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ECONOMIC VALUATION OF SURFACE IRRIGATION WATER: SHIRE VALLEY, SOUTHERN MALAWI

Esau BANISI[*1], Julius MANGISONI[2], Davies NG'ONG'OLA[2], Sika GB'EGB'EL'EGB'E[3], Kennedy MACHILA[2]

[1]Department of Irrigation, Lilongwe, Malawi
[2]Department of Agriculture and Applied Economics, Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
[3]International Institute for Tropical Agriculture, Lilongwe, Malawi
*Corresponding author: esbanisi@yahoo.com

ABSTRACT

Economic valuation of surface irrigation water and the factors that determine willingness to pay for such resource for sustainable purposes is not clearly defined in Malawi. This paper evaluated economic value of surface water used in irrigation and identified factors influencing farmers' decision to participate in water markets for rice and sugarcane production in Upper Shire Valley of Southern Malawi. A cross-sectional data from 310 households involved in irrigation activities was used. General Algebraic Modelling System (GAMS) was employed to determine the economic value of surface water. Craggit Double Hurdle Model and Range-WTP procedure was employed to determine factors influencing farmers' decision to participate and pay for surface water solicit the social value of the surface water. The results revealed an economic value of 480.77 Malawi Kwacha[1] (MK)/m^3 for surface water in the valley, but specifically pointed out that surface water value for rice and sugarcane production was MK 512.96/m^3 and MK 448.58/m^3 respectively. Households irrigating rice and sugarcane revealed a willingness to pay for water at MK 1.67/m^3 and MK 2.87/m^3 respectively. Farming as a livelihood, plot status, crop type and market prices are reported to be influencing household participation in the water market. The study recommends that: (i) Farmers must always be informed of the economic value of irrigation water and be prepared to pay for it; and (ii) The allocated land should have a well-defined period of access and crop types to be grown in the valley should be of high economic value.

Key Words: *Economic valuation, Craggit Double Hurdle Model, Irrigation water, Sugarcane, Rice.*

[1] 1US$=MK720.12 www.exchange-rates.org. Accessed on 17th April, 2019

INTRODUCTION

Water is increasingly becoming scarce all over the world (UN-WAP, 2017) while its demand is continuously increasing due to the expanding population and rising prosperity, changes in diet (Syaukati *et al.*, 2014) and climate change (Samarawickrema and Kulshreshtha, 2009). Due to its unique characteristics, water is very important natural resource in agriculture for prosperity and wealth creation (Kiprop *et al.*, 2015; Karthikeyan, 2010). FAO (2003) estimated that more than 70 percent of water withdrawn from rivers is used for irrigated agriculture and increases beyond 80 percent in Sub Saharan countries (Angola, Ghana, Lesotho, Malawi, South Africa, Zimbabwe, Botswana, Zambia).

The rising population (NSO, 2018) and the huge investment in new irrigation development of 42,500 hectares supported by the World Bank (GoM, 2017) in the Upper Shire Valley mean that available water resources have to be managed properly. The current water management challenges in the Upper Shire Valley is attributed to several management (water pricing, distribution), natural (water availability, drought; flooding) and socio economic (poor access to water, inappropriate water pricing strategies, poor infrastructure management constraints (FAO, 2003). Hence, it is vital that optimal and sustainable forms of water use be established to meet the requirements of a growing population. By finding the economic value of surface irrigation water, we attempt to provide necessary guidance to stakeholders involved in irrigated agriculture by promoting water resource management and reduce water-related conflicts.

Description of the Upper Shire Valley Basin

The Upper Shire Valley is located in the Southern part of Malawi. It boasts of large commercial agriculture (sugar and rice) areas supporting more than half a million people (GoM, 2017). The valley often experiences warm-wet season which stretches from November to April, during which 95% of the annual precipitation takes place. Annual average rainfall varies from 725mm to 2,500mm. A cool, dry winter season is obvious from May to August with temperatures varying between 17 - 27°C. In addition, frostiness may occur in isolated areas in June and July. A hot, dry season lasts from September to October with average temperatures varying between 25 and 37 degrees Celsius. Humidity ranges from 50% to 87% for the drier months of September/October and wetter months of January/February, respectively (GoM, 2017).

The study was carried out in Nkhate Rice Irrigation Scheme, located in the Eastern Bank of the Shire River and Phata Sugarcane Scheme, located in the western bank of Shire River within the Valley. The sampled irrigation schemes have a total population of 2,117farmers (GoM, 2017). Nkhate Irrigation Scheme grows rice in its entire 300 hectares and has a population of 1,365 farmers. Phata Sugarcane Scheme grows sugarcane in its entire 250 hectares with a population of 752 farmers.

