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Estimation of future irrigation performance with times series analysis: a case study of Andırın, Kahramanmaraş, Turkey

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Abstract: Performance indicators are used to identify the weaknesses and strengths of irrigation schemes. Until now, evaluations have been made using several different statistical methods to determine the performance of irrigation schemes. However, these methods showed the current performance of irrigation schemes and the statistical relationship between them. It is planned to provide adaptation of irrigation networks to climate change with state policies. Therefore, it is of great importance to estimate the future performance of irrigation schemes. In this study, the future irrigation performance of the Andırın irrigation scheme in Kahramanmaraş province Andırın district was estimated using time series forecasting method. Using the data of the Andırın irrigation scheme between 2006 and 2019, the selected performance indicators were estimated until 2025. When examining the results, they suggest that the irrigation scheme has not shown consistency in the past years, so the future performance of the irrigation scheme may be adversely affected. The high amount of irrigation water distributed to per unit irrigated area in this irrigation scheme will result in poor performance in subsequent years if measures such as modernization, transition to pressurized system and modern irrigation methods are not taken and improvements are not made in the future.

Key words: Forecasting, time series analysis, irrigation performance

1. Introduction

With the rapidly growing population in the world, the need for food is increasing day by day. The importance of food production and supply chain safety in the world and in our country has become extremely important with the breaking out of epidemic diseases. Water is a scarce resource. A large part of fresh water is used for irrigation. The management of water used in production is of great importance to meet the food requirement and ensure its safety.

Organizations such as irrigation associations, cooperatives, and farmer unions are responsible for the transmission of water used in irrigation to users from the source. The importance of these organizations increases in areas where irrigation water is scarce. A number of indicators have been developed to identify and improve the strengths and weaknesses of irrigation associations and such organizations in irrigated areas (Boss et al., 1994; Molden et al., 1998; Malano and Burton, 2001; Burt, 2001; Renault et al., 2007).

Many studies have been conducted with irrigation performance indicators in the world and in Turkey. Değirmenci (2004) and Arslan and Değirmenci (2018) conducted studies using these indicators in Kahramanmaraş, Çakmak (2001) in Konya, Çakmak and Beyribey (2003) in Sakarya Basin, and Nalbantoğlu and Çakmak (2007) in Ankara. The most comprehensive study in Turkey with irrigation performance indicators was conducted by Kartal (2018).

The studies were conducted with performance indicators in Spain, in the Andalucia region (Rodriguez-Diaz et al., 2004; 2005; 2008; 2009), in the Castilla La Manca region (Corcoles et al., 2010), in Alicante (Abadia et al., 2010) in Murcia (Soto-Garcia et al., 2013a, 2013b), and also in southeastern Spain by Alcon et al. (2017). Zema et al. (2015) in the Calabria region in Italy; Zema et al. (2018) conducted studies using performance indicators.

In previous studies, irrigation schemes were evaluated using various statistical analysis methods. In some studies, performance indicators were calculated, as a result of these calculations evaluations were made by making comparison between years and between irrigation schemes.

Rodriguez-Diaz et al. (2008) used factor analysis to reduce the numerous irrigation performance indicators to a single value. They named the value obtained as a result of this analysis as score (quality index). They made

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a comparison by subjecting irrigation schemes to success ranking according to the quality index. In Italy, Zema et al. (2015) evaluated some irrigation schemes with quality index in Calabria region. In Turkey, Kartal et al. (2018) made evaluations in some irrigation schemes with this method in Central Anatolia.

In a study conducted in southeast Spain, Alcon et al. (2017) calculated performance indicators for some irrigation schemes and implemented panel regression analysis. With this analysis, they investigated the impact of time and some irrigation schemes characteristics on performance indicators.

Zema et al. (2018) used data enveloping analysis to indicate the importance of the number and type of performance indicators used to evaluate irrigation schemes located in southern Italy. Değirmenci et al. (2017) grouped irrigation schemes that resemble each other located in Lower Seyhan Plain in Turkey using cluster analysis and compared them with performance indicators. Kartal et al. (2020) used regression analysis to assess performance indicators and ANOVA to determine the differences between irrigation schemes.

