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Evaluation of the use of prepaid water meter on some irrigation management performance indicators: A case study

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Abstract

Volume based pricing in irrigation is an important application method in solving excessive and illegal water use problems. It is essential to use a properly selected water meter to accurately measure the amount of water. In this study, the irrigation system performance of Kayack Water User Association (WUA) was comparatively analyzed for the years 2012 to 2017. The prepaid water meter has been used for water measurement in Kayacık irrigation scheme since 2015. While it could be irrigated on 11.754 ha in 2012, the irrigated area reached 19.528 ha in 2017. It was determined that there was a significant water saving and economic recovery after the installation of prepaid water meters in the irrigation scheme. The quantity of water, which was 7,414 m3ha-1 in 2012, decreased to 3,617 m3ha-1 in 2017. The cost recovery ratios were 76% and 107% in 2013 and 2017, respectively. Consequently, prepaid water meter usage provides so many advantages in service delivery, economics and productivity. In addition, the quantity of water discharged into the drainage canal has significantly decreased. It is recommended that prepaid water meter usage should be prevalence in irrigation operation.

Keywords: Measuring irrigation water, Prepaid water meter, Service delivery performance, Financial performance, Production performance

Introduction

The state must effectively protect, develop and control distribute water resources to all who will use it. The demand for more efficient irrigation water use is growing. Countries have to find new solutions due to new developments and occasions in water resources management for more efficient water resources management.

Considering the amount of water per capita of 1380 m3 in Turkey, unfortunately, it is among the countries that no longer have enough water. By the end of 2018, approximately 74% of Turkey's water resources were appropriated for agricultural purposes (DSI, 2018). In this situation, the effective use of water and irrigation systems to save water are the most important matters to be taken into consideration.

Furthermore, irrigation water use efficiency (IE) and water productivity (WP) are closely related to other basic concepts of ongoing environmental resource management. The water is used by a variety of agricultural, environmental, urban, industrial, and recreational users (Bos et al., 2009).

In many countries, there are many different problems related to irrigation water management, such as excess and illegal water use, lack of technical experience for irrigation systems used, drainage, salinity, waterlogging, and irrigation water pricing. Improving IE and WP can provide less stress on water resources, reduce losses of water and nutrients to water resources, increase production and provide overall benefits. Thus, this increase potentially allows a greater area to be irrigated with a given volume of water (Koç, 2013). In some cases, water losses can be reused elsewhere; in other cases, they cannot be recovered due to salt water sinks. Onfarm water management practices, improved water distribution, and infrastructure can reduce these avoidable water losses (De Fraiture et al., 2014).

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If the extension services have provided the necessary knowledge, helping farmers to adapt and apply new practices, more benefits can be provided from improved irrigation technology. In many cases, the application of advanced irrigation technology has led to increased water prices without reaping all the potential benefits through water efficiency. Farmers usually have insufficient instruments and stimulations to know their crops' water consumption, actual irrigation practices' feedback to water management applications, and thus actual irrigation-efficiency levels (Levidov et al., 2014).

According to the experts, appropriate irrigation scheduling should provide improvements to higher water management performance. Appropriately managed irrigation not only increases crop yields and productivity but also declines pest infestations and precisely delivers and manages nutrients (Sedara and Sedara, 2020). The farmer should not be able to control the timing and the amount or volume of irrigation water in the practical application of the irrigation techniques and methods due to the non-economical pricing of water, the high cost of irrigation scheduling, insufficient education and demonstration, etc. In some cases, irrigation water price covers less than 30% of the total cost in many countries (Chartzoulakis and Bertaki, 2015). If irrigation is driven by non-economic objectives, farmers should not repay the full cost. Irrigation becomes increasingly uneconomical if the farmers are unable to pay for marginal (future) costs (Moll and Berkof, 2018).

In this context, water pricing based on volumetric of water is the most profitable method because of sustainability interaction between the amount of water used in irrigation and refund for it. So many studies on volume based pricing and efficient collection of irrigation water charges are a driving factor. (Ünver and Gupta, 2003). It is advised that the infrastructure for shifting to volumetric pricing should be established (Çakmak et al., 2010).

On the other hand, there are significant advances in the adoption of more efficient irrigation technologies with promoted government support. Adoption of efficient irrigation technologies by farmers can be promoted by introducing volume based pricing applications (Çakmak, 2010). Selection of a water measurement method for volumetric pricing should also consider past practice. When improved water measurement methods are needed, suggesting changes that build on established practice is often easier to institute than extreme changes (Anon., 2001). In order for this method to be applied effectively, a measurement device that records the quantity of water used for each field/land unit is needed. The reliability of the measurement device for volume based water fees is an important requirement (Burt, 2007). Suitably preferred and well-kept water meters can provide the most precise and easy way to measure the quantity of water in flowing into the farm and/or field (Baum et al. 2012; Golin et al. 2015).