MATERIALS AND METHODS

Since economic activities are intended to maximize income subject to constraints of any given technology, households engaged in irrigated agriculture are faced with challenges of optimizing the available surface water to maximize profits. Data from 310 randomly selected farmers from two irrigation schemes is used in this study. Specific assumptions are made in various fields of study including economics so as to deduce sets of rules that must be followed to obtain certain results. As yield under irrigated agriculture is a function of irrigation at a time, other additional factors are crucial for production to take place and can be expressed as:

$$Y\,(I) = f(land, water, labor, seed, fertilizer, chemicals, implements, capital)$$

All factors that enter the production function are not known and may not be finite in number. When one specifies output as a function of $x_{1,}$ through x_n, one explicitly assumes factors $x_{n+1,}$to x_p are held constant if it is known that *p* factors affect production. Based on this logic and following Leemans and Born (1994), a *ceteris paribus* scenario is adopted in the study. The crop production function is then employed and takes a transcendental form of:

$$Y(I_t) = \propto I^{\beta} e^{-\gamma I}$$

where $\mathrm{Y}(I_t)$ is yield which is a function of irrigation at time *t*, and *I* is the amount of irrigation water applied, while α, β, γ are constants and *e* is the exponential value. Following Hamsen (2000), water stock function is presented as:

$$R(S_t) = f\left(1 - e^{-g(K-S_t)}\right)$$

where: $R(S_t)$ is the stock flows in the river at time *t* which is an input for crop production. The right hand side is the amount of water present at that particular time *t*, implying that the more the water, the higher the yield and profit. Aggregating the crop production function and aquifer recharge function, gives a maximization problem presented as:

$$J(S_o) = \max_{I_t} \sum_{t=0}^{\infty} (\tfrac{1}{1+r})^t \left[p_y \alpha I^{\beta} e^{-\gamma I} - p_e \left(\frac{I_t}{c S_t^b} \right)^a \right]$$

subject to:

$$S_0 = \bar{S}$$

$$S_{t+1} - S_t = f\left(1 - e^{-g(K-S_t)}\right) - I_t\,;$$

$$t = 0, \dots\dots, \infty$$

Where, *J* measures the optimal value of the initial stock of water (S_o) in m^3. The right-hand side maximizes the net sum of discounted social net benefits from the total revenue realized from irrigation yield discounted at time *t*. The social discount rate is given as $\left(\frac{1}{1+r}\right)^t$. Applying the maximum principle, solution is obtained by maximizing the Hamiltonian *H*, as follows:

$$H_t = (\frac{1}{1+r})^t \left[p_y \alpha I^{\beta} e^{-\gamma I} - p_e \left(\frac{I_t}{cS_t^b}\right)^a\right] + \lambda_{t+1}\left[f\left(1 - e^{-g(K-S_t)}\right) - I_t\right]$$

We further develop procedures to derive Willingness to Pay (WTP) which are essential for developing an optimal water pricing strategy (Balderjahn, 2003). A single household is considered in this study, and in order to improve utility of an environmental good, this household will adopt this equation:

$$Max_k\, U = U(k, w) \quad s.t \;\; I = p_k k + p_w w$$

where *U (.)* is the utility function, *k* is the composite of all market goods and *w* is the public good quantity. p_k and p_w are the prices of a market good and the public good (water), respectively, and *I* is the household income. Thus, with the demand functions derived from the utility maximization process, we can form the indirect utility function ($V(p_k, p_w, I)$ that matches with the utility function ($U(k, w)$ as:

$$V(p_k, p_w, I) = U[(d^x(p_k, p_w, I), d^w(p_k, p_w, I)]$$

It can be said that improved surface water flow to individual household plots is when field plots receive enough uninterrupted flow of good quality but at a minimum price. Therefore, a quantifiable quality or quantity *q*, will change from the current status quo (*q0*) to a new status (*q1*), where *q0< q1*. Subsequently, the households' utility function is expected to change from $U_0 \equiv v(p_k, p_w, I, q_0)$ to $U_1 \equiv v(p_k, p_w, I, q_1)$. Thus, to measure the change in utility in monetary terms, the Hicksian measure of Consumer Surplus Utility (CSU) is used:

$$V(p_k, p_w, I, q_0) = V(p_k, p_w, I - CSU, q_1)$$

A further change from quantity q_0 to q_1 raises the utility levels of a household regarded as improvement of water services. To make the household indifferent between the two utility levels, CSU need to be positive and in this case measures the households WTP presented as:

$$V(p_k, p_w, I, q_0) = V(p_k, p_w, I - WTP, q_1)$$

We then followed Syaukat, (2014) by modifying Hanley and Splash, (1993) formulation of the WTP procedure in order to solicit values farmers are willing to pay as follows:

i. Setting up a hypothetical market for irrigation water.
ii. Obtained open WTP values from each household, of which Range WTP was categorised into five parts (MK1,000-1,500; 1,500-2,500; 2,500-5,000; 5,000-10,000; 10,000-25,000)
iii. Estimate mean WTP,
iv. Derive total value of the WTP