In National Water Plan (2019–2023) of Turkey, the importance of the water usage in agriculture was emphasised. In this context, transition to pressurized irrigation system should be spread in irrigated areas. As of 2018, irrigation efficiency is 50%, and it is planned to reach to 55% as of 2024. To achieve these goals, agricultural water usage should be prised by volume, and modern irrigation methods should be used by farmers (T.C. Tarım ve Orman Bakanlığı, 2019). For this kind of plans, prediction of future performance of water user associations may be helpful.

When earlier studies were examined, it was seen that no research was conducted to estimate the future performance of irrigation schemes. The aim of this study is to evaluate irrigation performance indicators of Andırın irrigation scheme located in Andırın district of Kahramanmaraş province, to predict future performance and to obtain data for the future with time series analysis. Based on the data obtained, recommendations were made to improve the performance of the irrigation scheme.

2. Materials and methods

2.1. Study area

In this study, the Andırın irrigation scheme in the Andırın district of Kahramanmaraş province was selected as a material due to adequate and healthy data. Data for this irrigation scheme for the years 2006–2019 have been obtained from the General Directorate of State Hydraulic Works (DSİ). The Andırın irrigation scheme was opened in 1983 and water transmission is ensured by gravity. The most commonly grown crops in the irrigated area are corn (66%), peanuts (22%), and forage crops (7%) (DSİ, 2019). The water source of Andırın irrigation scheme located in Ceyhan Basin is Andırın and Keşiş Rivers. The waters received from these sources are provided by flume-type transmission channels. The images of Andırın irrigation scheme water transmission systems are given in Figure 1. The existing secondary and tertiary flumes in the irrigation scheme consist only of flume-type channels. Almost all of the farmers in the irrigated area use irrigation with surface irrigation methods. The second product is also grown in the region. The area irrigated by farmers' own facilities in the irrigated area is about 5% of the total service area.

2.2. Method

Indicators and calculation methods given in Table 1 were used to determine the performance of selected irrigation schemes (Bos et al., 1997; Molden et al., 1998; Malano and Burton, 2001; Burt, 2001; Renault et al., 2007).

Figure 1. Andırın irrigation network images.

Table 1. Performance indicators used in calculations and calculation methods

	Indicators	Definition
System operation	Irrigated area/Command area ratio (%)	$\frac{\text{Irrigated area} * 100}{\text{Command area}}$
	Annual irrigation water delivery per unit of irrigated area (m^3 ha^{-1})	$\frac{\text{Total annual volume of irrigation supply}}{\text{Total annual irrigated crop area}}$
	Annual relative irrigation supply	$\frac{\text{Total annual volume of irrigation supply}}{\text{Total annual volume of crop water demand}}$
Financial indicators	Total MOM cost per unit command area (€ ha^{-1})	$\frac{\text{Total MOM cost}}{\text{Command area}}$
	(Total MOM cost per cubic metre of irrigation water supplied (€ m^{-3})	$\frac{\text{Total MOM cost}}{\text{Total annual volume of irrigation supply}}$
	Total cost per unit command area (€ ha^{-1})	$\frac{\text{Total expenditure}}{\text{Command area}}$
	Total cost per unit cubic metre of irrigation water supplied (€ m^{-3})	$\frac{\text{Total expenditure}}{\text{Total annual volume of irrigation supply}}$
Agricultural productivity	Output per unit irrigated area (€ ha^{-1})	$\frac{\text{Total annual value of agricultural production}}{\text{Command area}}$
	Output per cubic metre of irrigation water supplied (€ m^{-3})	$\frac{\text{Total annual value of agricultural production}}{\text{Total annual volume of irrigation supply}}$
	Output per cubic metre of irrigation water demand (€ m^{-3})	$\frac{\text{Total annual value of agricultural production}}{\text{Total annual volume of crop water demand}}$

2.3. Forecasting method

The data of the Andırın irrigation scheme between 2006 and 2019 was used in the research. Based on these data, estimations were made for irrigation activities to be conducted in 2020–2025 using time series forecasting analysis. Estimations were made for water distribution performance indicators for the period between 2020 and 2025 and for other performance indicators for the period between 2019 and 2025. While interpreting estimates of indicators, confidence intervals were used. Making evaluations based on confidence intervals minimizes the error. In other words, confidence intervals are used to provide more accurate estimates. The method is used for the first time to estimate performance indicators in the areas.

