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Characterization of Irrigation Farm Households and Economic Valuation of Irrigation Water: The Case of Ahero Rice Irrigation Scheme in Nyando District of Kenya

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Authors' contributions

This work was primarily carried out by author SOO. Author SOO performed under the supervision of author SG and KM as supervisors at the Department of Agricultural Economics, University of Nairobi, Kenya. Therefore, the first author designed the study, wrote the protocol and executed the study under the guidance of the second and third authors. The first author also wrote the first draft of the manuscript that was subsequently improved upon through editorial comments and contributions from the second and third authors. All authors thus read and approved the final manuscript.

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ABSTRACT

Irrigated farming can play a great role to enhance agricultural development in Kenya, given that Kenya's economy is predominantly agricultural based and that about 80% of Kenya's land area is arid and semi-arid land (ASAL) where annual rainfall rarely exceeds 400 millimetres. However, irrigation tends to be carried out under intensive water use and low water use efficiency in many parts of the world, Kenya included. Household characteristics and subsidized or low water charges have been identified as a major contributor to intensive water use and low water use efficiency in irrigation. Therefore, characterization of farm households that irrigate and determination of efficient prices for irrigation water should be a prerequisite to formulation of appropriate water pricing in irrigation development policies. Taking the Ahero Rice Irrigation Scheme (ARIS) that is managed by

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the National Irrigation Board (NIB) in Kenya as a case study, this paper analyzes the characteristics of the household at the ARIS and critically evaluates the implications of economic aspects of rice production on the pricing of irrigation water at the ARIS. For production at economic optimum, average total cost (ATC) should be equal to average total revenue (ATR) or the average gross margin (AGM). This study estimated the total volume of water used in rice production at the ARIS at 5,679 m^3 per acre per season, with the average total cost of rice production at the scheme being estimated at Ksh. 87,800 per acre per season. The cost of irrigation water accounts for about 44.65% of that cost of rice production. Given these figures, the residual value of irrigation water at the ARIS is thus Ksh. 39,202 per acre per season and this figure translates into a unit residual value of Ksh. 6.91 per m^3, which is the economic value of the irrigation water used at the ARIS. Since the NIB levies a water charge of Ksh. 3,100 per acre per season to meet its costs of operation and maintenance of the ARIS, this study implies that the NIB water charge is about 12.65 times below the economic value of the irrigation water. This water charge reflects a relatively high level of water use subsidy which is inefficient and unjustifiable from an economic criterion. The NIB should thus raise its charge for irrigation water to a reasonable level relative to the economic value of that water to minimize the misuse of the water and improve water use efficiency.

Keywords: Ahero irrigation scheme; Kenya; irrigation water use; farm household characteristics; economic valuation of irrigation water; residual value method.

1. INTRODUCTION AND RESEARCH ISSUES

Agriculture has been identified as a vital sector in ensuring economic growth, improvement in food security and poverty reduction in the Kenya's Vision 2030, the blueprint for the national development framework in Kenya, and also in the Kenya's Agricultural Sector Development Strategy 2010-2020 [1,2]. Growth in the agricultural sector has been found to be at least two times more effective in contributing to poverty reduction at the national level when compared to the impact of growth originating from other sectors [3].

Agricultural production in Kenya is primarily under rain-fed conditions. However, the capacity to increase agricultural production in the country through the expansion of cultivated land under of rain-fed conditions is severely constrained for two main reasons. First, only about 20% of the Kenya's land area is medium to high potential with respect to rain-fed agricultural production. The rest of the country's land area (about 80%) is classified as Arid and Semi-Arid Land (ASAL), and is often referred to as the rangelands. These rangelands mostly receive less than 400 millimetres (mm) of rainfall per annum. Agricultural production under rain-fed conditions in most of the rangelands is thus highly risky. The rangelands are used mainly for livestock keeping under pastoral conditions [4]. Second, the 20% of Kenya's land area that is arable hosts over 60% of the country's total human population and that population has been growing relatively fast (at an average of around 3% per annum) over the last five decades. These factors thus underscore the important role that irrigation development in the vast rangelands of Kenya can play in enhancing agricultural production toward achieving food security, employment creation and poverty reduction in the country [5,2].

