Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2021) 45: 634-641
© TÜBİTAK
doi:10.3906/tar-2105-16

Comparison of methods used in predicting irrigation performance indicators

Sinan KARTAL[1,*], **Fırat ARSLAN**[2]

[1]Alanya Alaaddin Keykubat University, Antalya, Turkey

[2]Alanya Alaaddin Keykubat University, Gazipaşa MRB Vocational School, Animal and Plant Production Department, Antalya, Turkey

Received: 05.05.2021 • **Accepted/Published Online:** 01.09.2021 • **Final Version:** 14.10.2021

Abstract: Decreasing availability of water and increasing consumption of it in recent years shows water management plans increase its value. Depending on water consumption in the current and previous years, it is important to predict water consumption in the coming years and make plans accordingly. Evaluation of the performance of water use in agriculture, identifying water resources that are most intensively used and prediction of the potential performance in the coming years have become increasingly important. Irrigation water management is of crucial importance for sustainable food security and needs to plan for saving water due to global warming and climate change in future. Some statistical methods such as regression and time-series to make accurate predictions are used to predict future irrigation management. However which methods are most suitable in this area is a gap in previous studies. This study aimed to determine the most accurate prediction method based on a comparison of the methods used in irrigation performance such as regression, time-series exponential smoothing and time-series ARIMA (autoregressive integrated moving average) model. In the study, Kahramanmaraş region was randomly selected and the irrigation data of 2006–2018 were used and the data of 2006–2017 were analysed to predict the data of 2018. Then, the values predicted using the methods were evaluated based on the actual values of 2018, and the method that projected values similar to the actual values was determined. The study results showed that the regression method gave the best predictions for the indicators in the water distribution dimension, while the time-series exponential smoothing method gave the best predictions for the indicators in the financial and agricultural activities dimension.

Key words: ARIMA, irrigation water, irrigation water performance, prediction, regression, time series

1. Introduction

The impact of human activities on nature also changes the way natural resources, especially water (Winz et al., 2008; Yang et al., 2018). Water resources, which are one of the most important sources for factors such as population growth, urbanisation, climate change and human-nature interactions are increasingly declining (Jiang, 2015). This poses a major threat to future generations, as well as regional sustainable development (Brown et al., 2015; Kotir et al., 2016; Yang et al., 2017). The unbalance between water supply and water demand has become a global problem that people have encountered for a long time, and in the future, it will continue to be the problem especially in developing countries and regions with an arid climate (Zhang et al., 2020). Therefore, it is necessary to determine the need according to the areas where water resources are used and to make consumption plans accordingly.

Irrigation water consumption explains the amount of water from reservoir to the plant root zone through farms. Irrigation water demand explain the total amount of irrigation water demanded by farmers through the farm (Zema et al., 2015; Zema et al., 2018; Marmontel et al., 2018; Bombino et al., 2019). In Turkey, water user associations are in charge of irrigation water distribution (Arslan et al., 2020). The most comprehensive study in Turkey shows that irrigation water management will be one of the most important problems in the future (Kartal, 2019).

In recent years, due to the growing water demand, investigation of water resources and consumption and prediction of water consumption have come to the fore (Brown et al., 2015; Blair et al., 2016; Choi et al., 2017; Ghodsvali et al., 2019). With water consumption and need on the agenda, the use of water resources has become the subject of both regional (Susnik et al., 2012; Liu et al., 2015; Sahin et al., 2015; Jeong andAdamowski 2016; Kotir et al., 2016; Wei et al., 2016), national and global (Duran-Encalada et al., 2017; Sun et al., 2017; Kelly et al., 2019) studies. However, the water need was also investigated regarding to factors such as climate change, urbanisation, economic development and population growth (Qi and Chang 2011; Hagemann et al., 2013; Gao et al., 2016).

* Correspondence: sinan.kartal@alanya.edu.tr

All of these studies point to the fact that water is a scarce resource and, therefore, should be used responsibly.

