

## THE EFFECTS OF MEASURING IRRIGATION WATER USING PREPAID WATER METER ON WATER SAVING AND ENVIRONMENT: A CASE STUDY FROM TURKEY

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### ABSTRACT

Many countries in the world are facing problems regarding irrigation operation, maintenance and management activities, over use of water, illegal use of water and pricing of water. The volumetric pricing in irrigation is becoming an important implementation method in resolving this problem. In order to accurately measure irrigation water, it is necessary to have a water meter (counter) in each parcel of land to record the amount of water. Pre-paid meters provide accuracy in measuring water and to collect in full. In this study, performance indicators of irrigation system including water distribution, financial, and production of Kayacık irrigation before and after usage of prepaid water meters were examined. It has been determined that there was a significant reduction in the amount of water usage in per the irrigation area after usage of prepaid water meters. While the amount of water usage in the irrigated area was 7 414 m<sup>3</sup>/ha in 2012, became 3.617 m<sup>3</sup>/ha in 2017. A savings of approximately 51% in the amount of water usage in the area was attained. As a result, significant amount of increase was realized in the production value for the amount of irrigation water usage in the area. The cost recovery ratio was calculated as 0,76 in 2013 and 1.07 in 2017. In summary, by using prepaid water meters for water distribution excess water usage in irrigation has been avoided and high water usage collection ratio has been carried out without problems. Furthermore, the amount of water evacuating to drainage canal has significantly been reduced.

**Keywords:** Water saving in agriculture, Reducing excessive water consumption in irrigation.

### 1. INTRODUCTION

Having a water potential of 1 380 m<sup>3</sup>/capita-year, Turkey cannot be classified as a water rich country. In the current situation approximately 73% of limited water resources of Turkey is allocated for agricultural purposes. Under these circumstances, effective water utilization and water saving irrigation systems are the most critical issues to be considered. Furthermore, water use efficiency is closely related to, and in several cases overlaps, other basic concepts of current environmental resource management.

There are so many problems regarding irrigation water using in most countries; excess and illegal water use, water loss and irrigation water pricing are among these problems. However, the high performance results obtained by the studies can be achieved to save water, increase productivity and reduce negative environmental impacts (Lencha, 2008). In this context, volume-based irrigation water pricing method

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is the most desirable method because sustaining the fixed relationship between the amount of irrigation water and payment for it. There are so many research studies that volumetric water pricing and effective collection of irrigation water fees are stimulating force (Unver and Gupta, 2003; Yildirim, 2004).

On the other hand there have been improvements in adopting more efficient water application technologies such as micro irrigation technology induced by government subsidies. The uptake of these technologies by irrigators can be further increased by shifting towards volumetric pricing practices (Cakmak, 2010). In order to effectively apply this method, a water meter instrument which records amount of water used for each parcel is required. The one of the minimum requirements for volumetric water charges is the accuracy of the flow rate measurement device (Burt, 2007). Properly selected and maintained water meters can give the most accurate and easiest method for measuring the amount of water entering the irrigation facility (Baum et al, 2012).

The prepaid water meters not only perform accurate water measure, but also guarantee to collect water fee. Prepayment system is the payment system based on the principle of calculating the water amounts of water users and paying the usage fee in advance. A subscriber card is defined for each water meter. With these cards, subscriber may charge as much credit as requested from the credit loading office. When the smart card is read into the meter, these credits are transferred to the water meter. The water meter closes valve when credit transferred fully. So the irrigator uses as much water as previously planned and uncontrolled water use is prevented.

In this study, Kayacık irrigation scheme operated by Kayacık Irrigation Association was taken as material for benchmarking irrigation performance for the years between 2012 and 2017. After 2015, prepaid water meter is used for water distribution in this system. Main purpose of this study is compared the irrigation performance indicators before and after usage of prepaid water meters. The system's performance is assessed using the water delivery, financial and productive performance indicators proposed by the International Programme for Technology and Research in Irrigation and Drainage IPTRID/World Bank study on benchmarking in the irrigation and drainage sector, and benchmark values for performance identified.

## 2. METHODS

The Kayacık irrigation area is located within the boundaries of Oğuzeli district of Gaziantep province in the Euphrates -Tigris basin (Figure 1.) Monthly mean temperature, mean precipitation are 16,40° C, 437.84 mm respectively (DSI, 2017).

Kayacık irrigation facilities has been gradually allowed for irrigation by the State Hydraulic Works since 2006. It was started to be operated completely in 2012. Project area has been irrigated by Kayacık Dam which feeds by Ayniyar, Tuzel and Sacir creeks. Total net irrigation area is 10 800 ha and has been irrigated by gravity. Canal type ratios as per irrigated area are: % 5 classic canal and % 95 pipeline (pressured) irrigation network. The responsibility of operation, maintenance and management of Kayacık irrigation facility is transferred to water user association. The development of Kayacık irrigation by years is given in Table 1.

