ECONOMIC VALUATION OF IRRIGATION WATER IN AHERO IRRIGATION SCHEME IN NYANDO DISTRICT, KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree/thesis research in any other university.

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DEDICATION

To my parents Benter Atieno Omondi and the late Dominic Omondi Onyango; siblings Francis Odhiambo (late), Anjeline Akinyi, Johnes Oduor, Mary Wasonga (late), Veronica Juma (late), Selina Awuor, Monica Akoth and Scholastica Achieng (late); fiancée Hyline Kwamboka; son Samuel Dominic Blessing

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LIST OF ABBREVIATIONS

ASALs	Arid and Semi-Arid Lands
ANOVA	Analysis of Variance
AERC	African Economic Research Consortium
AIS	Ahero Irrigation Scheme
ALDEV	African Land Development Unit
CMMAE	Collaborative Masters in Agricultural and Applied Economics
CNR	Change in Net Return
CV	Contingent Valuation
CVM	Contingent Valuation Method
GDP	Gross Domestic Product
GLM	General Linear Model
Kshs	Kenya shillings
NIB	National Irrigation Board
O&M	Operation and Maintenance
OLS	Ordinary Least Squares
RIM	Residual Imputation Method

RVM	Residual Value Method
SFA	Stochastic Frontier Approach
VMP	Value of Marginal Product
WTP	Willingness to Pay

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ABSTRACT

Water is an important input in most economic sectors hence necessary for economic development. However, water scarcity is on the increase due to human population growth, expansion of cities and rise in demand for water in agriculture and other sectors. Water utilization is highest in agriculture compared to other sectors of the economy. The most significant problem in agriculture is the intense use and low efficiency of water. To reduce the inefficiency and intense use, water must be treated as an economic good and more efficient prices be introduced. This requires estimation of the economic value of water and assessment of factors affecting farmers Willingness to Pay (WTP) for irrigation water.

The purpose of the study was to estimate the economic value of irrigation water in Ahero Irrigation Scheme. The specific objectives were: to estimate the economic value of irrigation water among smallholder rice farmers in Ahero Irrigation Scheme; to assess the factors influencing farmers' WTP for irrigation water in Ahero Irrigation Scheme; to determine whether irrigation water is a significant input in rice production in Ahero Irrigation Scheme.

Both Contingent Valuation Method (CVM) and Residual Value Method (RVM) were used to estimate the economic value of irrigation water while the Ordinary Least Square (OLS) was used to assess the factors influencing farmers' WTP for irrigation water. A production function was estimated to determine which factors influence rice output and whether water is a significant input in rice production. CVM was found to undervalue irrigation water, hence the economic value of irrigation water was estimated to be Ksh.7.54/m^3, based on the RVM results. Participation in off-farm income generating activities, access to credit and satisfaction with the management of water supply positively influence farmers' WTP for irrigation water at 1%, 10% and 1% levels of significance respectively. Volume of irrigation water was significant at 10%

level in determining rice yields in Ahero Irrigation Scheme, Nyando District, Kenya. Quantity of fertilizer and labour were also found to influence rice output positively at 10% level.

Irrigation water at Ahero Irrigation Scheme should be charged at appropriate price relative to its economic value of Ksh.7.54/m^3 to avoid its wasteful use. The findings of this study further reveal that irrigation water is a significant input in rice production and therefore its supply and management should be improved to ensure adequate amount of water during rice production periods. Smallholder farmers should also be encouraged to take credit and participate in Small and Medium Enterprises in order to improve off-farm income which consequently increases their WTP for irrigation water.

CHAPTER 1: INTRODUCTION

1.1 Background information

Water resources are important for humans and natural environment (Mallios, 2010). Availability of sufficient water for various uses is important for economic development because water is an important input in production in most economic sectors. According to the World Health Organization (2009), the problem of water scarcity is getting worse as cities and populations grow, and the demand for water increases in agriculture, industry, and households.

Fresh water utilization is highest in agriculture, among all the economic sectors in most countries (Mallios, 2010). According to Mallios, intense water uses coupled with low water use efficiency are the most significant problems encountered in agriculture. Mallios further argues that to achieve efficient water use and allocation, water must be treated as an economic good and more efficient water prices be introduced. Knowledge of reliable economic value of water is necessary for establishing efficient water prices (Mallios, 2010; Akter, 2006).

Rainfall patterns in Kenya make irrigation water a valuable input in farming since only about 20% of the country has a high or medium potential for arable agricultural production. Although the agricultural sector remains the backbone of Kenya's economy, the scope for expanding agricultural production through expansion of arable agricultural land is severely constrained. The estimated potential area for irrigation and drainage in Kenya is about 540,000 hectares (3,240Km^2) and 600,000 hectares (3,600 km^2) respectively (NIB website; Muthigani, 2011). Table 1 shows the irrigation potential in different basins in Kenya.

Table 1.1Irrigation potential in different basins in Kenya

Basin	Irrigation potential (ha)
Tana	205,000
Lake Victoria	200,000
Kerio Valley	64,000
Athi	40,000
Ewaso Ng'iro	30,000
Total	**539,000**

Source: Muthigani (2011); Ngigi (2002).

According to the National Irrigation Board (NIB website) and Muthigani (2011), the irrigation history in Kenya dates back to over 400 years. Irrigation has been practised along the lower reaches of River Tana and in the pre-2000 Elgeyo-Marakwet, West Pokot and Baringo districts. In 1946, the African Land Development Unit (ALDEV) initiated a number of irrigation schemes, including Mwea, Hola, Perkerra, Ishiara and Yatta, as an agricultural rehabilitation programme. In 1966, through an Act of Parliament (cap 347), National Irrigation Board (NIB) was established and it took over the activities of ALDEV. The NIB thus took over the running of Mwea, Hola and Perkerra and later developed Ahero, West Kano, Bunyala and Bura irrigation schemes.

The government of Kenya is cognizant of the importance of agriculture to the economic growth of the country. Agriculture contributes about 26% to Kenya's Gross Domestic Product (GDP). The Agricultural Sector Development Strategy (ASDS) 2010-2020 targets the agricultural sector to reduce poverty levels in Kenya to 25% and reduce food insecurity by 30% by the year 2015. However, about 80% of the total land area in Kenya is classified as Arid and Semi -Arid Lands

(ASALs), implying that irrigation plays an important role in agricultural development (Republic of Kenya 2010).

Kenya has an irrigation potential of 1.3 million hectares but only 114,000 hectares are under irrigation. Commercial large scale farms, smallholder farmers and government managed irrigation schemes account for about 40%, 42% and 18% respectively of the total irrigated land in Kenya (Republic of Kenya 2010). Kenya's Vision 2030 targets to transform between 600,000 and 1.2 million hectares of land in the ASALs through irrigation. However, Kenya has been classified as a water scarce country and the per capita water consumption is expected to decline to 235m^3 by 2025, mainly due to the expected increase in population and economic development (Republic of Kenya, 2007). There is therefore a need to reduce wasteful use and improve efficiency of water use in irrigation.

South Africa water pricing strategy ensures full recovery of costs incurred in supplying water, which ensures financial sustainability of the water management institutions and water supply utilities. Furthermore, the strategy also promotes water use efficiency and reduction in pollution of water resources (Hassan and Crafford, 2006).

Historically, irrigation water in Australia was free of charge where the operational costs for water supply were fully covered by the government through subsidies. However, the water reform policy of 1994 required the signing of contracts between farmers and water suppliers, as a strategy for improving water use efficiency and encouraging water trading, and in some States, previously government owned schemes have been privatized. The water reform policy ensured full cost recovery, consumption-based pricing and elimination of subsidies for sustainability of the schemes (Parker and Speed, 2010).

1.2 Problem statement

Agriculture is the largest consumer of fresh water worldwide, Kenya included. Pricing of the water used in agriculture and cost recovery plays a significant role in promoting water use efficiency. Salman and Al-Karablieh (2004) argue that although water is essential for human survival, it does not mean that governments must provide water services to the consumers freely or at subsidized price. Under-pricing of water and lack of cost recovery leads to excessive use, pollution, resource misallocation and non-sustainable water supply service. Moreover, people tend to use water carelessly when water charges are low (Al-Karablieh et al., 2012). Hellegers and Davidson (2010) argue that although one price for water may exist, all users do not value water to the same degree. Those charged with water management could achieve a better water allocation that improves social welfare if the value of water is known by use, region and season. Wasike and Hanley (1998) noted that water in most cases water for household use, irrigation and industries is subsidized or supplied free in most countries, regardless of degree of water scarcity. Based on literature review, there is no study that has been conducted in Kenya to determine the economic value of irrigation water.

Management of irrigation water is important for improving agricultural production and enhancing livelihood security. Formulation and implementation of effective water management system is however, a complex task for those involved in policy making. Important requirements for effective water management are knowledge of farmers' willingness to pay for irrigation water and its spatial demand over time. This information is important for accurate cost benefit analyses of investments in irrigation and for determining optimal distribution of water resources between different users, which is critical in the formulation of water pricing policies (Storm et al., 2010). Therefore, this study aimed at shedding some light on the economic value of irrigation water and the factors that determine the farmers' WTP for irrigation water. This information is important in pricing irrigation water and promoting water use efficiency. The study further assessed whether irrigation water is a significant input in rice production.

Both Contingent Valuation Method (CVM) and Residual Value Method (RVM) were used to estimate the economic value of irrigation water and a comparison of the two approaches was made. This was done to assess the robustness of the results and also to be able to recommend a better method in valuing irrigation water. A stochastic Translog production function was also estimated to determine whether irrigation water is a significant input in rice production.

1.3 Purpose

The purpose of this study was to estimate the economic value of irrigation water among smallholder farmers in Ahero Irrigation Scheme, Nyando District, Kenya.

1.4 Specific objectives

The specific objectives of the study were:

1. To estimate the economic value of irrigation water among smallholder rice farmers in Ahero Irrigation Scheme in Nyando District, Kenya.
2. To assess the factors that affect farmers' Willingness to Pay for irrigation water in Ahero Irrigation Scheme in Nyando District, Kenya.
3. To determine whether irrigation water is a significant input in rice production in Ahero Irrigation Scheme in Nyando District, Kenya.

1.5 Hypotheses

Objectives 2 and 3 were achieved by testing the following hypotheses:

1. That each of the following socio-economic factors do not influence the farmers' willingness to pay for irrigation water: age of the farmer, gender of the farmer, household size, education level of the farmer, off-farm income, access to credit, land size and satisfaction with the management of water supply.
2. That irrigation water is not a significant input in rice production.

1.6 Research question

Objective 1 was achieved by answering the following research question.

What is the economic value of irrigation water among smallholder rice farmers in Ahero Irrigation Scheme in Nyando District, Kenya?

1.7 Justification

Irrigation water is an important input in rice production in Ahero Irrigation Scheme in Nyando District of Kenya, yet no estimation of its economic value has been done. An evaluation of the Willingness to Pay (WTP) is an economic concept that aims at determining the amount of money a consumer is willing to pay for the supply of a good or service, such as water. The WTP for water is an important consideration for decision makers in developing countries where demand is rapidly increasing faster than the existing infrastructure can supply. The revenues from purchases of water should be used to cover the costs of developing a country's public water utility.

Hussain et al. (2007) state that reliable estimates of water value could help make informed choices on designing water pricing policies, analyzing and comparing performance of irrigation systems, assessing socioeconomic impacts of water management decisions and evaluating policy decisions on sustainable water use, water allocations and reallocations among water using sectors and investments decisions in water resources development/rehabilitation. Decision making on water sector investment and cost recovery schemes could be inappropriate if dimensions of water value, such as availability and use, benefits and costs and temporal and spatial aspects, are not properly accounted for in valuation.