Multivariate and univariate time series are used to predict a specific performance or state. For example, Maidment et al. (1985), Jowitt and Xu (1992), and Zhou et al. (2002) used time series to make daily urban water consumption estimate. Caiado (2007) used time series to make water demand estimates. Similarly, time series can be used to estimate the annual water consumption quantity in the irrigation of agricultural areas.

2.4. Data analysis

In the analysis of the data, the R program forecasting package was used and the codes used are given in Table 2. The time series offers different models depending on the status and indicators discussed. The ARIMA (autoregressive integrated moving average) method offers strong predictions with a single indicator (Engle, 1982; Nelson, 1991; Campbell and Diebold, 2005). In the study, the amount of irrigation between 2006 and 2018 constitutes the basic data, so the ARIMA method was used for strong estimations.

Bayes information criteria (BIC) and some suitability of compliance statistics were used in the final stage by comparing ARIMA and possible models. BIC is an index used in Bayesian statistics to compare which model is best suited among two or more models (Neath and Cavanaugh, 2017). R offers the most suitable model by making this comparison.

3. Results

As first information of fit statistics are given in blow. After than estimation of indicators are presented under the different titles.

The R program uses an algorithm for determine to the best model. Some fit index are used for determine to the best forecasting model. For example in this study RMSE, MAPE, MAE and BIC index were used. As a result of fitting test, the best models are presented in Table 3. Which ARIMA model gives minimum BIC value, the model is determined as the best model. The best models according to fit statistics are given in Table 3.

3.1. System operation indicators

Estimation values for system operation performance indicators in 2020–2025 using time series forecasting analysis are given in Table 4. As a result of the analysis, the maximum and minimum estimations made at the 80% confidence level are given in blue and 95% confidence estimations are given in a light gray color in Figure 2.

When Table 4 is examined, it is seen that irrigated area/command area ratio point forecasting for the Andırın irrigation scheme was estimated as 74.16%; the minimum estimation value of 2020–2025 at 80%, confidence level was 57.63%, and the maximum estimated value was 90.68%. Irrigated area/command area ratio of 100% indicates irrigation in all areas of the irrigation scheme, while below 100% indicates low performance. Accordingly, it can be stated that the minimum values, the maximum values, and the point estimates are below this rate.

Annual irrigation water delivery per unit of irrigated area point forecasting value was calculated as 8496.5 $m^3 ha^{-1}$. In the estimations made at the 80% confidence level for years between 2020 and 2025 the minimum value was calculated as 5395.2 m^3 ha^{-1} and maximum value was calculated as 16,093.4 m^3 ha^{-1}. Annual relative irrigation supply point forecasting value is 0.75. This value is expected to be 2.42 in Andırın irrigation scheme in 2025.

3.2. Financial indicators

The estimation values made for financial indicators as a result of the analyses are given in Table 5. Indication values for financial indicators for 2006–2019 and estimated indication values for years 2020–2025 are graphically given in Figure 3.

Table 2. R Program time series codes.

```
library(fpp2)  #### main package used for estimations
Y<-ts(data$variable, start = c(year,1), f=1)    #### code used to create the time series
autoplot(Y)  ### code used to draw the plot of time series
fitarima<-auto.arima(Y, stepwise=F, approximation = F, trace = T, seasonal = F) ### Code used for modelling with ARIMA
checkresiduals(fitarima) #### code used to control the residuals of the model
fc<- forecast(fitarima, h=6) #### code used for forecasting
plot(fc, main="…", ylab="…", xlab="…") #### Code used to draw the forecast plots
print(summary(fitarima))  #### Code in which the outputs of modeling with ARIMA are printed
print(summary(fc)) #### The code used to print the forecast values
```

Table 3. Fit statistics of ARIMA models.

