THE ASSESSMENT OF IRRIGATION WATER USAGE CONSIDERING WATER PRODUCTIVITY INDICATORS, ECONOMIC VALUE OF WATER AND ECONOMIC EFFICIENCY – CASE STUDY: KERMAN PROVINCE, IRAN

EVALUATION DE L'UTILISATION DE L'EAU D'IRRIGATION COMPTE TENU DES INDICATEURS DE PRODUCTIVITE DE L'EAU, DES VALEURS ECONOMIQUES DE L'EAU ET DE L'EFFICIENCE ECONOMIQUE – ETUDE DE CAS: PROVINCE KERMAN, IRAN

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ABSTRACT

The limitation and scarcity of consumable water reservoirs in agriculture sector, have introduced water as an economic good. Water productivity and water valuation are two of the most important tools in water usage assessment economically. In this research these tools have been used in order to assess the irrigation water usage situation in three districts in Kerman Province, Iran. A mathematical model has been developed using four different methods, in order to determine the economic value of water. The model has been executed for three independent case studies; Soghaan, Ghoochaabaad and Chaahnaarenj districts of Kerman Province, IRAN, and the water value has been calculated for each crop in each district based on Irrigated area, Volume of water consumed, Percentage of net annual income and Crop type. The economic efficiency and Water productivity based on Physical, combined Physical and economical and economical approaches have also been calculated. Eventually, water productivity indicators and the economic efficiency for each crop have been compared and water usage situation in each district has been assessed. According to the results, it was concluded that water productivity indicators or economic efficiency are not individually

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sufficient for assessing the water usage situation. Rather, the economic value of water is to be studied in each district separately and the water value is to be considered in decision making and in setting managerial policies. The areas having complex economic situation are needed to be studied accurately in order to find a better method to calculate the water productivity and water price.

Keywords: *Irrigation water productivity, Economic value of water, Mathematical model, Economic efficiency.*

RESUME

La limite et la pénurie des réservoirs d'eau de consommation dans le secteur agricole ont présenté l'eau en tant que bien économique. La productivité de l'eau et la valorisation de l'eau sont, parmi d'autres, les deux plus importants outils utilisés dans l'évaluation économique de l'utilisation d'eau. Dans cette étude, ces outils ont été utilisés pour évaluer la situation concernant l'utilisation de l'eau d'irrigation dans trois périmètres de la Province Kerman de l'Iran.

Un modèle mathématique fut développé en utilisant quatre méthodes différentes pour déterminer la valeur économique de l'eau. Le modèle a été mis en place pour mener trois études de cas indépendantes : Périmètres de Soghaan, de Ghoochaabaad et de Chaahnaarenj de la Province Kerman (Iran). La valeur d'eau a été calculée pour chaque culture dans chaque périmètre compte tenu de la superficie iriguée, du volume d'eau utilisé, du pourcentage du revenu annuel net et du type de culture.

Il a été procédé au calcule de l'efficience économique et de la productivité de l'eau compte tenu des aspects physique, physio-économique et économique. Par la suite, il a également été procédé à la comparaison des indicateurs de la productivité de l'eau et de l'efficience économique de chaque culture, et à l'évaluation de l'usage de l'eau dans chaque périmètre. Compte tenu du résultat, il a été conclu que les indicateurs de la productivité de l'eau et de l'efficience économique de culture ne s'avèrent pas être suffisants pour évaluer la situation en ce qui concerne l'utilisation de l'eau. La valeur économique de l'eau doit être étudiée dans chaque quartier séparément, et il est nécessaire de tenir compte de la valeur d'eau dans le processus de prise de décisions et des politiques de gestion. Les régions où la situation économique est complexe, doivent être étudiées plus précisément pour trouver une meilleure méthode de calcul de productivité de l'eau et du prix d'eau.

