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Seasonal ARIMA model for generation and forecasting evapotranspirtion of Solapur district of Maharashtra

S.D.GORANTIWAR[1], D.T.MESHRAM[2] and H. K. MITTAL[3]

[1]*Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra*
[2]*National Research Center on Pomegranate (ICAR), Solapur, Maharashtra*
[3]*College of Technology and Engineering, Udaipur, Rajasthan*
Email: sdgorantiwar@gmail.com

ABSTRACT

This paper deals with the stochastic modeling of weekly reference crop evapotranspiration in semi-arid climatic condition by using seasonal Auto Regressive Moving Average (ARIMA) model. The weekly values of reference crop evapotranspiration (ETr) estimated by Penman Monteith method for 23 years (1984 to 2006) were used to fit the ARIMA models of different orders. ARIMA models up to 1^{st} order were selected based on autocorrelation function (ACF) and partial autocorrelation function (PACF) of the ETr series. The parameters of the selected models were obtained with the help of maximum likelihood method. The ARIMA models that satisfied the adequacy tests were selected for forecasting. One year ahead forecast (i.e. for 2007) of ETr values were obtained with the help of these selected models. The root mean square error (RMSE) was computed between forecast and actual values of ETr of 2007. The lowest RMSE was obtained for ARIMA (1,1,0) $(1,0,1)_{52}$ and hence is the best stochastic model for generating and forecasting of weekly ETr values.

Key Words: Stochastic model, reference crop evapotranspiration, seasonal ARIMA Model.

Evapotranspiration is important for the efficient management of available water resources; as it is a major component of the water requirement of crops and governs irrigation scheduling. The evapotranspiration of a crop (ETc) is computed by multiplying reference crop evapotranspiration (ETr) with crop coefficient (Kc) which varies with crop and its growth stage; thus taking into consideration the effect of crop and its age on the water requirement (Doorenbos and Pruitt, 1977).

Often the historical series of several climatological parameters that determine the ETr is short and inadequate for irrigation planning. However for appropriate planning and management of water resources, it is necessary to know the long term values of ETr. Hence it is necessary to generate the synthetic sequences of ETr that have the properties similar to the historical values of ETr. It is also necessary to know the estimates of ET_r few time periods ahead for real time operation of water resources system. Stochastic models are useful for generating the long term sequences of ETr that are having the statistical properties representing to those of historical sequence. As the stochastic models of certain class for example Auto Regressive Integrated Moving Average (ARIMA) models also have the ability to forecast the data for short term, these are useful for growers for managing their water resources more efficiently. ARIMA models were used for modeling monthly or intraseasonal flows (Gorantiwar *et al.,* 1995; Montanari *et al.*, 2000; and Trawinski and Mackay, 2008). ARIMA models of different orders were also fitted for generation and forecasting of the weekly evaporation series (Mohan and Arumugam, 1995; Sahoo and Mohan 1995; Salvisa, 1998; Hamdi, 2008 *et al*). This study is concerned with the irrigation planning using ARIMA models to forecast ETr for Solapur district of Maharastra state.

MATERIALS AND METHOD

Data used

As the Penman-Monteith method has strong likelihood of correctly predicting ETr in a wide range of location and climates (Allen *et al.,* 1998), this method was used for estimating the daily values of reference ETr. The Penman-Monteith method needs the location and climatological data of the location for which ETr values are to be estimated. Therefore, the daily data in respect of maximum temperature (Tmax, ^{0}C) and minimum temperature (Tmin, ^{0}C), maximum relative humidity (RHmax, %) and minimum relative humidity (RHmin, %), wind speed at height of 2m (U_2, km h^{-1}), actual sun shine hours (n, hr), and latitude and longitude etc. were collected for 24 years (1984-2007) from the Indian Meteorological Department, Pune and NRC on Pomegranate, Solapur. The ETr values for 23 years were used for developing ARIMA models and ETr values of last one year were used for validating or selecting the model. The average value of reference crop evapotranspiration (ETr) series are shown in Fig. 1.

