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DETERMINING THE ECONOMIC OPTIMUM RATE OF WATER USE IN AGRICULTURAL PRODUCTS
(Case Study in Kohgiluyeh and Boyer-Ahmad Province-Iran)

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Abstract:

Water is the main limiting factor in agricultural products. Occurrence of drought phenomenon in recent years makes the need to careful planning for efficient use of existing water resources in agricultural consumptions essential. The aim of this study was to determine the technical and economical optimal level of water use in agriculture sector. Required statistics and data were collected through completing 155 questionnaires by farmers under coverage of traditional irrigation system in Kohgiluyeh and Boyer-Ahmad province using the simple random sampling method from the tables relevant to all beneficiaries of the traditional irrigation system of the district water organization related to counties of Boyer-Ahmad, Gachsaran and Dehdasht in the year 2009/2010. Demand functions for selected products were extracted by profits maximizing method using quadratic production function. The results of the study showed that technical optimum level of water use in farms of wheat, barley and canola, respectively, were as 6786, 4839 and 8277.31 cubic meters that these volumes of water are necessary for maximizing the production rate of each of these products. Economically optimal amount of water to maximize the producers' profits of wheat, barley and canola, respectively, were as 6718.706, 4808.73, and 8277.14 cubic meters of water; meaning, this amount of water is required to maximize the profits of the producers of mentioned crops. Comparing the technical and economic optimum levels of water use on selected farms showed that the two values are very close together. The closeness of technical and economic optimum levels of water use is due to the very low price of water.

KEYWORDS:

Optimum level, Water, Agricultural products, Kohgiluyeh and Boyer-Ahmad.

INTRODUCTION:

Necessity to establish balance between agricultural products and conservation and sustainability of natural resources requires that policy making on water use as a vital limited resource, especially in countries with high demand for water consumption and scarce water resources, is performed with regard to environmental, social and economic aspects. Drought conditions in recent years emphasize more than ever on the need for planning in agricultural water Issues.

Strong need to provide food for the increasing population of our country, Iran, on one hand and the need to achieve self-sufficiency in agricultural production issue on the other hand requires that the rate of agricultural production will be increased in the country as much as possible. But as most parts of Iran are located in arid and semi-arid regions, our country's water resources are limited. Thus, the first and the most important limiting factor in increasing the agricultural production is water. It is also anticipated that climate changes in the future tend to more warming, and as a result, the water need of plants will increase and using of water resources become limited more than ever. Hence, the need for accurate planning in efficient use of existing water resources, especially in agriculture uses that include the major part of the nation's water resources consumption, is seriously felt (7). Factors such as indiscriminate use of some of the available water resources, lack of proper nourishment of surface and underground aquifers, lack of maintenance and conservation principles of soil and water resources, the growth of industrial sector and urban development, and finally the incidence of drought phenomenon in recent years have caused the destruction of some water resources in the country and increased the limit severity of this production input (4). Given that about 90% of water supply in Iran is dedicated to agricultural sector, saving water in this sector may reduce environmental effects resulting from overuse of water meanwhile development of irrigated cultivation (1). In conditions that three important sectors of water use (agriculture, industry and drinking) are facing water shortage, optimum exploiting and as far as possible from these water resources is considered as an appropriate solution. The approach to such an important issue should be considered more than ever due to the recent droughts in the country. The purpose of this study was to determine the economic optimum level of water use in agricultural productions. What should be taken into consideration in calculating the economic optimal level of water consumption is performing field studies in various parts of the country, since the farmers' behavior in relation to water use in agriculture sector in different regions of the country is different. Kohgiluyeh and Boyer-Ahmad province has abundant water resources that mismanagement of water resources in the province emphasizes on the need to serious planning on agricultural water issues. Some studies have been conducted on agricultural water use and demand inside and outside Iran that some of them are mentioned in the following.

REVIEW OF LITERATURE

In a study, Shajari et al. (2010) using Cobb-Douglas production function and profit maximizing method tried to determine the price elasticity of water demand and water input productivity value in producing date palm as well as the water marginal cost. The research results showed that the final efficiency and final production value of water in the drip and flooding irrigation methods were as 0.194 kg and 204.06 Rials and 134.0 kg and 7140.73 Rials, respectively. Also, the cost per cubic meter of water based on rate of 20% was calculated as 67.23 Rials.

