Estimation of Irrigation Water Demand in Rice Production Tanzania

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Abstract

The agriculture sector is one of the major users of water resource for irrigation activities. In Tanzania irrigation water demand for rice is still increasing due to the area being irrigated continues to expand while the amount of water for irrigation is decreasing. The purpose of this paper was to develop the demand function for estimation of irrigation water in rice production in Tanzania. The secondary data were collected from various sources such as the Ministry of Agriculture, Food Security and Cooperatives at Statistics Unit, and relevant basin authorities and zonal irrigation units. A demand function was estimated after carrying out the relevant statistical tests. The Breush and Pagan Lagrangian Multiplier Test were used to select whether to use the Pool or Panel Data approaches. The Panel model was verified to be more suitable than the Pool model. The fixed effect and random effect were compared in the Hausman's specification test. The price elasticity of irrigation water demand and other elasticity were also estimated using Ordinary Least Squares facilitated by STATA 11. A panel data of 16 regions of Tanzania in the period of 2007 - 2012 were used. The estimated average water demand found to be 8000m^3/ha whereas water productivity in rice cultivation found to be 0.3kg/m^3.

Keywords: Water demand function, Water productivity, Panel data, Rice, Irrigation water

1. Introduction

Tanzania is among of the countries in southern part of Sahara desert, its total area is about 945 090 km^2 and its population of people is about 44 928 923. The country is bordered in the north by Kenya and Uganda, in the east by the Indian Ocean, in the south by Mozambique and in the west by Rwanda, Burundi, the Democratic Republic of the Congo and Zambia. The Indian Ocean coast is some 1 300 km long, while in the northwest there are 1 420 km of shoreline on Lake Victoria, in the centre-west there are 650 km of shoreline on Lake Tanganyika and, in the southwest, 305 km of shoreline on Lake Nyasa. Land cover is dominated by woodland, grassland and bush-land which account for about 80 percent of the total land area. Cultivable area is estimated to be 40 million ha, or 42 percent of the total land area. (FAO, 2014)

Tanzania's economy continues to be dominated by agricultural production, which accounts more than 50% of GDP. Output remains predominantly based on smallholder production. The agricultural sector continues to lead economic growth as it provides work for 14.7 million people, or 79% of the total economically active population. The main food crops grown are maize, sorghum, millet, rice, wheat, sweet potato, cassava, pulses and bananas. Maize is the dominant crop with a planted area of over 1.5 million hectors during recent years, followed by rice with more than 0.5 million hectors over recent years. (FAO, 2014)

1.1 Background of the problem

Irrigation water demand is still increasing due to the area being irrigated continues to expand while the amount of water for irrigation is decreasing. Globally, 70 percent of freshwater diverted for human purposes goes to agriculture. In the developing countries, irrigation uses almost 85% of available water (Rosegrant, 2000). It is known that, one of the main principles of capital aspect almost in every country, is water resource. Thus water resource has major role in any economy of a particular country (Sadeghi et al, 2012).

Tanzania is an agricultural country and its economy mostly depends on agricultural sector. Therefore Agriculture plays an important role in the Tanzanian economy and rice is among of crops which are primarily staple food as well as essential cash crops for farmers in Tanzania. A great amount of irrigation water is used in the production of rice as the staple food which feed about half of the world population.

Since the agricultural sector is the back bone to development in Tanzania, and a major factor in poverty reduction, there is a need of developing a mathematical model that estimates the demand for irrigation water for rice production.

2. Literature review

Water demand is an economic concept, which assumes that the quantity of water used is a function of its price and other economic variables such as income. Price and income are the key factors on demand concept. Price influence the quantity of water the consumer is willing to pay and income determine the farmer's ability to pay for water. (Dziegielewski et al, 2002)

The production function that relates crop production to the use of water and other inputs is very crucial element for the estimation of the demand for and value of water in the agriculture sector. Production functions describe the connectivity between the use of water and crop output. Estimation of the demand for water and the resultant value of that water in production require also depend on irrigation technologies, water application level, cropping pattern and input and output prices (McKinney et al, 1999).

Estimates of the demand function for irrigation water and its price elasticity have commonly been based on the use of mathematical programming, especially linear programming (Saima et al, 2002). A mathematical programming framework involves the optimization of an objective function, subject to the underlying production technology and constraints on water and other resources.

The linear programming approach has the advantage in such a way that, it can be implemented with a minimum of data and problems can be reasonable approximated to the reality. Azamathulla et al, (2009) provide a good example of a linear programming model applied to real time reservoir operation in an existing Chiller reservoir system in Madhya Pradesh, India. The model ensures an optimum reservoir release over different time periods. In addition, they also ensure optimum allocation of the available water over the different crops in the fields.

Several studies have been done on agricultural production using the production function model. The Cobb-Douglas functions are among the best known production functions utilized in applied production analysis.

Sahibzada (2002) used Cobb-Douglas production function to estimate the relationship between total aggregated farm output, fertilizer use, labor supply, tractor use, and irrigation water input. He revealed that irrigation water demand is price inelastic.

Sadeghi (2010) in his study of the impact of pricing policy on the demand for water in

Iran agricultural sector, again used the Cobb-Douglas production function to estimate the relationship between total aggregated output, fertilizer, labour, tractor and machinery services, animal fertilizer, irrigated area, seed, pesticide, consumed (demanded) water, and input prices, in different crops. The crops involved in his study were wheat, barley, lentil, pea, onion, pinto bean, tomato, potato, cucumber, watermelon, cotton and sugar beet. The estimated coefficients for output were positive and significant for all crops. These coefficients, in logarithmic functions, indicate the elasticity of water usage given a change in the quantity of output. This means, farmers tend to use more water when the demand for crops is higher.