Auto regressive integrated moving average (ARIMA)

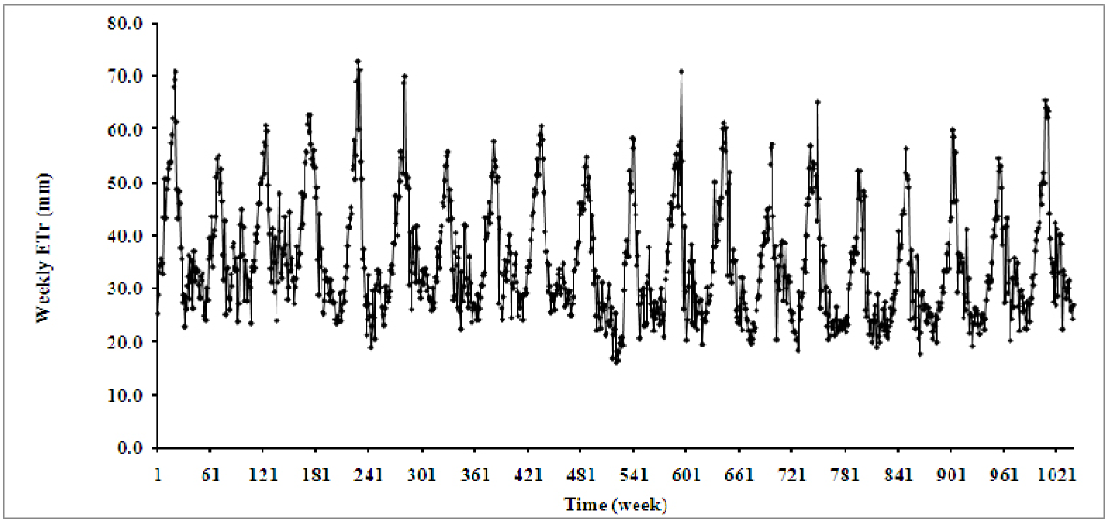

Fig. 1: Weekly reference crop evapotranspiration series in Solapur from 1984 to 2007

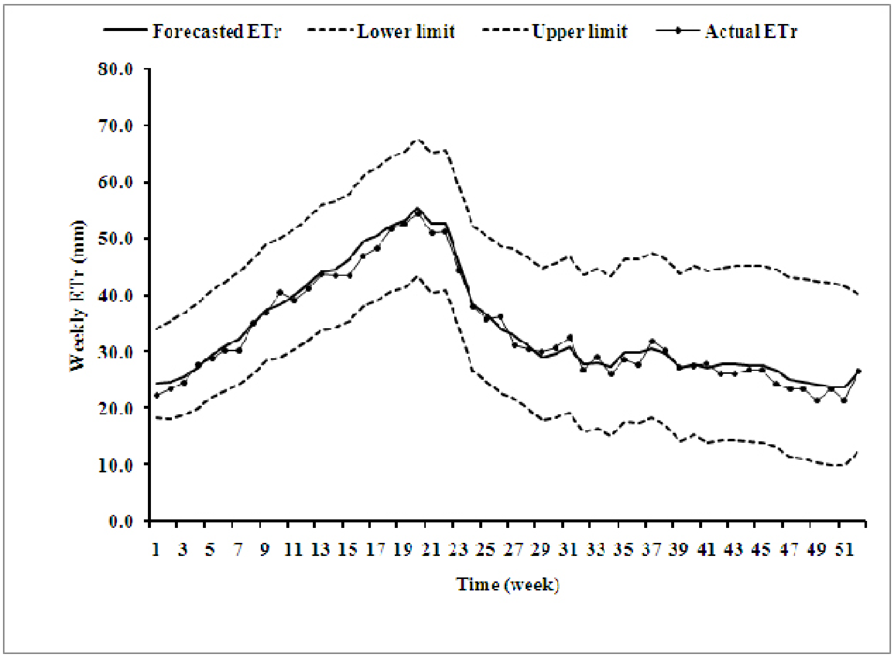

Fig. 2: Comparison of forecasted ETr and actual ETr by ARIMA $(1,1,0)(1,0,1)_{52}$ model