Mots-clés: *Productivité de l'eau d'irrigation, valeur économique de l'eau, modèle mathématique, efficience économique*

1. INTRODUCTION

Water has been considered an essential ingredient for human survival and development throughout the history. Water is an integral component of the global system, and it will most certainly undergo major changes during the next 25 years. In fact, water management practices and processes are likely to experience more change during the next 25 years than has occurred during the past 2000 years.

Customarily, water professionals have mostly ignored the global forces that influence the water sector, even though these are likely to shape water use, availability and management practices of the future in some very significant ways. It is now widely predicted and believed that the world will face a major water crisis in the coming decades because of increasing water scarcities in numerous countries (Biswas, 2005).

It is obvious that the shortage of one commodity can increase the demand for it and in this situation that commodity can be called "economic". Thus, the first major step towards optimum water consumption is accepting water to have an economic value. The ever increasing limitations of water resources and competition among the various water consumers can tell the importance of managerial scheduling (Cai et al., 2001: (A) & (B) and 2003 (C).

There no doubt that water pricing is a very useful tool in order to manage different departments having the responsibility of conveying high quality water. In such a situation, determining the water value is an obligation (Biswas, 2005; Aguadelo, 2001).

It should be noted that water resources limitations will be followed by more need to invest bigger capitals, which most countries specially the developing ones cannot afford. In addition, Because of the major importance of water consumption management as a social approach, economic value of water is an effective factor in optimum consumption and supply-demand management (Johansson, 2001; Sawyer et al., 2005).

Increasing the productivity of water in agriculture will play a vital role in easing competition for scarce resources, prevention of environmental degradation and provision of food security. The argument for this statement is simple: by growing more food with less water, more water will be available for other natural and human uses. Increasing productivity of water is particularly important where water is a scarce resource. Physical scarcity, when there is no additional water in a river basin to develop for further use, is common in an increasing number of either dry or intensively developed basins. In these cases, it is likely that increasingly less water will be available for agriculture and that, to sustain production, increases in water productivity will be necessary (Molden et al., 2003).

Water is an extremely complex resource. It is both a public and a private good; it has multiple uses; the hydrology and externalities require that we examine potential productivity gains at the farm, system and basin levels; both quantity and quality are important in measuring availability and scarcity; and the institutions and policies that govern the use of water are typically flawed. Given these complexities, it is small wonder that there is little agreement among scientists, practitioners and policy makers as to the most appropriate course of action to be taken to improve the management of water resources for the benefit of society. This fact notwithstanding, the growing scarcity of water increases the need and demand for sound economic analyses (Barker et al., 2003).

The term water productivity (WP) is defined and used in a variety of ways. There is no single definition that suits all situations. As mentioned previously, in general terms, productivity is a ratio referring to the unit of output(s) per unit of input(s).The most encompassing measure of productivity used by economists is total factor productivity (TFP), which is defined as the value of all output divided by the value of all inputs. But the concept of partial factor productivity (PFP) is more widely used by economists and non-economists alike. Partial productivity is relatively easy to measure and is commonly used to measure the return to scarce or limited resources, such as land or labor (Barker et al., 2003).

Until recently, water has not been considered a scarce resource. Now, with mounting water shortages and water-quality concerns, there is a growing interest in measures to increase WP, which is a specific example in the general class of PFPs. WP is most commonly measured as crop output per cubic meter of water (Barker et al, 2003).

Economic efficiency (EE) takes into account values of output, opportunity costs of inputs and externalities and is achieved when scarce resources are allocated and used such that the net value or net returns (returns minus costs) are maximized. Unlike IE, which is a ratio by definition, EE is a criterion that describes the conditions that must be satisfied to guarantee that resources are being used to generate the largest possible net benefit (Seckler et al., 2003).

In the aforementioned researches, mostly the hydrological concept has been assessed. In almost all of the researches that has been done in water pricing and water productivity assessment, basin scale has been considered and smaller scales have not been paid enough attention. In this paper, the system scale has been used so that the writers could assess water productivity in a smaller scale. This would help studying water productivity in farms and basins separately in order to assess the relationship between irrigation efficiency and water productivity.

