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Studying the Economic and Environmental Effects of Selected Irrigated Agricultural Enterprises in Iran

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Abstract: It is hard to argue that water scarcity has become an important issue in the world. The figures in all over the world indicate that agriculture sector has a large share in water consumption. Due to drought seasons in recent years, irrigated agriculture has increased significantly and the depletion of underground aquifers has become serious issue. In this study the environmental performance index (EPI) was applied to measure the economic and environmental performance of main irrigated agricultural enterprises in Iran. The EPI index was computed using data envelopment analysis (DEA) techniques. The results indicated that the environmental effects of irrigated enterprises vary significantly among enterprises and across the years of study. The results showed that wheat has the most EPI score among enterprises of study that this indicates least environmental effects and high economic return and walnut has the least EPI score that this indicates greater environmental effects and low economic return.

Key words: DEA · EPI · Irrigated enterprises · Ecological effects · Ramsar

INTRODUCTION

The relationship between irrigated agriculture and its effects on ecosystems has been performed an important role between the human need for food and nature [1]. Irrigation has been practiced for at least 4,000 years, primarily because it allows for increased productivity through more optimal timing of water application [2]. It is estimated that around 5 percent of agricultural land globally (264 million ha) is irrigated, with South Asia (35%), Southeast Asia (15%) and East Asia (7%) showing a high dependency on irrigation [3]. Irrigation accounts for approximately 70 percent of the water withdrawn from freshwater systems for human use [3]. Only 30-60 percent is subsequently used downstream, making irrigation the largest net user of freshwater [4]. While environmental impacts have been recognized as important in assessing agricultural projects and assessment processes exist, active monitoring against baseline pre-project conditions have not kept pace with developments in productivity. Some aspects often regarded as important in assessment are hydrology, water and air quality, soil properties, erosion and sedimentation, biological and ecological change, socio-economic impacts, ecological imbalances and human health [2], although all aspects are not often covered for a given project, due to external factors affecting project implementation. The importance of natural flooding to fisheries and recession agriculture and groundwater recharge have been realized only recently [1]. In addition to these problems related to the dwindling quantities of available freshwater, significant water quality problems can be traced back to agriculture in general and to irrigated agricultural enterprises in particular [5]. Irrigation or activities associated with agricultural irrigation can cause adverse impacts to wetland ecological resources and also contribute to rising water tables as a result of water percolation below the root zone, or deepdrainage, which can in turn cause salt mobilisation and salt deposition in the soil profile [6, 7, 8].

Other types of pollution that can be linked to agriculture and to irrigation, such as excessive nutrient and pesticide deposition carried by run off or percolation, create serious water quality problems including eutrophication and algal blooms [5].

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The purpose of this study was the calculation and evaluation of environmental effects on the most important irrigated plants including Wheat, barley, corn, onion, potato, tomato, walnut, grapes in Iran.

MATERIALS AND METHODS

In this study has provided a formal index number of environmental performance for measuring the relative potential of plant in producing desirable output while reducing undesirable outputs. This index measures with the ratio of a quantity index of desirable output to a quantity index of undesirable output and can be accounted as an environmental performance index [9]. However, our goal in this study is that of finding the highest environmental performance index. Since we apply some outputs that have not observable price, we apply distance function to compute our indexes [10]. Following notation are defined for the vector of inputs, the desirable outputs and the undesirable outputs respectively.

$X=(x_1, x2, x3 ...) \in R^M_+$
$Y= (y_1, y2, y3 \dots) \in R^M_+$
$d= (d_1, d2, d3\dots) \in R^M_+$
$U= (u_1, u2, u3\dots) \in R^M_+$

Hence, the technology has all feasible vectors (x,y)
{T=(X, Y): X can produce Y = (u, d)}

Two introduced assumptions are as following:

- Weak disposability of outputs:

if $(x, u, d) \in R^M_+$ and $0 \leq \theta \leq 1$, $(x, \theta u, \theta d) \in R^M_+$

The weak disposability assumption makes sure that both the desirable and the undesirable outputs can be disposed proportionally. It also implies that it is not possible to reduce only the undesirable outputs holding the inputs and the desirable outputs constant.