1.8 Organization of the thesis

The thesis is organized as follows. Chapter 1 provides a background to the study, problem statement, purpose and objectives, research questions, hypothesis and justification of the study. Chapter 2 provides literature review, both theoretical and empirical reviews. Chapter 3 presents the methodology. Results and discussions are presented in chapter 4. Summary, conclusion and recommendations are presented in chapter 5. Finally, the references are presented in chapter 6.

CHAPTER TWO: LITERATURE REVIEW

2.1 Theoretical Framework

Valuation of irrigation water is not easy since competitive markets for irrigation water do not exist (Lange and Hassan, 2006). Economic valuation of irrigation water cannot be undertaken as a straight forward process because this type of water is a non-marketed resource (Jaghdani et al., 2009; Birol et al., 2006; Ward and Michelsen, 2002). Nevertheless, there is a variety of methods developed by economists for estimation of the economic value of water. Water valuation techniques are based upon either revealed (indirect) or stated (direct) preferences approaches. Revealed preferences approaches value an item based on observable demand of a marketable good or service whereas stated preference approaches value a good or service based on the willingness to pay or willingness to accept an outcome.

The main methods which can be used for the estimation of the economic value of water resources are: hedonic pricing, travel cost, Residual Value Method (RVM) and Contingent Valuation Method (CVM). The first three belongs to the category of indirect methods while the last one belongs to that of direct methods (Birol et al., 2006). According to Anderson (2010), travel cost method looks at the expenditures in market for travel, which serves as a complement to environmental goods. In valuing irrigation water for instance, its economic value would be equal to the total expenditures incurred to collect the water.

Hedonic pricing evaluates differences in the prices of goods or services caused by environmental assets or liabilities (Anderson, 2010). Land is assumed to have many attributes, water included, and this results in differences in rents for land with water and that without. The difference in the rents is assumed to be due to the water component and this is viewed as water value.

Contingent Valuation Method (CVM) elicits an individual's WTP for a given good or service in a hypothetical market. CVM is easy to implement and the data required to estimate irrigation water is easily collected from farm household survey (Storm et al., 2010). It also does not rely on a real irrigation water market but a hypothetical market. In RVM, the value of water is calculated by deducting all the non-water costs from the revenue, then dividing by the price of output. In this case, water is used an intermediate input in production.

Young (2005) defines non market economic valuation as the analysis of actual and hypothetical human behavior to derive estimates of the economic value called accounting or shadow prices of goods and services in situations where market prices are absent or distorted.

Based on available literature, no previous study appears to have been carried out in Kenya to estimate the economic value of irrigation water using either revealed or stated preference valuation techniques. The current study attempted to estimate the economic value of irrigation water by eliciting farmers' WTP for it in Ahero irrigation scheme. The study aimed at contributing information that can be used to formulate policies for agricultural water policy reform in order to enhance efficiency and promote sustainability of water use in irrigation agriculture.

Both CVM and RVM were used to estimate the economic value of irrigation water in Ahero.

2.1.1 Contingent Valuation Method (CVM)

The concept of economic value is embedded in the utilitarian approach. According to the utilitarian approach, a commodity has economic value when its users are willing to pay for it rather than do without it. The economic value of a good or service is the price a person would pay for it. In competitive markets, the forces of demand and supply establish a price that represents the marginal economic value, i.e. the value of the last unit sold. However, water is rarely supplied by competitive markets and the price, if any, charged for water does not reflect its economic value. In the absence of water markets or in situations where markets function poorly, a valuation technique must be used to estimate the economic value of water (Lange and Hassan, 2006).

Contingent valuation (CV) is a stated preference method (direct method) of estimating the value of a non-market or non-priced good or service (Birol et al., 2006) and usually employs the WTP approach. An individual is asked how much he/she is willing to pay for a particular good or service or willing to accept for the loss of a good or service in a hypothetical market. The aim is to elicit valuations or bids that are close to what would be revealed if an actual market existed. According to Anderson (2010), the purpose of CV is to estimate an individual's WTP for changes in the quantity or quality of goods or services as well as the effect of covariates on WTP.

Contingent valuation offers great flexibility compared to the revealed preference (indirect) methods. It also estimates total value, including non-use values, unlike the revealed preference methods which only estimate the use value (Carson et al., 2001). CV is also easy to implement and requires smaller dataset compared to revealed preference methods, such as hedonic pricing. According to Mitchell and Carson (1989), another advantage of CV is that it does not require the conceptual linkage between market prices and a non-market resource, since the researcher elicits information on the value of the amenity directly by using a questionnaire or interview to create a hypothetical market or referendum in which individuals state the values they place on the resource.

There are essential considerations needed for CV analysis (Carson et al., 2001). The first essential and most important consideration of CV is the design of questionnaires and survey procedure. A CV question asks a respondent about monetary valuation or equivalent of a service that is meaningful to the respondent. The service must be limited geographically and temporally and be defined in terms of characteristics that can reasonably enter a respondent's preference function. The second element of CV question is that of the payment method or payment vehicle, such as tax payments and payments in utility bills, must be clearly stated. This represents where the stated WTP is to be paid in real situation. The third element is the method of asking questions. The method confronts the respondent with a given monetary amount which induces a response. The various approaches of asking questions include (Anderson, 2010):

1. Open ended CV: A CV question format in which the respondent is asked to provide the interviewer with a point estimate of his/her WTP.
2. Bidding game: This is a CV question format in which individuals are iteratively asked whether they would be willing to pay a given amount. The amounts are raised (lowered) depending on whether the respondent was (was not) willing to pay the previously offered amount. The bidding stops when the iterations have converged to a point estimate of WTP.
3. Payment cards: This is a CV question format in which individuals are asked to choose a WTP point estimate (or a range of estimates) from a list of values predetermined by the surveyors and shown to the respondent on card.
4. Dichotomous or discrete choice CV: This is a CV question format in which respondents are asked simple yes or no questions.

Some of the drawbacks of contingent valuation method, according to Anderson (2010) and Hussen (2000) include:

1. Hypothetical bias may result from respondents who do not take the hypothetical question seriously or provide unrealistic responses since they actually do not have to pay the amount they assign to resources.
2. Strategic bias may also occur when respondents understate their WTP if they are against the policy or exaggerate it if they favour the policy.
3. Embedding effects can also become a concern when many benefits can accrue from a given action because stated values might apply to more than the benefit being evaluated. To counter this problem, CVM study should carefully clarify the change to be evaluated and/or include follow up questions to discern what benefits respondents have associated with their stated WTP.
4. Information bias may occur when respondents have insufficient information about the resource to be valued.
5. Sampling bias occurs when the sample selected is small and unrepresentative of the population.
6. Starting point bias occurs when the initial bid has an impact on the final bid. When the initial bid is very high, most respondents may end up rejecting it.
7. Payment vehicle bias arise when the respondents WTP varies depending on mode of payment such as user fees, tax or labour hours (Assefa, 2012). Tuner et al. (2004) recommends on avoidance of controversial payment vehicles.

2.1.2 Residual Value Method (RVM)

The use of water in a production process can be determined using the RVM. Residual value approach is most suitable where residual input contributes significantly to output. It aims at finding the maximum return attributable to the use of water by calculating the total returns to production and subtracting all non-water related expenses (Barton and Taron, 2010; Turner et al., 2004). This approach assumes that the residual value is equal to the returns to water (Berbel et al., 2011; Turner et al., 2004) and it represents the maximum amount a producer would be willing to pay for water and still cover input costs. A short run value of water is derived if only variable input costs are subtracted, but if all non-water inputs are subtracted including rate of return on capital, then a long run water value is obtained.

For the approach to be valid, it is required that profit maximizing producers use productive inputs up to the point where marginal product is equal to the opportunity cost and that the total value of the product is divisible such that each input can be paid according to its marginal productivity so that the total value of the product is exhausted (Berbel et al., 2011; Turner et al., 2004). Residual value approach is most suitable where residual input contributes significantly to output as is the case in Ahero irrigation scheme where rice production is greatly dependent on irrigation water.

RVM is applied to an item that is used as an intermediate input to production, such as water in irrigated agriculture. Data on production, cost or revenue is used to estimate indirectly a marginal value of the intermediate input through cost minimization or profit maximization. This technique is very sensitive to small variations in the specification of the production function. If an input to production is omitted or underestimated, its contribution (value) is erroneously attributed to the intermediate input. Estimation of some inputs, such as family labor and farm management, also poses a challenge. Also, in cases where inputs and outputs prices are subsidized, the distortion must be corrected first (Lange and Hassan, 2006). RVM is thus appropriate in the valuation of irrigation water.

There are other alternative methods for valuing irrigation water and these include: hedonic pricing and production function methods. Hedonic pricing method evaluates differences in pricing or services caused by environmental assets or liabilities. In the case of land, it is assumed to have a number of attributes which contribute to its value. For example, water as an attribute will increase the value of a piece of land where it is available and a piece of land without water is expected to have a lower value. The difference in value of the two pieces of land is assumed to be due to water availability and hence its economic value. One limitation of hedonic pricing just like the other price based valuations is that there are often passive use values that do not enter into the prices of products associated with a given resource. Also, large datasets are required to establish statistically significant relationships between prices and environmental variables while holding other price determinants constant (Anderson, 2010). The approach is also largely dependent on property values and as such has a limited application (Hussen, 2000).

The production function method is used in situations where demand for water as an input of production is not directly observable (no information on sales price) but data on quantity of water and other inputs used in production are available to estimate production function. A major limitation of this method is that accurate data on the actual quantities of water used are not usually available. The method is also highly sensitive to model specification.

2.1.3 Production function

To determine whether irrigation water is a significant input in rice production, stochastic Cobb Douglas, quadratic and Translog production functions were specified and test runs with the production data conducted to determine the most appropriate type of model specification. A production function is a mathematical representation of the process in which inputs are converted into outputs. A frontier production function is the maximum output from a bundle of inputs, given an existing technology (Battese, 1991). Frontier production functions have been widely used in agriculture to assess agricultural productivity through estimation of efficiency scores and the elasticity of inputs used in production.

Frontier production functions can either be stochastic or deterministic in nature, depending on the assumptions of the error term. It is assumed that in a stochastic frontier production function, the difference between the observed output (actual harvest) and the maximum potential output is caused by random shocks (such as measurement errors in production and weather) and technical inefficiencies among farmers (Mastromarco, 2008; Battese, 1991).

Deterministic frontier production functions on the other hand assume that the difference between the observed output (actual harvest) and the maximum potential output is caused only by technical inefficiencies among farmers (Mastromarco, 2008; Battese, 1991). The technical inefficiencies are influenced by farmer specific factors such as experience and level of education among other factors, which result in differences in technical efficiency scores among farmers. Since agriculture is highly affected by weather conditions, measurement errors and differences in farmer specific variables, stochastic frontier production function is a more appropriate production function compared to a deterministic frontier production function.

Two specifications of the stochastic production functions have been widely used in estimating agricultural production functions: Stochastic Cobb Douglas production function and stochastic Translog production function. However, Cobb Douglas production function is the most widely used form (Derbertin, 2012). This is because of its simplicity (Derbertin, 2012) and ease of interpretation of the coefficients. The coefficients of Cobb Douglas production function are interpreted as the elasticities of the various inputs. However, Cobb Douglas production function assumes constant input elasticities.