Sadeghi et al, (2012) in a study of estimation of water demand function for watermelon in Iran, he revealed that, the estimated coefficient for quantity of output is positive and the estimated parameter coefficient suggests the elasticity of water use, with respect to the quantity of output is positive, which indicates that the increase in the watermelon will result in increase in the use of water. Thus this shows that, the amount of crops has a strong effect on the usage of water.

Saima et al, (2002) conducted a study on linear program modeling for determining the value of irrigation water. They found that the net return from each farm was decreasing with decreasing water supply levels.

Many studies of irrigation water demand rely on simulated data. Bontemps and Couture (2002) use a dynamic framework to estimate irrigation water demand in southwestern France. They simulate water demand data and analyze demand for a single crop. Their study revealed that water demand is inelastic in arid regions, and as the quantity of water increases, water demand becomes more elastic.

Results of a simulation by Hooker and Alexander (1998) find that demand is inelastic across a large range of prices, but becomes elastic beyond some threshold level. Their analysis uses parameter estimates based on water use in the San Joaquin Valley. On the other side they found that the quantity of crops significantly influences water consumption.

Naveen et al, (2011) applied a multi-output production model developed by Moore and Negri (1992) in their study on estimation of irrigation water demand, a case study for the Texas High Plains. The model used to demonstrate the optimal allocation of fixed inputs in multi-output production. The results revealed that, water demand in the region is more sensitive to water price than to crop price.

Values of elasticity of demand are normally negative, as demand falls when price increases. Higher absolute values of elasticity point out that the percentage change in amount demanded is large compared with the percentage change in price. Price elasticity estimates from a study in OECD countries vary greatly, from -17.7 to -0.05 (Cornish, 2004). Elasticity depends on various factors, among them are; Initial price of water, the lower the price, the less responsive farmers are to price increases. Another factor is production costs, the high production costs lead to low elasticity.

Water demand is inelastic only up to a given price level. Above this price level, water demand may be very price responsive. The level of this price depends on the economic productivity of water, price of water compared to overall production costs and the irrigation technologies in place (Cornish, 2004).

3. Materials and Methods

The secondary data were collected from various sources such Ministry of Agriculture, Food Security and Cooperatives-Statistics Unit, and relevant institutions such as Pangani, Rufiji and Ruaha basin authorities. Also some of information was obtained from zonal irrigation units and published documents.

A panel data of 16 regions of Tanzania in the period from 2007 to 2012 corresponding to a total number of 96 observations were used. The variables for estimation of water demand function were the input prices which are seed, water, wage, machinery rent cost, land rent cost, fertilizer cost and rice production and for dependent variable, quantities of water required for rice was used.

Regression analysis technique was used to estimate the values of parameters of the models, and Ordinary Least Squares was applied. The parameters of demand functions were estimated using the econometric method on panel data, where EXCEL and STATA 11 were accommodated in the study.

3.1 Model development

3.1.1 Economic model

The economic model normally used to determine the relationship between the various inputs and output in agriculture is the production function model. In agriculture, the production inputs consist of land, labor and capital are the basic factors of production (Mpawenimana, 2005).

The simplified form of production function of those inputs is given by:

$$Q = f(LN, K, L)$$

Where Q is the production output, which is function of land (LN); the capital (K) and the labor force (L) used for the production of the same output. A production function may be defined as a mathematical equation showing the maximum amount of output that can be realized from a given set of inputs.

In the estimation of irrigation water demand, different approaches have been suggested and adopted. In the current study, direct method approach was adopted to estimate the irrigation water demand function associated with rice product.

The optimal demand for each of several inputs as a function of the price inputs and expected output, can obtained using conditional factor demand function. Conditional demand functions are obtained using the Shepard's Lemma where the cost minimization problem is the production of a specified level of output with the least expenditure on inputs (Arrigada, 2004; Sadeghi, 2010).

The recent study utilized the Cobb-Douglas production function model which is used widely in theoretical and applied research. Cobb-Douglas production function explains the relationship of input and output. The Cobb-Douglas production function was used with the reason that, the solution could easily transferred into linear and resulting to regression coefficient which is the elasticity quantity. Also the Cobb-Douglas production function provides a simpler model structure, is easier to estimate, and is less likely to violate the classical regression assumptions. It may be particularly useful in cases where the analyst must work with limited data.

(Michael, 2006)

The design of a Cobb-Douglas production function model includes few steps. First, the general model structure should be determined, input and output parameters as well as their mutual relationships should be established. Then, parameter values should be determined by first linearizing the models through logarithmic transformation and then applying the method of least squares to the linearized parameters.

The mathematical general form of the Cobb-Douglas production functions is given by;

$$Q = A\prod_{i=1}^{n} X_i^{\beta_i}$$

Where Q and X_i denote output and each bundle of inputs respectively. A and β_i are Parameters.

Thus if k and l are respectively, capital and labour force of the firm, then one can write the Cobb Douglas production function in a simple manner as;

$$Q = k^{\alpha} l^{\beta} \quad \text{(1)}$$

Where α and β are still the parameters. Therefore, the total costs can be written as;

$$Tc = \gamma l + \eta k \quad \text{(2)}$$

Where, γ and η are the parameters associated with labour and capital respectively.