Despite Kenya having an irrigation potential of about 1.3 million hectares, only about 114,000 hectares of land in the country is under irrigation, with the smallholder and large scale farmers accounting for about 42% and 40% of the irrigated land respectively. The government-managed irrigation schemes in Kenya, mainly under the operation and maintenance of the National Irrigation Board (NIB) constitute about 18% of the total irrigated land [2].

Worldwide, the largest proportion of the available fresh water is utilized in agriculture, mainly for crops irrigation [6]. However, water continues to become increasingly scarce as human population and cities grow and the demand for water use in agriculture, households and industries continues to grow [7]. To exacerbate this problem of water scarcity, irrigation is mostly associated with intensive water use and low water use efficiency in many parts of the world, Kenya included. Although water is essential for human survival, economic growth and development, it should not be provided at subsidized prices or free of charge to avoid its profligate use and other undesirable effects, such as pollution and non-sustainable water supply [8]. Water for household use, irrigation and industries is mostly subsidized or supplied free of charge in many parts of the world, irrespective of the degree of water scarcity [9].

People tend to use water carelessly when water charges are low [10]. Subsidized water prices and hence low water charges have thus been identified as a major contributor to the intensive water use and low water use efficiency in irrigation. However, and especially in irrigated farming, other socio-economic and household variables may interact with the level of water charges to influence the intensity and efficiency of water use. In this study, gender, age and education level of the head of the household, average household size, average farm size, access to off-farm income and credit, and the number of farm household contacts with extension workers were assumed to be the significant farm household variables that are likely to influence the way the households behave in the use of irrigation water in rice production. The study also sought to establish if the farmers were satisfied with the current level of the supply of irrigation water, and the number of times the farmers had irrigated their rice fields during any rice given production period.

To mitigate problems in the use of irrigation water, water should be treated as an economic good and appropriate water use and pricing policies developed. The rationale is that characterization of farm households and determination of efficient water prices are a prerequisite to formulation of appropriate water pricing and irrigation development policies. The objective would be to minimize unnecessary use of irrigation water and thus improve efficiency in water use [6,11]. In any case, and particularly from a planning perspective, efficient water use prices are needed in the development of water resources, such as for irrigation schemes [12]. Taking the Ahero Rice Irrigation Scheme (ARIS) which is managed by the National Irrigation Board (NIB) in Kenya as a case study, this study thus aimed to contribute to knowledge in two major ways. Firstly by analyzing and presenting the characteristics of the farm households that are likely to influence their intensity and efficiency in the use of irrigation water. Secondly by determining the economic value of irrigation water and comparing that value with the existing charges for the use of irrigation water. By implication, rice is the main crop produced under irrigation at the ARIS.

2. RESEARCH PLAN AND METHODS

2.1 Study Area, Sampling and Data Collection

The study was conducted in the Ahero Rice Irrigation Scheme (ARIS) in Nyando District, Kenya, in April 2012. The main rice varieties cultivated in the scheme are IR 2793-80-1, ITA 310 and Basmati 370. The scheme is managed jointly by the National Irrigation Board (NIB) and the rice farmers. However, the NIB charges farmers Ksh. 3,100 per acre per year to as an irrigation Operation and Maintenance (O&M) levy for the use of the irrigation water that is pumped from River Nyando and then supplied to the rice fields through gravity. The normal irrigation O&M activities thus include the pumping of irrigation water and the maintenance of the water canals.

Farm households at the ARIS were used as the basic sampling unit. Hence the list of all farmers in the various blocks in the scheme constituted the sampling frame. Random sampling techniques were used to select a sample of 221 farm households from whose heads the relevant socio-economic and input/output data were collected through person-to-person interviews using a pretested household questionnaire. Additional data were obtained from the official records of the NIB office at the ARIS.