While a Cobb Douglas production function specification has only linear parameters, Translog production function specification has linear, interactive and quadratic parameters. Translog production function is a modification of the Cobb Douglas production function which has both square and interactive terms. The quadratic specification is a reduced form of the Translog production function, without the interactive terms. The test runs conducted on the three forms of the production functions indicated that the Translog production function specification fitted the data best and was thus adopted in this study.

2.2 Empirical studies

2.2.1 Studies that used CVM in valuation of irrigation water

Mezgebo et al. (2013) used CVM to estimate the economic value of irrigation water in Ethiopia. The authors used a double bounded dichotomous format to elicit WTP for irrigation water. Probit model was used to assess the factors that conditioned farmers' WTP for irrigation water. Monthly household income, farmers' age, size of cultivated land and awareness on the availability of irrigation water and environmental problems positively influenced WTP. Age and starting bid level negatively influenced farmers WTP for irrigation water.

Alhassan et al. (2013) conducted a study on the WTP for improved irrigation water in Northern Ghana. The authors used payment card elicitation format to establish farmers' WTP. They further used Maximum Likelihood Estimation to assess the factors influencing WTP. Farm location and land lease price were found to be negatively related with WTP for irrigation water. Land ownership positively influenced farmers' WTP for improved irrigation.

Tang et al. (2013) using CVM analyzed farmers' WTP for irrigation water in China. Using a Logit model to determine the factors affecting farmers' WTP for irrigation water, it was found out that bid level and household size negatively influenced WTP. On the other hand, income, farm size, use of ground water and satisfaction with the management of water delivery positively affected farmers' WTP for irrigation water.

Assefa (2012) valued irrigation water using contingent valuation and choice experiment in Ethiopia. Single bounded elicitation format with a follow up open ended question were used to determine the bid amounts. Random Parameter Logit model, Probit and Multinomial Logit models were used to determine the factors influencing WTP. Market access, off farm activities, household income and households' experience with irrigation were found to be important determinants of WTP for irrigation water. Jaghdani and Brümmer (2012) conducted a CVM study on the WTP for ground water in spot market in Iran. Using a Heckman model, use of wells, having other jobs, age of fruit trees in the orchard, water level and quota as well as share of labour costs were found to influence WTP.

Mesa-Jurado et al. (2011) estimated the economic value of guaranteed irrigation water supply in Southern Spain during water scarce periods. The authors used payment card elicitation format and applied Tobit model to determine factors influencing farmers' WTP. Household income, respondent's age, household size, agricultural training and water dose were significant in determining WTP for irrigation water.

Karthikeyan (2010) used CVM and crop water production function to estimate the economic value of irrigation water in India. The author used Logit model to assess the factors influencing farmers' WTP for irrigation water. The results indicated that during the wet season, family labour force and area under rice cultivation negatively influenced WTP. Storm et al. (2010) using Least Absolute Deviation (LAD) to determine the factors affecting WTP for irrigation water found a negative relationship between age and WTP for surface water and a negative non-significant relationship between age and WTP for ground water.

Basarir et al. (2009) analyzed the WTP for quality irrigation water. Using a Tobit model, the authors found out the size of land under vegetable cultivation, gender and whether irrigation water is dirty positively influenced farmers' WTP for quality irrigation water. Jaghdani et al. (2009) used CVM, Value of Marginal Product (VMP), and Change in Net Return (CNR) methods to value irrigation water in Iran. In CVM, bidding game elicitation format was applied. The authors noted that the economic value of irrigation water was much higher than the official water prices. The authors argued that low water prices encouraged conservative farming methods that wasted water and that CVM and VMP could be used to set up policies that would ensure efficient use of water.

Chandrasekaran et al. (2009) used both CVM and quadratic production function to value irrigation water for dry and wet seasons in South India. The authors applied Logit model to determine factors affecting WTP for tank irrigation. Family labour, land size cultivated and plant water requirements were found to be important determinants of WTP for tank irrigation.

Weldesilassie et al. (2009) applied CVM to estimate the economic value of safe use of wastewater for crop production in Addis Ababa, Ethiopia. The authors used double bounded dichotomous choice elicitation question format to elicit urban farmers' value of the improvement program. The authors further analyzed the determinants of WTP of farm households using different econometric specifications, including double bounded bivariate probit, single bounded probit and interval data models. It was found out that the number of years with irrigation experience, total annual yield value, education, kind of policy option and location of the farm significantly affects farmers' WTP for wastewater for irrigation.

Yokwe (2009) investigated the productivity and value of water in Zanyokwe and Thabina irrigation schemes in South Africa. The author applied the RVM, WTP and cost based approaches to evaluate water productivity and water values per crop, per farm and per scheme. Results indicated that irrigation improved revenues from maize cultivation. However, the value of water in maize production was lower compared to water value in butternuts, potatoes, cabbages and tomatoes production. Leyva and Sayadi (2005) conducted a study on the farmers WTP for irrigation water for fruit farming in Spain. Farmers who had a higher proportion of avocadoes trees, those who attended training courses and orchard size positively influenced WTP for irrigation water.

Birol et al. (2007) used CVM to elicit Cypriot farmers WTP for recycled water in farming. Using OLS to establish the determinants of WTP for recycled water, the authors found out that water quality and quantity, total irrigated land, farming experience, education level of the decision maker, percentage of water from well used for irrigation, high salinity problem and low water quality problem positively influenced farmers' WTP for recycled water.

Akter (2006) used CVM to determine the economic value of irrigation water in an irrigation scheme in Bangladesh. The author used single bounded closed ended questions to elicit farmers' WTP for government managed irrigation water supply project. Logit model was used to assess the factors that influenced farmers WTP for irrigation water. The variables that were found to influence WTP are the farmer's age, bid level, education level, household size, number of income sources, land ownership and decision of change in crop.

Tiwari (1998) used both CVM and other revealed preference methods to estimate the economic value of irrigation water in Northern Thailand. In CVM, both open and closed ended questions were used to elicit farmers' WTP for irrigation water for wet and dry seasons. The author used Logit, Tobit and OLS to determine the factors affecting WTP for irrigation water. Water sufficiency, sex, age, household size and total agricultural income were significant in determining WTP in Logit and OLS regressions. For the open ended WTP bids, the author used Tobit and OLS for the determinants of WTP. Farmers' attitude, household size, out migration, area planted and land mortgaged in the bank were found to be significant variables determining WTP. The author recommended the use of CVM in valuing irrigation water in developing countries.

2.2.2 Studies that used CVM in valuation of domestic water and other resources

Wendimu and Bekele (2011) analyzed the determinants of WTP for quality water supply using CVM in Ethiopia. Using a Tobit model, reliability of water supply, perception on water supply and household income were found to significantly influence WTP positively. Education level of the respondent, household size and respondent's age were found to significantly influence their WTP negatively.

In the valuation of improved domestic water services in Palestine rural, urban and refugee camps, Awad and Hollander (2010) used CVM. The authors used dichotomous choice and open ended elicitation formats to determine WTP bids. They further analyzed the determinants of WTP using Tobit and OLS. The results of Tobit model indicated that living in rural areas, water consumption and income determined WTP for improved domestic water services. OLS results, on the other hand, indicated that age, living in rural areas, water consumption, use of water filters and income were important variables in determining WTP for domestic water.

Haq et al. (2008) conducted a study on household's WTP for safe drinking water in Pakistan. The authors used averting behavior model and CVM to value drinking water. Three categories of WTP choices were used and consequently a multinomial logit model was used to assess the factors that influenced household's WTP for safe water. Location of the household, education level of the household head and water source were found to be significant variables in determining WTP for safe drinking water.

Ojeda et al. (2008) carried out a study to estimate non-market values for water in the Yaqui River Delta in Ciudad, Obregon Mexico. The authors used dichotomous choice format for elicitation of the WTP and water bill as the payment vehicle. The authors used Logit and OLS models to determine the factor influencing WTP for or potential environmental services sustained by water flows in Yaqui River. Age, amount of income, initial bid, occupation, education level, level of information about the environmental situation and dependence ratio were found to significantly influence the WTP.

Ntshingila (2006) used a contingent valuation method to elicit households WTP for improvement in water quality and quantity and also the factors that determine their WTP. Using a Tobit model to assess the factors that influence WTP for water quantity and quality improvements, the author found out that income, respondent's age and gender positively influenced both the WTP for water quantity and quality improvements.

Mbata (2006) also used CVM to estimate household's WTP for water services in Botswana's rural areas. The author used iterative bidding to elicit WTP values. Using OLS, the factors affecting WTP for water services were assessed. Education level and employment and level of awareness of the household head, income and distance from water source were found to affect household's WTP for water services.

Bane (2005) valued the non-agricultural uses of irrigation water in Ethiopia. The author used probit model to assess the factors influencing WTP for non-agricultural uses of irrigation water. Income, age, education, quantity of water consumed, initial bid and quality of irrigation water were found to influence WTP. Raje et al. (2002) also used CVM to estimate consumers' WTP for Municipal supplied water in India. A Logit regression was further used to assess the factors that influenced WTP for water. Affordability and faith in the water management system were found to positively influence households' WTP for Municipal water supply.

In valuing maintenance of river water quality in Beijing, China, Day and Maurato (1998) applied CVM. The authors recommended the use of CVM in non-market valuation in developing countries. However, they discouraged the use of dichotomous choice elicitation format because of the tendency of respondents responding 'yes' to all bid values. Wasike and Hanley (1998) conducted a CVM study in Webuye, Kenya to determine WTP for piped water connections. The authors used open ended WTP question format and water charge as the payment vehicle.

Student's t-test and paired rank Wilcoxon tests were used to test for differences in WTP between different water connection profiles.

CVM has also been used in valuing other environmental resources. Adekunle and Agbaje (2012) valued ecosystem functions of a peri urban forest using CVM. The authors using a double log multiple regression found out that income and household size were significant determinants of WTP for ecosystem services. Belkayali et al. (2010) also valued Goreme historical national park in Turkey using CVM. Foster (2010) used CVM to value urban forest in the city of Tampa, Florida. The author used mailed dichotomous choice elicitation format and found out that income and education level positively influence WTP to increase the coverage of Tampa urban forest.

2.2.3 Studies that used RVM in valuation of irrigation water

Al-Karablieh et al. (2012) used Residual Imputation Method to estimate the economic value of irrigation water in Jordan, which was found to be different across the different crops studied. Berbel et al. (2011) conducted a study on the economic analysis of irrigation water at the basin level for the Guadalquivir River, Southern Spain. The authors estimated the average residual value at the basin to be 0.31€/m^3. The distribution of total Gross Value Added (GVA) of irrigated land among the factors of production was: 62% for water, 20% for land, 5% for man-made capital and 13% for management and family labour.

Speelman et al. (2011) applied RVM in valuing irrigation water in North West Province, South Africa. The authors computed water values per crop, per farm, per irrigation scheme and per irrigation scheme type. A further analysis using General Linear Model (GLM) was conducted to determine factors contributing to variation in water values. Crop choice, type of irrigation scheme and educational level of the farmer were significant in variability of water values.

However, the authors noted that personal characteristics of the farmers only influence variability in water values marginally. Speelman et al. (2008) used RVM to value irrigation water in small scale irrigation schemes in South Africa. Water values were calculated per crop, per irrigation scheme, per type of irrigation scheme and per farm. Analysis of Variance (ANOVA) was used to determine if there were any differences in water values.

Hellegers and Davidson (2010) conducted a study to determine the disaggregated economic value of water in India using RVM. It was found out that the economic value of irrigation water was not equal across crops, regions and seasons. Using RVM and Change in Net Income Method, Hussain et al. (2009) found out that the economic value of water was much higher than the water price charged for both winter and summer crops. Ashfaq et al. (2005) used the RVM in valuation of irrigation water in Pakistan. The authors estimated both the financial and economic values of water for different crops.