However, individual consumption measurement is difficult in some situations. There is a risk of tampering with water meters by irrigators if there are drastic limitations on their use or increases in their water charges (Molle, 2009). Prepaid water meters perform accurate water measurements and guarantee the collection of water charges as well. The total water usage of the water users is calculated and provided payment in advance in the prepayment system. With a subscriber card, which belongs to only one water meter device, the water user can take as much credit as he wants. As soon as the smart card is scanned by the water meter device, present credits are transported to the device. The water user uses water on a schedule, and controlled water use is provided this way.

In this study, Kayacık irrigation system was taken as the material for benchmarking irrigation performance for the years between 2012 and 2017. Kayacık Irrigation Facility's irrigation, maintenance, and management responsibilities have been undertaken by Kayacık WUA. Approximately 60% of the people in the region, where the study area is located, earn their living from agriculture. Since 2015, the prepaid water meter has been used for water measuring in Kayacık Irrigation Facility. The main purpose of this study is to compare the irrigation system performance indicators before and after using the prepaid water meters. While evaluating the performance indicators of the irrigation system, performance indicators were used as suggested by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) and benchmark values for performance categorized (Malano and Burton 2001). Water delivery, financial performance, and productive performance were examined within the scope of evaluations.

Materials and Methods

Kayacık irrigation area is located in the Euphrates-Tigris basin, in the Oğuzeli district of Gaziantep province. The monthly mean precipitation is 438 mm and the avarage monthly temperature is 16.4 ^{o}C.

State Hydraulic Works built Kayacık irrigation scheme and put it into operation. While irrigation area was 600 ha in first year, it reached 10 800 ha by increasing each year in 2012. It was fully operational in 2012. It was started to be operated completely in 2012. The water resource of irrigation project area is Kayacık Dam fed by Aynifar, Tuzel, and Sacir creeks. The irrigation conveyance systems include an open canal system of 5% and a pipeline irrigation network of %95. Operation, maintenance, and management duties of the irrigation facility were undertaken by Kayacık WUA in 2006. Some data regarding the irrigated area and irrigation ration according to the years are given in Table 1.

Table 1. Spatial change based on command and a irrigated area

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

The domain crop pattern in the irrigation district consists of mainly cereals, cotton, and maize, and some fruits and vegetables are cultivated as well. Crop patterns based on years are given in Table 2.

Table 2. The crop pattern of Kayacık irrigation

ars	Cereals (ha)	Cotton (ha)	Maize (ha)	Vegetable (ha)	Fruit (ha)	Off season Irrigation (ha)
2012	7.368	-	4.215	-	171	-
2013	4.660	339	6.041	39	37	-
2014	5.393	459	2.229	112	51	-
2015	4.305	172	4.699	605	85	-
2016	7.004	269	1.872	1.229	818	3.351
2017	10.140	886	1.007	5.924	1.072	499

According to the Evaluation Report of Irrigation Facilities Operated and Transferred by DSI for 2012, farmers irrigated the entire irrigated area by surface method, including furrow and border (Anon., 2013). Over time, farmers started to irrigate by sprinkler and drip irrigation methods instead of surface irrigation methods (Anon., 2018).

Volume-based irrigation started to apply by installing the prepaid water meter in irrigation scheme in 2014. Some water distribution problems related to the use of prepaid water meters were observed in the first years, but they started to be used successfully in the following years.

In this study, some performance indicators in Kayacık irrigation scheme are compared before and after the use of the prepaid water meter. The water delivery, financial, and productive efficiency performances of the irrigation system were evaluated within the scope of this study. These performance indicators have been suggested by the IPTRID/World Bank study on benchmarking in the irrigation sector. Benchmark values for performance have been determined in this manner (Malano and Burton, 2001). Some performance indicators used in this study are shown in Table 3.

Table 3. The performance indicators considered in the benchmark study (Malano and Burton, 2001).

Domain	Indicators
Service delivery performance	Seasonal relative irrigation supply
	Delivered irrigation water per unit command area during the season (m^3 ha^{-1})
	Delivered irrigation water per unit irrigated area during the season (m^3 ha^{-1})
Financial performance	Cost recovery ratio
	Maintenance cost to revenue ratio
	Total MOM cost per unit area (US$ ha^{-1})
	Revenue collection performance
	Employed staff numbers per unit area (persons ha^{-1})
Productive efficiency	Output(net revenue) per unit command area (US$ ha^{-1})
	Output(net revenue) per unit irrigated area (US$ ha^{-1})
	Output per(net revenue) unit irrigation supply (US$ m^{-3})

All of the data in this study came from a technical report on irrigation scheme monitoring and evaluation prepared by DSI and Kayak WUA and used to determine the performance indicators. Also,

Service delivery performance

field observations were made for 6 years.