Water resources are mainly consumed for domestic, industrial and agricultural purposes. The most common use area of water is the agricultural sector, accounting for about 70% of water use worldwide (Tanrıverdi and Değirmenci, 2011; Alcon et al., 2017). In Turkey, 18% of the available water is used for domestic purposes, 10% is used in industry and 72% is used in the agricultural sector (DSI, 2019). Although agriculture is the area where water resources in the world are most commonly used, domestic water consumption has been the subject of further studies. Previous studies include various research focusing on the use of drinking water and the prediction of the need for drinking water in the coming years. For example, Howe and Linaweaver (1967) predicted drinking water by regression analysis using cross-sectional data. This study was also one of the first studies to predict water consumption. Cassuto and Ryan (1979), Maidment et al. (1985) and Billings and Agthe (1998) produced predictions for domestic water consumption in light of factors such as socioeconomic level and population density using the regression method. Similarly, Hansen and Narayanan (1981), Maidment et al. (1985), Jowitt and Xu (1992), Caiado (2007) and Ryu and Park (2019) made predictions for short-term and long-term drinking water usage using time-series models.

Although the amount of water used in the agricultural sector in both Turkey and the world is higher compared to other areas; there are fewer studies in the literature for predicting the amount of water used in agriculture. Studies have been conducted on subjects such as determination of water need for a crop pattern in a particular region and estimation of water need and its economic consequences (Feddes et al., 1978; Drastig et al., 2016; Taehva and Yongchul 2016; Ali, 2018; Mirschel et al., 2018; Sun et al., 2018; Ma et al., 2020; Mirschel et al., 2020).

It is essential to determine water needs in all areas and to predict water consumption in the future, for the planned and correct use of water resources. Today, the developments in computer and software have led to the development of many statistical techniques for making estimations in various fields, such as education, economics, finance, and agriculture, for the coming years. Planning for the next year or even years in many areas is based on the prediction of the future situation based on the current situation. Therefore, a future prediction is of great importance in all areas. Regression and time-series models seem to be the most commonly applied methods in studies of water need or consumption. However, the studies have no comparison and results for which prediction method offers better prediction.

Regression analysis is the expression of a relationship of any variable (dependent variable) with one or more variables (independent or descriptive variables) as a mathematical function. The prediction is made using the established regression equation. Prediction of the independent variables affecting the dependent variable helps to determine which variables gain importance in the plans and policies to be developed on this variable (Ballot, 1986; Çağlar, 2007). Time series model is based on the arrangement of historical data over time and provides a prediction for the future based on them (Üreten, 2005). The time series model offers different models such as the moving averages method, exponential smoothing method, and ARIMA depending on the indicators and the situation addressed (Box et al., 1994). It has been stated that, among these models, the ARIMA method offers strong predictions with one indicator, while the exponential smoothing method offers strong predictions if time-dependent data is irregular (Engle, 1982; Nelson, 1991; Campbell and Diebold, 2005).

In irrigation water management, especially prediction of performance of water user associations to make plans for future, some prediction methods are used, however, in the area, the statistical methods for the area should be investigated to figure out which is the best for researcher to use one of them but does not say which one is the best for irrigation practice and plans for future.

This study aims to compare the performances of regression, time series—exponential smoothing method and time series—and ARIMA methods for predicting the future in terms of irrigation performance indicators and aimed to determine the method offering the most accurate predictions. Accurate (particularly, as closest as possible) future predictions in the establishment of irrigation policies are of great importance for developing proper plans for water management. Therefore, it is believed that the study will provide methodical guidance for both researchers and agricultural policymakers.

2. Materials and methods

The study compared the methods for predicting irrigation and performance in the coming years using certain performance indicators based on the amount of irrigation water used in Kahramanmaraş Irrigation Scheme in 2006–2018. Kahramanmaraş Irrigation Scheme is managed by 2 water user associations (Left Bank and Right Bank), covers 20,000 ha. And about 1500 farmers are getting irrigation service. The main crops are corn, cereals and cotton. The water resources are Aksu River and Kartalkaya Dam (Arslan and Değirmenci, 2018; Sesveren and Karakaya, 2019).

Based on the irrigation data from Kahramanmaraş region, regression, time series—exponential smoothing and time series—and ARIMA methods were compared. In this study, the irrigation performance for the next year was predicted based on the irrigation data. For this purpose, the data of 2006–2017 from the irrigation data of 2006–2018 were analysed by the methods mentioned above to produce predictions for 2018. The predictions were compared to the actual irrigation data of 2018, and the method offering the closest forecasting was determined.