Rodgers and Hellegers (2005) conducted a study on water pricing and valuation in Brantas basin, Indonesia. The mean gross and net values of irrigation water for paddy, maize, soybeans and groundnuts were estimated by dividing the net returns per hectare by estimated field level water demand. Irrigation water was found to have a value of \$0.02-0.05/m^3 for paddy, \$0.08-0.11/m^3 for maize, \$0.04-0.05/m^3 for soybeans and \$0.04-0.08/m^3 for groundnuts.

2.2.4 Studies that have applied Production Functions

Stochastic Cobb Douglas, Quadratic and Translog production functions have mostly been used to estimate technical efficiency scores of producers (farmers) and the determinants of technical efficiency. Some of these studies have been reviewed below.

Rahman et al. (2012) estimated a stochastic Cobb Douglas production function to determine technical efficiency and factors affecting efficiency of rice farmers in Bangladesh. In another study in Myanmar, Aung (2011) estimated a stochastic Cobb Douglas production function to measure technical efficiency and determinants of technical efficiency of rice farmers. Khai and Yabe (2011) and Huy (2009) also applied the Stochastic Cobb Douglas production function to measure the technical efficiency of rice farmers in Vietnam.

Obiero (2010) conducted a study in Mwea irrigation scheme to determine the response of rice yield to quantity of irrigation water. In addition, the author estimated technical, allocative and economic efficiency scores of rice farmers and the factors affecting efficiency. The author used a Cobb Douglas production function to determine the responsiveness of rice yield to quantity of irrigation water. Narala and Zala (2010) also used a stochastic Cobb Douglas production function to estimate efficiency scores and factors affecting efficiency of rice farmers in Central Gujarat, India.

In Mwea Irrigation Scheme, Kenya, Kuria et al. (2003) compared efficiency scores and determinants of efficiency of two different production systems. The two production systems (single rice crop in a year vs. double rice crop in a year) were compared through estimation of stochastic Cobb Douglas production functions. Kebede (2001) also used stochastic Cobb Douglas production function to estimate efficiency level and the determinants of efficiency among rice farmers in Nepal. Ahmad et al. (1999) also used a stochastic Cobb Douglas production function to estimate farm level technical efficiency and the determinants of technical efficiency of Pakistani rice farmers.

Seyoum (1998) also applied stochastic Cobb Douglas production function to compare technical efficiency of maize farmers in Ethiopia. The two groups compared were farmers in the region where the Sasakawa Global 2000 (SG-2000) project was initiated and those farmers outside the target region. Other studies that applied stochastic Cobb Douglas production function are Oladeebo and Fajuyigbe (2007), Abedullah and Mushtaq (2007) and Idiong (2007).

A number of studies have also applied Translog production function in the estimation of farmers' technical efficiency. Maganga (2012) specified Translog production function to estimate farm level technical efficiency of potato farmers in Malawi. Baten et al. (2009) using panel data, estimated both Cobb Douglas and Translog production functions to determine technical efficiency of tea farmers in Bangladesh.

Bäckman et al. (2011) estimated both the Cobb Douglas and quadratic production functions to determine technical efficiency of rice farmers in Bangladesh. The author found that quadratic specification fitted the data well compared to Cobb Douglas specification. Obwona (2006) estimated a Translog production function to estimate technical efficiency of small and medium scale tobacco farmers in Uganda.

Kibaara (2005) using Stochastic Frontier Approach (SFA) specified a Cobb Douglas, quadratic and Translog production functions with an aim of estimating technical efficiency of Kenyan maize producers. The author estimated different functional forms of production function and based on the results adopted the Translog production function results.

2.2.5 Critical Assessment of CVM, RVM and production function studies

In the previous sections, studies that focus on valuation of irrigation water and domestic water have been reviewed. These studies are considered relevant to the current study because they offer possible approaches to the valuation of irrigation water and in the analysis of the various factors that influence farmers' WTP for irrigation water. However, of all the studies reviewed on CVM and RVM, only the one by Wasike and Hanley (1998) was done in Kenya, although it estimated WTP for domestic piped water. Therefore, for CVM and RVM, there are no known studies from Kenya that are directly comparable to the current study.

On determination of whether irrigation water is a significant input in rice production, this study applied the stochastic Cobb Douglas production function, among other production function specifications, which is the approach that was used by Obiero (2010). The Obiero (2010) study was conducted in Mwea Irrigation Scheme with an objective of determining the response of rice yields to volume of water used. Kibaara (2005) specified Cobb Douglas, quadratic and Translog production functions. The current study, therefore, drew on approaches employed in the above studies i.e. how to implement CVM, RVM and production function.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

Both CVM and RVM were used to estimate the economic value of irrigation water. CVM was used to estimate the economic value of irrigation water directly from the farmers' WTP while RVM was used to estimate the residual value of irrigation water indirectly through production function approach. The results of the approaches were then compared. A stochastic Translog production function was also estimated to determine whether irrigation water is a significant input in rice production in Nyando District, Kenya.

3.2 Area of study

This study aimed at estimating the economic value of irrigation water in Ahero Irrigation Scheme in Nyando District, Kenya. The scheme is located in Kisumu County in the outskirts of Kisumu city. The landscape consists of a wide alluvial plain. The climate of the area is relatively dry with high temperatures. Black cotton soil is the predominant soil type which is fertile but difficult to drain. The area experiences seasonal flooding from River Nyando causing water logging due to the flat terrain. Nearly all irrigated farmland is used for paddy cultivation.

The scheme stalled operation in 1999/2000 due to fund depletion. The government of Kenya through the Ministry of Water and Irrigation funded the scheme's rehabilitation in 2003 by buying two water pumps. In the year 2005, two other pumps were bought. The pumping station is therefore equipped with 4 pumps. Pumps 1 and 2 have a capacity of 1100 litres per second while pumps 3 and 4 have a capacity of 650 litres per second.

The study was conducted in the month of April 2012 in Ahero Irrigation Scheme, Nyando District, Kenya. The scheme is managed by the NIB in partnership with the farmers who are charged Kshs.3100/acre/year for scheme Operation and Maintenance (O&M). The area under cultivation is 2,168 acres which is divided into 12 blocks with a total of 1,650 farmers. Each farmer in the scheme is a member of one of the 30 farmer groups available.

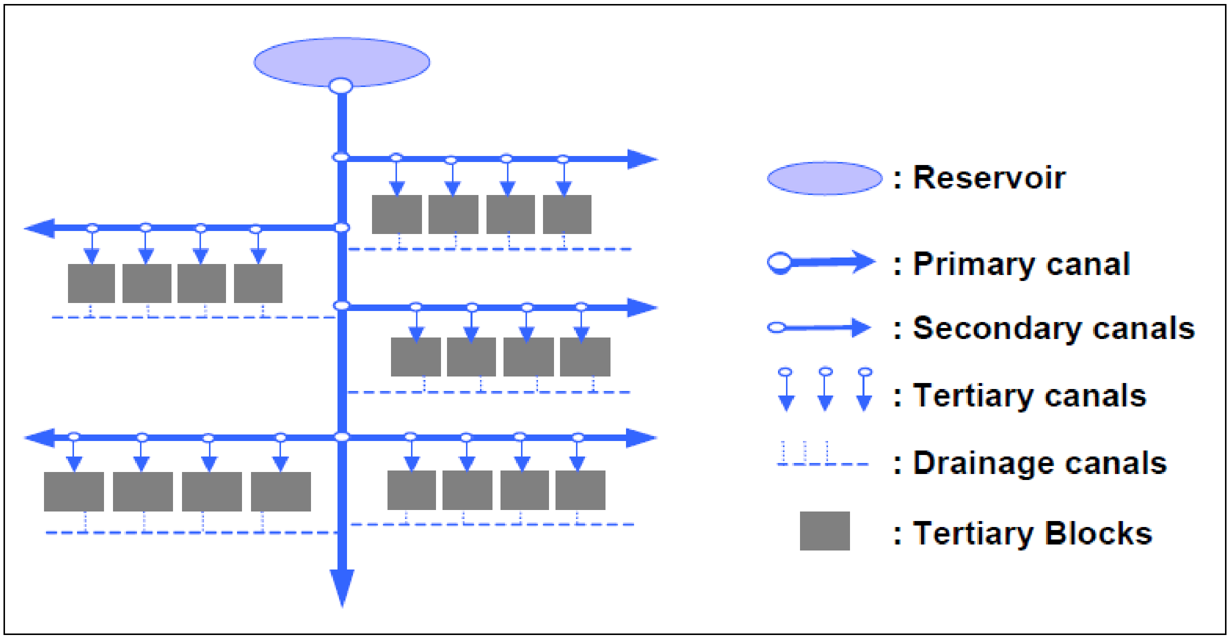
Figure 3.1: Map of Ahero Irrigation Scheme

Source: NIB- Ahero

The main crop grown in the scheme is rice, mainly IR 2793-80-1 and ITA 310 varieties. However, a small number of farmers plant maize and tomatoes after harvesting rice for sale and subsistence consumption. Inputs such as seeds and fertilizer are supplied by the NIB but farmers can buy from any other source. Farmers have a revolving fund which the manager of NIB-Ahero is the chairman. Farmers can borrow loans from the revolving fund at an interest rate of 8% for land preparation and labour expenses and repay the loan immediately after sale of rice. Farmers can sell their rice to buyers of their choice.

The scheme gets its water from River Nyando, a feeder river of Lake Victoria. Irrigation water is pumped from the river then it flows through gravity to the rice fields. The flow of water from the pumping station to the rice fields is shown in Figure 3.2 below. Water is pumped from River Nyando then channelled to the primary canal through weirs. It is then diverted to the secondary canals through water gates and finally to the tertiary canals. From the tertiary canal water is directed to paddy fields and on the opposite end excess water drains out of the fields.