Then from the two equations above, (1) and (2), the minimization problem can be formulated as follows;

$$minimize \quad \gamma l + \eta k$$
$$subject\ to \quad Q = k^{\alpha} l^{\beta}$$

By introducing the concept of Lagrangian, then the Lagrangian expression for cost minimization of producing Q_0 can be written as;

$$L(k, l, \mu) = \eta k + \gamma l + \mu(Q_0 - k^{\alpha} l^{\beta}) \quad \text{(3)}$$

By equating to zero the partial derivatives of the Lagrangian expression, then it satisfies the first order conditions for the cost minimization, thus;

$$\frac{\partial L}{\partial k} = \eta - \alpha\, \mu k^{\alpha-1} l^{\beta} = 0 \quad \text{(4)}$$

$$\frac{\partial L}{\partial l} = \gamma - \beta \mu k^{\alpha} l^{\beta-1} = 0 \quad \text{(5)}$$

$$\frac{\partial L}{\partial \mu} = Q_0 - k^{\alpha} l^{\beta} = 0 \quad \text{(6)}$$

From here, the rate of technical substitution should be determined. The rate of technical substitution measures the rate at which one input can be substituted for another while holding output constant.

$$RTS_{ij}(x) = \frac{\partial f(x)/\partial x_i}{\partial f(x)/\partial x_j}$$

For instance, a firm that produces a single commodity in the quantity $L(k)$ with two inputs, k and l, where k and l are factors of production that comprise factor combination k.Therefore;

$$RTS_{k,l}(k, l, \mu) = \frac{\partial L(k,l,\mu)/\partial k}{\partial L(k,l,\mu)/\partial l}$$

Thus by dividing equation (5) by equation (4) gives

$$\frac{\gamma}{\eta} = \frac{\beta k^{\alpha} l^{\beta-1}}{\alpha\, k^{\alpha-1} l^{\beta}}$$

$$\frac{\gamma}{\eta} = \frac{\beta}{\alpha} \cdot \frac{k}{l}$$ which is the rate of technical substitution, RTS.

By solving for k , gives;

$$k = \frac{\alpha}{\beta}\ \frac{\gamma}{\eta}.l \quad \ldots\ldots\ldots \quad (7)$$

By substituting equation (7) into the production function gives

$$Q = \left(\frac{\alpha}{\beta}\frac{\gamma}{\eta}l\right)^{\alpha} l^{\beta} \Rightarrow Q = \left(\frac{\alpha}{\beta}\frac{\gamma}{\eta}\right)^{\alpha} l^{\alpha+\beta} \quad \ldots\ldots\ldots \quad (8)$$

From equation (8), solving for l gives;

$l = Q^{\frac{1}{\alpha+\beta}}\left(\frac{\alpha}{\beta}\ \frac{\gamma}{\eta}\right)^{\frac{-\alpha}{\alpha+\beta}}$ which can be simplified as;

$$l = Q^{\frac{1}{\alpha+\beta}}\left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(\frac{-\alpha}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)} \quad \ldots\ldots\ldots \quad (9)$$

The same procedure will be for k, thus;

$$k = Q^{\frac{1}{\alpha+\beta}}\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{-\beta}{\alpha+\beta}\right)} \quad \ldots\ldots\ldots \quad (10)$$

Thus from equation (2) then the total cost can be written as;

$$C(\eta,\gamma,Q) = \eta\left[Q^{\frac{1}{\alpha+\beta}}\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{-\beta}{\alpha+\beta}\right)}\right] + \gamma\left[Q^{\frac{1}{\alpha+\beta}}\left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(\frac{-\alpha}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\right] \quad \ldots\ldots\ldots \quad (11)$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\left[\eta\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{-\beta}{\alpha+\beta}\right)} + \gamma\left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(\frac{-\alpha}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\right]$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\left[\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\right]$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\left[\left(\frac{\alpha}{\beta}\right)^{\frac{\beta}{\alpha+\beta}} + \left(\frac{\beta}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta}}\right]$$

$$C(\eta,\gamma,Q) = Q^{\frac{1}{\alpha+\beta}}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}J\,\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)} \quad \ldots\ldots\ldots \quad (12)$$

Where $J = \left(\frac{\alpha}{\beta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)} + \left(\frac{\beta}{\alpha}\right)^{\left(\frac{\alpha}{\alpha+\beta}\right)} \Rightarrow J = (\alpha+\beta)\alpha^{\left(\frac{-\alpha}{\alpha+\beta}\right)}\beta^{\left(\frac{-\beta}{\alpha+\beta}\right)}$ which is a constant that involves only the parameters α and β

Economists studying the behavior of a firm find it is easier to estimate its cost function than its production function. Thus Contingent demand functions for all inputs can be derived from the cost function. Shephard's lemma is particularly useful in deriving the production function which corresponds to a given cost function. Thus, with the help of Shephard's lemma, the contingent demand function for any input is given by the partial derivative of the total-cost function with respect to that input's price. The contingent demands for inputs depend on both inputs' prices.