Approximately 60 percent of the population is engaged in agriculture in the region including study area. Cropping pattern mainly consists of cereal, maize and cotton. Vegetables and fruits are also grown.



**Figure 1.** The location of Kayacık irrigation area in Turkey.

**Table 1.** The development of Kayacık irrigation

Years	Irrigation command area (ha)	Irrigated area (ha)	Irrigation ratio (%)
2012	10 800	11 754	109
2013	10 800	11 116	103
2014	10 800	8 245	76
2015	10 800	9 866	91
2016	10 800	14 543	135
2017	10 800	19 528	181

Volume based irrigation was started by instating prepaid water meter in irrigation facility in 2014. First year there were some problems in terms of application but following years water distribution using prepaid water meter has done successfully.

In this study, performance of Kayacık irrigation scheme is assessed for the years before and after usage of prepaid water meter. The study period is between 2012 and 2017. The system's performance is assessed using the water delivery, financial and productive efficiency performance indicators proposed by the International Programme for Technology and Research in Irrigation and Drainage IPTRID/World Bank study on benchmarking in the irrigation and drainage sector, and benchmark values for performance identified. Used performance indicators are shown in Table 2.

**Table 2.** Used performance indicators in the study (Malano and Burton, 2001)

Domain	Performance Indicators	Data required
Water delivery performance	Annual relative irrigation supply	Total daily measured water inflow to the irrigation system Total annual volume of crop water requirement
	Annual irrigation water delivery per unit command area (m <sup>3</sup> /ha)	Total daily measured water inflow to the irrigation system Total command area
	Annual irrigation water delivery per unit irrigated area (m <sup>3</sup> /ha)	Total daily measured water inflow to the irrigation system Total annual irrigated crop area
	Cost recovery ratio	Total revenues collected from water users Total management, operation and maintenance

Domain	Performance Indicators	Data required
Financial		(MOM)cost
	Maintenance cost to revenue ratio	Total maintenance expenditure Total revenue collected from water users
	Total MOM cost per unit area (US\$/ha)	Total management, operation and maintenance expenditure Total command area
	Revenue collection performance	Total revenues collected from water users Total service revenue due
	Staffing numbers per unit area (persons/ha)	Total number of MOM personnel employed Total command area serviced by system
Productive efficiency	Output per unit command area (US\$/ha)	Total annual value of agricultural production Total command area
	Output per unit irrigated area (US\$/ha)	Total annual value of agricultural production Total command area
	Output per unit irrigation supply (US\$/m <sup>3</sup> )	Total annual value of agricultural production Total daily measured water inflow to the irrigation system

The data used in the determination of the performance indicators were obtained from the DSI Monitoring and Evaluation reports and Kayacik Irrigation Association. Also field observations were made.

### 3. RESULTS AND DISCUSSION

#### 3.1 Water Delivery Performance

For determining the water delivery performance, the annual relative water supply ratio (Table 3), total annual water delivery per command area and total annual water delivery per irrigated area (Table 4) were investigated.

**Table 3.** The annual relative water supply ratio

Years	Total annual volume of irrigation water inflow (m <sup>3</sup> )	Total volume of water required by crop (m <sup>3</sup> )	Relative water supply
2012	87 150 000	69 889 284	1.25
2013	81 872 010	85 037 400	0.96
2014	57 480 000	51 086 020	1.13
2015	66 400 000	74 646 156	0.89
2016	68 412 500	75 507 256	0.91
2017	70 640 000	98 382 064	0.72

**Table 4.** Total annual water delivery per command and irrigated area

Years	Total annual volume of irrigation water inflow (m <sup>3</sup> )	Irrigation command area (ha)	Irrigated area (ha)	Water delivery per command area (m <sup>3</sup> /ha)	Water delivery per irrigated area (m <sup>3</sup> /ha)
2012	87 150 000	10 800	11 754	8 069.44	7 414.50
2013	81 872 010	10 800	11 116	7 580.4	7 365.24
2014	57 480 000	10 800	8 245	5 322.22	6 971.50
2015	66 400 000	10 800	9 866	6 148.15	6 730.18
2016	68 412 500	10 800	14 543	6 334.49	4 704.15
2017	70 640 000	10 800	19 528	6 540.74	3 617.37

The annual relative water supply ratio was the highest in 2012 with 1.25. After installed prepaid water meter this ratio has declined. If the water supply ratio is 1, the water given to the irrigation is sufficient, if it is less than 1, it is insufficient, and in condition that it is greater than 1, it is too much (Beyribey, 1997). Total annual water delivery per command area was the lowest in 2014 with 5 322, and the highest in 2012 with 8 069,44 m<sup>3</sup>/ha. Total annual water delivery per irrigated area was the lowest in 2017 with 3 617.37 m<sup>3</sup>/ha and the highest in 2012 with 7 414.50 m<sup>3</sup>/ha. According to the Table 3 and 4, both based on volume and area the quantity of water used in irrigation was very high before installing prepaid water meter but it has started to decrease afterwards.

