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Assessment of Water Use Efficiency Indices in Selected Plains of Fars Province, Iran

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Abstract

This paper aimed to evaluate Water Use Efficiency (WUE) indices for crops and horticulture productions. In doing so, after gathering data from 164 farmers, we investigated water withdrawal cost indices and monetary return per cubic meter of water through two econometric and managerial approaches. Besides, water shadow pricesand dry matters of per cub meter of water were calculated. The results revealed that the average monetary return per cubic metre of water is 3875.4 IRR[1] (0.134 USD) and cost per cubic metre of well water equals 839.3 IRR (0.029 USD), four times more than the value of some current development projects of water resources. Finally, according to the findings, we suggested a corrected price trade term to adjust water monetary return indices. Control policies and government participation in funding of artificial recharge of undergorund aquifers projects were recommended as well.

Keywords:
Monetary return, Withdrawal Cost, Dry matter, Water use efficiency, Water shadow Price

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[1] *3875.4 Iranian Rials (IRR)≈US $ 1*

INTRODUCTION

Given the limited water in arid and semi-arid regions along with global warming (Hanjra and Qureshi, 2010) and the fact that almost 93 percent of renewable surface and underground water resources go into watering (Turner, 2004), Water Use Efficiency (WUE) is a serious criterion for sustainable production (Neal *et al.*, 2011). Currently, In areas with low rainfall and consecutive droughts, underground waters withdrawal has substantially increased which leads to dramatic loss of underground water levels and therefore, a water crisis in the near future is not unexpected (Hanjra and Qureshi, 2010). On way to deal with this crisis and its consequences, is determining Water Use Efficiency (WUE) and its indices e.g. monetary return, dry matter production, the cost of water per cubic meter of water and the cost of water per hectare. A precise evaluation of these indices, at least, help us for rational allocation of scarce water (Ward and Michelsen, 2002) and aid to avoid worsening the conditions through optimal management of water resources. In doing so, we can find a wide variety of research in this context. For instance, Medrano *et al.* (2015) had a review on water use efficiency of vineyards in semi-arid regions. They indicated cover crops in these areas have a desirable effect, but to avoid excessive water consumption, it is necessary to careful management by these cover crops. At a case study in the North China Plain Lu *et al.* (2016), investigated changes in water use efficiency in grain production in a long term. According to their findings, water footprint technique is better than WUE in evaluating the effectiveness of crop water use.Using a mathematical approach, Medellín-Azuara *et al*. (2010) evaluated the economic value of agricultural water under changing conditions. They concluded that the economic value of water at both the farm and aggregated level are similar. By adopting a mathematical programming, Sabuhi *et al.* (2012) also determined the efficiency of water consumption for rice producers in Fars province of Iran. Their results showed that rice producers had the potential of 65% reduction in water consumption. Using the same approach, Farija *et al.* (2009) investigated WUE of Tunisia greenhouse and its effective factors. The results indicatededuction and investment in irrigational technologies have positive effects on WUE, while the size of land has negative effects. Speelman *et al.* (2008) also analyzed WUE of farm's South Africa using DEA and it's effective factors. Their results demonstrated that factors such as method of irrigation, land ownership, land size, and crop selection are effective on WUE. Pala and Oweis, (2001) did a study on WEU and concluded that in regions with available water resources, agriculture production and WUE can be higher than complete irrigation through supplement irrigation. Tennakoon and Milroy (2003) investigated water use efficiency on irrigated cotton farms in Australia. They indicated that there is a huge potential to enhance the efficiency among the farmers. Wise *et al.* (2011) had a comparison of the biophysical and economic water-use efficiencies and finally found a better inform resource allocations. Some studies like, Berbel *et al.* (2000), de Andrade Resende Filho *et al.* (2015), Johansson (2000), Molden *et al.* (2010), Orprecio *et al.* (2016), Rogers *et al.* (2002), Speelman *et al.* (2009), Shahraki and Yaghoubi (2014), Tsur *et al.* (1997), Tang *et al.* (2015), also have analyzed water pricing and its link with efficiency and the costs of per cubic meter of water. However, to the best of authors' knowledge, no study can be found on investigating water use efficiency indices in Fars province of Iran. This is especially important because, this province is the pole of agricultural production and despite Iran severe water restrictions, increasing tendency of farmers to develop cultivation, demands for digging new wells and more intensive extraction of water resources of existent well are boosting. Therefore, the clarification of WUE indices are of policy priorities and to achieve more in saving water resources, determining water extraction costs are the principal aim of the present study.