2.2 Method

There are various approaches for economic valuation of irrigation water: hedonic pricing, travel cost, Contingent Valuation Method (CVM) and the Residual Valuation Method (RVM). The current study considered the RVM to be more appropriate in the determination of the economic value of irrigation water.

The RVM aims at estimating the maximum return to a given input through the calculation of the total revenue and subtraction of the total cost of all inputs other than the given input. The approach assumes that the residual value is equivalent to the returns to the given input [13,14,15]. Taking irrigation water as the given input, the residual value, therefore, is the maximum amount of money that a producer who utilizes irrigation water as an input in production would be willing to pay over and above the cost of the other inputs in production.

The premises of RVM are that the profit maximizing producers utilize an input up to the point where its marginal product is equal to its opportunity cost. In addition, the total value of the product should be divisible in such a way that each input is paid according to its marginal productivity, with the total value of the product being exhausted [15,13]. Based on economic theory, at equilibrium, a profit maximizing firm under competitive conditions should produce at that level of output where the average total revenue equals to or is greater than the average total cost. Residual value approach is most suitable where a residual input contributes significantly to output, as is the case in agricultural production under irrigated conditions (for example in the case of the Ahero Rice Irrigation Scheme (ARIS) where rice production is greatly dependent on irrigation water). Some of the studies that have applied the RVM in the valuing of water include: [10,12,15,16-19]. However, no such studies have been undertaken in the valuation of irrigation water in Kenya. The RVM was applied in the valuation of irrigation water at the ARIS as discussed hereafter.

Following [10,15,12,20,21] the residual value model was specified as follows:

Y=f(F,S,C,L,T,R,M,I,ST,Q_(w))......................(1)

where Y = amount of harvested rice; F = fertilizer; S = seed; C = chemicals; L = labour; T = transport; R = land rent; M = management; I = loan interest; ST = storage; and Q_{W} = volume of irrigation water used.

The total value of production can then be written as shown in Equation 2:

$$Y.P_Y = VMP_F.F + VMP_S.S + VMP_C.C + VMP_L.L + VMP_T.T + VMP_R.R + VMP_M.M + VMP_I.I + VMP_{ST}.ST + VMP_W.Q_W \text{......................(2)}$$

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

Assuming that the farmer utilizes each factor up to the point where $VMP_i = P_i$ (Mesa-Jurado et al. 2008), VMP_i is replaced with prices and Equation 2 can be rewritten as follows:

$$Y.P_Y = P_F.F + P_S.S + P_C.C + P_L.L + P_T.T + P_R.R + P_M.M + P_I.I + P_{ST}.ST + P_W.Q_W \text{..............................(3)}$$

The residual value of irrigation water (P_w) is then calculated as the difference between the total value of the harvested rice and the costs of all non-irrigation water inputs to production divided by Q_{w}, as indicated below:

$$P_W = \frac{Y.P_Y - (P_F.F + P_S.S + P_C.C + P_L.L + P_T.T + P_R.R + P_M.M + P_I.I + P_{ST}.ST + P_W.Q_W)}{Q_W} \text{.....................(4)}$$

2.3 Estimation of the Volume of Water Used Per Acre

The total volume of water pumped in the rice fields was calculated from the records obtained from the office of the NIB at the Ahero Rice Irrigation Scheme (ARIS) pumping station. The amount of water supplied to each farmer was then estimated depending on the number of times each farmer irrigated his/her rice field, as given in Table 1

3. RESULTS

3.1 Descriptive Statistics: Characterization of The Farm Households

The descriptive statistics to characterize the types of farmers found in the Ahero Rice Irrigation Scheme were generated using the SPSS version 17.0, based on the data from the farm household survey, and are presented in Table 2.

3.1.1 Gender, household size, off-farm income and access to credit

The Table 2 descriptive statistics reveal that 70% of the farmers interviewed were male; the rest were female. The average household was found to comprise 6 individuals. The table also shows that, of those interviewed, about 39% had earned some off-farm income while 30% had access to some credit during the year 2011.