2.1. Data analysis

Equations of performance indicators were given in Table 1. These indicators has used by many researcher in previous studies (Malano and Burton, 2001; Çakmak et al., 2004; Rodriguez-Diazve et al., 2008; Çakmak et al., 2010; Zema et al., 2015; Arslan et al., 2019; Kartal et al., 2019; Kartal et al., 2020). Some performance indicators are selected among many indicators for the comparison of statistical methods to predict its future value. Irrigated area/command area ratio (%) defines the area irrigated in percentages, annual relative irrigation supply gives a ratio to understand if irrigation water is enough for crop water demand, total cost per unit cubic meter of irrigation water supplied ($ m^{-3}) shows total cost for a unit water supplied, output per cubic meter of irrigation water demand ($ m^{-3}) illustrates the cost for a unit water demand (Kartal et al., 2019). These indicators have been used to manage irrigation water, future water policy for sustainable water distribution and determine the current situation for any water user associations (Kartal et al., 2020).

The R program was used in the analysis of the data. The 'Forecasting' package was used for moving average-based time-series and time-series ARIMA model predictions, and the 'Psych' package for regression. The irrigation performance indicators to be predicted using regression and time-series methods were determined as irrigation rate, water supply ratio and total expense per unit of irrigation water and production value per unit of irrigation water need. The indicator values for 2018 were predicted using these indicators obtained from the analyses based on the data of 2006–2017. The predicted value was compared to the actual values of 2018 and the method offering the closest value was determined. The codes presented below were used in the analysis of the data (Table 2).

3. Results

The results from the methods used to forecast irrigation performance indicators are presented below.

On examining Table 3, it is seen that the method offering the closest prediction to the irrigation rate of 51.2 for 2018 is the regression method. Exponential smoothing method was found to be the furthest from the actual value. Irrigation area/command area ratio estimates are shown in Figure 1. When Figure 1 is examined, it is seen that the estimation closest to the real value is made by regression method for irrigation ratio.

When the values given in Table 4 are examined, the method offering the closest prediction to annual relative irrigation supply values for 2018 seems to be the regression method, in terms of irrigation rate. Time series exponential smoothing and ARIMA methods results were found approximately same and were far from actual value.

Among the performance indicators for irrigation water, the irrigation rate and the water supply rate are the indicators of water distribution. The regression method provided the closest prediction to the actual value in the future prediction of these two indicators. Accordingly, it can be said that the regression method gives better results than the time-series exponential smoothing and ARIMA methods in the prediction of the water distribution indicators. Annual relative irrigation supply estimates are shown in Figure 1.

When Figure 1 is examined, it is seen that the estimation closest to the real value is made by regression method for annual relative irrigation supply estimates too.

When the predictions for total expense per unit of irrigation water given in Table 5 are examined, the methods offering the closest prediction to the value of 2018 seems

Table 1. Equations of performance indicators selected.

Performance indicators	Formula
Irrigated area/command area ratio (%)	$\frac{\text{Irrigated area} * 100}{\textit{Command area}}$
Annual relative irrigation supply (no unit)	$\frac{\textit{Total annual volume of irrigation supply}}{\text{Total annual volume of crop water demand}}$
Total cost per unit cubic meter of irrigation water supplied ($ m^{-3})	$\frac{\text{Total expenditure}}{\textit{Total annual volume of irrigation supply}}$
Output per cubic meter of irrigation water demand ($ m^{-3})	$\frac{\text{Total annual value of agricultural production}}{\text{Total annual volume of crop water demand}}$

Table 2. Codes used for R.

```
####the code used to install the required packages###
>library(forecast)
>library(psych)
###for creating a time series for time series models
>name<-ts(variablename$dataname, start = c(2006,1), f=1)
### for forecastin with ets, arima and regression
>name<-ts(variablename$dataname, start = c(2006,1), f=1)fitets<-ets(Y)
>estimation<-forecast(fitets,h=1)
>autoplot(estimation)
>print(summary(estimation))
>name<-ts(variablename$dataname, start = c(2006,1), f=1)
>arimaestimation<-auto.arima(name, stepwise=F, approximation = F, trace = T, seasonal = F)
>print(summary(arimaestimation))
>forecastwitharima<- forecast(arimaestimation, h=1)
>residuals(arimaestimation)
>print(residuals(arimaestimation))
```

Table 3. Predictions for irrigated area/command area ratio.