Figure 3.2: Surface irrigation system network

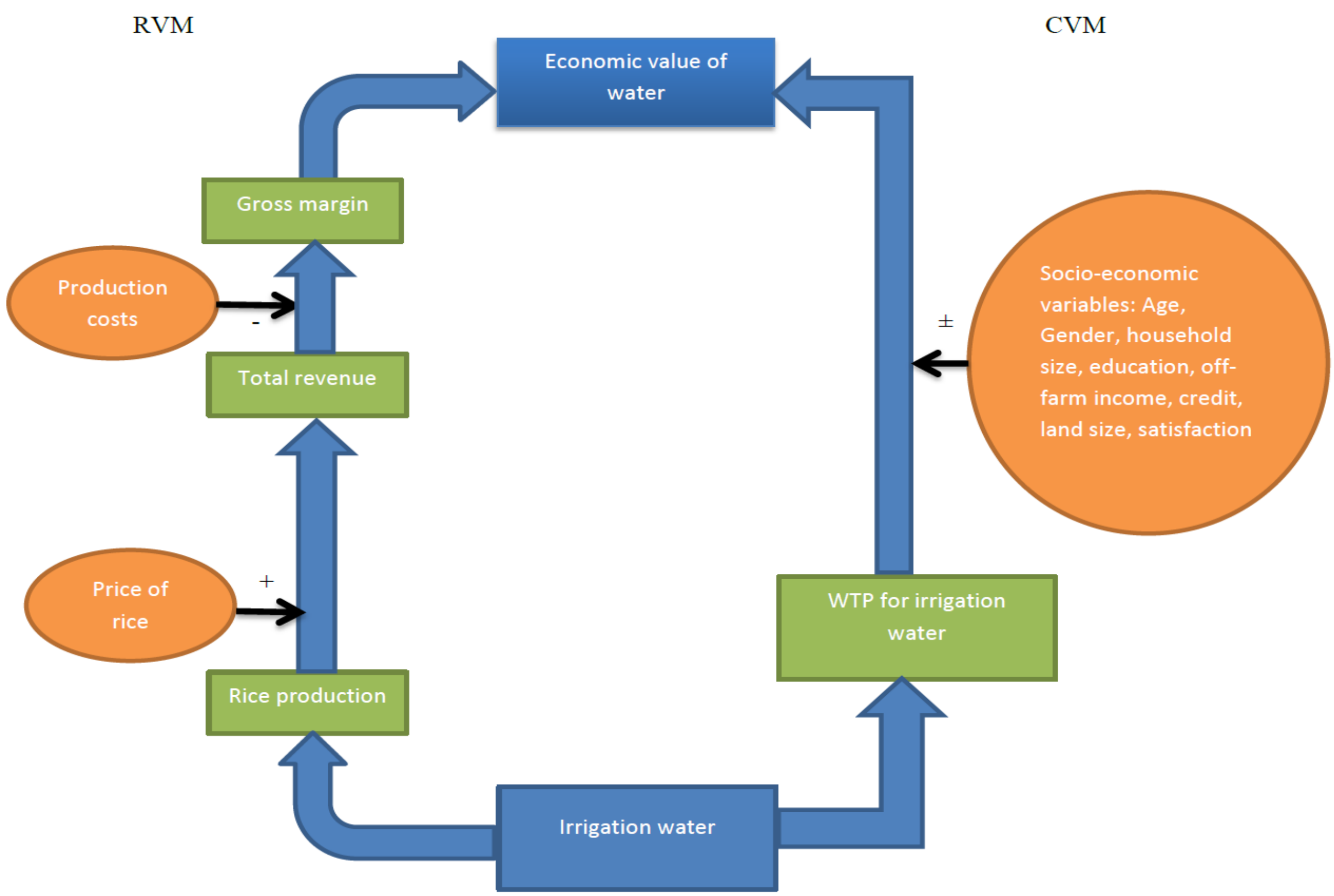


Source: Rodgers and Hellegers. (2005). Water Pricing and Valuation in Indonesia: Case Study of the Brantas River Basin

3.3 Conceptual framework

The conceptual framework for economic valuation of irrigation water is presented in Figure 3.3. This study conceptualized rice farmers as consumers of irrigation water with the objective of profit maximization. In RVM, farmers utilize irrigation water as an intermediate input to produce rice, which earns them profits. The data required are the quantities of inputs used, prices of inputs, volume of water utilized for rice production and rice yield and price. The economic value of irrigation water is then computed by subtracting all the non-water inputs from the gross margin, divided by the volume of water used in rice production. As farmers utilize irrigation water, there are a number of factors that were hypothesized to influence farmers' WTP for irrigation water, as shown in Figure 3.3. The variables required for the study have been discussed in detail in sections 3.4, 3.5 and 3.6.

Figure 3.3: Conceptual framework for estimating economic value of irrigation water



Source: Adapted from Yokwe (2009). Water Productivity in Smallholder Irrigation Schemes in South Africa

3.4. Contingent Valuation Method (CVM)

Using CVM, the value of water to a user is taken as the maximum amount that the user would be willing to pay for the use of the resource. The respondent is asked how much he/she is willing to pay (WTP) for the irrigation water rather than have it taken away. The irrigation water sustains the user's utility and the WTP for it, is supposedly the amount of money the consumer is willing to have deducted from his/her income to sustain his/her utility.

Equation 1 below represents a farm household's utility in the status quo scenario, i.e. the current water supply system with inadequate water and irregular water supply. Equation 2 represents a farm household's utility function in the hypothetical market, i.e. with enough water throughout the year. Farmers have to pay for the change by an amount equal to M. A farm household will agree to pay for irrigation water if the condition in Equation 3 is satisfied i.e. the utility derived after paying M for change is greater than utility derived without the change.

$$U^0 = V^o(q^0, I, F, S, e_0) \qquad (1)$$

$$U^1 = V^1(q^1, I - M, F, S, e_1) \qquad (2)$$

$$V^1(q^1, I - M, F, S, e_1) \succ V^o(q^0, I, F, S, e_0) \qquad (3)$$

Where e_0 and e_1 in Equations 1 and 2 are the error terms distributed normally with mean zero and variance of one .'I' denotes average household income; F stands for farm characteristics and S stands for socio-economic characteristics of the household. 'M' is the WTP (money amount household is willing to trade off) in the hypothetical market with improvement in the irrigation water supply system.

Bidding game was used in the current study to elicit WTP values. Bidding game is identical to an ordinary auction, which is familiar to the respondents. It provides a 'market like' situation by which to base their valuation. The initial bid is iteratively changed until the respondent states his/her maximum WTP (Chowdhury, 1999).

Ordinary Least Squares (OLS) was used to assess the factors influencing farmers' WTP for irrigation water. The dependent variable was specified as the natural logarithm of stated WTP for irrigation water. WTP values were logged to reduce the variability in the dependent variable. The model was specified as follows:

$$\ln WTP = \alpha + \beta_1 AGE + \beta_2 GEN + \beta_3 HHSIZE + \beta_4 EDUC + \beta_5 INC + \beta_6 CREDIT + \beta_7 LAND + \beta_8 SATISFACTION + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (4)$$

Description of variables used in the OLS and the expected signs

$\ln WTP$ is the natural logarithm of stated WTP for irrigation water per acre per year

α is the constant

β_s are the coefficients to be estimated

AGE is the categorical age group of the household head in years (1=15-30, 2=31-45, 3=46-55, 4=56-70). Age is used as a proxy for experience. Older farmers are likely to realize the benefits of irrigation hence a positive relationship with WTP.

GEN is a dummy variable for gender of the household head (1=male, 0=female). The sign of gender coefficient can be positive or negative.

HHSIZE is the number of individuals in a household. The coefficient of number of people in the household is expected to be negative. This is because a household with high number of dependants is likely to have high expenditure for household commodities and food, hence lower expenditure for irrigation water.

EDUC is the education level completed by household head (1=None, 2=Primary, 3=Secondary, 4=College, 5=University). The coefficient for education is expected to be positive because as the respondents' education improves, they are likely to know the benefits of irrigation on farm productivity.

INC is a dummy variable for off farm income (1= household head earns off farm income, 0=household head does not earn off farm income). The coefficient for off farm income can be positive or negative. When off farm income supplements farm income, the coefficient is expected to be positive. When off farm income is high and the income from farming is minimal, the coefficient for off farm income is expected to be negative.

CREDIT is a dummy variable for access to credit (1=access to credit, 0=no access to credit). Credit improves the ability to invest in improved technologies like irrigation. The coefficient is therefore expected to be positive.

LAND is the size of land cultivated during the 2011/2012 season in acres. The coefficient for land size is expected to be positive.

SATISFACTION is a dummy for satisfaction with the management of water supply system (1=Satisfied, 0=Not satisfied). The coefficient for satisfaction with the management of water supply system is expected to be positive. Farmers satisfied with the management of water supply system will be willing to pay more compared to the unsatisfied farmers.

3.5 Residual Value Method (RVM)

RVM in the valuation of irrigation water in Ahero Irrigation Scheme was applied as discussed hereafter. Following Al-Karablieh et al. (2012), Berbel et al., (2011), Hussain et al. (2009), Lange and Hassan (2006) and Young (2005) the residual value model was specified as follows:

$$Y = f(F, S, C, L, T, R, M, I, O\&M, ST, Q_w) \quad (5)$$

Where Y is the harvested rice, F-fertilizer, S-seed, C-chemicals, L-labour, T-transport, R-land rent, M-management, I-loan interest, O&M-operation and maintenance, ST-storage and Q_W-volume of irrigation water.

The total value of production can then be written as shown in Equation 6.

$$Y.P_Y = VMP_F.F + VMP_S.S + VMP_C.C + VMP_L.L + VMP_T.T + VMP_R.R + VMP_M.M + VMP_I.I + VMP_{O\&M}.O\&M + VMP_{ST}.ST + VMP_W.Q_W \quad (6)$$

Where $Y.P_Y$ is value of harvested un-milled rice per acre and VMP_i are the value of the marginal product of fertilizer, seed, chemicals, labour, transport, land rent, management, interest, operation and maintenance, storage, and volume of irrigation water.

Assuming that the farmer will consume each factor up to the point where $VMP_i = P_i$ (Mesa-Jurado et al., 2008), VMP is replaced with prices and Equation 6 can be written as follows.

$$Y.P_Y = P_F.F + P_S.S + P_C.C + P_L.L + P_T.T + P_R.R + P_M.M + P_I.I + P_{O\&M}.O\&M + P_{ST}.ST + P_W.Q_W \quad (7)$$

The residual value of irrigation water (P_w) is then calculated as the difference between the total value of un-milled rice and the costs of all non-water inputs to production divided by Q_w.

$$P_W = \frac{Y.P_Y - (P_F.F + P_S.S + P_C.C + P_L.L + P_T.T + P_R.R + P_M.M + P_I.I + P_{O\&M}.O\&M + P_{ST}.ST + P_W.Q_W)}{Q_W} \ldots\ldots (8)$$

3.6 Production functions specification

The volume of irrigation water, whose coefficient is of interest to the study, was specified as an input in the production functions. In addition, quantities of fertilizer, seed, labour (man-days) and the cost of fungicides/pesticides were included in the model. The production functions specified were Cobb Douglas, quadratic and Translog production functions. Despite estimating production parameters, the stochastic production function also has the technical inefficiency component. Since technical efficiency is not a focus of this study, the technical inefficiency model will not be estimated.

3.6.1 Stochastic Cobb Douglas Production Function

Following Aigner et al. (1976), a stochastic Cobb Douglas production function was specified as follows:

$$y_i = x_i\beta + (v_i - u_i) \ldots\ldots (9)$$

Where y is the quantity of rice harvested; x_i is a vector of inputs' quantities used in production e.g. seed, fertilizer, chemical cost, labour and irrigation water; β is a vector of parameters to be estimated; f ($x_i\beta$) is the frontier production function which measures the maximum potential output from a vector of inputs. The error components v_i and u_i causes deviations from the frontier. v_i is the random error component which captures random deviations from the frontier, caused by factors beyond farmers' control such as temperature and natural hazards. v_i is assumed to be independently and identically distributed with a mean of zero and constant variance –N (0,

σ_v^2) and independent of u_i. u_i is a non-negative error component that captures deviations from the frontier caused by controllable factors. It represents the inefficiencies in production. It is assumed to be half normal, identically and independently distributed with a mean of zero and constant variance-N (0, σ_u^2).

Equation 9 can be transformed to a log-log function that is linear in parameters (Equation 10):

$$lny = \beta_0 + \beta_1 lnFERT + \beta_2 lnSEED + \beta_3 lnLAB + \beta_4 lnCHEM + \beta_5 lnWATER + v - u \ldots. \quad (10)$$

Where ln is the natural logarithm; y is the quantity of rice harvested (kg/acre); FERT is the quantity of fertilizer used (kg/acre); SEED is the quantity of seed used (kg/acre); LAB is the amount of labour used (man-days/acre); CHEM is the cost of fungicides/pesticides (Kshs. /acre); WATER is the volume of water used (m^3/acre); β_0 is the constant; β_{1-} β_5 are the parameters to be estimated; v and u are as defined in Equation 9.