Table 1. Estimation of volume of water used in rice production in AIS per season

Total volume of water pumped (m^3)	12,311,640
Number of times water was pumped	6
Total acreage in the scheme (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)	$X * frequencyofirrigation$

Source: Author's computation

Table 2. 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
Satisfaction with water supply (1=Yes; 0=No)	0.44	0.03

Source: Author's Survey (2012)

3.1.2 Household farm size, extension contacts and satisfaction with irrigation water supply

The average land size cultivated per farm household during the year 2011/2012 season was 3.24 acres. The farmers, on average, had 1.8 contacts with extension workers per year. Of those interviewed, about 44% were satisfied with the current supply of irrigation water. The rice farmers irrigated their rice fields six times in the entire production period.

3.1.3 Education level of the household head

Fig. 1 indicates the education level of the head of the household and shows that most of those interviewed (61%) were in the primary school category. About 28% were in the secondary school category, and about 8% had no formal education. Only about 3% of the respondents had college/university (degree) level of education. On average, the rice farmers in the Ahero Rice Irrigation Scheme have 7 years of schooling, corresponding to the primary school level.

3.1.4 Farmer's age (years)

Fig. 2 indicates the ages of the heads of the farm households in years and shows that about 38% of them were in the 56-70 years age group, followed by 28% in the 31-45 years category. About 21% of the respondents were between 46 and 55 years. Only 3% of the farmers were between 15 and years while 10% were above 70 years old. The average age across all age groups was found to be 54 years.

3.2 Residual Value of Irrigation Water

Conceptually, the residual value with regard to a given input (irrigation water in this case) gives the proportion of the estimated gross margin from production that is attributable to the productivity of the given input in production. The residual value of irrigation water (RVIW) as an input in rice production was thus calculated as the difference between the gross margin from rice production and the non-water costs incurred in rice production. Based on economic theory, average total revenue should equal to or be greater than average total cost for a firm in equilibrium under competitive conditions. The gross margin reflects expected total revenue and is thus a pointer to the profitability of an enterprise, the break-even point being where the average gross margin which is basically the price of the output is equal to or greater than the average total production cost. The variables used in the computation of the residual value for irrigation water are presented in Table 3.

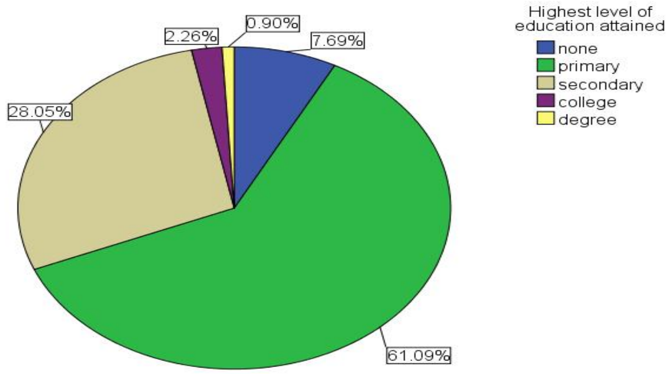

Fig. 1. Household head education level
Source: Author's survey (2012)

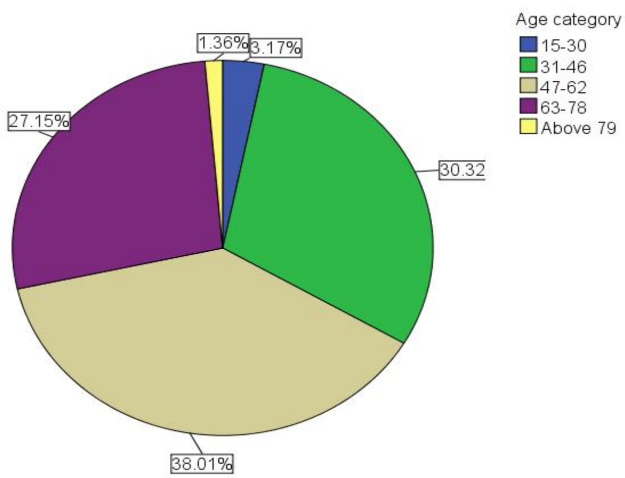

Fig. 2. Household heads' ages (years)
Source: Author's survey (2012)

