is the amount they are willing to pay depending

on various factors. This is the reason why in this case, farmers' willingness to pay has been investigated using only open ended questions.

The mean WTP obtained from the open-ended question was 400 Rwf per plot (0.05 Ha) equivalent to 8000 Rwf per Ha per annum (US\$ 13.3 per Ha per annum).

*Factors affecting farmers' willingness to pay for irrigation water*

To test the effect of various factors, which were hypothesized to determine farmers' willingness to pay for

irrigation water, regression equation was employed. This equation was aimed at examining the influence of farmers' characteristics (age, gender, and education), farm size, irrigation water availability, invested capital, membership to WUA, access to credit, and contribution of supplementary crops on farmers' income from farming in the scheme. The equation examined the effect of the mentioned factors to dependent variable, that is, "farmers' willingness to pay for irrigation water" in the scheme.

Table 7: Multiple regression analysis results  
 (Dependent Variable: Logarithm of the farmers' WTP)

Variable	Estimated coefficients	Std. Error	T-ratio
Constant	8.719	0.320	35.055*
Age of the respondent	0.000	0.006	0.123
Education level of the respondents	0.021	0.046	0.019
Gender (Sex of the respondent)	0.037	0.076	0.762
The plot size cultivated by the respondents in the scheme	0.321	0.056	2.820*
Irrigation water availability	0.588	0.048	9.468*
Membership to WUA	0.345	0.086	2.894*
Access to credit facilities	0.323	0.089	2.380*
Capital invested in farming in the season 2010	0.120	0.015	1.400
Contribution of supplementary crops	0.001	0.000	3.207*

$R^2 = 76.4\%$      $F\text{-value} = 54.6^*$     \* = Significant at 5%

It can be noted from the results in Table 9, that all coefficients as expected were positively related to the dependent variable (Farmers' WTP for irrigation water), and that jointly the estimated variables as indicated by the F-value ( $F = 54.6$ ) were statistically significant ( $p > 0.05$ ). It is also noted that the coefficient of determination ( $R^2$ ) is 76.4%, meaning that all of the independent variables together account for 76.4% of the total variation in the farmers' WTP for irrigation water. On the other hand, the results show that 23.6% of the variations in the farmers' WTP are attributed to other factors not included in the model.

*Water allocation and management in the scheme*

The farmers use the water according to their own perceived needs and in most cases they do not want to be told what to do with the water supplied to them. Farmers are very much aware of their right of the share of water supply according to their zones in the scheme. However, at the plot level, farmers are not monitored (by the scheme, technical personnel and/or other farmers), to see how effectively they use the water. The absence of a monitoring mechanism is a weakness in water management, and which consequently raises questions on sustainability of the scheme. Attention has to be paid at a plot level because poor water management results into reduced crop productivity.

At the scheme level, the issue of equity in water allocation is important in order to avoid conflict among water users. To avoid inequalities, the irrigation management committee has divided farmers in the scheme into different zones and each zone is organised has a well established schedule for water distribution.

The scheme runs jointly by a water users association (WUA) and a farmers' cooperative (from the survey and scheme leaders). The WUA, who is in charge of water management, holds a water permit and signs an irrigation management transfer (IMT) with the Ministry of Agriculture. The farmers' cooperative, which is in charge of supporting crop production, holds the land lease and marshland management agreements. The cooperative signs yearly performance contracts with the district so that farmers act as an engine of economic growth.

*Farmers' involvement in operation and maintenance of the scheme*

Basing on the importance of Operation and Maintenance (O&M) activities of irrigation infrastructures in the scheme, there has been an institutional change (Irrigation Management Transfer) through the establishment of water users association in the scheme that made farmers responsible for their water control (allocation and management).

The study examined how farmers are involved in these activities, since O&M and agricultural productivity have a cause and effect relationship, that is, the sustenance of one depends on the good performance of the other (Samakande *et al.*, 2007).

In irrigation, agricultural productivity increases with the increase of water productivity, hence, water value. Therefore, O&M activities are considered as some of the means by which economic water value, allocation and maintenance can be increased

On responding to the question, how does the scheme involve farmers in the operation and maintenance activities; the irrigation officer in the scheme, the district

agricultural officer, the scheme leader and farmers themselves said that farmers were involved in diverse ways; this particularly because the maintenance of the rice scheme depends on the free labour input of its members.

- ✓ The scheme is sensitized and has formed an active Water use association in which operation and maintenance activities are included,
- ✓ Scheduling all O&M activities at the beginning of each season on zonal basis
- ✓ Organisation of communal works that involve farmers in various activities to maintain irrigation infrastructures in the scheme.