Furthermore, reduction of negative environmental effects such as soil salinization and high water table caused by excess watering has been provided.

### 3.2 Financial Performance

Indicators of cost recovery ratio (Table 5), maintenance expenditure to revenue ratio (Table 6), operating cost per unit area (Table 7), revenue collection performance (Table 8) and staffing numbers per unit area (Table 9) were used to determine the financial performance.

**Table 5.** Cost recovery ratio

Years	Total revenue collected from water users (US\$)	Total (MOM) cost (US\$)	Recovery ratio (%)
2012	608 985	717 242	0.85
2013	779 417	1 029 042	0.76
2014	480 267	585 857	0.82
2015	786 879	753 404	1.04
2016	631 251	598 747	1.05
2017	725 006	678 664	1.07

**Table 6.** Maintenance expenditure to revenue ratio

Years	Total maintenance expenditure (US\$)	Total revenue collected from water users (US\$)	Maintenance expenditure to revenue ratio (%)
2012	12 006	608 985	2
2013	544 297	779 417	70
2014	183 941	480 267	38
2015	249 431	786 879	32
2016	185 503	631 251	29
2017	231 458	725 006	32

**Table 7.** Operating cost per unit area

Years	Total operation expenditure (US\$)	Total irrigated area (ha)	Operating cost per unit area (US\$/ha)
2012	717 242	11 754	61
2013	1 029 042	11 116	93
2014	585 857	8 245	71
2015	753 404	9 866	76
2016	598 747	14 543	41
2017	678 664	19 528	35

**Table 8.** Revenue collection performance

Years	Total revenue collected from water users (US\$)	Total revenue due (US\$)	Revenue collection performance
2012	608 985	663943	0.92
2013	779 417	820458	0.95
2014	480 267	496266	0.97
2015	786 879	786879	1.00
2016	631 251	635645	0.99
2017	725 006	725006	1.00

**Table 9.** Staff numbers per unit area

Years	Total number of MOM staff	Irrigation command area (ha)	Irrigated area (ha)	Staff numbers per unit command area (person/ha)	Staff numbers per unit irrigated area (person/ha)
2012	26	10 800	11 754	0.0024	0.0022
2013	26	10 800	11 116	0.0024	0.0023
2014	28	10 800	8 245	0.0026	0.0034
2015	28	10 800	9 866	0.0026	0.0028
2016	26	10 800	14 543	0.0024	0.0018
2017	26	10 800	19 528	0.0024	0.0013

Cost recovery ratios were calculated based on revenue collected from the irrigators. As shown in Table 5, cost recovery ratio started to increase with installing prepaid water meter depending on increase in revenue collected from irrigators. Maintenance expenditures to revenue ratios were calculated by dividing total maintenance cost by total collected revenue. As shown in Table 6, the ratio was the lowest in 2012 with 2% and the highest in 2013 with 70%. It can be concluded that total collected revenue was sufficient to compensate for the maintenance costs except 2012. Operating cost per unit area was highest in 2013 with 93 U\$/ha but this value has declined in the following years. In the Table 8, it can be seen that the revenue collection performance was % 100 after installing prepaid water meter. Staffing numbers per unit command and irrigated area are presented in Table 9. Staffing numbers per unit command area is were almost the same between 2012 and 2017. But staffing numbers per unit irrigated area has declined because of increasing irrigated area by means of installing prepaid water meter.

### 3.3 Production Performance

Indicators of output per unit command area (Table 10), output per unit irrigated area (Table 11) and output per unit irrigation supply (Table 12) were used to analysed production performance.