In a study, Najafi and Najafi (2011) reviewed the factors influencing on water demand in fish aquaculture farms in Kohgiluyeh and Boyer-Ahmad province. The results of the study showed that the price elasticity of water demand in price equal to the value of marginal production of water is equivalent to (-1.27), which suggests the elasticity of demand function than to the price of water. The researchers suggested that appropriate and reasonable pricing policy for water has a positive impact on reducing water consumption and prevents water overusing.

In a study called as irrigation water demand management, Torkmani and Shajari (2009) indicated that homogeneous groups of farmers show different behavior patterns than to the irrigation water. In this regard, water use of more risk avoider farmers is significantly less than the water amount they have access to; they believe that such farmers, in higher rates of water fees, will significantly reduce their total amount of water demand as well as average their water use in per hectare by changing cropping patterns and attitudes towards producing crops with low-consumption irrigation methods and cultivation of rain-fed crops.

Dinar and Yaron (1992) calculated the price elasticity of water demand using cross-sectional data in the United States by logarithmic method. These researchers examined several methods of water pricing, and due to the price elasticity of water demand than to the price of water, assessed the water pricing policy as an appropriate approach in order to prevent indiscriminate uses and promoting efficient use of water resources.

Hamedi et al. (1995) studied the water crisis in the Mediterranean and agricultural water demand management in this area in a research. The researchers mentioned that due to water crisis, particularly in developing countries, there is a more tendency to water demand management rather than water supplying.

Petra and Helgerz (2002) argue that the use of water as an economic good means to make decisions regarding the water use and its allocation among the consumers based in exchanging analyses. They believe that in addition to economic efficiency, other criteria such as social equality and the necessity of desirable social status may play role in this regard.

According to the studies mentioned, some researchers tried to determine the inputs relationships in an agricultural process with one of the most common yield performance functions to this input. To achieve such a goal, some researchers used the production function technique and the profit maximization method in order to extract the water demand function.

RESEARCH METHODOLOGY

Since the main objective of farmers is to obtain maximum revenue, the production function, meaning the relationship between the irrigation rate and the crop amount as well as the cost function, meaning the relationship between water quantity and its cost are required to determine the amount of water that provides the objective. The optimum irrigation rate (economic optimum rate) is achieved in a point that the net income, the difference between irrigation total revenue and its cost, is at its maximum value; this volume of water use is called as economic optimum. In other words, the economic optimum amount of water is an amount that makes the final output value (final efficiency) of water equal to the marginal cost (water price) (5). Also, the technical optimum amount of water is the water amount that maximizes the crop amount or the crop gross income. A study was conducted Hexem and Heady in U.S. regarding the selection of appropriate production function in order to study the product reaction to water and fertilizer that the results showed the best function for this type of studies is the polynomial quadratic function form(11).

The quadratic production function form is as follows:

$$Y = \alpha_0 + \alpha_1 W + \alpha_2 N + \beta_1 W^2 + \beta_2 N^2 + \beta_3 NW \qquad (1)$$

Wherein:
Y: The amount of crop production per hectare
W: The amount of water used in terms of cubic meters per hectare
N: The amount of fertilizer used in terms of kilograms per hectare

In this study, the water demand function is established using the profit maximization method directly and without using the duality theorem. In a perfect competition market, the necessary or first-order condition for maximizing the producer's profit is obtained from the equality of final production of each input with its price. Also, the second-order or sufficient condition for maximizing the producer profit is that the production function should be strictly concave in the neighborhood of the critical point derived from the first order conditions.

Using the function (1), the income function is obtained as function (2):

$$R = r(y) \qquad (2)$$

$$R = r(y(W, N)] \qquad (3)$$

The cost function is as:

$$C = e[W, N) \qquad (4)$$

Using the functions (3) and (4), the profit equation is obtained as follows:

$$\pi = r[y(W, N)] - C(W, N) \qquad (5)$$

First order conditions for maximizing the profit from the above equation are as follows:

$$\pi_1 = \left[\frac{dr}{dy}\right]\left[\frac{dy}{dw}\right] - \frac{\delta C}{\delta W} = 0 \qquad (6)$$

$$\pi_2 = \left[\frac{dr}{dy}\right]\left[\frac{dy}{d_N}\right] - \frac{\delta C}{\delta N} = 0 \qquad (7)$$