The cost function is given as;

$$C(\eta,\gamma,Q) = \eta k + \lambda l = Q^{\left(\frac{1}{\alpha+\beta}\right)}J\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)}$$

The partial derivatives of the cost function are;

$l^{c}(\eta,\gamma,Q) = \frac{\partial c}{\partial\gamma} = \frac{\beta}{\alpha+\beta}.Q^{\left(\frac{1}{\alpha+\beta}\right)}J\eta^{\left(\frac{\alpha}{\alpha+\beta}\right)}\gamma^{\left(\frac{-\alpha}{\alpha+\beta}\right)} \Rightarrow \frac{\partial c}{\partial\gamma} = \frac{\beta}{\alpha+\beta}.Q^{\left(\frac{1}{\alpha+\beta}\right)}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{-\alpha}{\alpha+\beta}\right)}$ and

$$k^c(\eta,\gamma,Q) = \frac{\partial c}{\partial \eta} = \frac{\alpha}{\alpha+\beta}.Q^{\left(\frac{1}{\alpha+\beta}\right)}J\eta^{\left(\frac{-\beta}{\alpha+\beta}\right)}\gamma^{\left(\frac{\beta}{\alpha+\beta}\right)} \implies \frac{\partial c}{\partial \eta} = \frac{\alpha}{\alpha+\beta}.Q^{\left(\frac{1}{\alpha+\beta}\right)}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)}$$

From the partial derivatives, by applying natural logarithm on both sides, gives;

$$\ln \mathrm{l}(\eta,\gamma,\mathrm{Q}) = \ln\left[\frac{\beta}{\alpha+\beta}.Q^{\left(\frac{1}{\alpha+\beta}\right)}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{-\alpha}{\alpha+\beta}\right)}\right] \quad (13)$$

$$\ln \mathrm{k}(\eta,\gamma,\mathrm{Q}) = \ln\left[\frac{\alpha}{\alpha+\beta}.Q^{\left(\frac{1}{\alpha+\beta}\right)}J\left(\frac{\gamma}{\eta}\right)^{\left(\frac{\beta}{\alpha+\beta}\right)}\right] \quad (14)$$

Then equation (13) and (14) by applying logarithm principles, becomes;

$$\ln \mathrm{l}(\eta,\gamma,\mathrm{Q}) = \ln\frac{\beta}{\alpha+\beta} + \frac{1}{\alpha+\beta}\ln Q + \ln J - \frac{\alpha}{\alpha+\beta}\ln\gamma + \frac{\alpha}{\alpha+\beta}\ln\eta \quad (15)$$

$$\ln \mathrm{k}(\eta,\gamma,\mathrm{Q}) = \ln\frac{\alpha}{\alpha+\beta} + \frac{1}{\alpha+\beta}\ln Q + \ln J + \frac{\beta}{\alpha+\beta}\ln\gamma - \frac{\beta}{\alpha+\beta}\ln\eta \quad (16)$$

From equation (15) and (16) then it can be generalized as;

$$\ln \mathrm{l}(\eta,\gamma,\mathrm{Q}) = \ln \mathrm{A} + \mathrm{a}\ln \mathrm{Q} - b\ln\gamma + c\ln\eta \quad (17)$$

Thus the Cobb-Douglas production function is linear in logarithms

Where a indicates the elasticity of water use given changes in output quantity, b is water price elasticity and c is cross – price elasticity of water demand (Sadeghi, 2010)

3.1.2 Empirical model

The water demand was specified directly using a water demand function that includes water consumed (demanded), output quantity and input prices. The supposition here was, under cost minimization, the water demand function is a function in terms of output quantity and the prices of the six inputs namely, water price, fertilizer price, land rent cost, seed price, wage cost and machinery rental cost. In mathematical form the water demand function is:

$Dw = f(Wp, F, L, S, w, Q, M)$ .Where Dw is amount of water demanded, Wp is price of water, F is price of fertilizer, L is land rent, S is price of seeds, w is wage cost, Q is output quantity and M is machinery cost.

The following was the suggested production function in linear logarithms from the C-D production function as developed in the previous section which was simulated.

$$\ln Dw_{i,t} = \beta_0 + \beta_1 \ln Wp_{i,t} + \beta_2 \ln F_{i,t} + \beta_3 \ln L_{i,t} + \beta_4 \ln S_{i,t} + \beta_5 \ln w_{i,t} + \beta_6 \ln Q_{i,t} + \beta_7 \ln M_{i,t} + \varepsilon_{i,t}$$

Table 1: Variables and Parameters of the model description

Variables and Parameters description in i[th] region in year t			
s/n	Variable	Description	Unit
1	$Dw_{i,t}$	Amount of water demanded	m^3
2	$Wp_{i,t}$	Vector of the water price used in rice production	$Tshs/m^3$
3	$F_{i,t}$	Vector of fertilizer prices used in rice production	$Tshs/kg$
4	$L_{i,t}$	Land rental cost	$Tshs/m^2$
5	$S_{i,t}$	Vector of seed prices used in rice production	$Tshs/kg$
6	$w_{i,t}$	Wage cost	$Tshs/ha$
7	$Q_{i,t}$	Irrigated production	kg
8	$M_{i,t}$	Vector of machinery rental cost	$Tshs/m^2$
9	$\varepsilon_{i,t}$	Represents the effects of the omitted variables that are peculiar to both the individual region and time periods.	
	Parameters	Description	
1	β_0	The total factor efficiency parameter for composite primary factor inputs in region *i*	
2	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, and\ \beta_7,$	Production elasticity.	

The equation is log-linear because both the dependent variable and the independent variables have been log-transformed. The coefficients in log-linear equations are elasticity.