**Table 10.** Output per unit command area

Years	Annual total agricultural production (US\$)	Command area (ha)	Output per unit command area (US\$/ha)
2012	16 041 096	10 800	1 485
2013	13 883 560	10 800	1 286
2014	113 541 657	10 800	10 513
2015	16 977 217	10 800	1 572
2016	20 398 898	10 800	1 889
2017	40 967 985	10 800	3 793

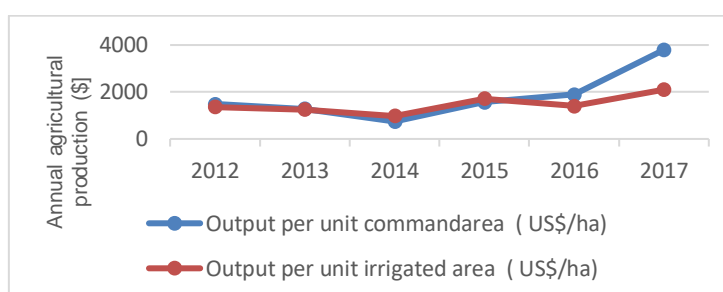
**Table 11.** Output per unit irrigated area

Years	Annual total agricultural production (US\$)	Irrigated area (ha)	Output per unit irrigated area (US\$/ha)
2012	16 041 096	11754	1 365
2013	13 883 560	11116	1 249
2014	113 541 657	8 245	13 771
2015	16 977 217	9 866	1 721
2016	20 398 898	14 543	1 403
2017	40 967 985	19 528	2 098

**Table 12.** Output per unit irrigation supply

Years	Annual total agricultural production (US\$)	Total annual volume of irrigation water inflow (m <sup>3</sup> )	Output per unit irrigation supply (US\$/m <sup>3</sup> )
2012	16 041 096	87 150000	0.18
2013	13 883 560	81 872 010	0.17
2014	113 541 657	57 480 000	1.98
2015	16 977 217	66 400 000	0.26
2016	20 398 898	68 412 500	0.30
2017	40 967 985	70 640 000	0.58

Output per unit command area was the highest in 2017 with 3 793 U\$/ha and the lowest in 2014 with 743 U\$/ha. And simultaneously, output per unit irrigated area was the highest in 2017 with 2 098 U\$/ha and the lowest in 2014 with 973 U\$/ha. The changes in the production values per the unit area are shown in the Figure 2. According to the Figure 2, both performance indicators tend to increase.



**Figure 1.** The changes in the production values for unit area.

As can be seen from Table 12, the output per the unit irrigation water was the highest in 2014 with 1,98 U\$/m<sup>3</sup> and the lowest in 2013 with 0,17 U\$/m<sup>3</sup>. This performance indicator has changed depending on quantity of water used and annual market value of each crop.

#### 4. CONCLUSIONS

The one of the most important task of the state to protect water resources effectively, develop, control and to make its distribution to everyone will benefit from it. Agricultural irrigation is the largest water consumer sector, when compared with the other sectors. There is increasing pressure on more efficient use of agricultural irrigation water. The countries in order to have more efficient management of water resources have to find new solutions, in view of new changes and opportunities in water resources management.

In this study, it is assessed to water distribution, financial and productive performance of Kayacik irrigation scheme operated by Kayacik Water User Association for the

years before and after using prepaid water meter. The results of this study showed significant improvements in performance indicators after prepaid water meter installed in irrigation scheme. In condition that, the irrigation water distributes by charging on volume based increased irrigation efficiency. A saving of approximately 51% was achieved in the amount of water used. In 2017, if the rate of water consumption per hectare had not changed compared to 2012, it could be irrigated only 9 528 ha (70 640 000 m<sup>3</sup> / 7 414 m<sup>3</sup> / ha) with the water inflow to the irrigation system. On the other hand, the actual irrigated area reached to 19 528 ha in 2017. Therefore, a benefit of 10 000 ha (19 528 ha - 9 528ha) was obtained. The contribution of Kayacık Irrigation to Gross National Agricultural Income (GNAI) is determined as 217 US \$ / da. Therefore, the contribution of the irrigation of the additional 10 000 ha area to GSMZ is 21 700 000 US \$.

Commonly used irrigation performance indicators for assessing the success of irrigation systems are irrigation rate, cost recovery ratio and operation-maintenance costs. The cost recovery ratio and the ratio of maintenance cost to water usage service cost collected from the irrigator have been increased with the use of prepaid water meter. On-time collection of irrigation water fees and regular performance of operation-maintenance services have resulted to have such high performance values. While the output per unit command and irrigated area was in a downward trend from 2012 to 2014, they started to increase after 2014. As well as improvement in performance indicators, according to field observation reduction of negative environmental effects such as soil salinization and high water table caused by excess watering has been provided.

As a result, prepaid water meter usage was found to be very effective in terms of water conservation, increase of productivity and economic benefit, and reduction of negative environmental effects in Kayacık irrigation. It is recommended that infrastructure for transition to volume-based (m<sup>3</sup> or hour) pricing should be established.

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