MATERIALS AND METHODS

We collected data by interviewing 164 farmers used well water, through questionnaires in selected Fars Province plains (i.e., Shiraz,

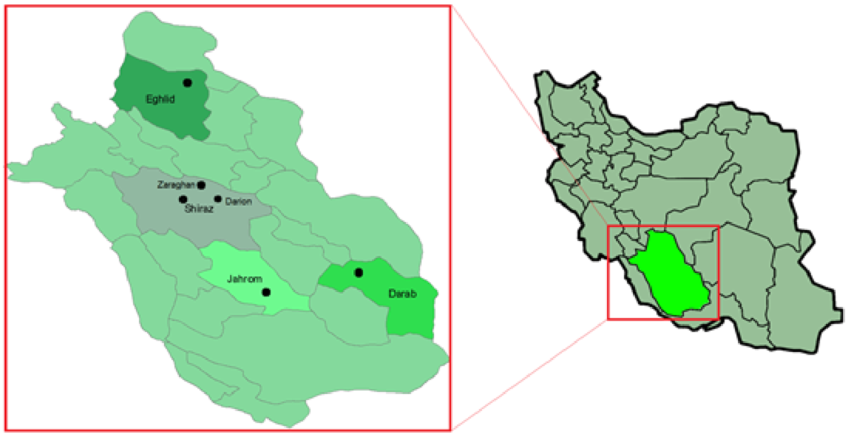

Figure 1: The geographical locations of the study area, Fars province, Iran

Zarghan, Jahrom, Darion, Darab and Eghlid) through integrating two purposive and multistage cluster sampling techniques. This province, with an area of 133,000 Kilometers, is located in the south of Iran (Figure 1).

In the first step, the amount of water withdrawal, water consumption and water requirements for each crop were determined. Next, in order to determine the monetary returns of water per cubic, an econometric approach was used. To evaluate WUE indices, we applied both econometrics and managerial methods. In Managerial method, we used a model of residual value. This relationship shows average production of a crop toward its water use. Furthermore, marginal and average productivity and the value of monetary return of water per cubic were determined. Important details of the equations and models are as follows:

Calculating the cost of water withdrawal at water wells

We used an econometric approach to calculate the costs. In this relation, not only the costs of water withdrawal of the well were considered, but also the level of costs related to distribution and transfer of water were taken into account as follows:

1- Cost of investment (wells, purchase and installation of pump motors and related equipments)

2- Operating costs (maintenance and management, fuel, repairs, etc.)

3- Transmission cost of water (pipes, construction of canal water, and other pressurized irrigation equipments from the location of the pump motor to the targeted field.)

Considering the life of well and equipments and an adequate interest rate, primary investment was converted into annual investment (Soltani, 1992). In doing so, first, the effect of inflation was neutralized. Next, the following equation was applied to convert fixed investment into annual investment.

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \quad (1)$$

where, *i* represents discount rate (25%), P shows the current value of investment and *an* equals uniform investment during the life of well. Then, this cost was added up to annual variable costs (annual operation and maintenance of wells) and thereafter the total annual costs of well were attained. Through dividing annual aggregated cost to the level of water use of each production, we obtained monetary cost of each cubic meter of water, extracted from wells.