- Null-jointness

if $(x, u, d) \in R^M_+$ and $d = 0$ then $u = 0$

This assumption means that it is technically impossible to produce only desirable outputs without producing any of undesirable outputs. It also means that the only way to totally eliminate the production of the undesirable outputs is to stop the production of the desirable outputs.

Then we can define an output distance function as defined by Shephard [11] for the desirable output:

$$D_d(x, d, u) = \inf \{\theta: (x, \frac{d}{\theta}, u) \in R^M_+\}$$

The value of the desirable output distance function measures the maximum amount by which the desirable output vector can be deflated by a factor θ, given input vector and undesirable output vector [12]. If x° and u° be the input and the undesirable output vectors respectively and d^k and d^l be the desirable output vectors that are being compared we can define the quantity index of desirable output as:

$$Q_d(x^\circ, u^\circ, d^k, d^l) = \frac{Dd(x^{\Xi}, d^k, u^{\Xi})}{Sd(x^{\Xi}, d^1, u^{\Xi})}$$

This index shows the achievement of unit (k) in expanding its desirable output while using the same level of inputs and producing the same level of undesirable output as another unit [13].

This index satisfies the following properties.

1. Homogeneity:

$$Q_d(x^\circ, u^\circ, \lambda d^k, d^l) = \lambda Q_d(x^\circ, u^\circ, d^k, d^l)$$

2. Time reversal:

$$Q_d(x^\circ, u^\circ, d^k, d^l). Q_d(x^\circ, u^\circ, d^l, d^k) = 1$$

3. Transitivity:

$$Q_d(x^\circ, u^\circ, d^k, d^l). Q_d(x^\circ, u^\circ, d^l, d^s) = Q_d(x^\circ, u^\circ, d^k, d^s)$$

4. Dimensionality:

$$Q_d(x^\circ, u^\circ, \lambda d^k, \lambda d^l) = Q_d(x^\circ, u^\circ, d^k, d^l)$$

A distance function for the undesirable outputs similar to the desirable outputs is determined by Shephard [11] as:

$$D_u(x, d, u) = \sup \{\lambda: (x, d, \frac{u}{\lambda}) \in R^M_+\}$$

This index shows the achievement of unit (k) in contracting its undesirable output while using the same level of inputs and producing the same level of desirable output as another unit [13].

From the tradition of Hicks-Moorsteen we can describe environmental performance index as ratio between these two indexes i.e. desirable output and undesirable output following as:

$$EPI^{k,L} = \frac{Qd(x^{\Xi}, d^{\Xi}, d^{k}, d^{1})}{Qu(x^{\Xi}, d^{\Xi}, u^{k}, u^{1})}$$

This index can measure production rate of desirable output versus per unit of undesirable output. In computing the environmental performance indicators for every irrigated plants in our sample, we chose gross revenue of each irrigated plant as the desirable output and the salinity impact index and the ecologically weighted water withdrawal index (EWWWI) are two undesirable outputs and inputs including volume of water applied for irrigation and cost of all inputs excluding water for measurements we utilized the Azad [13] methodology.

To create undesirable output, we calculated damage cost resulting from the environmental pressure exerted by each irrigated enterprise with ecologically weighted water withdrawal index (EWWWIij). This index includes some environmental specifications that are being damaged. In this study we considered ecologically characteristics that are being harmed in international wetlands of Iran. The Convention on Wetlands of International Importance, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The Ramsar Convention is the only global environmental treaty that deals with a particular ecosystem. The treaty was adopted in the Iranian city of Ramsar in 1971 and the Convention's member countries cover all geographic regions of the planet. A wetland is identified as being of international importance if it meets at least one of the nine criteria [12]. These are: (1) the site contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biographic region; (2) it supports vulnerable, endangered or critically endangered species or threatened ecological communities; (3) it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biographic region; (4) it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions; (5) it regularly supports 20,000 or more water birds; (6) it regularly supports one percent of the individuals in a population of one species or subspecies of water birds; (7) it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity; (8) it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend; and (9) it regularly supports one percent of the individuals in a population of one species or subspecies of wetland dependent non-avian animal. Our study's region has 4 characteristics of these characteristics.