	Regression		Exponential smoothing		ARIMA		2018 actual value
Prediction	63.14*		69.13		65.58		51.2
95% confidence interval	Min	Max	Min	Max	Min	Max	
	25.94	100.33	45.57	92.68	42.04	89.12	

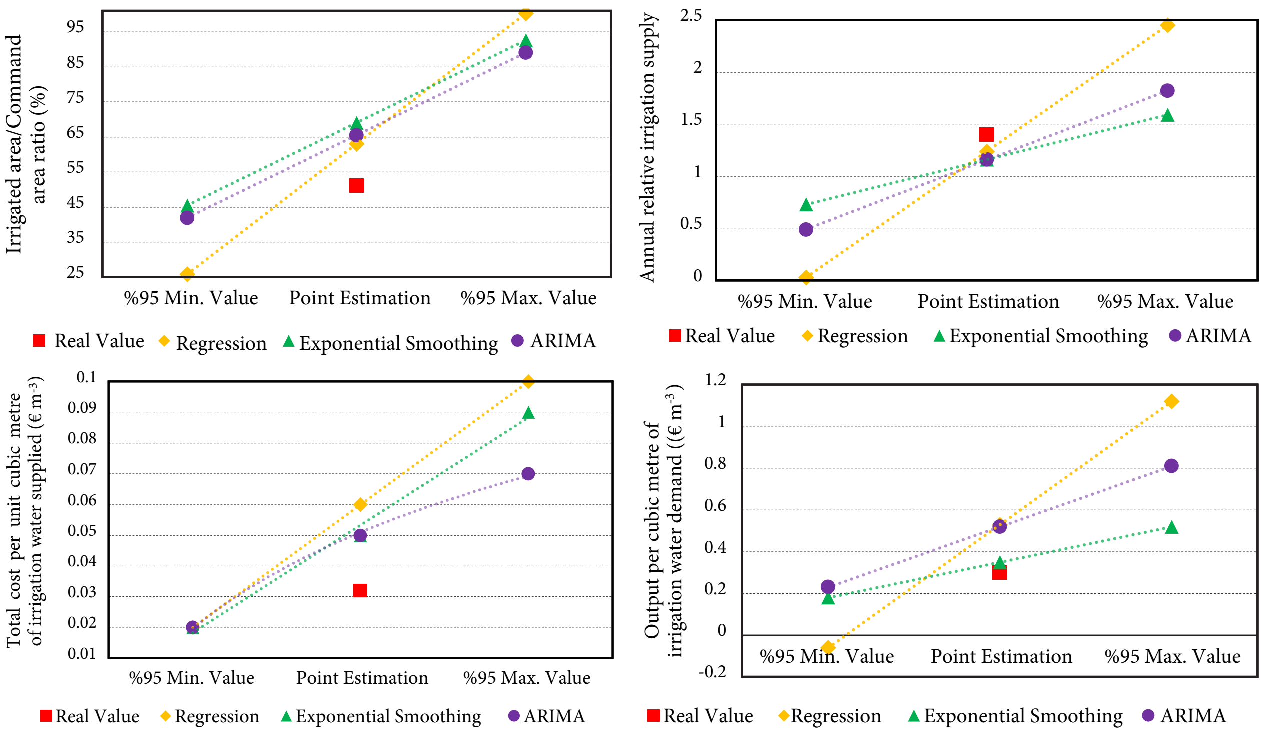

Figure 1. Estimates of performance indicators.

to be the time-series ARIMA and exponential smoothing methods. Regression method gave the closest value to the actual value. Total cost per unit cubic metre of irrigation water supplied estimates are shown in Figure 1.

When Figure 1 is examined, it is seen that the estimation closest to the real value is made by time series model methods for total cost per unit cubic metre of irrigation water supplied.

When the production values per unit of irrigation water need given in Table 6 are examined, the time-series exponential smoothing method seems to provide the closest prediction to the value of 2018. When the 95% confidence level intervals provided by the regression method are examined, it is seen that the minimum value falls below what it should be, becoming a negative value. This indicator, calculated in USD, should not be a negative value, so the use of the regression method may not be recommended for these and similar indicators. Output per cubic metre of irrigation water demand estimates are shown in Figure 1.