Evaluating monetary returns per cubic meter of water

To determine the crops with more efficiency and monetary return of production, we applied the following model:
residual value model:

$$y = \frac{TR - (VC - WYC)}{VW\ (m3)} \quad (2)$$

By equation (2), monetary return per cubic meter of water can be calculated for each of crops or for the whole farm.

where, Y represents monetary return per cubic

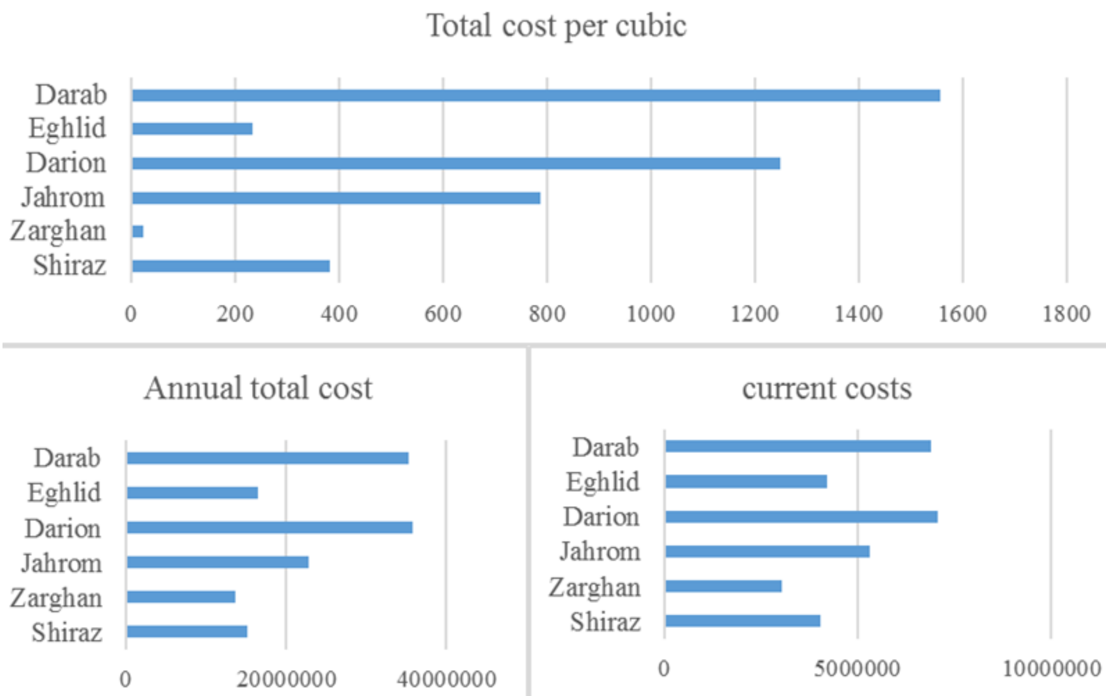

Figure 2: Clustered bar of the total cost, annual total cost and current cost

meter of water, TR is total revenue, VC shows annual production costs of crops, WYC equals annual water cost and VM indicates the volume of water use.

It is worth to note that the annual water cost of production costs was also considered. The above formula shows that how much of the monetary return connected to a production is due to water use. Since monetary return is related to the other inputs, equation (2) does not indicate monetary return of water clearly. In other word, it does not show the return per cubic meter of waterpurely.. However, its results can be usedfor comparative purposes.

Calculating dry matter of per cub meter of water use

This ratio is considered as one of the agricultural water efficiency indices, simply calculated by dividing the total amount of product (s) on water consumption.

Calculating value marginal production of water and determining optimal water use

Through estimating the following production functions, i.e., linear forms of Cobb-Douglas and transcendental function, we can assess the value marginal production of water i.e., its shadow price:

$$LnY = LnA + \beta1LnX1 + \beta2LnX2 + \ldots + \beta nLnXn \quad (3)$$

$$Y = A\Pi_{i=1}^{n} X_i^{\alpha_i} e^{\beta_i x_i} \quad (4)$$

$$Vmp = Px1 \quad (5)$$

where, X is the amount of wheat's inputs, Y reperesents wheat's production and A shows constant coefficient. *VMP* is the value marginal production of last per cubic meter of water and Px1 shows the water price. Needless to say, VMP>Px1 reveals underused water and VMP<Px1 indicates overused water. To estimate above relations, two SPSS and Excel softwares were used.