	Fit statistics				
	RMSE	MAPE	MAE	Normalized BIC	Model
Irrigated area/Command area ratio (%)	5.07	5.02	3.76	82.64	ARIMA(0,1,0)
Annual irrigation water delivery per unit of irrigated area (m3 ha⁻1)	2332.00	14.16	1685.09	242.04	ARIMA(0,1,0)
Annual relative irrigation supply	0.514	21.59	0.371	23.12	ARIMA(0,1,0)
Total MOM cost per unit command area (€ ha⁻1)	13.49	21.34	11.43	99.95	ARIMA(0,1,0)
Total MOM cost per cubic metre of irrigation water supplied (€ m⁻3)	0.002	21.37	0.001	111.2	ARIMA(0,1,0)
Total cost per unit command area (€ ha⁻1)	34.38	6.40	29.17	134	ARIMA(0,0,0)
Total cost per unit cubic metre of irrigation water supplied (€ m⁻3)	0.012	19.47	0.010	66.79	ARIMA(0,1,0)
Output per unit irrigated area (€ ha⁻1)	649.63	20.30	484.94	192.93	ARIMA(0,1,0)
Output per cubic metre of irrigation water supplied (€ m⁻3)	0.078	26.13	0.057	23.61	ARIMA(0,1,0)
Output per cubic metre of irrigation water demand (€ m⁻3)	0.136	28.94	0.11	9.82	ARIMA(0,0,0)

Table 4. System operation performance indicators.

Years	Irrigated area/ Command area ratio (%)			Annual irrigation water delivery per unit of irrigated area (m^3 ha^{-1F})			Annual relative irrigation supply		
	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)
2020	67.41	74.16	80.903	5395.2	8496.6	11597.9	0.06	0.75	1.43
2021	64.62	74.16	83.698	4110.5	8496.6	12882.6	–0.22	0.75	1.72
2022	62.47	74.16	85.843	3124.8	8496.6	13868.4	–0.44	0.75	1.93
2023	60.66	74.16	87.650	2293.8	8496.6	14699.4	–0.62	0.75	2.12
2024	59.07	74.16	89.243	1561.7	8496.6	15431.5	–0.78	0.75	2.28
2025	57.63	74.16	90.683	899.7	8496.6	16093.4	–0.93	0.75	2.42

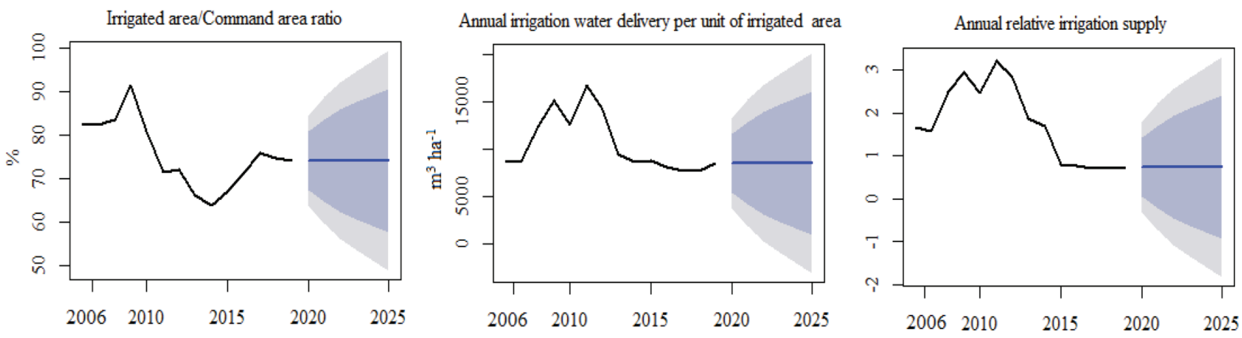

Figure 2. System operation performance indicators.

Table 5. Financial indicators.