When Figure 1 is examined, it is seen that the estimation closest to the real value is made by exponential smoothing model methods for output per cubic metre of irrigation water demand.

The total expense per unit of irrigation water given in Table 5 is a financial indicator of irrigation water performance and is calculated based on USD. Similarly, the output per cubic meter of irrigation water demand ($ m^{-3}) given in Table 6 is calculated based on the USD, and it is an indicator in the agricultural activity dimension in the irrigation water performance evaluation indicators. For both indicators, the regression method provided predictions far from the value of 2018.

4. Discussion

When evaluating the performance of regression, time-series exponential smoothing and time-series ARIMA methods, the performance indicator values of 2018 were taken as the base values. Therefore, from the data of 2006–2018, the data of 2006–2017 were used, particularly, analysed using these methods to predict the values of 2018. These predicted values obtained were compared to the actual values of 2018 and the method offering the closest prediction was determined.

The study results showed that the regression method provided the closest prediction for irrigation rate and water supply rate indications which are in the water distribution dimension. Accordingly, researchers may be advised

Table 4. Predictions for annual relative irrigation supply.

	Regression		Exponential smoothing		ARIMA		2018 actual value
Prediction	1.24*		1.16		1.16		1.40
95% confidence interval	Min	Max	Min	Max	Min	Max	
	0.03	2.45	0.73	1.59	0.49	1.82	

Table 5. Predictions for total cost per unit cubic meter of irrigation water supplied.

	Regression		Exponential smoothing		ARIMA		2018 actual value
Prediction	0.06		0.05*		0.05*		0.032
95% confidence interval	Min	Max	Min	Max	Min	Max	
	0.02	0.10	0.02	0.09	0.02	0.07	

Table 6. Predictions for output per cubic meter of irrigation water demand.

	Regression		Exponential smoothing		ARIMA		2018 actual value
Prediction	0.53		0.35*		0.52		0.30
95% confidence interval	Min	Max	Min	Max	Min	Max	
	–0.06	1.12	0.18	0.52	0.23	0.81	

to choose the regression method when it is required to produce a prediction for the water distribution dimension.

For the total expense per unit of irrigation water indicator in the financial dimension, it was seen that both the time-series methods provided the results closest to the actual value. For the production value per unit of irrigation water need indicator in the agricultural activity dimension, the exponential smoothing method among time-series models gave the closest result to the actual value. In accordance with these results, the time-series exponential smoothing method may be recommended for the financial and agricultural activities dimensions. The regression method offers the farthest values. The regression method is linear and tends to sort dependent and independent variables on a single line using the method of smallest errors (Ballot, 1986). The indicators in the agricultural activity and financial dimensions are calculated according to the USD rate, and any fluctuations in the exchange rate distract the time-dependent change of performance indicators from linearity. Therefore, it can be suggested that a prediction based on the regression method distracts from the actual value for these dimensions. It can be stated that the performance indicators in both dimensions are calculated based on USD and the corresponding fluctuations are brought to the normal band with the time-series exponential smoothing method, so this method is a more successful prediction method than the other two methods. The time-series exponential smoothing method offers strong predictions in cases where data are irregular (Engle, 1982; Nelson, 1991; Campbell and Diebold, 2005). It can be suggested that fluctuations in the exchange rate also lead to the irregularity of these performance indicators. Therefore, the time-series exponential smoothing method provides more realistic predictions in this case.

Given these results, when evaluating the irrigation performance, the regression method can be used to provide predictions for irrigation rate, the amount of irrigation water per the unit of irrigation area, and water supply rate in the water distribution dimension for the coming years. The time-series methods, especially the exponential smoothing method, can be used to provide predictions for the indicators in the financial and agricultural activity dimensions. These are the methods offering the closest prediction. Considering the possible future values of indicators, such as irrigation rate, production value per unit of irrigation water when making future irrigation water plans will lead to realistic and practicable plans. Therefore, it is essential to use the method offering the closest prediction for any future predictions.