RESULTS

The results of calculating water use efficiency indices (i.e. water withdrawal cost, monetary return and dry matter production per cubic meter of water) for different plains are represented below:

Evaluate and comparison the cost of withdrawal water:

Average annual current costs of water is 4644753 IRR [1] and the equivalent annual cost

[1] *1.00 IRR=0.0000344700 USD*

Table 1. Statistic characterize of annual withdrawal cost of water in Fars Province, Iran (2013)

	Current costs (IRR)	Annual total cost (IRR)	Total cost of per cubic (IRR)
Total	4644753	24666196	840
Shiraz	4037037	15164723	382
Zarghan	3056000	13712499	22
Jahrom	5326315	22767384	786
Darion	7065583	35772154	1249
Eghlid	4197727	16541180	234
Darab	6891903	35303239	1557

(EAC) - the annual depreciation for investment in well - for each well equals 20021443 IRR. Total annual cost of each farm (well) is 24666196 IRR. The cost of per cubic meter of withdrawal water of underground resources equals 839.3 IRR, four times of some development projects of water resources.

Figure 2 intuitively shows the total cost, annual total cost and current cost of the study areas.

From these clustered charts, we can quickly become aware of the possibility of cost reduction. As these three bars show us, unlike specially Darion and Darab, Zarghan has the minimum level of the total cost, annual total cost and current cost. So then by relying on management practices, some costs of production can significantly be reduced and the production process would be more affordable.

According to Table 1, the cost of water withdrawal in Jahrom, Darion and Darab are nearly double in comparison with other plains. Evaluation of initial data also indicates making higher investment in these plains with the aim of withdrawal water from deep wells.

Calculating monetary return per cub meter of water:

Table 2 states some statistical characteristics of water monetary return in selected plains which shows high dispersion around the mean of the observations.

Monetary return of per cub meter of water of Shiraz, Zarghan, Jahrom, Darion, Eghlid and Darab are 2737.3, 4383.1, 4124, 3450, 2137.5 and 5267.5 IRR, respectively. The standard deviation of monetary return per cubic meter of water in these plain are 2184.1, 4105, 3448.7, 2906.3, 2227.7 and 7409 IRR. Therefore, the amount of standard deviation in selected plain is considerably less than standard deviation of the whole plains. This is a natural consequence. Because monetary return depends on inputs use and various combinations of inputs that these amounts are more uniform in comparison to the whole province.

Calculating the shadow price and production of dry matter per cub meter of water:

Considering wheat's base year price i.e., 2200 IRR/kg for transcendental and Cobb-Douglas functional forms, the water shadow price equal 280 and 310 IRR/m^3, and by taking into account the price 2070 IRR/kg are 261 and 290 IRR/m^3, respectively (Table 3). Marginal product and water price indicate most farmers are in the third region of production. This overuse reminds the necessity of promotional-educational programs. Therefore, besides consider technical progress in planning of cropping pattern policy makers, the WUE indices need to be taken into account as a basic planning cultivation.

Another water use efficiency index is the pro-

Table 2: Statistical characteristics monetary return per cub meter of water (2013)

	Description (IRR per cub meter)	f	Min	Max	Mean	SD
1	Monetary return crop and horticultural products in total	164	67	46697	3875	4748
2	Monetary return crop and horticultural products in Shiraz	28	211	9203	2737	2184
3	Monetary return crop and horticultural products in Zaraghan	25	263	13896	4383	4105
4	Monetary return crop and horticultural products in Jahrom	20	688	11908	4124	3448
5	Monetary return crop and horticultural products in Darion	24	598	12062	3450	2906
6	Monetary return crop and horticultural products in Eghlid	22	67	10951	2137	2228
7	Monetary return crop and horticultural products in Darab	45	187	46697	5267	7409