4. Results and Discussion

4.1 Descriptive statistics of 2012 and 2007 to 2012

Table 2: Statistical Analysis of the Study Variables 2012

Descriptive statistics 2012					
Variable	**Obs**	**Mean**	**Std dev**	**Min**	**Max**
Water demand (m^3)	16	3.70e+08	2.89e+08	1.96e+7	8.56e+08
Water cost(Tshs/ha)	16	46 875	11 529	30 000	60 000
Water price (Tshs/m^3)	16	5.9	1.4	3.8	7.5
Wage cost(Tshs/ha)	16	325 313	25 329	280 000	380 000
Fertilizer (Tshs/ha)	16	250 625	10 626	240 000	270 000
Seed cost(Tshs/ha)	16	75 625	9 689	55 000	87500
Machinery cost(Tshs/ha)	16	183 125	34 587	120 000	250 000
Land cost(Tshs/ha)	16	373 250	76 896	180 000	462 000
Production (ton)	16	107 580	98 068	3 777	312 596
Area (ha)	16	46 244	36 129	2 455	106 941
Ton/ha	16	2.1	0.5	1.2	3.1
Water productivity	16	0.3	0.1	0.2	0.4
Sells/100kg bag	16	151 250	19 379	110 000	175 000
Amount received (Tshs/ha)	16	3 147 694	947 897	1 846 161	5 261 544
Total cost(Tshs/ha)	16	1 254 813	121 789	993 000	1 477 500
Profit(Tshs/ha)	16	1 892 882	906 795	661 161	3 784 044

Table 3: Statistical Analysis of the Study Variables 2007 to 2012

Descriptive statistics 2007-2012					
Variable	**Obs**	**Mean**	**Std dev**	**Min**	**Max**
Water demand (m^3)	96	4.09e+08	4.46e+08	7 093 958	2.37e+09
Water cost(Tshs/ha)	96	43 958	14 453	20 000	70 000
Water price (Tshs/m^3)	96	5.5	1.8	2.5	8.75
Wage cost(Tshs/ha)	96	298 510	33 428	220 000	380 000
Fertilizer (Tshs/ha)	96	293 276	50 408	200 000	360 000
Seed cost(Tshs/ha)	96	37 036	18 480	20 000	87 500
Machinery cost(Tshs/ha)	96	143 177	40 705	85 000	250 000
Land cost(Tshs/ha)	96	255 541	94 857	140 000	46 200
Production (ton)	96	106 012	103 666	508	469 242
Area (ha)	96	51 160	55 789	887	296 576
Ton/ha	96	2.5	2.1	0.49	14.96
Water productivity	96	0.31	0.26	0.06	1.87
Amount received (Tshs/ha)	96	1 771 420	1 367 133	265 136	9 198 270
Total cost(Tshs/ha)	96	1 071 500	138 323	807 000	1 477 500
Profit (Tshs/ha)	96	699 920	1 313 512	-811 864	8 023 271

For the year 2012 the average water demand was estimated to be $3.70x10^8m^3$ and the area cultivated was estimated to be 46 243ha, while the water price was estimated to be 5.86Tshs/ha. The water productivity was estimated to be 0.3kg/m^3 and the production was 2.08ton/ha. The average water demanded per hector when other factors are kept constant was estimated to be 8001m^3. However the average profit received by the farmer was estimated to be 1 892 882Tshs/ha.

For the year 2007-2012, the average water demand was estimated to be $4.09x10^8m^3$ and the area cultivated was estimated to be 51 160ha, while the water price was estimated to be 5.5Tshs/ha. The water productivity was estimated to be 0.3kg/m^3 and the production was 2.5ton/ha. The average water demanded per hector when other factors are kept constant was estimated to be 7999m^3. However the average profit received by the farmer was estimated to be 699 920Tshs/ha.

Therefore, from the two analyses, it is observed that the bigger the area the huge amount of water used in rice cultivation. The average water demanded per hector when other factors are kept constant was approximated nearly to 8 000m^3. Several studies have shown that irrigated rice can be easily cultivated using 8 000 to 10 000 m^3/ha. The water productivity and the production is almost the same in the period of 2012 and 2007 to 2012, as it has shown in table 2 and table 3 above.

4.2 Regression results

The equation of water demand, as a function of the price of water, fertilizer and seed prices, wage, land rent, machinery and the output quantity, was estimated using the panel data method comprising of 96 observations from 16 rice producer regions for the period of 2007 to 2012. The Breush and Pagan Lagrangian Multiplier Test were used to select whether to use the Pool or Panel Data approaches. The Panel model was verified to be more suitable than the Pool model. The fixed effect and random effect were compared in the Hausman's specification test by using STATA 11. The comparison found that the irrigation water demand function of rice could be best derived using the random effect approach. The regression results are as follows;

4.3 Model results

Table 4: Regression results

Dependent Variable: ln DW				
Independent variable	Coefficient	Std. Error	t-Statistic	Prob.
β_0	17.21	7.91	2.18	0.032
ln w	-2.03	1.27	-1.60	0.112
Ln Wp	-0.03	0.31	-0.08	0.935
ln M	1.21	0.58	2.09	0.039
ln Q	0.60	0.08	7.80	0.000
ln L	-0.35	0.60	-0.58	0.562
ln S	-0.70	0.41	-1.71	0.090
ln F	0.16	0.76	0.21	0.833
Cross-section fixed (dummy variables)				
R-squared	0.48	Adjusted R-squared	0.45	
F-statistic	11.97	Wald Ch2(7)	83.79	
Prob(F-statistic)	0.000			
Statistically significant at the 5% level				

The natural logarithm of variables estimated using Ordinary Least squares (OLS) as specified above in the model. From the results adjusted R^2 =0.45, imply that 45% of the variation in irrigation water demand in rice is explained by the explanatory variables. In other words, 45% of the model is perfectly fit.