The Initial Objectives of this paper are to determine the Water price, TFP and PFPs in which, the first one is being executed by writing a mathematical model. The main end of this research is to discuss those above parameters and compare their effects and roles in the economy of irrigation water.

2. MATERIALS AND METHODS

The research has been done for three different districts in Kerman Province, Iran. These areas were selected based on their meteorological situations, economic situations, cropping patterns, level of modernization in agriculture and irrigation systems. All of these districts have arid climate and limited water resources, practise traditional irrigation methods and face their negative results economically and professionally.

The Visual FORTRAN 6.0 was used as the model writing language. The water price was calculated by using the model and several different data.

The water value was calculated for each crop in each district based on irrigated area, volume of water consumed, percentage of net annual income and crop type. Considering the effective and useful factors and the quality of the results, the water price calculated based on crop type has been discussed. The methods used to calculate the water price and reasons why some factors were chosen or ignored are discussed in this paper:

2.1. Percentage of income based method

In this method a certain percentage of the net annual income was considered as the water price. This method is not accurate and does not consider the effective factors in water pricing such as the type of crop, the irrigated area, the price of crop, the amount of produced yield and the volume of consumed water.

2.2. Area based method

This method calculates the water price based on the actual irrigated area:

$$P_w = \frac{C_{O\&M}}{A_{actual}} \quad (1)$$

In this equation, P_w is water price (*Rls/ ha/ year*), $C_{O\&M}$ is a water delivery operation and maintenance cost *(Rls /year)* and A_{actual} is actual irrigated area which can include a single crop or different types of crops (Rls = Rials: 1.00 USD ≈ 10,000.00 Iran Rials). It should be added that considering the type of irrigation and drainage network, the parameter of equation 1 can be changed for one period of cultivation, one year or more than one year. In addition, accurate measurement of irrigated area will play a significant role in precision of the result (Easter, 2005). The method does not take into account all the factors and the effect of the crop is also not considered.

2.3. Water volume based method

In this method, gross water volume consumed all over the irrigated area is the base of water pricing:

$$P_w = \frac{C_{O\&M}}{V_{total}} \quad (2)$$

In equation 2, P_w is water price (*Rls/ m^3/ year*), $C_{O\&M}$ are water delivery operation and maintenance costs (*Rls / year*) and V_{total} is the total volume of consumed water (*m^3 / year*) (Easter, 2005). Gathering all the data needed in this method is a time consuming work which can be rarely done in a right way.

2.4. Crop based method

The type of irrigated crop is the main factor in this method:

$$P_W = P_Y \times \frac{\partial Y}{\partial W} \quad (3)$$

In this equation, P_w is the water price (*Rls/ m^3/ year*), P_y is the crop price (*Rls / Kg*) and $\frac{\partial Y}{\partial W}$ is the relative change of crop yield and water consumption (Easter, 2005).

As it can be seen, in this method unlike the three others, more important factors have been considered such as crop price and relative changes of crop yield and water consumption, which itself contains more effective factors. Due to this reason, the crop based method was chosen for discussion along with the economic efficiency and water productivity (Omidi et al., 2007 A, B and Omidi et al., 2009 C).

2.5. Water productivity indicators

Partial water productivity can be expressed in physical or economic terms as follows (Seckler et al, 2003):

1. Pure physical productivity is defined as the quantity of the product divided by the quantity of the input. Examples include crop yield per hectare or per cubic meter of water either diverted for or consumed by the plant. For example, the International Water Management Institute (IWMI) sees 'Increasing the crop per drop', as one of its primary objectives. This factor is shown by PFP1 in this paper.
2. Productivity, combining both physical and economic properties, can be defined in terms of either the gross or the net present value of the product divided by the amount of the water diverted for or consumed by the plant. This factor is shown by PFP2 in this paper.
3. Economic productivity is the gross or net present value of the product divided by the value of the water either diverted or consumed by the plant, which can be defined in terms of the value or opportunity cost in the highest alternative use. This factor is shown by PFP3 in this paper.