Years	Total MOM cost per unit command area (€ ha^{-1})			Total MOM cost per cubic metre of irrigation water supplied (€ m^{-3})			Total cost per unit command area (€ ha^{-1})			Total cost per unit cubic metre of irrigation water supplied (€ m^{-3})		
	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)
2019	47.5	65.5	83.5	0.008	0.011	0.013	423.3	469.2	515.1	0.055	0.073	0.090
2020	40.0	65.5	90.9	0.007	0.011	0.014	423.3	469.2	515.1	0.048	0.073	0.097
2021	34.3	65.5	96.7	0.006	0.011	0.015	423.3	469.2	515.1	0.043	0.073	0.102
2022	29.5	65.5	101.5	0.005	0.011	0.016	423.3	469.2	515.1	0.038	0.073	0.107
2023	25.3	65.5	105.7	0.004	0.011	0.017	423.3	469.2	515.1	0.034	0.073	0.111
2024	23.4	65.5	107.8	0.004	0.011	0.017	423.3	469.2	515.1	0.030	0.073	0.115
2025	21.4	65.5	109.6	0.003	0.011	0.018	423.3	469.2	515.1	0.027	0.073	0.118

The smallest estimated value made for total MOM (Maintenance Operation and Management) cost per unit command area is 21.4 € ha^{-1} in 2025, and the highest value is estimated as 109.6 € ha^{-1} in 2025. The point forecasting value of this indicator is 65.5 € ha^{-1}. The point forecasting value of total MOM cost per cubic meter of water supplied is 0.011 € m^{-3}, the maximum and minimum values for estimations are 0.0033 € m^{-3} and 0.018 € m^{-3}, respectively. Total cost per unit command area point forecasting value was 469.2 € ha^{-1}, minimum and maximum values are not changed; they have been estimated between 423.3 and 515.1 € ha^{-1} respectively. The forecasting point value of these values remained constant because their maximum and minimum values did not reach a trend in this indicator between 2006 and 2018.

3.3. Agricultural productivity indicators

Estimations for agricultural productivity indicators are given in Table 6, and its graphical representation is given in Figure 4.

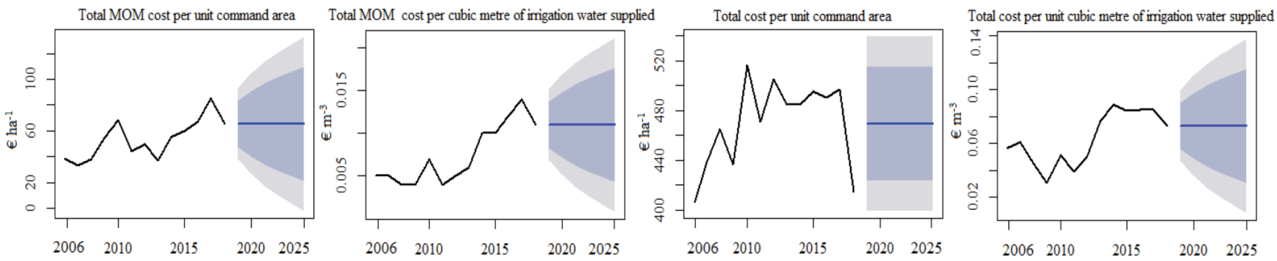

Figure 3. Financial indicators.

Table 6. Agricultural productivity indicators.

Years	Output per unit irrigated area (€ ha^{-1})			Output per cubic metre of irrigation water supplied (€ m^{-3})			Output per cubic metre of irrigation water demand (€ m^{-3})		
	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)	Lower (%80)	Forecast	Upper (%80)
2019	1384.2	2250.7	3117.2	0.190	0.295	0.399	0.223	0.405	0.587
2020	1025.2	2250.7	3476.2	0.147	0.295	0.442	0.223	0.405	0.587
2021	749.8	2250.7	3751.6	0.113	0.295	0.476	0.223	0.405	0.587
2022	517.6	2250.7	3983.8	0.085	0.295	0.504	0.223	0.405	0.587
2023	313.1	2250.7	4188.3	0.061	0.295	0.528	0.223	0.405	0.587
2024	128.1	2250.7	4373.3	0.038	0.295	0.551	0.223	0.405	0.587
2025	-41.9	2250.7	4543.3	0.018	0.295	0.571	0.223	0.405	0.587