Displaying the final value of production as MVP and the final cost of input or the production factor MFC, we will have:

$$MVP_W = MFC_W \quad (8)$$

$$MVP_N = MFC_N \quad (9)$$

The second-order conditions can be examined by evaluating Hessian determinant.

$$\begin{vmatrix} \frac{\delta\left[\left(\frac{dr}{dy}\right)\left(\frac{\delta y}{\delta w}\right)\right]}{\delta w} - \frac{\delta\left(\frac{\delta c}{\delta w}\right)}{\delta w} & \frac{\delta\left[\left(\frac{dr}{dy}\right)\left(\frac{\delta y}{\delta w}\right)\right]}{\delta N} - \frac{\delta\left(\frac{\delta c}{\delta w}\right)}{\delta N} \\ \frac{\delta\left[\left(\frac{dr}{dy}\right)\left(\frac{\delta y}{\delta N}\right)\right]}{\delta w} - \frac{\delta\left(\frac{\delta c}{\delta N}\right)}{\delta w} & \frac{\delta\left[\left(\frac{dr}{dy}\right)\left(\frac{\delta y}{\delta N}\right)\right]}{\delta N} - \frac{\delta\left(\frac{\delta c}{\delta N}\right)}{\delta N} \end{vmatrix}$$

One interpretation of second-order conditions as fulfillment of these conditions means that the MVP curve cuts the MFC curve from the top.

Data and statistics required in this study were collected through completing 155 questionnaires by farmers covered by traditional irrigation system in Kohgiluyeh and Boyer-Ahmad province. The sample farmers were selected using the simple random sampling method from the tables relevant to all beneficiaries of the traditional irrigation system of the district water organization related to counties of Boyer-Ahmad, Gachsaran and Dehdasht in the year 2009/2010. Additional information was obtained from the costs tables of Agriculture Organization in Kohgiluyeh and Boyer-Ahmad province, interviews with farmers and experts of the regional Water Organization.

RESULTS AND DISCUSSION

The study area in this research included wheat, barley and canola farms in counties of Boyer-Ahmad, Gachsaran and Dehdasht. In Kohgiluyeh and Boyer-Ahmad province, the product-to- product method based on the area under cultivation is used for water pricing in agriculture sector. Given that most of the producers use traditional irrigation networks to irrigate their farms, the water price paid by these farmers is very low, which leads to the indiscriminate use of water in the farms of agriculture sector. The received price of water per acre for crops of wheat, barley and canola are respectively as 67650, 50160 and 81400 Rials.

ESTIMATING OF QUADRATIC PRODUCTION FUNCTIONS FOR SELECTED PRODUCTS

In order to study the product reaction to water and fertilizer, different production functions (Cobb-Douglas, transcendental, polynomial, etc.) were estimated for each of the three products. Finally, according to the econometric criteria, the quadratic production function was chosen as the best model for selected products.

The results from estimation of the quadratic production function for wheat crop are given in table (1). All variables are significant at 95% and 99% levels. Durbin-Watson statistic (D.W = 2.11) indicates the lack of self-correlation in the model. The coefficient of determination is as R2 = 0.93, which indicates that the independent variables show up to 0.93 of changes in dependent variable. The closeness of $\overline{R}^2 and R^2$ indicates the good fitness of the model.

The results from estimation of the quadratic production function for barley crop are given in table (2). All variables in this function except for intercept are also significant at 95% and 99% levels. Durbin-Watson statistic (D.W = 2.11) indicates the lack of self-correlation in the model. The coefficient of determination is as R2 = 0.94, which indicates that the independent variables show up to 0.94 of changes in dependent variable.

The results from estimation of the quadratic production function for canola crop are given in table (3). All variables in this function are also significant at 95% and 99% levels. Considering the closeness of Durbin-Watson statistic to 2, the lack of self-correlation in the model is confirmed. In this function, independent variables show up to 0.85 of changes in dependent variable.

Calculating the technical optimum level of water use

Wheat crop

The quadratic production function form of wheat is as follows:

$$y = 672/36 - 16/27W + 76/43N - 0/0048W^2 - 0/341N^2 + 0/085WN \quad (10)$$

By differentiation of wheat production function than to inputs and simultaneously solving of the production function derivatives, the technical optimum level of water use is obtained:

$$\frac{\partial y}{\partial w} = -16/27 - 0/0096W + 0/085N = 0 \quad (11)$$

$$\frac{\partial y}{\partial N} = 76/43 - 0/682N + 0/085W = 0 \quad (12)$$

The technical optimum level of water use in wheat production is equal to 6786 cubic meters, which means by this amount of water use, the wheat production will be maximized.