2.6. Economic efficiency

The relationship of economic efficiency (EE) and water productivity varies in different levels. In plant level, varietal improvement can cause EE improvement. In farm level yield increasing and water saving technologies can result improvement. In system or district level benefit – cost analysis can lead to improvement (Randolph et al., 2003). In this regard, the benefit – cost analysis was done for each district based on the most economic crop in each, which was distinguished through comparison among all the crops. In addition to benefit – cost analysis for each district, the Total Factor Productivity (TFP) was calculated in order to assess the economic efficiency in a whole area. The TFP comes from the ratio of total costs over total benefits for each area separately.

3. RESULTS AND DISCUSSION

The Benefit – Cost analysis results for each district are shown in Table 1. The EE for Soghan is -0.47 which means that the benefit, even for the most economic crop, is less than the cost of production and hence, is profitable to grow. To change this scenario, the cropping pattern must be reconsidered and changed if needed.

As for Ghoochaabad, the EE is 3.71, which means that for the most economic crop in this area, benefits are more than costs (EE is greater than 1) and the cropping pattern is profitable.

The EE for Chahnarenj is 0.62 which is less than 1. It means that the benefit for the most economic crop is less than the production cost. This can be corrected by reconsidering the cropping pattern and irrigation system.

Table 1: Benefit – Cost analysis for Soghan, Ghoochaabad and Chahnarenj

Districts	Economic Efficiency (Benefit – Cost analysis)
Soghan	-0.47
Ghoochaabad	3.71
Chahnarenj	0.62

Table 2 shows the Total Factor Productivity for each district. The TFP for Soghan, Ghoochaabad and Chahnarej are 1.33, 8.14 and 1.68 respectively. This shows that the total costs are more than total benefits in all three areas. It means that the whole project in each area must be restudied and the faults (if there are any) must be corrected or changes must be made in them.

Table 2: Total Factor Productivity (TFP) for Soghan, Ghoochaabad and Chahnarenj

Districts	Total Profit (MUS$)	Total Cost (MUS$)	TFP
Soghan	1.74	1.3	1.33
Ghoochaabad	1.7	2.04	8.14
Chahnarenj	1.65	0.97	1.68

Table 3 illustrates the PFP for Soghan. Pure physical productivity is more than 1 for just three crops. The PFP1 for potato, watermelon and tomato are 2.1, 4.86 and 8.21 respectively. The PFP2 is more than 1 for only one crop which is pistachio with 1.74 for PFP2. The PFP3 is more than 1 for the entire cropping pattern in Soghan. The results shown in Table 3 mean that the pure physical productivity or a combination of physical and economical productivity are

Table 3: Partial Factor Productivity for Soghan

Crop Type	1.Yield Quantity (kg/ha)	2.Net Water Quantity (m^3/ha)	3.Crop Price (US$/kg)	4.Water Price (US$/$m^3$)	PFP1 (1/2)	PFP2 (3/2)	PFP3 (3/4)
Wheat	3200	5450	1.85	0.66	0.6	0.37	2.81
Barley	2500	4550	1.39	0.54	0.55	0.33	2.56
Corn	5000	8340	0.93	0.16	0.6	0.12	5.8
Alfalfa	10000	11770	0.93	0.12	0.85	0.08	7.46
Potato	20000	9550	1.03	0.16	2.1	0.12	6.55
Watermelon	30000	6170	0.74	0.29	4.86	0.13	2.53
Tomato	33000	4020	3.04	0.55	8.21	0.82	5.5
Pistachio	3000	4030	6.48	1.05	0.74	1.74	6.15
Pomegranate	5000	9650	3.24	0.99	0.51	0.36	3.26

based on one or two factors (such as the quantity of yield or crop price) whilst the economic productivity is based on both quantity and price. Based on the data shown in Table 3, PFP3 and then PFP1 can be better factors to assess the water productivity with them. It is clear that the PFP3s are the most reliable parameters in economic assessment.