Table 3. Variables used in computation of residual value

Item	Amount
Average total revenue (Ksh. per acre)	87,800
Average total costs (Ksh. per acre, without water cost)	48,598
Gross margin to irrigation water use (Ksh. per acre)	39,202
Volume of water used (m^3)	5,676
Residual value (RVIW) (Ksh./ m^3)	6.91

Source: Author's Survey (2012)

The estimated volume of water used in rice production per acre per season was 5,676 m^3. The average total revenue from rice production amounted to Ksh. 87,800 per acre per season while the average total cost (less the average cost of irrigation water) was Ksh. 48,598 per acre per season respectively. Therefore, the average gross margin to irrigation water use was Ksh. 39,202 per acre per season, implying that the residual value of irrigation water used in rice production was Ksh. 6.91 per m^3.

4. DISCUSSION, CONCLUSION AND IMPLICATIONS

This study has given a characterization of the socio-economic and other household variables that are likely to influence the way irrigation water in the Ahero Rice Irrigation Scheme (ARIS) in

Kenya is used. These household variables include gender, age and education of the head of household, household size, average irrigated farm size, availability of off-farm income, access to credit, and farmer-extension contacts. Even though the study has characterized the farm households on the basis of these variables, it has not attempted to examine how the variables individually and jointly influence the behaviour of the farm households in the use of irrigation water at the ARIS.

The study has also estimated the economic value of irrigation water at the ARIS. On the basis of economic theory, an enterprise would be said to be profitable if the average total cost (ATC) is less than or equal to the average total revenue (ATR) under equilibrium or competitive conditions, provided that all the costs are properly accounted for. The study indicates that the average total revenue from rice production amounted to Ksh. 87,800 per acre per season while the average total cost, less the average cost of irrigation water, was Ksh. 48,598 per acre per season. The difference between the two figures, that is Ksh. 87,800 less Ksh. 48598, which is Ksh. 39,202, thus gives the average farm gross margin (AFGM) attributable to irrigation water as an input in rice production, assuming equilibrium conditions. This AFGM thus gives the total economic value of the water that is used in irrigation at the ARIS on the "per acre per growing season" basis. Since the total quantity of the water used in irrigation was estimated at 5,676 m^3, the residual value of irrigation water at the ARIS was thus estimated to be Ksh. 6.91 per m^3.

The residual value of irrigation water should give the appropriate level of the charge that the NIB should levy on rice farmers for every m^3 of the water used in irrigation in the case of the ARIS in Kenya. For the operation and maintenance (O&M) of the ARIS, the NIB charges Ksh. 3,100 per acre per season. Since the total economic value of the amount of water used in rice irrigation at the ARIS is Ksh. 39,202 per acre per season, this study indicates that the NIB water charge is about 12.65 times below the economic value of the irrigation water. This charge thus reflects a heavy level of irrigation water use subsidy by the NIB at the ARIS. This level of subsidy is inefficient and unjustifiable from economic considerations. Such a situation is likely to encourage an intensive and excessive use of irrigation water when available, thus contributing to inefficiency in the use of irrigation water. However, as the results of this study show, only about 44% of the rice farmers at the ARIS were satisfied with the current water supply system of the NIB, which is characterized by frequent system breakdowns [22].

To improve efficiency in the use of irrigation water and also enhance the sustainability of the irrigation scheme, the NIB should charge a price for the use of irrigation water that is reasonable in relation to the economic value of that water. However, for the rice farmers at the ARIS to agree to pay more for irrigation water than the current NIB water charge of Ksh. 3,100 per acre per season, the NIB would have to put a mechanism in place to ensure that the supply of water for rice irrigation is reliable and adequate in volume throughout the rice growing season.

Since the economic value of irrigation water is determined by the level of profits in agricultural production, technologies that improve yields, such as improved rice varieties in the case of the ARIS, should also be introduced and promoted.

Note:--for currency comparisons, the Average Foreign Exchange Rate in the year 2012 was US $1 = Ksh 84.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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