Azad [11] for measuring ecologically weighted water withdrawal index (EWWWI), first measured environmental pressure caused by irrigation of plants with water withdrawal Index (WWI).

WWI is measured as follows:

$$WWI_{ij} = (A_{ij} . R_{ij}) / W_j$$

where WWIij denotes water withdrawal index of an plant of type I (i=1, …, I) in a given region j (j=1,…J); Aij is the average annual area under irrigation for enterprise of type i within region j; Rij is the water application rate in a given year for enterprise of type i in region j and Wj indicates average annual surface water availability in region j [13]. For calculation harmed characteristic that results from water withdrawals from irrigation, we described an index named as Ecological Assets Index (EAI) simulated Azad [13], that could be accounted as:

$$EAI_j = \left(\sum_{r=1}^{R} \frac{C_r - C_k}{N_c} * A_j \right)$$

C_r represents the number of Ramsar criteria met by Ramsar wetlands, C_k represents the number of Ramsar criteria of wetlands that damaged, A_j is the area Ramsar, N_c is the maximum number of Ramsar criteria (Nine in this case). Ecologically weighted water withdrawal index calculated as:

$$EWWWI_{ij} = WWI_{ij} \times EAI_j$$

The $EWWWI_{ij}$ then represents a proxy damage cost weighted quantity index of undesirable output from a given type of irrigation enterprise in a given area and can be used in deriving an EPI for that type of enterprise [13].

Appendix

Table 1: Mean values of the economic variables and environmental pressures for irrigated enterprises, 2001-2011

Irrigated Enterprises	Mean of Volume of water applied (m^3/ha)	Mean of All cost (excluding water) (million Rial)	Mean of Gross revenue (million Rial)	Mean of Ecologically weighted water withdrawal index ('000')
Wheat	6570	386711	495810	81.8
Barley	6326	323277	366314	350.2
Corn	4323	533475	1356030	253.9
Onion	4435	1875962	3040949	97.4
Potato	4762	1923308	3582493	191.2
Tomato	9133	1371478	2502384	135.8
Walnut	6009	4762339	9621723	118.2
Grapes	6060	3577442	9053144	44.7
Mean	5952.25	1844249	3752356	159.15

Note: Data obtained from Agricultural Research and Education and extension Organization and research

Wheat, barley, corn, onion, potato, tomato, walnut, grapes are the eight types of irrigated plants investigated in this study. Production rates, annual area planted and cost data for each of these irrigated plants has collected from ministry of agriculture of Iran [14] in 2001-2011. Water application rate in a given year for each plant was gathered from the Agricultural Research, Education and Extension Organization (AREEO) [15]. The gross revenue and cost data and Salinity level of soil were obtained from published sources and research reports [15, 16, 17]. Data for average annual surface water availability, water inflows and outflows in region and salinity data for water were gathered from Ministry of Regional Water and Ministry of Management of Water Resources [18]. As stated gross revenue was treated as desirable output and ecologically weighted water withdrawal index (EWWWI) and the salinity impact on soil and water were acted as undesirable outputs and applied water and all costs (excluding the cost of water) acted as inputs. The mean values of these variables for each of these irrigated plants were presented in Table 1 in appendix. With these data the component of distance function as described in above Equations were obtained with mathematical program. In this study equations were solved using the General Algebraic Modeling System (GAMS). Then undesirable output index and desirable output index used to obtain the environmental performance index (EPI) for each irrigated plant.

RESULTS AND DISCUSSIONS

The results for the indexes of desirable output, undesirable outputs and environmental performance index (EPI) obtained using the methodology described above are shown in Table 2 in appendix.