The output per unit irrigated area point forecasting value was estimated at 2250.7 € ha^{-1}. The range of estimation of this indicator at an 80% confidence level between 2019 and 2025 shows an increasing estimate range. Output per cubic meter of irrigation water supplied forecasting value was estimated as 0.295 € m^{-3} between 2019 and 2025, for output per cubic meter of irrigation water demand, this value was estimated as 0.405 € m^{-3}. The difference between these two indicators shows the profit to be obtained in the transmission of irrigation water through the channels and in the absence of losses in the field. The value of this difference is 0.110 € m^{-3}.

4. Discussion

Turkey's irrigation rate for many years has been 64% (DSİ, 2019). In some irrigation schemes using modern irrigation techniques in the south of Spain, this rate exceeds 90% (Corcoles et al., 2010; Alcon et al., 2017). In some irrigation schemes in Italy similar to Andırın irrigation scheme, the average rate is about 30% (Zema et al., 2015; Zema et al., 2018). The Andırın irrigation scheme is between the values made in these two countries (Spain and Italy) with the irrigation rate between 2020 and 2025 (74.16%). The irrigation rate of the Andırın irrigation scheme in the coming years suggests that it is above the irrigation rate of Turkey. The reasons for not irrigating the non-irrigated areas in the Andırın irrigation scheme are dry farming (43%) and leaving the fields empty (DSİ, 2019). In areas where dry farming is practiced, farmers consider precipitation as sufficient and do not demand water.

Kartal and Değirmenci (2019), in their study, calculated the average annual irrigation water delivery per unit of irrigated area in Andırın between 2006 and 2019 as 11,216.1 m3 ha^{-1}. Arslan and Değirmenci (2018) calculated this value in Kahramanmaraş irrigation as 9572.9 m3 ha^{-1}; Kartal et al. (2019a) calculated this value between 12,246.4 and 8168.5 m^3 ha^{-1} in their study in the Aegean region. In some irrigation schemes in Spain, this value ranges from 1500 to 6000 m^3 ha^{-1}. The value of this indicator varies according to the plant variety. However, the loss in the transmission of irrigation water increases due to the use of surface irrigation methods by farmers.

Relative water supply value of 1 indicates that the required amount of water is delivered to the network (Molden et al., 1998; Malano and Burton, 2001). Zema et al. (2018) calculated relative water supply value as approximately 4 in their study conducted in some irrigation schemes located in the south of Italy. The relative water supply value of greater than 1 indicates that irrigation water is overused, which shows that water losses are being experienced. In the Andırın irrigation scheme, the estimated relative water supply value is 0.75 between

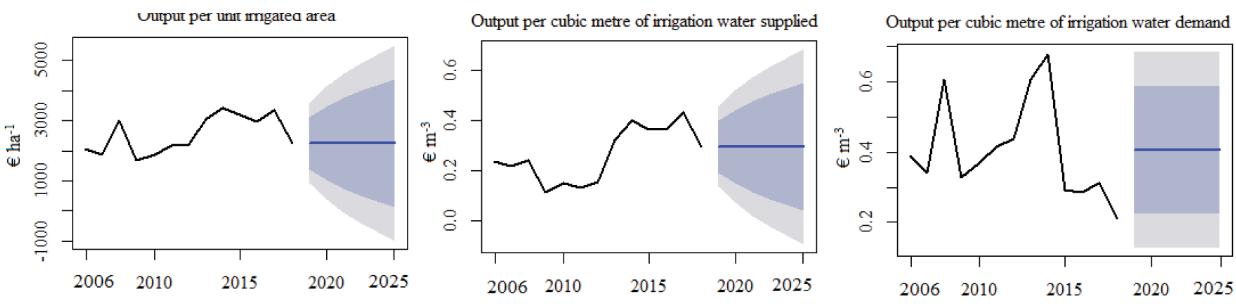

Figure 4. Agricultural productivity indicators.

2020 and 2025. In this case, irrigation water is insufficient and limited irrigation will be made.