Barley crop

The quadratic production function form of barely is as follows:

$$y = 8920/05 + 7/035W + 0/75N - 0/00076W^2 - 0/054N^2 + 0/0026WN \quad (13)$$

The above production function is differentiated than to the input:

$$\frac{\partial y}{\partial w} = 7/035 - 0/00152W + 0/0026N = 0 \quad (14)$$

$$\frac{\partial y}{\partial w} = 0/75N - 0/108N + 0/0026W = 0 \quad (15)$$

By simultaneous solving of the barely production function derivatives than to the input price, technical optimum level of water use for barley crop is obtained as 4839 cubic meters, which means this amount of water use can maximize the production level of barely.

Canola crop

The quadratic production function form of canola is as follows:

$$y = 378/02 - 35/63W - 22/35N + 0/0023W^2 + 0/0022N^2 - 0/0025WN \quad (16)$$

The first order derivatives of the function than to inputs are as follows:

$$\frac{\partial y}{\partial w} = -35/63 + 0/0046W - 0/0025N = 0 \quad (17)$$

$$\frac{\partial y}{\partial N} = -22/35 + 0/44N - 0/0025W = 0 \quad (18)$$

Using the first-order derivatives of the quadratic production function of canola crop, the technical optimum level of water use in canola fields is obtained as 8277.31 cubic meters, which means this amount of water is required for maximum production of canola crop.

Calculating the economic optimum level of water use

In order to obtain the economic optimum level of required water use, the water demand is individually obtained for each of the products. Based on what mentioned in methodology, the profit maximization conditions are used in order to derive the demand functions. The necessary condition to derive the demand function using the production function is that the production function should have diminishing returns than to the scale. Using Wald test, the diminishing return than to the scale was ratified for each of three functions.

Wheat crop

Water demand function for wheat crop is as follows:

$$W = 6663/23 + \frac{125}{P_{yw}}(80/02r_w + r_n) \quad (19)$$

Wherein:
W: Water demand rate in terms of cubic meters per hectare in wheat fields
P_{yw}: Wheat crop price, which is equal to 3200 Rials
r_w:Price of water input for each cubic meter in wheat fields is equal to 10 Rials
$r_{N:}$Price of fertilizer input for each kilogram is equal to 620 Rials

Based on water demand function in wheat fields, the relationship between the price of water and the water demand rate is positive, which means increased water price has no impact on reducing the water consumption in wheat fields. The reasons can be considered due to a very low price of water, the high cost of this crop and its share in household consumption basket. Thus, the rising cost of wheat production, including increased water price, has little effect on the cultivation of this crop and consumption of water input up to a limit. If the price of water increases more than a certain limit, the farmers will be certainly forced to reduce the agricultural water use.

By replacing the inputs' prices and product price in the water demand function for wheat crop, the economic optimum level value of water use for wheat is obtained as 6718.706 cubic meters, which means the wheat producers require 6718.706 cubic meters water to maximize their profits. As can be seen, the economic optimum level of water use in wheat fields is very close to the technical optimum level of water use in these fields. The reason is a very low price of water, which means the farmers consider water as a free good.

Barley crop

Water demand function for barley crop is as follows:

$$W = 4815/59 - \frac{16/56}{P_{yb}}(rN + 41/53rW) \quad (20)$$

Wherein:
W: Water demand rate in barely fields
P_{yb} :Barely crop price, which is equal to 3200 Rials for each kilogram
r_W :Price of water input for each cubic meter in barely fields is equal to 10 Rials
r_N :Price of fertilizer input for each kilogram is equal to 620 Rials

Water demand function for barley crop indicates the negative relationship between the price of water and the water demand rate, which means the increase in water price causes reduced water consumption in barely fields. By replacing the inputs' prices in the water demand function, the economic optimum level of water use for wheat crop is obtained as 48.8.73 cubic meters. Due to the very low price of water, the economic and technical optimum levels of water use in barely fields are also very close to each other.