model

Seasonal ARIMA models are useful for modeling seasonal time series in which the mean and other statistics for a given season are not stationary across the year. The basic ARIMA model in its seasonal form is described as a straightforward extension of the nonseasonal ARMA and ARIMA models (Hipel *et al.*1977; and Box and Jenkins, 1994). A time series involving seasonal data will have relations at a specific lag, s, which depends on the nature of the data, e.g. for monthly data s = 12 and weekly s = 52. Such series can be successfully modeled only if the model includes the connections with the seasonal lag as well. Such models are known as multiplicative or seasonal ARIMA models.

Development of ARIMA Model

The different stages involved in fitting of ARIMA models to historical hydrological series as suggested by Hipel *et. al. (*1977) and Box and Jenkins (1994) were followed in

Table 1: The values of ARIMA model parameter and RMSE between forecast and actual ETr of selected ARIMA models that passed diagnostic check

Sr No	ARIMA Model	Model parameters					RMSE
		ϕ_1	θ_1	Φ_1	Θ_1	c	
1	ARIMA(1,0,1)(0,1,1)$_{52}$	0.8139	0.462	--	0.9546	-0.332	0.600
2	ARIMA(1,0,1)(1,0,1)$_{52}$	0.8543	0.854	0.4117	0.9883	35.19	0.629
3	ARIMA(0,1,1)(0,1,1)$_{52}$	--	0.715	--	0.9539	0.0012	0.749
4	ARIMA(1,0,0)(1,0,1)$_{52}$	0.6129	--	0.9863	0.8606	35.2	0.627
5	ARIMA(1,1,0)(1,0,1)$_{52}$	-0.3054	--	0.9895	0.9336	-0.001	0.597
6	ARIMA(1,1,0)(0,1,1)$_{52}$	-0.3325	--	0.945	--	-0.0001	0.628
7	ARIMA(1,1,1)(0,1,1)$_{52}$	0.3405	0.918	--	0.9426	0.0022	0.921
8	ARIMA(0,0,1)(1,0,1)$_{52}$	--	-0.447	0.9891	0.8066	35.58	0.629
9	ARIMA(0,0,1)(1,0,0)$_{52}$	--	-0.499	0.6463	--	35.57	0.972
10	ARIMA(0,0,1)(0,1,1)$_{52}$	--	-0.406	--	0.9368	-0.336	0.609

this study for identification of the models, determination of the parameters of selected models, diagnostic checking and selection of the model.

The adequacy of the selected models was checked. Standard error of the models parameters, observing ACF and PACF of the residuals and Akaike Information Criteria (Salas *et. al.* 1980 and Akaike,1974) were used in this study for diagnostic checking. The root mean square error (RMSE) criterion was used for selecting the most appropriate ARIMA model for ETr forecasting amongst all the ARIMA models that passed the adequacy tests or diagnostic checking.The model that gives the least value of RMSE was selected as the most appropriate model.

RESULTS AND DISCUSSION

Fitting of ARIMA model

The ACF and PACF of original ETr time series were estimated for different lags. On the basis of information obtained from ACF and PACF, 32 ARIMA models were identified. The parameters of the selected models were estimated by maximum likelihood method. Out of 36 ARIMA models, 10 models satisfied standard error test for all the parameters (Table 1). Akaike Information Criteria (AIC) (Akaike,1974) values were computed for 10 ARIMA models.