References

Alcon F, García-Bastida PA, Soto-García M, Martínez-Alvarez V, Martin-Gorriz B et al. (2017). Explaining the performance of irrigation communities in a water-scarce region. Irrigation science 33 (3): 193-203. doi: 10.1007/s00271-016-0531-7

Ali MK (2018). Estimation of irrigation water use efficiency with a stochastic frontier model. International Association of Agricultural Economists (IAAE), 2018 Conference, July 28-August 2, 2018, Vancouver, British Columbia.

Arslan F, Değirmenci H, Kartal S, Alcon F (2020). Mapping performance of irrigation schemes in Turkey. Agronomy Research 18 (4): 2303–2316.

Ballot M (1986). Decision Making Model in Production & Operations Management. Robert E. Krieger Publishing Company, Florida.

Billings RB, Agthe DE (1998). State-Space versus Multiple Regression for Forecasting Urban Water Demand. Journal of Water Resources Planning and Management 124 (2): 113-117.

Blair P, Buytaert W (2016). Socio-hydrological modelling: A review asking "why, what and how?". Hydrology and Earth System Sciences 20: 443–478. doi: 10.5194/hess-20-443-2016

Bombino G, Denisi P, Gómez JA, Zema DA (2019). Water infiltration and surface runoff in steep clayey soils of olive groves under different management practices. Water 11 (2): 240.

Box GEP, Jenkins GM, Reinsel GC (1994). Time Series Analysis; Forecasting and Control. Prentice Hall Englewood Cliff, New Jersey.

Brown CM, Lund JR, Cai X, Reed PM, Zagona EA et al. (2015). The future of water resources systems analysis: Toward a scientific framework for sustainable water management. Water Resources Research 51: 6110–6124. doi: 10.1002/2015WR017114

Çaglar T (2007). Talep tahmininde kullanılan yöntemler ve fens teli üretimi yapan bir işletmede uygulanması. Master Thesis, Kırıkkale Üniversitesi, Turkey.

Caiado J (2007). Forecasting Water Consumption in Spain Using Univariate Time Series Models. Proceedings of IEEE Spanish Computational Intelligence Society, 415-423.

Cakmak B, Beyribey M, Yildirim YE, Kodal S (2004). Benchmarking performance of irrigation schemes: a case study from Turkey. Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage 53 (2): 155-163. doi: 10.1002/ird.130

Cakmak B, Kibaroglu A, Kendirli B, Gokalp Z (2010). Assessment of the irrigation performance of transferred schemes in Turkey: a case study analysis. Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage 59 (2): 138-149. doi: 10.1002/ird.452

Campbell S, Diebold F (2005). Weather forecasting for weather derivatives. Journal of the American Statistical Association 100: 6-16. doi: 10.1198/016214504000001051

Cassuto AE, Ryan S (1979). Effect of Price on the residential Demand for Water Within an acency. Journal of the American Water Resources Association 15: 345–353. doi: 10.1111/j.1752-1688.1979.tb00337.x

Choi S, Lee SO, Park J (2017). A comprehensive index for stream depletion in coupled human-water systems. Journal of Hydro-Environment Research 16: 58–70. doi: 10.1016/j.jher.2017.07.002

Drastig K, Prochnow A, Libra J, Koch H, Rolinski S (2016). Irrigation water demand of selected agricultural crops in Germany between 1902 and 2010. Total Environ 569–570: 1299–1314. doi: 10.1016/j.scitotenv.2016.06.206

DSI (2019). Irrigation Schemes. 15th District General Directorate of State Hydraulic Works. Retrieved in December, 11, 2019 from URL. http://bolge15.dsi.gov.tr/toprak-ve-su-kaynaklar%C4%B1

Duran-Encalada JA, Paucar-Caceres A, Bandala ER, Wright GH (2017). The impact of global climate change on water quantity and quality: A system dynamics approach to the US–Mexican transborder region. European Journal of Operational Research 256: 567–581. doi: 10.1016/j.ejor.2016.06.016

Engle R (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom ináation. Econometrica 50: 987-1008

Feddes RA, Kowalik PJ, Zarandy H (1978). Simulation of Field Water Use and Crop Yield. Wiley, New York.