Table 3: The results of production function for evaluating the value of per cubic meter of water in wheat production (2013)

Wheat price (IRR)	Production elasticity of water (Cobb-Douglas form)	Production elasticity of water (transcendental form)	Value per cubic meter of water (transcendental form) (IRR)	Value per cubic meter of water (Cobb-Douglas form) (IRR)
2200	.000126	.00014	277.2	308
2070	.000126	.00014	261	290

Table 4: Some statistical characteristics of the dry matter production per cub meter of water

	Description	f	Min	Max	Mean	SD
1	The production of dry matter of crop and horticultural products in total (Ton)	162	0.1	32.8	3.3	3.7
2	The production of dry matter of crop and horticultural products in Shiraz (Ton)	27	0.2	7.1	2.7	1.9
3	The production of dry matter of crop and horticultural products in Zaraghan (Ton)	25	0.2	11.1	3.6	3.5
4	The production of dry matter of crop and horticultural products in Jahrom (Ton)	20	0.4	7.5	2.8	2.1
5	The production of dry matter of crop and horticultural products in Darion (Ton)	24	0.4	18.9	3.8	3.7
6	The production of dry matter of crop and horticultural products in Eghlid (Ton)	21	0.1	14.5	2.5	3.1
7	The production of dry matter of crop and horticultural products in Darab (Ton)	46	0.1	32.8	3.8	5.1

duction of dry matter. Table 4 shows statistical characteristics of production of dry matter per cub meter of water.

The results indicate the average of production of dry matter per cub meter of water and standard deviation are 3.3 and 3.7 respectively. Minimum and maximum of the production of dry matter per cub meter of water are 0.1 and 32.8 respectively. This shows high dispersion of observations around the mean. The results state total average of the production of dry matter per cub meter of water for Shiraz, Zarghan, Jahrom, Darion, Eghlid and Darab are 2.7, 3.6, 2.8, 3.8, 2.5 and 3.8 kg/m^3. As a result, the production of dry matter per cubic meter of water among the plains is almost equal.

CONCLUSION AND RECOMMENDATIONS

In determining water monetary return, applying econometric and mathematical programming approaches are more reliable than residual models. The results showed that the residual model and production function methods have a different monetary return. By finding factors caused these differences, we can provide the possibility of improving positive factors and decaying negative ones. Thus, factors that influence WUE indices change monetary return per cubic metre of water as well. Here, monetary return per cubic meter of water is influenced by inputs and outputs prices and their the level of use as well. Total factor productivity has a direct relationship with water use efficiency. As the prices of crops increase in a crop-year, water shadow price relatively will increase, quickly. Hence, correcting the price trade off relation, will correct the alleged water monetary productivity indices (monetary return).

Water withdrawal costs of critical plains are considerably increased. Therefore, if policies related to the control of underground water crisis do not apply, increasing direct withdrawal costs of water endangers economic use of underground water.

One of the agricultural features of Fars province is dependency to water resources on underground water. This causes that water distribution has drawbacks in comparison with other provinces that their water resources of agriculture attain through investigating in water resources development projects (dams and weir). Thus, due to the high potential withdrawal cost reduction, decline in direct costs of rinse and government participation in funding of artificial recharge of groundwater aquifers projects are necessary. According to the results, cost per cubic meter of water from underground water equals 839.3 IRR that is almost four times more than water resources development costs. Farmers in Fars province are forced to pay their withdrawal costs of water. While, for instance farmers of Payab dam, supply their water resources only with almost nothing pay (about 500000 IRR per hectare under cultivation). Therefore, amending the fair distribution of water is also indispensible.

High cost of underground water withdrawal suggests an inevitably endeavor to maintain the underground water resources and keep the underground water table. Notwithstanding the consequences of global warming, low raining, droughts and unequal distribution of rainfall, the possibility of development projects cannot be attained for most water resources. Therefore, development of artificial recharge schemes and strengthening the aquifers through performing watershed projects (maintain upstream vegetation cover) has also a high priority.

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