Several models qualify based on the diagnostic checking explained in above section. However, for selecting the best model amongst these, the model should forecast significant one year ahead ETr. For this purpose, the ETr values were forecast for one year with using 10 identified ARIMA models. These values were compared with the actual values of ETr for one year by calculating the root mean square error (RMSE). The RMSE values along with the values of the parameters of these 10 identified ARIMA models are presented in Table 1. Based on the lowest values of RMSE, (0.597) the ARIMA (1,1,0)(1,0,1)$_{52}$ of models was selected for generating and forecasting ETr time series. The actual and forecast values of ETr by ARIMA (1,1,0)(1,0,1)$_{52}$ are shown in Fig. 2.

CONCULSION

The study indicated that the ARIMA model is viable tool for forecasting the reference crop evapotranspiration. The ARIMA (1,1,0) (1,0,1)$_{52}$ satisfied the different tests of diagnostic checking and resulted in the lowest value of RMSE between actual ETr and forecast ETr. Hence ARIMA (1,1,0) (1,0,1)$_{52}$ is the best stochastic model for generation and forecasting of weekly ETr values for Solapur, Maharashtra, India.

REFERENCES

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Trans. Autom. Control. AC.,* 19(6): 716-723.

Allen, R.G., Pereira, L.S., Raes, D and Smith, M. (1998). "Crop Evapotranspiration, Guideline for Computing Crop Water Requirements". FAO Irrigation and Drainage Paper 56. FAO Rome, Italy. pp. 300.

Box, G.E.P and Jenkins. G.M. (1994). Time Series Analysis, Forecasting and Control. Revised Edition, Holden-Day, San Francisco, California, United States.

Doorenbos, J. and Pruitt. W.O. (1977). Guidelines for Predicting Crop Water Requirement: FAO Irrigation and Drainage Paper No. 24, FAO, Rome, Italy. pp.156.

Gorantiwar, S. D. (1984). Investigating applicability of some operational hydrology models to WB streams. M.Tech.

Thesis submitted to IIT, Kharagpur.

Gorantiwar, S.D., Majumdar, M. and Pampattiwar, P. S. (1995). Application of autoregressive models of different orders to annual stream flows of Barkar river with their logarithmic transformation. *J. Appl. Hyd.,* 8:33-39.

Hamdi, M. R., Bdour, A. N. and Tarawneh, Z. S. (2008). Developing reference crop evapotranspiration time series simulation model using class A Pan: A case study for the Jordan valley/Jordan. *Jordan J Ear. Envi. Sci.* 1(1): 33-44.

Hipel, K.W., McLeod, A.I. and Lennox, W.C. (1977). Advances in Box Jenkins modeling: 1.Model construction. *Wat. Reso. Res.,* 13: 567-575.

Maier, H. R. and Dandy. G. C. (1995). Comparison of Box-Jenkins procedure with artificial neural network methods for univariate time series modeling, Research Report No. R. 127, Department of Civil and Environmental Engineering, University of Adelaide, Australia, pp.120.

Mohan, S. and Arumugam, N. (1995). Forecasting weekly reference crop evapotranspiration series. *J. Hyd.Sci.,* 40(6): 689-702.

Montanari, A., Rosso, R. and Taqqu, M.S. (2000). A seasonal fractional ARIMA model applied to the Nile river monthly flows at Aswan. *Wat. Reso. Res.,* 36(5):1249-1259.

Sahoo, P. K. and Mohan, S. (1995). Stochastic modeling of weekly evapotranspiration series. *J. App. Hyd.,* 8(1-4): 67-82.

Salas, J. D., Dellur, J. W., Yevjevich, V. and Lane, W. L. (1980). Applied modeling of Hydrological Time Series. Water Resources Publication, Littleton, Coloredo; pp. 484.

Slavisa, T. (1998). Comparison of prediction models of reference crop evapotranspiration. *The Sci. J. FACTA Univ., Yogoslavia.*, 1(5): 617-625.

Trawinski, P.R. and Mackay, D.S. (2008). Meteorologically

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