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Results and Discussion

Within the scope of service delivery performance,

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the seasonal relative water supply ratio (RWS) (Table 4), total seasonal water delivery per command area used to determine the performance indicators. Also, evaluation prepared by DSI and Kayak WUA and field observations were made for 6 years. (WDC) and total seasonal water delivery per irrigated area (WDI) (Table 5) were computed. Required data are daily measured water entering the irrigation system and periodic volume of crop water requirement during the irrigation season.

Table 4. The annual relative water supply ratio

Years	Total seasonal volume of irrigation water inflow (m^3)	Total volume of water required by crop (m^3)	RWS
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

For calculating RWS, two data points are required: daily measured water inflow to the irrigation system and periodic volume of crop water requirement during the irrigation season. RWS was the highest (1.25) in the irrigation season of 2012. After the prepaid water meter was installed, this ratio started to decline. If the water supply ratio is 1.0, the water diverted to the irrigation scheme is enough. If it is less than 1.0, it is not enough. And if it is greater than 1.0, it means that much more was used (Beyribey, 1997). While it was possible to irrigate only 11.754 ha in 2012 with the water entering the irrigation scheme, the real irrigated area reached 19.528 ha in 2017. Therefore, an increasing of 7.774 ha was obtained.

Table 5. Water delivery per command and irrigated area by years

Years	Seasonal volume of irrigation water inflow (m^3)	Irrigation command area (ha)	Irrigated area (ha)	WDC (m^3 ha^{-1})	WDI (m^3 ha^{-1})
2012	87.150.000	10.800	11.754	8.069	7.414
2013	81.872.010	10.800	11.116	7.580	7.365
2014	57.480.000	10.800	8.245	5.322	6.971
2015	66.400.000	10.800	9.866	6.148	6.730
2016	68.412.500	10.800	14.543	6.334	4.704
2017	70.640.000	10.800	19.528	6.541	3.617

For assessing WDC, daily measured water inflow to the irrigation system and total command area were used during the irrigation. WDC was the lowest value in the irrigation season of 2014 with 5.322 m^3 ha^{-1}, and the highest WDC (8.069 m^3 ha^{-1}) in the irrigation season of 2012. WDI was calculated by using the data points of total daily measured water inflow to the irrigation system and total seasonal irrigated crop area. WDI was the lowest value in the irrigation season of 2017 with 3.617 m^3 ha^{-1} and the highest value in the irrigation season of 2012 with 7.4140 m^3 ha^{-1}. As can be seen the data from Table 5, both WDC and WDI were higher compared to the data before installing the prepaid water meter. The quantity of water used in irrigation has started to decrease after installing the prepaid water meter.

Furthermore, the prepaid water meter use has reduced adverse environmental effects such as soil salinization and the height of the water table caused by excess watering because of the less irrigation water used.

Financial Performance

The cost recovery ratio (CR) (Table 6), maintenance cost to revenue ratio (MCR) (Table 7), operating cost per unit area (OC) (Table 8), revenue collection performance (RCP) (Table 9) and employed staff numbers per unit area (SNC and SNI) (Table 10) were considered to revealed financial performance. These performance indicators were calculated to equalities given in Table 3.

For calculating CR, revenues collected from water users during season and annual total management, operation and maintenance (MOM) cost values were used. CR was analyzed, considering revenue collected from the irrigated farmers. According to Table 6, CR started to increase with the installation of the prepaid water meter, dependently the improvement in revenue collected from irrigators.

Table 6. Cost recovery ratio

Years	Revenue collected from water users (US$)	MOM cost (US$)	CR (%)
2012	608.985	717.242	85
2013	779.417	1.029.042	76
2014	480.267	585.857	82
2015	786.879	753.404	104
2016	631.251	598.747	105
2017	725.006	678.664	107

The maintenance expenditure and revenue collected from water users during irrigation season are required data points for determining MCR. As shown in Table 7, MCR was the lowest with 2% in 2012 and the highest with 70% in 2013. It is understood that collected revenue was enough to make amends for the maintenance costs for all but 2012.

Table 7. Maintenance cost to revenue ratio

Years	Maintenance expenditure (US$)	Revenue collected from water users (US$)	MER (%)
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

The OC is calculated by considering total income and total service income collected from water users data points. OC was highest in 2013, at 93 U $/ha^{-1}, but it fell in subsequent years (Table 8).