$$\ln Dw_{i,t} = 17.21 - 0.03 \ln Wp_{i,t} + 0.16 \ln F_{i,t} - 0.35 \ln L_{i,t} - 0.70 \ln S_{i,t} - 2.03 \ln w_{i,t} + 0.60 \ln Q_{i,t} + 1.21 \ln M_{i,t}$$

Based on research findings, the coefficient of water price is negative as it is -0.03. Implying that as water price increasing by 1%, the water demand in rice production will decrease by 0.03%. This is significant at 5% level. This confirms what Karina (2004), Clayton and Noel (1989), and Cornish (2004) said in their literature, the expected relationship between water demand and water price is that, as the higher the water price the lesser the water demanded. As it has been shown, the estimated coefficient of water price is very close to zero. This implies that the demand for water has low elasticity, thus farmers are not sensitive enough to the changes in the price of water (Sadeghi, 2012). Hence the price of water is not efficient. In addition to that, despite of low response of farmers to the price of water, again farmers tend to reduce the use of water as price becomes higher although in small amount.

The water demand from rice production is positively related to irrigated output (rice) as shown in the findings, where the coefficient is positive 0.60. This Indicates that as rice output increasing by 1%, the water demand will increase 0.60%. This is significant at 5% level. The estimated parameter coefficient shows the elasticity of water use, provided that the changes in the quantity of output is 0.60, which implies that, a 1% increase in the output quantity leads to a 0.60% change in the use of water. Thus irrigated output affects water usage intensively in Tanzania's agricultural sector as it has positive effect on water demand in rice farms.

Likewise, the regression analysis shows that the coefficient of fertilizer is positively related to water demand, as shown from the current study. The fertilizer price coefficient is 0.16, showing that as fertilizer price increasing by 1%, the water demand will increase by 0.16%. This is significant at 1% level. This indicates that farmers are somehow sensitive to the price of fertilizer because price of fertilizer is efficient as it is at least far from zero.

On the hand, the coefficient of machinery cost is positive, as it has shown from the findings it is 1.21. This implies that, as machinery cost increasing by 1%, the water demand will increase by 1.21%. This is significant at 5% level. Because the coefficient on machinery is positive, it means that, water and agricultural machines (tractors) are substitute inputs. The positive sign of the above coefficient indicates that a full usage of machines in cultivation of rice is not possible in all regions of the country, and thus, most of the activities associated with cultivation and harvesting of rice are to be done by labour force (Sadeghi et al, 2010).

Direct from results, the coefficient of land rental cost is negative, which is -0.35. Implying that, as land rental cost increasing in rice production by 1%, the water demand will decrease by 0.35%. This is significant at 5% level. It indicates that as land rental costs increases, farmers will not be able to hire big portion of land for rice cultivation, as a result of decreasing the water usage.

However, water demand for rice production is negatively related to seed price and wage cost as it has shown their coefficients are -0.70 and -2.03 at 5% significant level respectively. Implying that as seed price and wage cost increasing in rice production by 1%, the water demand will decrease by 0.70% and 2.03% respectively. This also shows that as seed price increases, farmers will not be able to buy reasonable quantity of seeds and automatically will decrease the area for rice cultivation as a result of decreasing the amount of water demanded for rice cultivation. In case of wage, an increment on wage cost will lead the farmers to decrease the area for rice cultivation as a result of decreasing the amount of water demanded. Since the coefficient of seed price, wage and land rent costs are all negative, meaning that water with seeds, wage and land are complementary inputs, as the increase of 1% of seed price, wage and land rental cost, lower the water use by 0.70%, 2.03% and 0.35% respectively.

5. Conclusions and Recommendations

5.1 Conclusions

In this study the structure of irrigation water demand in rice farms in Tanzania was investigated. Irrigation water demand in rice farms estimated by data related to 16 regions of Tanzania from 2007 to 2012. The major results of the analysis including that, the quantity of rice significantly influences water consumption. This relationship could be used to determine the impact of rice production on water use and reformulation of policies on water use. The average water demanded per hector when other factors are kept constant was approximated nearly to 8 000m^3 as it is also reported in various studies that that irrigated rice can be easily cultivated using 8 000 to 10 000 m^3/ha.

The water demand for rice cultivation was influenced much by output quantity (rice). The water demand increases by 6% whenever output quantity increases by 10%.Thus irrigated output affects water usage intensively in Tanzania's agricultural sector as it has positive effect on water demand in rice cultivation.

5.2 Recommendations

Even though rice irrigation in Tanzania is seen as utilizing too much of the available water resources, but still rice plays an essential part in enhancing food security and income to Tanzanians.

Based on the findings, this paper recommends that emphasis should be put on effective and efficient use of water in order to improve its productivity in rice production. Famers should apply water at a right time avoiding water loss. Various water management strategies should be practiced to boost up the recent water productivity. Among those strategies include optimisation of water use in rice field operations and reducing water use during crop growth by maintaining the soil in sub-saturated condition by alternating drying and wetting the rice field without affecting yields, instead of continuous submergence methods. Furthermore, if possible restrict rice cultivation to only rainy season by making more effective use of rainfall. Lastly, a national network for wetland development should be established. Among other duties, the network will organize data collection of wetlands and provide a forum for solving the water constraints.

Therefore it is suggested that, not to stop the rice production instead striving to boost irrigation efficiency and improve the productivity. Improving water productivity is one of the most important strategies toward tackling water scarcity.