Obviously, smallholder farmers cannot do all of the activities manually, this is because some of these activities require special materials, and skills. Therefore, financial resources in ensuring smooth running operation and maintenance activities are unavoidable. To meet these requirements water fee including O&M fees are indispensable. Despite that water fee is crucial, the results show that on average the collection rate of such fees is just 72.3% (according to the scheme office) which, according to the leaders, is not enough. This is because the envisaged collection target is 100% which is intended to be achieved though sensitizing more farmers and enforce the methods and modalities of fee collection.

The timing as to when to collect water fee is very important because in most cases farmers do not have enough income for them to have enough servings which would otherwise be used for making any time payments. In the case of Kibaya-Cyunuzi scheme, water fees payment for the season that follows is paid during the harvesting time of the current season. This method is seen as suitable since it enables farmers to avoid spending water fees on other needs.

However, it was reported that owners of some plots which did not receive water properly even after the completion of the irrigation structure were hesitant in paying for the service that they were not sure of. Thus, it is recommended that the canal networks be extended as fast as possible in the whole area under the scheme.

## VII. CONCLUSION

The value of the water was calculated only for paddy crop because paddy was identified as a major crop in the scheme. The average value of irrigation water calculated to 5.23 Rwf per m<sup>3</sup> of water. One obvious reason identified was that Kibaya- Cyunuzi scheme suffered serious water shortage the previous season due to drought making a big part of it have insufficient water. The average productivity of irrigation water (paddy produced per drop) was very low in the scheme. The study reveals that the average water productivity is 0.08 kg/m<sup>3</sup>. It was also reported that the price charged for water does not reflect the actual cost of supplying the water to the site.

The WTP value in the current study was reviewed for irrigation water, operation, and maintenance of irrigation infrastructure. Given that this value is perceived by farmers as combined, there is no value, which was attributed to irrigation water only. The mean WTP

obtained from the open-ended question was 400 Rwf per plot (5 are or 0.05 Ha), which is equivalent to 8000 Rwf per annum (US\$ 13.3 per Ha per annum). All farmers in the scheme admitted to have been aware of that contribution, they reported to have known its importance very well and that they were willing to pay.

Pricing the water is important not only for generating revenues but also for promoting efficient use of water resources. A free or very low water charge encourages overuse, reduces the incentive for farmers to cooperate or participate in irrigation obligations, and may result in low system productivity and poor conservation. The charges could also create a sense of ownership among the farmers, which would ultimately lead to better use of available water and increased crop production. Collecting irrigation fees should not create any disincentive for farmers to irrigate, which means that the cost recovery mechanism should be compatible with the resource use. This can be achieved if the fees are treated as payment for the service rendered and not as tax.

The socio-technical framework has allowed us to show the actual water management in our case study (Kibaya-Cyunuzi scheme). The transformation made in marshlands and water management in Rwanda has generated the emergence of new and formal arrangement in irrigation water management. The main driver of this change was the individualization of farming through Irrigation Management Transfer (IMT).

In this view, it has been revealed that the scheme is run jointly as a water users association (WUA) and as a farmers 'cooperative. The WUA, which is in charge of water management, holds a water permit and signs the irrigation management transfer (IMT) with the Ministry of Agriculture. The farmers' cooperative, which is in charge of support to crop production, holds the land lease and marshland management agreements, signs yearly performance contracts with the district and farmers, and act as an engine of economic growth.

## RECOMMENDATIONS

In view of the major findings of the study and from the above conclusions, the following recommendations can be drawn.

- ✓ Based on the result, the economic value of irrigation water for paddy is low but paddy is among traditional crops that thrive well and produce better yield during rainy season. Thus, paddy provides a viable alternate for millions of resource-poor rural farm families in Rwanda. The role that irrigated paddy plays as the major source of income must not be underestimated.
- ✓ Since farmers are willing to pay for irrigation water and for operation and maintenance of infrastructures, the government should strengthen the existing WUA by empowering them to fix rational water charges for irrigation and collect it from the farmers to meet O & M activities. This option would promote the sustainable use of irrigation water and manage it effectively.
- ✓ The government should facilitate equitable water distribution by encouraging pumping of water to areas that

are topographically not inclined to receive water from the common irrigation channels in the scheme. Thus, it is important to have additional investments in the maintenance of scheme (especially for clearing the irrigation canals) and in the new infrastructure for areas in the tail ends with poor reach-ability of water from the main source (dam).

✓ Training on improved irrigation water management and control, farm management, economics and marketing skills should be organized at farmer's level for farmers in the scheme.

✓ Financial institutions including banks, local government and NGO's should consider giving rural farmers including farmers in the irrigation schemes loans to enable them purchase basic farm inputs and other requirements.

✓ All problems mentioned by farmers are solvable if all stakeholders would work together to improve water allocation and management, and hence attain sustainable irrigation farming. To take into consideration farmers' opinions about their priorities can also be an incentive for farmers to be active and take care of all the services that are delivered to them. A collective responsibility among stakeholders is highly recommended.

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