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Evaluation of Irrigation Cooperatives Situated in Izmir Province by using Data Envelopment Analysis

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Abstract

Considering the enlargement of agricultural areas, irrigation efficiency should be increased to obtain the sustainable use of limited water resources. In this study 13 irrigation cooperatives situated in Izmir province of Turkey selected and visited to evaluate their performance. To make this, Data Envelopment Analysis has been used. This analysis is a linear programing technic to determine the relative efficiency of decision making units (DMU) (in this study irrigation cooperatives). In this study, the input oriented DEA model has been used to focus on the efficient use of irrigation water. The objective of the analysis has been to determine where the application of water is the most profitable. While evaluating the performance of cooperatives irrigation water volume (m3) and total irrigated area (ha) have been used as input, and financial agricultural gain (TL) has been used as an output. In addition to this, irrigation water loss of each irrigation cooperative has been calculated by subtracting irrigation water amount from projected water amount by using DEAP software. The results have provided the efficiency scores of irrigation cooperatives and determined which ones have been the most efficient. DEA is a useful analysis to determine irrigation performance of cooperatives situated in İzmir province of Turkey.

Keywords: Data envelopment analysis • Irrigation • Efficiency • Izmir province

Introduction

Irrigation water is becoming an increasingly scarce resource for agriculture in many regions of the world. Water shortage has become an increasingly social and economic concern for policy makers and for those who must compete for these resources.

With increasing population of the world, the usage of water also increased. Nearly 70 per cent of water is used in agriculture in the world. Turkey uses 74 per cent of water in agriculture sector (TÜSİAD, 2008). In 2003, the average amount of water used for agricultural purposes is 29.6 km^3 of the total use of 40.1 km^3 water (DSI, 2006a).

The objective of this study is to determine the irrigation performances of selected irrigation cooperatives situated in Izmir province of Turkey. Comparing the efficiencies of irrigation cooperatives one can infer how the application of water produces the highest benefit and where irrigation is most effective in relation to gains of irrigation cooperatives.

Materials and Methods

Irrıgation Cooperatives

In this study irrigation performances of selected irrigation cooperatives situated in İzmir province have been evaluated by using Data Envelopment Analysis.

According to number 1163 law in Turkey, maintenance, governance and responsibility of irrigation facilities have been given to irrigation cooperatives Irrigation cooperatives came into being to safeguard farmers' economic wellbeing and to help them. They can be organized by villages, municipalities, special governing bodies and individuals as well. Studying areas of irrigation cooperatives are as follows;

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- To give agricultural education to its members,
- To make land rehabilition,
- To ensure credits to its members,
- To ensure electricity to its members,
- To distribute agricultural instruments and items,
- To help irrigation practices [1]

According to Turkey's Cooperative Report (2015), there are 2534 irrigation cooperative and 303968 cooperative member in our country. State Waterworks (2015) states that 478421 hectare lands are irrigated from wells found in these cooperatives in Turkey [2].

According to raport mentioned above, 14 out of 81 provinces lack irrigation cooperatives. Considering provinces, Konya has the greatest number of cooperatives and is followed by Afyonkarahisar, Mersin, Burdur, Denizli, Isparta and İzmir.

In Izmir province there are 65 irrigation cooperatives which irrigate 13487 hectare lands. For this study, 14 irrigation cooperatives have been selected and data belonging to these cooperatives have been obtained by visiting these cooperatives. Data's have included 2012-2016 years period. (**Table 1**)

Data Envelopment Analysis

Although the DEA approach has been widely used in different areas, its application to water resources management problems, particularly to irrigation water management alternatives, is specific examples include the efficiency studies of the water companies in U. K [3], the irrigation districts in Andalusia (Spain) and the reservoir systems in the Paraguacu river basin in Brazil [4]. This study proposes the use of data envelopment analysis while using a series of inputs and outputs for each irrigation cooperative. DEA obtained relative efficiency of a given unit (in this study irrigation cooperative) and finds the optimal and the best performing unit (irrigation cooperative). The main advantages of DEA are as follows:

- Multiple inputs and outputs can be used while ascertaining efficiency and a specific production function is not recurred,
- Decision maker doesn't need prior information about weights of inputs and outputs.
- For each decision making unit (in this study irrigation cooperatives),

Table 1: Selected Irrigation Cooperatives used in this Study İncluding 2012-2016 Period.

Municipality Name	Name Of Irrigation Cooperative	Area (da)	Number of Members	Number Of Wells	Operation Starting Date
Kemalpaşa	Armutlu	4500	484	11	1973
Kemalpaşa	Ören	8000	661	17	1980
Menderes	Çamönü	2000	131	6	2000
Tire	Kahrat	3000	237	7	1972
Torbalı	Tulum	2000	69	5	1993
Bayındır	Kızılcaova	2000	120	6	1977
Bayındır	Turan	2400	106	4	1982
Ödemiş	Kaymakçı	2620	160	6	1983
Ödemiş	Yolüstü	2200	262	11	1982
Selçuk	Selçuk	6000	280	4	1976
Kemalpaşa	Bağyurdu	8000	817	19	1972
Bergama	Aziziye	450	57	4	1997
Bergama	Ahmetbeyler	1100	165	7	2000
Tire	Karateke	1000	75	4	2001

efficiency id compared to that of an ideal unit (irrigation cooperative) rather than an average performance [5].