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Table 5: General trend of rice production in selected regions of Tanzania (‘000’Tonnes)

General trend of rice production in selected regions of Tanzania (‘000’ Tons)						
YEAR	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
MBEYA	162.63	164.06	121.74	295.19	174.87	212.75
IRINGA	42.50	17.71	49.88	37.86	18.49	15.44
RUVUMA	40.42	55.67	71.12	180.49	82.97	71.62
MOROGORO	148.11	294.71	246.83	469.24	246.32	185.22
ARUSHA	14.26	2.27	9.18	12.10	180.89	312.60
DAR-ES-SALAAM	3.88	3.33	0.51	3.50	4.02	3.78
KAGERA	5.74	30.81	6.82	34.57	11.48	8.63
KIGOMA	58.64	6.37	77.38	89.31	116.20	98.92
KILIMANJARO	63.25	8.83	58.27	210.35	22.56	21.19
MARA	63.23	9.62	11.11	34.18	3.46	16.53
MWANZA	168.63	178.44	114.09	278.53	212.10	204.40
PWANI	47.64	33.21	33.00	88.91	403.08	64.19
SHINYANGA	178.60	257.94	212.41	353.64	170.82	147.97
TANGA	25.02	13.32	19.31	36.54	70.16	20.35
RUKWA	167.32	127.24	128.40	332.68	166.74	94.83
TABORA	82.04	131.51	68.26	64.27	215.07	242.86

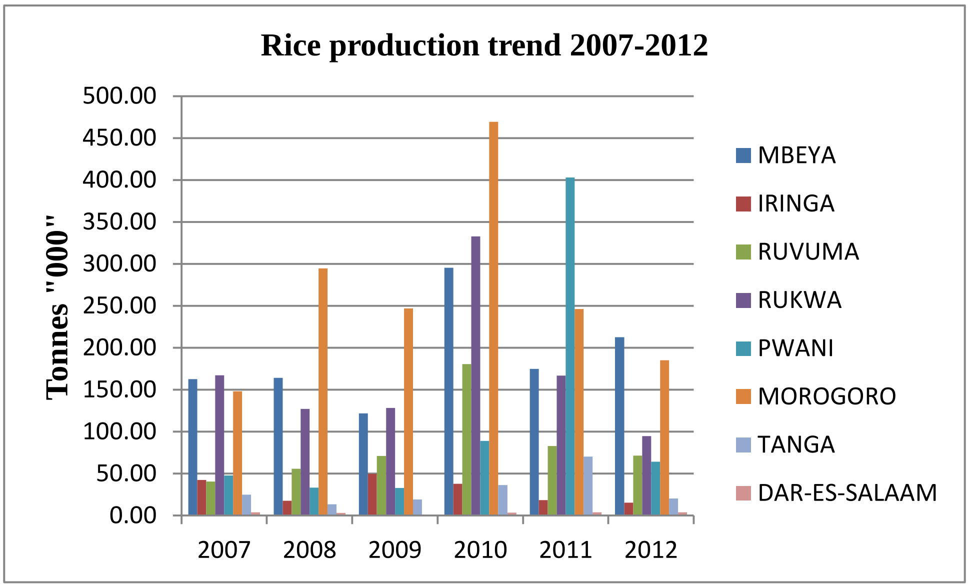
Source: Statistics Unit, Ministry of Agriculture Food Security and Cooperatives, Tanzania

Table 6: Area for rice production in Tanzania 2007 to 2012

Area for rice production in '000'ha						
Year/Region	2007	2008	2009	2010	2011	2012
MBEYA	30.16	81.27	66.56	79.54	54.13	69.14
IRINGA	8.63	6.53	14.17	14.65	10.92	10.03
RUVUMA	25.08	48.49	56.75	67.18	41.48	38.793
MOROGORO	65.82	169.76	142.33	180.55	114.36	92.61
ARUSHA	1.67	0.89	2.63	2.86	106.89	106.94
DAR-ES-SALAAM	3.45	5.02	0.96	1.51	2.90	2.455
KAGERA	1.55	14.10	6.25	9.98	6.79	5.61
KIGOMA	14.99	5.78	33.04	41.04	47.21	42.864
KILIMANJARO	22.22	4.97	12.69	16.01	13.33	10.59
MARA	4.23	5.67	22.63	17.84	1.61	8.27
MWANZA	64.26	124.42	90.30	112.79	86.17	83.037
PWANI	28.59	28.58	33.26	41.61	262.01	52.155
SHINYANGA	167.34	175.19	133.43	296.58	74.02	73.986
TANGA	8.78	12.99	14.16	16.53	38.01	12.026
RUKWA	30.76	46.49	68.11	82.38	63.75	38.526
TABORA	41.06	99.27	61.03	60.76	99.85	92.859