The most value of environmental Performance index (EPI) for these irrigated enterprises is 6.746, whereas the desirable output quantity index is 156.771 and the undesirable quantity index is 87.708. The quantity index of desirable output for wheat (156.771) indicates that this crop produces 156.771 times the level of output (gross revenue) producing the same level of environmental effects and using the same level of inputs as the hypothetical reference unit. On the other hand, the quantity index of undesirable outputs shows that wheat produces 23.239 times as many bad outputs unit. The ratio of these two indexes produces an environmental performance index of 6.746. As was stated before the EPI measures production rate of desirable output per undesirable output therefore higher value of the EPI indicates the better environmental performance.

The most value of environmental Performance index (EPI) belong to wheat and the lowest value belong to walnut. It is observable that in this sample walnut and grapes has the most damage on environment.

Low EPI score indicates the greater environmental effects and low economic return or in the other word, a high EPI score indicates the least environmental effects and high economic return. For a good comparison we need to incorporate observation for 10 years period. The value of Environmental performance index (EPI) for each of these irrigated plants between 2001 and 2011, was presented in Table 3 in appendix.

This performance variation of the same enterprise in different years has several reasons. The main reason is due to amount of rainfall. Another factor is dependent on the methods of irrigation that affects the amounts of water withdrawals. In addition there are many differences between irrigation enterprises in each year. The main cause of this variability is due to the environmental impact that occurs by water withdrawals during the irrigation of enterprises.

Table 2: Mean values for quantity indexes and environmental performance index of the irrigated enterprises in 2001-2011

Irrigated enterprises	Mean of quantity index of desirable outputs	Mean of quantity index of undesirable outputs	Mean of Environmental performance index (EPI)
Wheat	156.771	23.239	6.746
Barley	139.058	30.697	4.53
Corn	127.22	69.368	1.834
Onion	98.72	39.252	2.515
Potato	100.439	17.486	5.744
Tomato	78.232	18.988	4.12
Walnut	109.372	87.708	1.247
Grapes	161.55	77.668	2.08
Mean	121.42	45.55	3.602

Note: Data obtained from research

Table 3: Environmental performance index (EPI) of irrigated enterprises between 2001 and 2011

Year	Wheat	Barley	Corn	Onion	Potato	Tomato	Walnut	Grapes
2001	6.852	3. 122	1.62	2.106	3.535	3.418	0.804	1.098
2002	7.629	3.272	2.21	0.988	4.654	4.663	0.831	2.545
2003	5.532	3.367	0.76	1.087	3.812	2.603	0.868	1.219
2004	8.878	4.009	0.99	1.8066	4.539	2.089	1.333	0.588
2005	7.088	2.535	0.082	1.16	4.87	1.173	0.953	1.131
2006	4.722	3.099	1.32	1.7001	3.509	2.785	0.798	1.1175
2007	6.498	3.76	0.77	1.0914	4.257	1.624	0.969	1.235
2008	7.635	2.09	1.378	3.022	3.22	2.9	0.638	1.21
2009	4.966	3.232	1.94	2.907	4.6	4.093	0.833	1.112
2010	8.661	4.7	2.082	1.976	4.381	4.4	1.541	2.339
2011	5.745	3.099	1.52	2.872	3.509	3.207	0.698	2.438

Note: Data obtained from research

CONCLUSION

In this paper an index was introduced to estimate the economic and environmental performance of irrigated agricultural enterprises. The environmental performance index accounts the desirable economic outputs from a production process and the undesirable environmental impacts associated with the production process. To approximate the potential damage costs caused by water withdrawals, an index was used to weigh the water withdrawal for irrigation that has been named Ecological Assets Index and uses the characteristics of Ramsar wetlands. The results of EPI scores indicate the trade-offs between the economic and environmental performance of irrigated enterprises [20]. This paper computed the environmental performance index for selected enterprises in the years of study that its results can use to identify enterprises which water withdrawals are creating environmental pressure and has not creating considerable economic returns.

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