Gao W, Hong B, Swaney DP, Howarth RW, Guo H (2016). A system dynamics model for managing regional N inputs from human activities. Ecological Modelling 322: 82–91. doi: 10.1016/j.ecolmodel.2015.12.001

Ghodsvali M, Krishnamurthy S, de Vries B (2019). Review of transdisciplinary approaches to food-water-energy nexus: A guide towards sustainable development. Environmental Science & Policy 101: 266–278. doi: 10.1016/j.envsci.2019.09.003

Hagemann S, Chen C, Clark DB, Folwell S, Gosling SNet al. (2013). Climate change impact on available water resources obtained using multiple global climate and hydrology models. Earth System Dynamics 4: 129–144. doi: 10.5194/esd-4-129-2013

Hansen RD, Narayanan R (1981). A monthly time series model of municipal water demand. Journal of the American Water Resources Association 17: 578-585. doi: 10.1111/j.1752-1688.1981.tb01263.x

Howe CW, Linaweaver FP (1967). The impact of price on residential water demand and its relation to system design and price structure. Water Resources Research 3 (1): 13– 32. doi: 10.1029/WR003i001p00013

Jeong H, Adamowski J (2016). A system dynamics based socio-hydrological model for agricultural wastewater reuse at the watershed scale. Agricultural Water Management 171: 89–107. doi: 10.1016/j.agwat.2016.03.019

Jiang Y (2015). China's water security: Current status, emerging challenges and future prospects. Environmental Science & Policy 54: 106–125. doi: 10.1016/j.envsci.2015.06.006

Jowitt PW, Xu C (1992). Demand Forecasting for Water Distribution Systems. Civil Engineering System 9: 105-121. doi: 10.1080/02630259208970643

Kartal S, Değirmenci H, Arslan F (2019). Assessment of Irrigation Schemes with Performance Indicators in Southeastern Irrigation District of Turkey. Journal of Agricultural Sciences 26 (2): 138-146. doi: 10.15832/ankutbd.512677

Kartal S, Değirmenci H, Arslan F (2019). The Effect of Irrigation Channel Type and Length on Irrigation Performance Indicators. KSU Journal of Agriculture and Nature 22 (3): 444-450.

Kelly C, Onat NC, Tatari O (2019). Water and carbon footprint reduction potential of renewable energy in the United States: A policy analysis using system dynamics. Journal of Cleaner Production 228: 910–926. doi: 10.1016/j.jclepro.2019.04.268

Kotir JH, Smith C, Brown G, Marshall N, Johnstone R (2016). A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana. Total Environ 573: 444–457. doi: 10.1016/j.scitotenv.2016.08.081

Liu H, Benoit G, Liu T, Liu Y, Guo H (2015). An integrated system dynamics model developed for managing lake water quality at the watershed scale. Journal of Environmental Management 155: 11–23. doi: 10.1016/j.jenvman.2015.02.046

Ma W, Meng L, Wei F, Opp C, Yang D (2020). Sensitive Factors Identification and Scenario Simulation of Water Demand in the Arid Agricultural Area Based on the Socio-Economic-Environment Nexus. Sustainability 12 (10): 3996. doi: 10.3390/su12103996

Maidment DR, Miaou S, Crawford M (1985). Transfer Function Models of Daily Urban Water Use. Water Resources Research 21: 425–432. doi: 10.1029/WR021i004p00425

Malano H, Burton M (2001). Guidelines for Benchmarking Performance in the Irrigation and Drainage Sector. IPTRID and FAO, Rome, Italy.

Marmontel CVF, Lucas-Borja ME, Rodrigues VA, Zema DA (2018). Effects of land use and sampling distance on water quality in tropical headwater springs (Pimenta creek, São Paulo State, Brazil). Science of the Total Environment 622: 690-701.

Mirschel W, Wenkel KO, Berg M, Wieland R, Terleev V et al. (2018). ZUWABE: a model for estimation of spatial irrigation water demand for agricultural crops. In: Sychev VG, Müller L (eds) Novel Methods and Results of Landscape Research in Europe, Central Asia and Siberia (Monograph in 5 Volumes)—vol IV Optimising Agricultural Landscapes. Russian Academy of Sciences: FSBSI "All-Russian Research Institute of Agrochemistry named after D.N. Pryanishnikov", Moscow, Chapter IV/74: 361–365. doi: 10.25680/1712.2018.54.77.339

Mirschel W, Wieland R, Luzi K, Groth K (2020). Model-Based Estimation of Irrigation Water Demand for Different Agricultural Crops Under Climate Change, Presented for the Federal State of Brandenburg, Germany. In: Mirschel W, Terleev V & Wenkel KO (eds) Landscape Modelling and Decision Support. Innovations in Landscape Research. Springer, Cham. doi: 10.1007/978-3-030-37421-1_16.