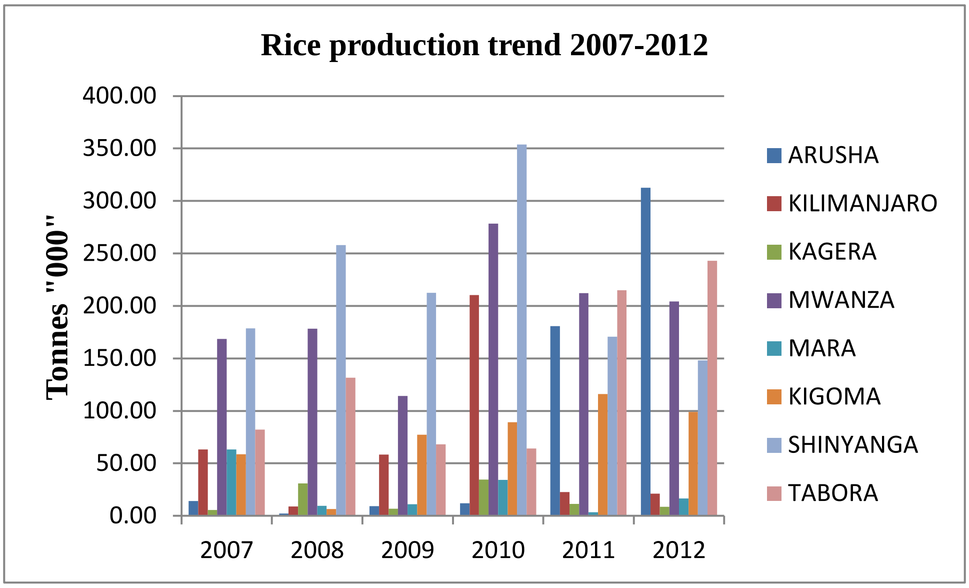
Source: Statistics Unit Ministry of Agriculture, Food Security and Cooperatives, Tanzania

Figure 1: General trend of rice production in 2007-2012, Southern and Eastern regions



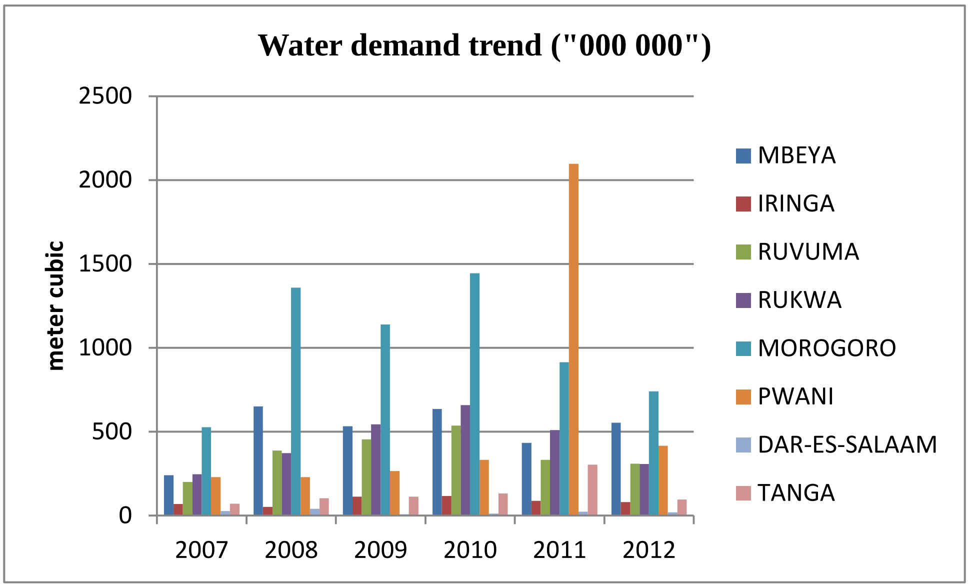
Source: Statistics Unit, Ministry of Agriculture, Food Security and Cooperatives, Tanzania

Figure 2: General trend of rice production in 2007-2012, Northern and Central regions



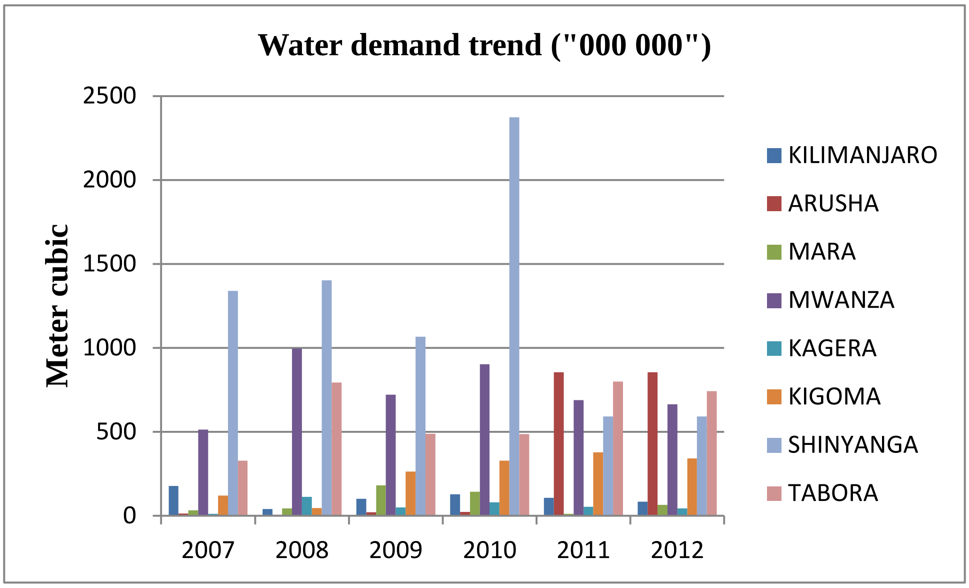
Source: Statistics Unit, Ministry of Agriculture, Food Security and Cooperatives, Tanzania

Figure 3: General trend of water demand in rice production Southern and Eastern regions



Source: Statistics Unit, Ministry of Agriculture, Food Security and Cooperatives, Tanzania

Figure 4: General trend of water demand in rice production Northern and Central regions



Source: Statistics Unit, Ministry of Agriculture, Food Security and Cooperatives, Tanzania

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