Table 8. Operating cost per unit area

Years	Operation expenditure (US$)	Irrigated area (ha)	OC (US$ ha^{-1})
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	67.664	19.528	35

For analyzing RCP, required data points are the number of MOM personnel employed and the command area serviced by irrigation facility. As can be seen from Table 9, RCP was 100% after the installation of the prepaid water meter.

Table 9. Revenue collection performance

Years	Revenue collected from water users (US$)	Revenue due (US$)	RCP
2012	608.985	663.943	0.92
2013	779.417	820.458	0.95
2014	480.267	496.266	0.97
2015	786.879	786.879	1.00
2016	631.251	635.645	0.99
2017	725.006	725.006	1.00

SNC and SNI were calculated by dividing the number of MOM personnel employed by commend area and irrigated area services by system, respectively. SNC and irrigated SNI area are presented in Table 10. SNCs were almost the same between 2012 and 2017. However, SNI declined

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because of the increase in irrigated area because of the measuring and distributing of water through the prepaid water meter.

Table 10. Staff numbers per unit area

Years	Total number of MOM staff	Irrigation command area (ha)	Irrigated area (ha)	SNC (person ha^{-1})	SNI (person ha^{-1})
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

Production performance

Indicators of OUC and OUI (Table 11) and (OUIS) (Table 12) were used to analyze production performance.

OUC and OUI were calculated by dividing the total seasonal value of agricultural production by the command area and total command area, respectively. OUC was calculated as the highest in 2017 at 3.793 U.S.$ ha^{-1} and the lowest in 2014 at 743 U.S.$ ha^{-1}. Correspondingly, OUI was calculated as the highest in 2017 at 2.098 U.S.$ ha^{-1} and the lowest in 2014 at 973 U.S.$ ha^{-1}.

Table 11. Output per unit command and irrigated area

Years	Seasonal agricultural output (US$)	Command area (ha)	Irrigated area (ha)	OUC (US$ ha^{-1})	OUI (US$ ha^{-1})
2012	16.041.096	10.800	11.754	1.485	1.365
2013	13.883.560	10.800	11.116	1.286	1.249
2014	8.024.879	10.800	8.245	743	973
2015	16.977.217	10.800	9.866	1.572	1.721
2016	20.398.898	10.800	14.543	1.889	1.403
2017	40.967.985	10.800	19.528	3.793	2.098

Required data points are the total seasonal agricultural production value and daily measured water entering the irrigation system. As it can be seen from Table 12, OUIS was the highest in 2014 with 1.98 U.S.$ m^{-3} and the lowest in 2013 with 0.17 U.S.$ m^{-3}. This performance indicator has changed by the quantity of water used and the annual market value of each crop.

Table 12. Output per unit irrigation delivery

Years	Seasonal agricultural production (U.S.$)	Seasonal volume of irrigation water entering (m^3)	OUIS (U.S.$ m^{-3})
2012	16.041.096	87.50.000	0.18
2013	13.883.560	81.872.010	0.17
2014	8.024.879	57.480.000	0,14
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

Conclusion

The performance indicator values obtained from this study revealed that remarkable advancements were achieved after installing prepaid water meters in the irrigation scheme. Irrigation efficiency has increased in cases where irrigation water is charged on volume basis. With the use of prepaid water meters, the cost recovery rate and the ratio of maintenance fee to water usage service fee have increased significantly. Punctual collection of irrigation water charges and on-time and complete operation, maintenance, and repair services have ensured that it has high-performance values. The production per both the unit command area and the irrigated area tends to decrease before the prepaid water meter is used, it starts to increase after use. According to field observations, adverse environmental effects caused by excessive irrigation have decreased and performance indicators have improved. According to field observations, adverse environmental effects caused by excessive irrigation have decreased and performance indicators have improved. Significant progress has been made in terms of soil salinization and water table height. Consequently, it has been determined that performance indicators have improved over time thorough the prepayment meter was installed in the irrigation facility. The reason for this time-dependent improvement is that farmers adopt the use of prepaid water meters over time and gain habit. It is possible to recover irrigation costs and adjust pricing as an instrument to manage water demand in agriculture by using the prepaid water meter where appropriate and applicable technically, socially, and economically. The prepaid water meter used as a management tool that can result in water savings and thus effects energy used from pumping water. According to the results of this study, the use of prepaid water meters in Kayacık irrigation is very effective in terms of water saving, increasing efficiency and economic benefit, and reducing adverse environmental effects. Especially, under conditions of water shortage, all farmers are able to benefit from water more equitably and efficiently. In addition, the energy cost of pumping irrigation per hectare reduces thanks to water saving provided by using the prepaid water meter. In addition, it is possible to cultivate second crop in the same area.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Not applicable.

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