Data envelopment analysis is a multifactor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units (in this study irrigation cooperatives). The efficiency score ıı the precence of multiple input and output factors is defined as:

$$Ef=\frac{Weighted\ sum\ of\ outputs}{Weighted\ sum\ of\ inputs}$$

Where;

Ef= Efficiency

Assuming there are 'n' Decision Making Units, each of with m inputs and s outputs, the relative efficiency score of a test decision making unit (irrigation cooperative) is obtained by following model proposed by [6]:

$$\sum_{k=1}^{s} V * Y : \sum_{j=1}^{m} u * x$$

Where;

k= 1 to s,

j=1 to m,

V=weight given to output k,

Y= amount of output produced by DMU,

U=Weight given to input j,

X= amount of input utilized by DMU.

To analyze potential efficiency gained accurately based upon benchmarks requires that we consider all inputs and outputs simultaneously. That is, it is necessary to take a systemic approach to efficiency analysis. DEA is a non-parametric mathematical programming methodology based upon the work of Farrel (1957) [7]. It involves the use of linear programming to construct an efficiency programming that provides a means by which all units can be assessed in terms of relative efficiency. DEA takes the observed input and output quantities to form a production possibility space against which the individual farms (irrigation cooperatives) are compared to determine their technical efficiency. The efficiency of a farm can be assessed in term of input and output use. Input use efficiency is assessed in terms of how much extra output can be produced for a given set of inputs presently being used.

Output efficiency measures the amount by which the output of a farm (irrigation cooperative) can be increased without the need to increase the inputs. The appeal of DEA is that it deals with multiple inputs and outputs providing quantitative insights into the farm and to magnitude of adjustments needed to render an inefficient farm (irrigation cooperative) efficient [8].

In this study, we focus on technical efficiency measurement with an input oriented DEA model because in the context of increasing water scarcity, it is more relevant to consider potential decreases in water use than increase in output. Input oriented efficiency scores range between 0 and 1, whereas output oriented efficiency scores range between 1 to infinity; in both cases 1 is efficient score.

Several software is available for DEA to solve any efficiency problem. Since it is a freeware program and gives the projected values of inputs and outputs for each DMU (irrigation cooperative), DEAP software is used in this study.

Calculation of irrigation water input based on years 2012-2016

In this study, yearly irrigation water (m^3) given to each cooperative must be calculated and must be used as an input. To do this, financial documents belonging to cooperatives have been used to learn how much Money they earned in a year by selling water; this helped us in calculating pomp working time in a year.

Sample Calculation

Irrigation Cooperative: Oren

Area Of Cooperative: 800 hectare

Well Discharge: 25 lit/s = 90 m^3/hour

Financial Gain Obtained by Selling Water= 319480 TL/year (Taken from financial documents)

Money Gained per Irrigation Hour= 12 TL/hour

$$\text{Pomp Working Time}\ \left(\frac{\text{hour}}{\text{year}}\right)=\frac{\text{Financial Gain Obtained By Selling Wate}}{\text{Money Gained Per Irrigation Hour}}$$

$=\frac{319480}{12}$ = 26623 hour

Irrigation Water Input = Pomp Working Time (hour) * Well Discharge (m^3/hour)

=26623 (hour) * 90 (m^3/hour)

=2396070 m^3/year

In addition, financial agricultural gain of an irrigation cooperative in a year have been calculated by multiplying the unit price of every agricultural product (kg/TL) with amount of the product yielded per declare (kg) and area used for every agricultural product (declare). By adding this multiplication for every agricultural product, financial gain of every irrigation cooperative has been obtained [9].

While evaluating the irrigation performance of these cooperatives yearly agricultural financial gain (TL/year) has been taken as an output and irrigation water used in a year (m^3/year) and irrigated land has been taken (hectare) as an input. These output and input values are shown in (**Table 2**).

Table 2: Output and input values used in Data Envelopment analysis.

Name of İrrigation Cooperative	Output	İnput Amounts	
	Financial Gain *1000 (TL)	İrrigation Water (*1000 m³)	Area of Cooperative (hectare)
Ören	29512	2240	800
Armutlu	28558	914	450
Kahrat	18008	771	300
Yolüstü	17200	2047	220
Çamönü	113956	1070	200
Aziziye	30771	332	45
Turan	18462	588	240
Ahmetbeyler	11114	924	110
Selçuk	17897	1893	600
Bağyurdu	31062	3223	800
Kaymakçı	18556	599	262
Karateke	20500	948	100
Tulum	22826	1568	200

Table 3: Data Envelopment Analysis results of Irrigation Cooperatives.