3.6.2 Translog and Quadratic Production Functions

Following Maganga (2012) and Kibaara (2005), the Translog production function was specified as follows:

$$lny_i = \beta_0 + \sum_{k=1}^{5} \beta_k lnx_{ki} + \frac{1}{2}\sum_{k=1}^{5}\sum_{j=i}^{5} \varphi_{kl}\, lnx_{ki} lnx_{li} + \sum_{z=1}^{4}\sum_{j=2}^{5} \lambda_{zj} lnx_{zi} lnx_{ji} + v_i - u_i \ldots\ldots\ldots\ldots\ldots.. \quad (11)$$

Where ln, y, $\beta_{0,}$ v_i and u_i are as defined in equation 10. $\beta_{k,}$ φ_{kl} and λ_{zj} are parameters to be estimated. The first double summation in equation 11 constitute the square terms (e.g. ln{seed*seed}) while the second double summation constitute the interactive terms (e.g. ln{seed*fertilizer}). Equation 11 represents Translog production function specification, which can be linearized to be:

$$lny_i = \beta_0 + \beta_1 lnFERT + \beta_2 lnSEED + \beta_3 lnLAB + \beta_4 lnCHEM + \beta_5 lnWATER + \beta_6 \ln(FERT * FERT) + \beta_7 \ln(SEED * SEED) + \beta_8 \ln(LAB * LAB) + \beta_9 \ln(CHEM * CHEM) + \beta_{10} \ln(WATER * WATER) + \beta_{11} \ln(FERT * SEED) + \beta_{12} \ln(FERT * LAB) + \beta_{13} \ln(FERT * CHEM) + \beta_{14} \ln(FERT * WATER) + \beta_{15} \ln(SEED * LAB) + \beta_{16} \ln(SEED * CHEM) + \beta_{17} \ln(SEED * WATER) + \beta_{18} \ln(LAB * CHEM) + \beta_{19} \ln(LAB * WATER) + \beta_{20} \ln(CHEM * WATER) + v_i - u_i \quad \text{.........} 12$$

Where all the variables are as defined in equation 10. Equation 11 without the second double summation (interactive terms) represents the quadratic specification i.e. all the variables in equation 12 excluding variables β_{11}- β_{20}.

3.7 Questionnaire design

The questionnaire consisted of four sections: socio-demographic, input use and output and WTP for irrigation water under the hypothetical market. The socio-demographic section captured farmer related variables such as age, education, land size, access to credit among others. The input use and output sections was used to gather data on the various inputs used in rice production, their costs as well as the amount of un-milled rice harvested and sold. WTP section was used to elicit farmers' WTP for irrigation water and satisfaction with the management of water supply system.

3.7.1 Bidding game

The hypothetical market was improved water supply by ensuring that water is available throughout the year. The payment vehicle was through water user fees, paid to the NIB. Payment vehicle provides the form of payment and where to pay the stated WTP if the hypothetical market was real.

Bidding game was used to elicit WTP where Kshs.3,100 was used as the initial bid amount. This was informed by discussions held with farmers and also during questionnaire pretesting. During questionnaire pretesting farmers were asked to state their maximum WTP for irrigation water. To reduce starting point bias a mean of the stated WTP values was computed which was close to the current O&M cost of Kshs.3,100/acre/year. During the final survey respondents were asked if they were willing to pay Kshs.3,100. If the response was 'yes', the value was increased by 10% up to the point where he/she was not willing to pay. The previous bid amount was then recorded as his/her maximum WTP. If the response was 'No' to the first question, the bid amount was reduced by 10% up to the point where he/she was willing to pay. This value was then recorded as the maximum WTP. A follow up question then followed, asking the respondent why he/she stated that particular amount.

3.7.2 Estimation of the volume of water used per acre

There was no record of the total amount of water pumped in the rice fields during the year 2011/2012. Farmers were also unaware of the amount of water they used for irrigation since water supply is not metered. However, the frequency of irrigation per season was available for each farmer. The records available at the pumping station were for the hours used in pumping water for the various pumps each with its unique capacity.

The total volume of water pumped during the 2011/2012 season was estimated from records at Ahero pumping station. The total volume of water pumped was then divided by the total acreage to get the average volume of water utilized per acre for rice cultivation. However, the frequency of irrigation (number of times the crop was watered) varied between farmers, which enabled estimation of volume of water utilized by each farmer for rice production (Appendix 3). Obiero (2010) used the same approach to estimate volume of irrigation water but did not use frequency of irrigation to introduce variability in volume of water used.

3.8 Sampling

The study targeted rice farmers in Ahero Irrigation Scheme. The sampling frame which was a list of all the farmers in the various blocks was obtained from the Ahero regional office. Stratified sampling was done using the 12 blocks as strata. 8 blocks out of the 12 blocks were then randomly selected. Depending on the size of the blocks and number of farmers, proportional sampling was conducted to give a sample of 250 farmers.

3.9 Data sources and data collection methods

The study utilized primary data collected using a household questionnaire. Ten enumerators who were carefully selected and trained pre-tested the questionnaire prior to the actual survey. They later interviewed 250 rice farmers. The staffs of Nyanas Water and Sanitation Company were interviewed on the domestic water prices. Records of the volume of water pumped, total land under irrigation and number of farmers were obtained from the Ahero NIB offices. Existing literature on related studies were also reviewed.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1: Descriptive statistics

The descriptive statistics estimated from the sampled farm households are presented in Table 4.1. They were generated using SPSS version 17.0. The descriptive statistics reveal that 70% of the farmers interviewed were male while 30% were female. The average household was found to comprise 6 individuals. About 39% of the farmers interviewed earned off farm income, while 30% of the farmers had access to credit in the year 2011. The farmers on average had 1.8 contacts with extension workers. The average land size cultivated in the year 2011/2012 season was 3.24 acres. The average distance to input market and output market was 2.88km and 3.07km respectively.

The average quantity of rice seed and fertilizer (Sulphate of ammonia) per acre used were 25.25 and 83.60kg respectively. The average expenditure on fertilizer and seed per acre were Kshs.3,784 and Kshs.1,737 respectively. The mean expenditure on chemicals used in production was Kshs.494. Labour cost per acre was Kshs.24,314, about 50% of total costs. The average yield of un-milled rice was 2,024kg per acre while the revenue was about Kshs.87,800. Gross margin per acre was found to be Kshs.39,200.

The average volume of water used in rice production per acre was 5,679/m^3. About 44% of the interviewed farmers were satisfied with the current supply of irrigation water. The stated WTP for irrigation water averaged Kshs.2,773 per acre per year. The residual value of irrigation water among the rice farmers in Ahero irrigation scheme during the 2011/2012 season was Kshs.0.00754/litre.

Table 4.1: Summary of descriptive statistics

Variable	Mean	Std. Dev
Farmer specific variables		
Gender(1=male,0=female)	0.70	0.46
Household size	5.66	2.10
Off farm income(1=Yes,0=No)	0.39	0.49
Credit access (1=Yes,0=No)	0.30	0.46
Number of extension contacts	1.87	1.63
Farm specific variables		
Land size cultivated (acres)	3.24	1.23
Distance to input market (km)	3.07	2.18
Distance to output market(km)	2.88	1.72
Input use/acre		
Rice seed (kg)	25.25	3.12
Fertilizer (Sulphate of ammonia) –kg	83.60	30.52
Costs of production and output		
Seed cost(Kshs./acre)	1,736.88	365.57
Fertilizer cost (Kshs./acre)	3,783.73	1,455.40
Chemicals cost (Kshs./acre)	494.07	345.16
Labour cost (Kshs./acre)	24,313.72	3,150.24
Total costs (Kshs./acre)	48,600.32	14,759.04
Un-milled rice harvested (Kg/acre)	2,024.21	546.44
Price of un-milled rice (Kshs./kg)	43.37	3.78
Rice revenue (Kshs./acre)	87,799.91	24,983.48
Gross margin/acre (Kshs.)	39,199.59	27,641.66
Water used (m^3)	5,679.00	1,258.88
Residual value of irrigation water (Kshs. /Litre)	0.00754	0.00627
Stated WTP for irrigation water per acre per year (Kshs.)	2,772.96	787.14
Satisfaction with water supply (1=Yes,0=No)	0.44	0.03
Frequency of irrigation (number)	4.88	1.08

Source: Author’s Survey (2012)

Education level of the household head

The distribution of sampled farmers ages are presented in Table 4.2. Majority of the farmers interviewed (61%) were in the primary school category. About 28% were in the secondary school category, and about 8% having no formal education. Only about 3% of the respondents had college/degree education level. On average, rice farmers in Ahero irrigation scheme have 7 years of education corresponding to primary school level.

Table 4.2: Education level of the household head

Education level	Frequency	Percent
None	17	7.7
Primary	135	61.0
Secondary	62	28.1
College	5	2.3
Degree	2	0.9
Total	221	100.0

Farmers' age (years)

The distribution of farmers' ages is presented in Table 4.3. About 38% of the farmers were in the 47-62 years age group followed by 30% in the 31-46 years category. About 27% of the respondents were between 63 and 78 years. Only 3% of the farmers were between 15 and 30 years while 1% were above 79 years old. The average age across all age groups was found to be 54 years.

Table 4.3: Farmers' age (years)

Age (years)	Frequency	Percent
15-30	7	3.2
31-46	67	30.3
47-62	84	38.0
63-78	60	27.1
Above 78	3	1.4
Total	221	100.0

Farming experience (years)

The distribution of sampled farmers' ages is presented in Table 4.4. More than a quarter (25.3%) of the farmers had more than 23 years of farming experience. About 24% had 12-23 years of farming experience while 20% had experience of 6-11 years. Only 6% had between 0 and 5 years farming experience. On average, the farmers had farming experience of 18 years.

Table 4.4: Farming experience (years)

Farming experience (years)	Frequency	Percent
Less than 5	14	6.3
6-11	43	19.5
12-17	54	24.4
18-23	54	24.4
Above 23	56	25.3
Total	221	100.0

Annual household income (Kshs)

Income distribution of the surveyed respondents is presented in Table 4.5. Most farm families (about 50%) earned annual income in Kshs.60, 001-90,000 category, while 22% earned between Kshs.90, 001 -120,000 per year. About 19% of the farm families sampled earned an annual income of Kshs.30, 001-60,000. Only 3% earned less than Kshs.30, 000 annually. On average, the farm families sampled earned Khs.79,201 annually.

Table 4.5: Annual household income (Kshs)

Annual income (Kshs.)	Frequency	Percent
Less than 30,000	8	3.6
30,001-60,000	41	18.6
60,001-90,000	110	49.8
90,001-120,000	49	22.1
120,001-150,000	13	5.9
Total	221	100.0

Comparison of water values

Table 4.6 represents a comparison of water values for rice irrigation and for domestic uses. As indicated in Table 4.6, the residual value of irrigation water in rice production is Kshs. 7.54/m^3. Nyando district's domestic water is supplied by Nyanas Water and Sanitation Company.

Table 4.6: Comparison of water values

	Kshs./m^3
Residual value for irrigation water (rice)	7.54
Domestic water	35.00

Source: Author's Survey (2012)

According to an interview with Nyanas water and sanitation company staff, domestic potable water is sold at an average price of Kshs. 35/m^3. This reveals that water has a higher value for domestic uses compared to use in irrigating rice. The value of water for domestic uses is almost five times the value of water in rice production. The high cost of water for domestic uses could be attributed to treatment and supply cost.