Table 4 illustrates the PFP for Ghoochaabad. Pure physical productivity is more than 1 for just three crops. It is obvious that more yields per unit area can yield greater PFP1. The PFP1 for wheat, tomato and cucumber are 1.26, 8.25 and 15.34, respectively. The PFP2 is less than 1 for the entire cropping pattern which shows that the price of crop is so low that cannot respond to the big amount of water. The PFP3 is more than 1 for the entire cropping pattern. The results shown in Table 4 mean that PFP2 cannot be a very reliable factor to assess water productivity in this area. PFP3s have the same role as in Soghan.

Table 4: Partial Factor Productivity for Ghoochabad

Crop Type	Yield Quantity (kg/ha)	Net Water Quantity (m^3/ha)	Crop Price (US$/kg)	Water Price (US$/$m^3$)	PFP1	PFP2	PFP3
Wheat	3200	2540	1.85	0.56	1.26	0.8	3.3
Barley	2000	2040	1.39	0.39	0.98	0.74	3.54
Tomato	33000	4000	3.04	0.35	8.25	0.82	8.57
Cucumber	23000	1500	1.03	0.62	15.34	0.74	1.64
Alfalfa	9400	16550	0.93	0.10	0.57	0.06	8.96
Palm	3200	16860	2.08	0.70	0.19	0.13	2.97
Citrus	10000	11610	0.16	0.06	0.86	0.02	2.68

Table 5 illustrates the PFP for Chahnarenj. Pure physical productivity is more than 1 for just four crops. The PFP1 for wheat, barley, tomato and cucumber are 1.38, 1.37, 7.75 and

Table 5: Partial Factor Productivity for Chahnarenj

Crop Type	Yield Quantity (kg/ha)	Net Water Quantity (m^3/ha)	Crop Price (US$/kg)	Water Price (US$/$m^3$)	PFP1	PFP2	PFP3
Wheat	3500	2540	1.85	0.56	1.38	0.8	3.3
Barley	2800	2040	1.39	0.39	1.37	0.74	3.54
Corn	6800	7460	0.93	0.13	0.91	0.13	7.11
Alfalfa	8800	16550	0.93	0.10	0.53	0.06	8.96
Tomato	31000	4000	3.04	0.35	7.75	0.82	8.57
Cucumber	26000	1500	1.03	0.62	17.33	0.74	1.64
Watermelon	35000	5100	0.74	0.32	6.86	0.16	2.31
Palm	3500	16860	2.08	0.70	0.21	0.13	2.97

17.33, respectively. Regarding the irrigation efficiency, PFP1s show that water has had more productivity in Ghoochaabad than in the other two districts. The PFP2 is less than 1 for the entire cropping pattern which means the combination of physical and economical assessment does not work in this area. The PFP3 is more than 1 for the entire cropping pattern.

4. CONCLUSION

The results show that tomato in Soghan and cucumber in Ghoochaabad and Chahnarenj had the maximum physical productivity. Pistachio in Soghan, Tomato in Ghoochaabad and Barley and cucumber in Chahnarenj had the maximum physical-economical productivity. The interesting fact is that the maximum economical productivity has been obtained by considering alfalfa in all three districts.

In an overall aspect it can be concluded that choosing a productivity indicator is dependent on a variety of factors each of which is different for assorted cases and situations. For instance, depending on sensitive economic circumstances, economic productivity would simulate a better view of crop production and field situation but regarding the water saving policies, the physical productivity would be a more reasonable basement for decision making and management.

As for the three studied districts, EE and TFP can lead us to a better decision making in project level and system level while PFP can show us the road to choose an appropriate cropping pattern, irrigation system and water allocation pattern. The fact is that in each district in system level or project level a combination method for recognition of water productivity does not give us a clear explanation and the best thing to do is to determine each factor separately and then decide which one works better with the system situation.

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