We finally applied Craggit Double Hurdle Model to establish factors that influence farmers' participation in the water market follow the selectivity models (Zamasiya *et al*., 2014; Geoffrey *et al*., 2013). In selectivity models, the decision to participate is a sequential two-stage decision making process. In the first stage, farmers' make a discrete choice whether to participate in the payment of surface water fees. In the second stage, conditional on their decision to participate, households make continuous decisions on the extent of participation. Following Wooldridge (2002), a standard probit model which follows random utility model was based on and households' willingness to participate in the water market is then specified as:

$$WTP = \beta_0 + \beta_1 age + \beta_2 sex + \beta_3 education + \beta_4 livelihood + \beta_5 plotstatus + \beta_6\ plotstatus + \beta_7\ croptype + \beta_8\ marketprice + \epsilon_i$$

WTP is the probability that an *i*th household involved in irrigation is willing to participate in the water market; β_i is the coefficients of the explanatory variables; ϵ_i is the error term. The second hurdle which estimates the amount (fees) households are willing to pay is estimated using a regression truncated at zero, expressed as:

$$How\_much_i = How\_much_i^*\ if\ How\_much_i^* > 0, and\ How\_much_i^* = 0\ if\ otherwise$$

$$How\_much^* = \alpha_i'\beta + \mu_i$$

Where: How_much^* is the observed response on how much households are willing to pay for water fees; α is the vector of household, irrigation plot and institutional characteristics, β is a vector of parameters and μ_i is the error term which is randomly distributed.

RESULTS AND DISCUSSION

Results in Table 1 indicate that the economic value of surface water in the Upper Shire Valley is MK 480.77 per cubic meter. The results further reveal that the economic value of irrigation water in Nkhate Rice Scheme was MK 512.96 per cubic meter and MK 448.58 per cubic meter in Phata Sugarcane Scheme. This indicates that water is more valuable to produce rice than sugarcane in the valley. It also implies that for households to achieve optimal yields, they should manage properly water resources against other inputs unlike in sugarcane.

Table 1. Economic value of irrigation water

Irrigation Scheme	Economic value of irrigation water in a season [MK/ m^3]
Nkhate Rice Scheme	512.96
Phata Sugarcane Scheme	448.58
Overall water value	480.77

The test results revealed a *p*-value of 0.0143 implying that there is an economic value on irrigation water in the Upper Shire Valley. It therefore means that irrigation water in Nkhate Rice Scheme and Phata Sugarcane Scheme should be treated as an economic good which is supposed to be considered in coming up with economic efficient decisions. The findings are supported by similar studies conducted in the Southern Africa Region. Nieuwoudt *et al.* (2014), analyzed the value of water in the agriculture sector of the South African economy and observed that the economic value of irrigation water ranges from US\$ 0.6/m^3 to US\$2.10/m^3. The results in Table 2 show that 36 percent of the households had an expected mean WTP value of MK 316.11 in each season. The results further show that 23 percent had an expected WTP value of MK 341.67. This implies that more than half of the sampled households are willing to pay within the ranges of MK 316.11 and MK 341.67. Therefore, based on the sampled households, the average WTP was MK2, 355.56. According to FAO, (2003) irrigated lowland rice requires 16,500 cubic meters of water per hectare during a full season. Since Nkhate households are allocated an average of 0.1 hectare of land, it implies that each household was ready to pay an average of MK 1.67 per cubic meter of water. This is however, too low as compared to derived economic water value of MK 480.77/m^3 .

Table 2. WTP for water in Nkhate Rice Scheme in a season

WTP Category	Range (MK/season)	Response Percentage	Expected Mean WTP (MK/season)
1	1000-1500	36.1	361.11
2	1500-2500	22.7	341.67
3	2500-5000	21.6	541.67
4	5000-10000	16.6	833.33
5	10000-25000	2.7	277.78
Average WTP Value			2,355.56

According to Holden and McGuire (2010), irrigated sugarcane crop under sprinkler application requires a total of 1,000 cubic meters of water per hectare in a growing season. Since households are allocated an average of 0.5 hectare of land, it implies that households are willing to pay MK 2.87 per cubic meter of surface water. This willingness to participate and contribute differently in the water market was found to be influenced by livelihood main sources, plot status, crop type and market prices of crops produced by farmers

CONCLUSION

The study concludes that surface water for irrigation purposes in the Upper Shire Valley, Southern Malawi has mean economic value of MK 480.77/m^3. It therefore means that irrigation water in Nkhate Rice Scheme and Phata Sugarcane Scheme should be treated as an economic good which is supposed to be an input in all management decisions and plans. The smaller value of money farmers are willing to pay for water in the valley are too much below the established economic value as such sustainability of water management cannot stand. Unfortunately, water resources authorities allow farmers to abstract water even without settling their annual water fees. Since the study revealed that main livelihood as source of a household income, plot status and crop type are paramount in deciding participation and payment of water fees by farmers, priority in land allocation and crop types should be supported. The allocated land should have a well-defined period of access and crop types to be grown in the valley should be of high economic value.

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