4.2 Factors influencing WTP for irrigation water

The factors influencing farmers' WTP for irrigation water were determined through OLS using STATA version 10.0. The results of OLS regression are presented in Table 4.7. The dependent variable is the natural logarithm of the stated WTP. Prior to OLS estimation various diagnostic tests were performed. Multicollinearity tests were conducted through the evaluation of pair-wise correlations between explanatory variables and Variance Inflation Factor (VIF). Gujarati (2004) argues that when pair-wise correlation exceeds 0.8, there is a serious multicollinearity problem. The test in this study indicated that there were no serious correlations between explanatory variables (see appendix 1). None of the variables had R^2 in excess of 0.8. Variance Inflation Factor (VIF) results also indicated that there was no serious multicollinearity problem (see appendix 2). Gujarati (2004) further argues that VIF values exceeding 10, which occur when correlation between any two variables exceeds 0.9, are indicators of multicollinearity. However, none of the VIF of the variables included in the model exceeded 10 and the mean VIF was 1.25 (see appendix 2).

The OLS regression was found to have heteroskedasticity problem. Gujarati (2004) and Verbeek (2004) define heteroskedasticity as a case where the variances of the error terms of a regression vary across observations. This would lead to OLS estimators being inefficient (have large standard errors) or have reduced precision, which results to misleading inferences/conclusions about the studied population (Gujarati 2004; Dougherty, 2001). Wooldridge (2004), Gujarati (2004) and Verbeek (2004) suggested estimation of robust standard errors which correct the problem of heteroskedasticity. Therefore, robust standard errors were estimated in the current OLS regression**.**

The results of the OLS are presented in Table 4.7. The results indicate that 76% of the variation in the dependent variable (lnWTP) 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 92.10 and is significant at 1% level, indicating that the explanatory variables reliably predict the dependent variable.

Table 4.7: Results of OLS regression

Dependent variable: lnWTP			
Independent variables:	Coefficient	Robust Standard Errors	P value
Age	0.0035	0.0094	0.714
Gender	0.0167	0.0204	0.414
Household size	-0.0060	0.0043	0.166
Education	0.0257	0.0169	0.129
Off farm income	0.0545	0.0173	0.002***
Credit	0.0339	0.0199	0.091*
Land size	-0.0031	0.0074	0.672
Satisfaction	0.4420	0.0184	0.000***
Constant	7.6738	0.0532	0.000***
Number of observations	217		
F (8, 208)	92.10		
Prob>F	0.0000		
R^2	0.7644		
Root MSE	0.1234		

*, **, *** mean significance at 10%, 5% and 1% respectively

Out of the eight explanatory variables, three were significant at 10% or lower levels in determining farmers' WTP for irrigation water in Ahero Irrigation Scheme. These are the off-farm income, credit access and satisfaction with management of water supply system.

Off-farm income affected farmers' WTP for irrigation water positively. This finding agrees with Akter (2006) who found that farm households in Bangladesh that earned off-farm income were willing to pay more compared to those not earning off-farm income.

As expected, access to credit also positively influenced farmers' WTP for irrigation water. This could be due to the possibility that part of the credit offered is used to pay for irrigation water, among other inputs of rice production.

Satisfaction with the management of irrigation water supply system positively influenced farmers' WTP for irrigation water. Farmers satisfied with the management of irrigation water supply system were found to be willing to pay more compared to those unsatisfied with the management of irrigation water supply. This result is consistent with that of Tang et al. (2013).

4.3 Translog Production Function results

Three types of production functions, namely a stochastic Cobb Douglas, quadratic and Translog production functions were tested to determine which type of production function specification is more appropriate in the determination of the factors that influence output in irrigated rice production. The results of the test runs indicated that the Translog specification was more appropriate because the specification allows for interaction of the inputs and it is also less restrictive compared to Cobb Douglas production function. The Translog specification also gave more statistically significant variables compared to the other specifications. The Translog specification was thus adopted in this study. The results of the Translog production function are presented in Table 4.8.

Table 4.8 Results of Translog Production Function Estimate

Dependent variable: ln rice harvested (kg/acre)			
Independent variables:	Coefficient	Standard errors	P value
lnSeed	-11.846	10.604	0.417
lnFertilizer	6.796	3.893	0.081*
lnWater	10.686	6.041	0.077*
lnLabour	11.636	11.428	0.099*
lnFungicides/pesticides	-0.517	0.794	0.515
Ln(seed*seed)	0.182	0.195	0.351
Ln(fertilizer*fertilizer)	0.056	0.045	0.389
ln(water*water)	-0.206	0.121	0.089*
ln(labour*labour)	-0.510	0.225	0.023**
ln(Fungicides/pesticides* Fungicides/pesticides)	-0.015	0.003	0.000***
ln(Seed*Fertilizer)	0.627	0.967	0.517
ln(Seed*Water)	0.005	0.001	0.995
ln(Seed*Labour)	1.449	1.336	0.622
ln(Seed* Fungicides/pesticides)	-0.012	0.141	0.933
ln(Fertilizer*Water)	-0.601	0.213	0.005***
ln(Fertilizer*Labour)	-1.089	0.397	0.006***
ln(Fertilizer* Fungicides/pesticides)	0.074	0.037	0.049**
ln(Water*Labour)	-0.259	0.574	0.651
ln(Water*Fungicides/pesticides)	0.028	0.023	0.418
ln(Labour*Fungicides/pesticides)	0.045	0.088	0.612
Wald Chi^2	93.84		
Prob>Chi^2	0.0000		

*, **, *** mean significance at 10%, 5% and 1% respectively

The results indicate that the coefficient of volume of water used in rice production is positive and significant at 10% level in determining rice yield. This implies that increasing volume of water used for irrigation would increase rice yields. In addition, fertilizer and labour significantly influenced the rice yield at 10% level. Fertilizer and labour were found to have a positive relationship with yield, implying that increasing the use of the two inputs would increase the yield.

From this result, the Chi^2 value in the production function ($Prob>Chi^2=0.0000$) indicates that all the variables included in the model significantly determine rice yields at 1% level. Therefore, considered jointly, all the inputs in the model significantly influence rice yields.

4.3 Hypothesis Testing

Two hypotheses were tested in the study; that each of the following socio-economic factors do not influence the farmers' willingness to pay for irrigation water: age of the farmer, gender of the farmer, household size, education level of the farmer, off-farm income, access to credit, land size and satisfaction with the management of water supply; that irrigation water is not a significant input in rice production.

From the results of this study, the F value in the OLS model (Prob>F=0.0000) indicates that the variables included in the model jointly influence WTP for irrigation water. The variables that were found to significantly influence WTP for irrigation water are off-farm income, access to credit and satisfaction with the management of irrigation water supply. These findings lead to the rejection of the hypotheses that off-farm income, access to credit and satisfaction with the management of irrigation water supply do not influence farmers' WTP for irrigation water. However, the author failed to reject the hypotheses that age of the farmer, gender of the farmer, household size, education level of the farmer and land size do not influence farmers' WTP for irrigation water. The economic value of irrigation water was estimated to be Kshs. 7.54/m^3, hence answering the research question "What is the economic value of irrigation water among smallholder rice farmers in Ahero Irrigation Scheme in Nyando District, Kenya?"

Based on the results of the Translog production function estimate, the hypothesis that irrigation water is not a significant input in rice production was rejected. The coefficient of volume of water used was significant at 10% level in determining rice yields. In addition, all the inputs considered jointly (seed, fertilizer, labour, irrigation water and chemical costs) significantly influenced rice yields in Ahero irrigation Scheme, Nyando District, Kenya.

Farmers were willing to pay Kshs. 2,773 per acre per year for irrigation water. This value is relatively low compared to the O&M charges of Kshs.3,100 per acre per year. Obiero (2010) also reported that rice farmers in Mwea Irrigation Scheme felt that water charges were too high and that water should be supplied free of charge. This could be the reason why farmers in Ahero Irrigation Scheme also reported low WTP values for irrigation water. Using the RVM, irrigation water value was estimated to be Kshs. 7.54/m^3. A comparison of the results from the two methods, CVM and RVM, in the valuation of irrigation water revealed that the CVM tends to undervalue irrigation water. The RVM result was thus adopted as the economic value of irrigation water, estimated to be Kshs. 7.54/m^3.

The analyses conducted indicated that the economic value of irrigation water is Ksh. 7.54/m^3 and that the volume of irrigation water significantly influenced rice output. Farmers' access to credit, participation in off-farm income generating activities and satisfaction with the management of water supply system were found to influence farmers' WTP for irrigation water positively. This implies that in addition to improving farmers' access to credit and participation in off-farm income generating activities in order to improve WTP for irrigation water, the supply and management of irrigation water in Ahero Irrigation Scheme should also be improved. Since volume of water is a significant input in rice production, the NIB should ensure that they supply adequate volume of water throughout the production season. This would increase rice yields and also improve the economic value of irrigation water in rice production in Ahero Irrigation Scheme, Kenya.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusions

Water is used as an input in most production hence important for economic development. However, water scarcity is on the rise as urban areas and population grow coupled with increased demand for water in agriculture, industries and households. Agriculture is the biggest consumer of fresh water among the economic sectors in many regions of the world, and a sector characterized with intense water use with low efficiency. Therefore water must be treated as economic good and appropriate prices relative to its economic value be charged in order to achieve water use efficiency. The establishment of more efficient water prices requires reliable estimation of the economic value of water.

Pricing of agricultural water and cost recovery can play a significant role in promoting water use efficiency. Although water is essential for human survival, it does not mean that governments must provide water services to the consumers freely or at subsidized price. Under-pricing of water and lack of cost recovery leads to undesirable outcomes such as excessive use, pollution, resource misallocation and non-sustainable water supply service. When water charges are low, people tend to use water carelessly. Better water allocation could be achieved if the economic value of water is known by use, region and season. Knowledge of water value is also important for cost benefit analyses of investments in irrigation and formulation of water pricing policies.

The purpose of this study was to estimate the economic value of irrigation water in Ahero Irrigation scheme. The specific objectives of the study were: to estimate the economic value of irrigation water among smallholder rice farmers in Ahero Irrigation Scheme in Nyando District, Kenya; to assess the factors that affect farmers' WTP for irrigation water in Ahero Irrigation

Scheme in Nyando District, Kenya; and to determine whether irrigation water is a significant input in rice production in Ahero Irrigation Scheme in Nyando District, Kenya.

The hypothesis tested were that each of the following socio-economic factors do not influence the farmers' willingness to pay for irrigation water: age of the farmer, gender of the farmer, household size, education level of the farmer, off-farm income, access to credit, land size and satisfaction with the management of water supply, and that irrigation water is not a significant input in rice production. The study also sought to answer the following research question: What is the economic value of irrigation water among smallholder rice farmers in Ahero Irrigation Scheme in Nyando District, Kenya? Both CVM and RVM were used to estimate the economic value of irrigation water and the OLS technique was used to assess the factors influencing WTP for irrigation water. A Translog production function was estimated to determine whether water is a significant input in rice production.

The findings reveal that the economic value of irrigation water obtained from CVM (Kshs.2,773 per acre per year), undervalued irrigation water value, below the O&M charges (Kshs.3,100 per acre per year). On the other hand, a higher value of Kshs.7.54/ m^3 for rice irrigation water was obtained from the RVM. The study therefore estimated irrigation water value to be Kshs.7.54/ m^3. Three variables were found to significantly influence WTP for irrigation water, i.e. off-farm income, access to credit and satisfaction with the management of irrigation water supply system. Irrigation water was found to be a significant input in determining rice yields, hence the need to ensure reliable supply of irrigation water.

5.2 Recommendations

Domestic potable water is sold at an average price of Kshs.35/m^3, while the residual value of water in rice irrigation is Kshs.7.54/m^3. Farmers' WTP for irrigation water was estimated to be Kshs.2,773/acre/year while the O&M charges is Kshs.3,100 per acre per year. Since CVM tends to undervalue irrigation water, the economic value of irrigation water estimated at Kshs. 7.54/m^3 through the RVM is adopted in this study.