Nelson D (1991). Conditional heteroskedasticity in asset returns: a new approach. Econometrica 59: 347-370.

Qi C, Chang NB (2011). System dynamics modeling for municipal water demand estimation in an urban region under uncertain economic impacts. Journal of Environmental Management 92: 1628–1641. doi: 10.1016/j.jenvman.2011.01.020

Rodríguez-Dìaz JA, Camacho E, López R, Pérez L (2008). Benchmarking and multivariate data analysis techniques for improving the efficiency of irrigation districts: an application in Spain. Agricultural Systems 96: 250–259. doi: 10.1016/j.agsy.2007.07.010

Ryu JW, Park HK (2019). The analysis of influential factors for urban water supply system considering causality with time-series data. IOP Conference Series: Earth and Environmental Science. 351 012016. doi: 10.1088/1755-1315/351/1/012016

Sahin O, Stewart RA, Porter MG (2015). Water security through scarcity pricing and reverse osmosis: A system dynamics approach. Journal of Cleaner Production 88: 160–171. doi: 10.1016/j.jclepro.2014.05.009

Sesveren S, Karakaya FG (2019). Kartalkaya Sol Sahil Sulama Birliği Bazı Performans Göstergeleri, Sulama Problemleri ve Çözüm Önerileri. Journal of the Institute of Science and Technology 9 (1): 76-84.

Sun T, Huang Q, Wang J (2018). Estimation of Irrigation Water Demand and Economic Returns of Water in Zhangye Basin. Water 10 (1): 19. doi: 10.3390/w10010019

Sun Y, Liu N, Shang J, Zhang J (2017). Sustainable utilization of water resources in China: A system dynamics model. Journal of Cleaner Production 142: 613–625. doi: 10.1016/j.jclepro.2016.07.110

Susnik J, Vamvakeridou-Lyroudia LS, Savic DA, Kapelan Z (2012). Integrated System Dynamics Modelling for water scarcity assessment: Case study of the Kairouan region. Science of the Total Environment 440: 290–306. doi: 10.1016/j.scitotenv.2012.05.085

Taehva L, Yongchul S (2016). Estimation of Irrigation Water Amounts for Farm Products based on Various Soil Physical Properties and Crops. Journal of The Korean Society of Agricultural Engineers 58 (16): 1-8. doi: 10.5389/KSAE.2016.58.6.001

Tanriverdi C, Degirmenci H (2011). Assessment of management transfer of Kahramanmaras irrigation system. Scientific Research and Essays 6(3): 522-528.

Üreten, S (2005). Üretim/İşlemler Yönetimi, 5. Baskı Gazi Kitapevi, Ankara. doi: 10.5897/SRE10.186

Wei T, Lou I, Yang Z, Li Y (2016). A system dynamics urban water management model for Macau, China. Journal of Environmental Management 50: 117–126. doi: 10.1016/j.jes.2016.06.034

Winz I, Brierley G, Trowsdale S (2008). The Use of System Dynamics Simulation in Water Resources Management. Water Resources Management 23: 1301–1323. doi: 10.1007/s11269-008-9328-7

Yang D, Cai J, Hull V, Wang K, Tsang YP et al. (2017). New road for telecoupling global prosperity and ecological sustainability. Ecosyst. Health Sustain 2. doi: 10.1002/ehs2.1242

Yang D, Gao X, Xu L, Guo Q (2018). Constraint-adaptation challenges and resilience transitions of the industry–environmental system in a resource-dependent city. Resources, Conservation & Recycling 134: 196–205. doi: 10.1016/j.resconrec.2018.03.016

Zema DA, NicotraA, Mateos L, Zimbone SM (2018). Improvement of the irrigation performance in Water Users Associations integrating data envelopment analysis and multi-regression models. Agricultural Water Management 205: 38-49.

Zhang P, Zou Z, Liu G, Feng C, Liang S et al. (2020). Socioeconomic drivers of water use in China during 2002–2017. Resources, Conservation & Recycling 154. doi: 10.1016/j.resconrec.2019.104636