Canola crop

Water demand function for canola crop is as follows:

$$W = 8275/51 + \frac{12/755}{P_{yc}}(17/6r_W + r_N) \qquad (21)$$

Wherein:
W: Water demand rate in terms of cubic meters per hectare in canola fields
P_{yc} :Canola crop price, which is equal to 6200 Rials
r_W :Price of water input for each cubic meter in canola fields is equal to 10 Rials
r_N :Price of fertilizer input for each kilogram is equal to 620 Rials

As seen in the demand function of water demand for canola crop, the price of water has a positive relationship with the water demand rate in canola fields, which means the water price increase has no impact on reducing the water consumption. This can be attributed to the very low price of consumption water, high price of this crop and the major share of the crop in the household consumption basket and food industries. In these farms, the price of water is so low that the farmers do not realize the water price increase up to a range and its impact on the production cost. For this reason and the mentioned reasons, the water price increase has no effect on agricultural water use in canola fields up to a limit. The economic optimum level of water use on canola prices by placement of inputs and product prices will be equal to 8277.14 cubic meters. This means a volume of 8277.14 cubic meters of water is needed so that the canola crop producers' profit will be maximized. In canola fields similar to wheat and barely fields, the economic and technical optimum levels of water use are very close to each other due to low price of water, which means by water price increase, the economic optimum level of water consumption reduces.

CONCLUSIONS AND RECOMMENDATIONS

In this study, in order to determine the economic optimum level of water use in agricultural sector, profit maximizing method and quadratic production function were used. Required data and statistics were collected using the simple random sampling method from the costs tables of Agriculture Organization in Kohgiluyeh and Boyer-Ahmad province related to wheat, barley and canola fields as the selected crops. Considering that farmers use traditional irrigation networks, the price payment of water is very low. The water prices in wheat and canola fields have a positive relationship with water demand, while such a relationship in barely fields is negative. The positive relationship between water price and water demand suggests that water pricing has little effect on reduced water consumption in wheat and canola fields, which may be due to very low water price, strategic nature of these products, high prices of these products compared to other agricultural crops and their share in the household's consumption basket. For the same reasons, water price increase will be ineffective on agricultural water use up to a level.

In barely fields, water loss can be prevented in such fields through increasing the price of water. However, the plants water need should be considered in water pricing. The technical optimum levels of water use in wheat, barley and canola fields are, respectively, as 6786, 4839 and 8277.31 cubic meters, and these amounts of water are required to maximize the production of each of these products. The amount of water required for maximizing the producers' profits is different from technical optimum level of water use.

The economic optimum level of water use or the amount of water needed for maximizing the profits of producers of wheat, barley and canola are respectively as 6718.706, 4808.73 and 8277.14 cubic meters. That is, theses amounts of water are needed to maximize the producers' profits of the mentioned crops. Comparing the technical and economic optimum levels of water use in selected farms, these two values are very close to each other, and can even be said that they are coinciding. The closeness of these technical and economic optimum levels of water use is due to the extremely low price of water (10 Rials) or its free price. Since the producers' purpose of selected products is to maximize the profit, the rational way is to use water equal to economic optimum level. Considering that water loss is very high in the traditional irrigation system, investments on agricultural water transmission networks is recommended.

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Table 1: Results of quadratic production function of wheat

t-statistics	Coefficient	Variable
2/15	672/36*	C
-4/85	-16/27**	W
3/25	76/43**	N
-5/13	-0/0048**	W^2
-4/33	-0/341**	N^2
2/46	0/085*	W.N
= 0/931R^2	$\overline{R}^2 = 0/929$ = 2/11D.W	= 879/211F

*Significance at 5% level

**Significance at 1% level

Source: research findings

Table 2: Results of quadratic production function of wheat

t-statistics	Coefficient	Variable
1/49	8920/05	C
3/13	7/035**	W
2/01	0/75*	N
-3/67	-0/00076**	W^2
-2/94	-0/054**	N^2
2/36	0/0026*	W.N
= 0/941R^2	$\overline{R}^2 = 0/938$ = 1/95D.W	= 545/871F

*Significance at 5% level

**Significance at 1% level

Source: research findings

Table 3: Results of quadratic production function of canola

t-statistics	Coefficient	Variable
2/14	378/02*	C
-2/041	-35/63*	W
-3/871	-22/35**	N
2/271	/0023*	W^2
2/985	0/022**	N^2
2/023	0/0025*	W.N
= 0/862R^2 = 764/35F	$\overline{R}^2 = 0/858$	= 1/96 D.W

*Significance at 5% level

**Significance at 1% level

Source: research findings