The low WTP value compared with charges for domestic potable water and O&M charges could be attributed to the current system of water supply in irrigation schemes which farmers are unsatisfied with. Although the economic value of water is lower in agriculture compared to other sectors, it does not mean that it should be diverted to the sectors with higher productivity. Instead, the efficiency of water use in agriculture should be improved. Water used should be charged at appropriate prices relative to its economic value to avoid its wasteful use. Farmers should be educated on efficient use of water to help improve the value of this scarce resource.

Off-farm income and access to credit positively influenced WTP for irrigation water. This suggests that the income earned off the farm trickles down to agriculture. Therefore, Small and Medium Enterprises (SMEs) in rural areas to improve off-farm income should be promoted and the farmers should be encouraged to take credit which can be used as a channel to improve agricultural production.

Since volume of irrigation water was found to be significant in influencing rice output, its supply should also be improved to ensure adequate volume of water during rice production. This will increase rice output and consequently increase the economic value of irrigation water in rice production in Ahero Irrigation Scheme, Kenya.

5.3 Study limitations

The current study provides insights on the economic value of irrigation water for rice production, farmers' WTP for irrigation water and the determinants of rice yields in Ahero Irrigation Scheme. However, the study utilized cross sectional data because of lack of panel data which would have enabled assessment of economic value of irrigation water for rice production over several years. Future studies should therefore estimate economic value of irrigation water based on panel data and across different crops.

Based on literature review, the current study is the first to assess factors affecting farmers' WTP for irrigation water in Kenya, hence filling a considerable knowledge gap in valuation of irrigation water. The government of Kenya is cognizant of the importance of irrigation in ensuring food security, employment and reduction of poverty, and is therefore committed to expansion and rehabilitation of existing irrigation schemes as well as establishing new ones (Republic of Kenya, 2010). Therefore, more studies should be conducted in different regions and across different crops to estimate the economic value of irrigation water and factors affecting farmers' WTP for irrigation water.

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7.0 Appendices

Appendix 1: Partial correlation of explanatory variables

	Household size	Gender	Off farm income	Land size cultivated	Satisfaction	Credit	Education	Age
Household size	1.0000							
Gender	0.1778	1.000						
Off farm income	0.1004	0.1615	1.000					
Land size cultivated	-0.1314	0.0138	-0.1467	1.000				
Satisfaction	-0.1311	0.2185	-0.0408	0.1520	1.000			
Credit	0.0487	-0.1289	0.0327	-0.1844	-0.2858	1.000		
Education	0.0700	0.2822	0.2612	-0.0067	-0.0437	0.0513	1.000	
Age	-0.0885	0.0132	-0.3183	0.1774	0.0587	-0.0616	-0.3793	1.000

Appendix 2: Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
Education	1.33	0.7542
Age	1.32	0.7587
Gender	1.21	0.8279
Satisfaction	1.17	0.8516
Off farm income	1.18	0.8481
Credit	1.13	0.8812
Land size cultivated	1.12	0.8940
Household size	1.10	0.9127
Mean VIF	1.19	

Appendix 3: Estimation of volume of water used

Total volume of water pumped (m^3)	12,311,640
Number of times water was pumped	6
Total acreage (acres)	2,168
Average volume of water diverted to one acre of land per pumping (m^3)-denoted by X	$X = \frac{12,311,640}{6 * 2,168} = 946$
Total volume of water used by each farmer (m^3/acre)	$X * frequency\ of\ irrigation$

Appendix 4: Survey instrument

Economic valuation of irrigation water in Ahero Irrigation Scheme in Nyando district, Kenya

QUESTIONNAIRE

Questionnaire number

Date of interview: …./04/2012 Interviewed by: ……………………………………..

Farmer's (respondent) name……………………….. Block number………Mobile no………………………

Date checked: …/04/2012 Date entered: …../…. /2012

A. **Socio-Demographic information**

A1.Household Status (1= male headed, 0= Female Headed)	
A2. What is the size of your household?	
A 3. What is your age?	
A 4. Gender (1=Male,0=Female)	
A 5. Marital status(codes A)	
A 6.1Number of years of schooling	
A 6.2.Highest level of education attained(Codes B)	
A 7. What is your current status of employment?(Codes C)	
A 8. How much income does your household earn in an average year from:	

a. Agricultural employment:	
b. Non-Agricultural employment:	
c. Farming income: Rice (per season) Maize	
d. Remittances	
e. Other business:	
f. Other (specify ……………………)	
Total income	
A 9. Land size cultivated in scheme(acres)	
A 10.Experience with farming (years)	
A 11. Experience with irrigation (years)	
A 12. Number of extension visits during last season(2011)	

Codes

Codes A	**Codes B**	**Current status of employment**
1=Married	0=None	1= full time employed
2=Married but spouse is away	1=Primary	2=part-time employed
3=Separated	2=Secondary	3=self employed
4=Divorced	3=College	4=student
5=Single (never married)	4=Degree	5=retired
6=Widow/widower	5=Phd	6=on benefit
	6=Other (specify)	

		7=unemployed 8= other (specify)

B. **Social Capital Endowment:** Membership to farmer organizations/cooperative/clubs

B1. Are you a member of any farmer group?	1. Yes 0. No
B2.Name of the group	
B 3. If Yes Q1 Specify type(s) of farmer group	1. Community based org 2. Farmer cooperative 5. Saving and credit coop 3. Farmers' club/group 4. Women's club 6. Other, specify…………….
B 4. Year first joined	
B5. Functions of farmer group	1. Produce marketing 4. Soil & Water conservation 2. Input access/marketing 5. Input credit 3. Savings and credit 6. Other (specify)…
B 6. Most important benefit derived from group	1.Access to lucrative markets for produce 2.Access to inputs at low cost 3.Access to financial service 4.Access to important agric information 5. Support for social functions (funerals, wedding,

	out-dooring etc) 6.Other (specify)………………
B 7.Role played in the club	1.ordinary member 2. official
B 8.If not a member, why?	
B 9.How are decisions made in the group?	1.Imposed from outside 2.By leaders only 3.leaders consult members 4.Members consensus 5.Other(specify)
B 10.Do you attend meetings regularly	1.Yes 0.No
B 11.To what extend are you satisfied with the leadership of the group?	1.Very satisfied 2.Satisfied 3.Unsatisfied 4.very unsatisfied 5.Not sure
B 12.How much did you contribute in 2011 for management of your group?(Ksh)	
B 13.Does your group have rules/laws?	1.Yes 0.No
B 14.How do you rate your	1.Very poor

knowledge of the rules/laws?	2.poor 3.Good 4.Very good
B 15.What's your perception on the relevance of these rules?	1.Not relevant 2.Somehow relevant 3.Relevant 4.Highly relevant 5.Not sure
B 16.On average do you adhere to these rules?	1.Never adhere 2.Sometimes adhere 3.Fully adhere
B 17.Why do members find it difficult to adhere to the rules?	1.Too many rules 2.do not know the rules 3.No penalty 4. The rules are difficult to adhere to

C. Land holding (acres) during 2011 planting seasons

	Cultivated	Fallow (e.g. grazing)
C1. Own land in the scheme (A)		
C 2. Rented land (rented in) in the scheme(B)		
C 3. Owned land outside the scheme(C)		
Total		

D. Input use per acre

Input	Units	Price per unit (Ksh)	Total (Ksh)
Seed (Kg)			
a. Basmati 370			
b. IR 2793-80-1/ITA 310			
Fertilizer (Kg)			
a. Sulphate of Ammonia			
b. Urea			
c. DAP			
Insecticides (ml)			
a. Titan			
b. Tata umeme			
c. Pearl			
Fungicides (grams)			
a. Bavistin			
b. Rodazim			
c. Servian			
Labour			
a. Ploughing			
b. Rotavation			
c. Paddling			
d. Bund trimming			

e. Leveling			
f. Transplanting			
g. Fertilizer application			
h. 1st Weeding			
i. 2nd weeding			
j. Spraying			
k. Bird scaring			
l. Harvesting			
m. Stacking (heaping)			
n. Threshing			
o. Drying			
p. Winnowing			
q. Storage			
Total Man-days used			
Storage bags			
Transport			
Scheme operation&maintenance			
Land rent			
Farm management			
Capital interest rate			
Quantity of water used			
Frequency of			

irrigation(Number per season)	

E. Output/harvest

	Quantity harvested (Kg)	Quantity sold (Kg)	Price per unit (Ksh)	Total (Ksh)	Amount stored(Kg)	Gifts,tithe,donation,paid wages(Kg)
Rice (dried)						
Maize						
Crop residue/stalks						
Other (specify)						

F. Farm and household asset endowments

Asset name	**Number currently owned**	**Year bought/built**	**Current value (**LOCAL CURRENCY**)**
1. Ox-plough			
2. Ox-cart			
3. Chemical Sprayer/pump			
4. Sickle			

5. Spade/shovel			
6. Panga			
7. Hoes			
8. Wheel barrow			
9. Bicycle			
10. Tractor			
11. Plough			
12. Harrow			
13. Planter			
14. Reaper			
15. Other tractor drawn equipment (specify……..............			
16. Store for farm produce			
17. Other motorized vehicles (specify…..........................)			
18. Radio/radio cassette			
19. Mobile phone			
20. Television (TV)			
21. Computer/Internet			
22. Water pump			
23. Generator			
24. Other…...................			

G. Willingness to pay for irrigation water

Explain to the interviewee the hypothetical market scenario which is adequate supply of water throughout the year and the payment vehicle which is through the water user fees to the National Irrigation Board (NIB). Before expressing a certain amount of money, please ask yourself: "Am I willing to pay this amount of money for irrigation water? Or would I rather not pay this amount and remain in the current state of inadequate water during crop production and delays?" Please, do not agree that you are willing to pay a certain amount if you cannot afford it on a regular basis (annually), or if you feel that there are more important things you can do with your money or if you are not sure that you are prepared to pay such amount of money. (Currently farmers pay Ksh.3100/acre/year for operation and maintenance which is taken as the initial bid).We are asking for your most truly willingness to pay, so please, provide the sincere response, thank you.

1. Are you willing to pay some money for irrigation water?(1=Yes 0=No) If no, go to question 4	
2. Are you willing to pay Ksh 3100 per acre per year for irrigation water? (1=Yes 0=No),if no go to 4.	
3. If yes, if the fees were increased by 10%, would you be willing to pay Ksh 3410? (If yes, continue increasing by 10% up to where you get no)	
4. If no, if the fees were reduced by 10% would you be willing to pay Ksh 2790? (if no, continue reducing by 10% up to where you get yes)	
5. How would you classify your willingness to pay(WTP) (1=Probably sure	

2=Definitely sure)	
6. What are the reasons behind your zero WTP?: (*you can choose more than one choice)* 1=You are not supposed to pay for irrigation water 2=You are satisfied with the current scenario of water supply 3=You do not have enough money to pay 5= It is the government duty to supply irrigation water for free 4=Not confident that the money will be used to improve supply of irrigation water. 5=unable to determine the amount to spend on irrigation water. 6=other (specify)	
7. Are you satisfied with the current management irrigation water supply system?(1=Yes 0=No)	

H. Access to credit

K1.Has any member of your household received any form of credit in the past two years? 1.Yes 0.No	
K.2 If yes how much money? (Ksh)	
K2.If yes, source of credit: 1. Relatives/friends 2. Money lenders 3.microfinance institutions 4.Banks 5.Revolving fund 6.Other (specify)	