No	Name Of İrrigation Cooperative	Technical Efficiency	Pure Technical Efficiency	Scale Efficiency
1	Ören	0.124	0.148	0.835
2	Armutlu	0.293	0.363	0.808
3	Kahrat	0.219	0.431	0.509
4	Yolüstü	0.114	0.205	0.559
5	Çamönü	1.000	1.000	1.000
6	Aziziye	1.000	1.000	1.000
7	Turan	0.295	0.565	0.522
8	Ahmetbeyler	0.148	0.409	0.361
9	Selçuk	0.089	0.175	0.506
10	Bağyurdu	0.090	0.104	0.872
11	Kaymakçı	0.291	0.554	0.525
12	Karateke	0.300	0.450	0.666
13	Tulum	0.167	0.225	0.742
Mean		0.318	0.433	0.685

Results

In this study to find the mean technical efficiency (TECRS), pure technical efficiency (TEVRS) and scale efficiency of 13 irrigation cooperative situated in Izmir province have been found by using DEA (Data Envelopment Analysis). These values have been found as 0.318, 0.433 and0.685 respectively as shown in (**Table 3**).

Mean technical efficiency of cooperatives is 0.318. That means that there is a 69 per cent input loss in all cooperatives. This also means that irrigation cooperatives have difficulty ın using resources in a suitable way. According to this, cooperatives must use their resources in a better way and must increase their technical efficiency by 69 per cent.

According to DEAP software results, technical efficiency of Aziziye and Çamönü irrigation cooperatives has been found as 1. That meant that these 2 cooperatives are working effectively and can be regarded as successful and ideal considering input usage. Çamönü cooperative is ideal because agricultural yield per hectare is greater than other cooperatives. Also, farmers of Aziziye are raising products such as cotton and olive which have greater economic values. Besides they are using less water as an input. On the other hand, Aziziye irrigation cooperative has a small area of production and with a decrease of input. (Irrigation area) efficiency scores increases disproportionally.

DEA results of 13 irrigation cooperatives and their classification are given in table 4.

According to DEA results obtained, 8 out of 13 irrigation cooperative have a technical efficiency score of 0 and 0.25. Four of them have technical efficiency values between 0.25 and 0.50. Only one irrigation cooperative's efficiency score is 1. As can be seen in (**Table 4**), 26 per cent of all irrigation cooperatives have a technical efficiency between 0 and 0.25. Only 3 per cent of cooperatives have a technical efficiency score of 1.

Irrıgation Water Losses Calculated Using DEAP Software

Water losses due to inefficiencies of operation of cooperatives has been calculated as fallows;

Water Loss = İrrigation water per hectare (m³/hectare)-Projected water per hectare (m³/hectare).

Calculated irrigation water amounts have been given in (**Table 5**).

Irrıgation water losses of cooperatives are due to inefficient use of water resources in Izmir province. The mean irrigation water usage of irrigation cooperatives is 5159 m³/hectare. Ahmetbeyler cooperative used the greatest amount of water which is 8400 m³/hectare. On the contrary, Armutlu cooperative use the least amount of irrigation water totaling 2031 m³/hectare. According to Data Envelopment Analysis comprising 13 irrigation cooperatives' mean water loss have been found as 3796 m³/hectare. Çamönü cooperative is the only cooperative which has a zero difference between given and projected water amounts. That means that Çamönü cooperative hasn't lost any water in its operations. On the other hand, other irrigation cooperatives have used more water than projected values. Karateke cooperative has the greatest water loss of 8518 m³ per hectare while Armutlu has the least amount of water loss [10].

Table 4: Classification of DEA results.

Efficiency (%)	VRS Model	
	Number of Cooperatives	Percentage of İrrigation Cooperatives
0<TE<=25	8	26
25<TE<=50	4	13.3
50<TE<=75	1	3.3
75<TE<=100	2	6.6
Total	15	100

Table 5: Irrigation Water Losses of Irrigation Cooperatives.

No	Name of Irrigation Cooperative	Irrigation Water Per Hectare (m³/hectare)	Projected Water Amount per Hectare(m³/hectare)	Lost Irrıgation Water Per Hectare (m³/ha)
1	Ören	2800	1384	1416
2	Armutlu	2031	1340	691
3	Kahrat	2570	845	1725
4	Yolüstü	9304	807	8497
5	Çamönü	5350	5350	0
6	Aziziye	7377	1444	5933
7	Turan	2450	866	1584
8	Ahmetbeyler	8400	521	7879
9	Selçuk	3155	840	2315
10	Bağyurdu	4028	1458	2570
11	Kaymakçı	2286	871	1415
12	Karateke	9480	962	8518
13	Tulum	7840	1024	6816

Conclusion

Evaluation of irrigation systems and learning about system performance is very important to determine how water resources are being used and also necessary to compare the systems with each other. In addition, with this evaluation of systems we can learn if the objectives stated in planning stage of scheme have been met.

In this study performance evaluation of 13 irrigation cooperatives situated in Izmir province of Turkey has been made by using DEA analyst using DEAP software. The technical efficiency of 0.318 means that irrigation cooperatives have to increase their resource usage by 69 per cent. The irrigation cooperatives which are the best ones have technical efficiency scores of 1. These cooperatives are Çamönü and Aziziye irrigation cooperatives. Considering irrigation water losses Çamönü cooperative is the best performing cooperative.

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