Total MOM cost per unit command area does not represent the high or low performance of an irrigation scheme. This indicator refers to the costs of management, operation, and maintenance of the unit area. Total MOM cost per unit command area calculated for some irrigation schemes in Spain is 341.8 € ha^{-1} (Rodriguez-Diaz et al., 2008; Corcoles et al., 2010; Alcon et al., 2017). Kartal et al. (2019b) in their study in Central Anatolia region in Turkey, calculated this value as an average of 437.6 € ha^{-1}.

Rodriguez-Diaz et al. (2008) found the average total MOM cost per unit cubic meter of irrigation water supplied value as 0.08 € m^{-3} in the study conducted in the Andalusia region in southern Spain. The expected value of this indicator in the Andırın irrigation scheme for the years 2019–2025 is 0.011 € m^{-3}. This value is significantly lower than the indicator value calculated in Spain. This is because of the fact that modern irrigation techniques are not used in the Andırın irrigation scheme and operating costs are low.

Kartal et al. (2019b) calculated the average total cost per unit command area value between 295 and 860 € ha^{-1} in seven irrigation schemes in their study in Central Anatolia. In the Andırın irrigation scheme, this value was calculated as 469.2 € ha^{-1}.

Kartal and Değirmenci (2019) calculated the total cost per cubic meter of irrigation water supplied value as 0.025–0.278 $ m^{-3} in their study conducted in Kahramanmaraş province. Kartal et al. (2019b) found this value between 0.03 and 0.93 $ m^{-3} in their study in Central Anatolia region.

Rodriguez-Diaz et al. (2008) divided the irrigation schemes they were working on into four groups by cluster analysis in their study in Spain. The lowest and highest output per unit irrigated area values of these irrigation schemes were calculated between 2900 and 13,073 € ha^{-1}. Çakmak et al. (2009) calculated the highest value as 4930 $ ha^{-1} and the lowest value as 3534 $ ha^{-1} in Asartepe irrigation in Sakarya Basin. Çakmak et al. (2010) calculated this value between 325 and 2745 $ ha^{-1} in the transferred irrigation schemes located in the 5th zone of the DSİ. Değirmenci et al. (2003) found the output per unit cubic meter of irrigation water supplied value between 1223 and 9434 $ ha^{-1} in some irrigation schemes in the GAP project.

Alcon et al. (2017) calculated the average output per unit cubic meter of irrigation water supplied value as 4.7 € m^{-3} in their study in Murcia region. Kartal et al. (2019b) found this value between 0.08 and 1.87 € m^{-3} in the Central Anatolia region. The value of this indicator in the Andırın irrigation scheme between the years 2006 and 2018 is about 0.3 € m^{-3}. For the period between 2019 and 2025 for which estimations are made, the value of this indicator is expected to be 0.44 € m^{-3}. It can be said to be effective in Spain to reduce the amount of water used to increase the production value obtained from unit irrigation water and to grow products with high production value. Output per cubic meter of irrigation water demand remained constant because forecasting point did not find a trend in the past years.

5. Conclusion

In this study, time series forecasting method was used to determine the future performance of irrigation schemes. This method makes estimates using performance indicator values from past years in irrigation schemes. This allows the weaknesses and strengths of irrigation schemes to improve their future performance. Irrigation managers can improve agricultural irrigation management by taking measures for the future using the outputs of this study. In this study, estimations were made by time series forecasting method until 2025 using 2006–2019 data of the Andırın irrigation scheme. Eventually, the performance of the Andırın irrigation scheme does not show consistency in the past years. Therefore, performance indicators can also vary greatly in future predictions. According to the results of the analysis, especially the use of high amounts of irrigation water is seen as a factor that adversely affects the performance of this irrigation scheme. To ensure water safety in the future and allow further irrigation of the area, these problems can be solved with the development of transmission channels of the Andırın irrigation scheme, and the use of modern irrigation methods by the farmers in the region. Substantial benefit may be provided to the users for the use of modern irrigation techniques by switching to pressurized irrigation systems and minimizing losses during water transmission with modernization works. Modernization of irrigation systems through state policies will have a positive impact on irrigation performance in the future.

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