A Survey on Rainfall Prediction and Anomalies using Time Series Models in Different Climates

Mohammad Valipour*

Young Researchers and Elite Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran

Abstract: In this study, using 50 years of rainfall data and ARIMA model, critical areas of Iran were determined. For this purpose, annual rainfall data of 112 different synoptic stations in Iran were gathered. To summarize, it could be concluded that: ARIMA model was an appropriate tool to forecast annual rainfall. According to obtained results from relative error, five stations include IRANSHAHR, SIRJAN, NAEIN, ZAHEDAN, and KISH, were in critical condition. At 45 stations accrued rainfalls with amounts of less than half of average in the 50-year period. Therefore, in these 45 areas, chance of drought is more than other areas of Iran.

Keywords: Iran, precipitation, water, ARIMA, autoregressive.

1. INTRODUCTION

Forecasting annual rainfall is significantly important in water resources management and crop pattern design. In this study, ARIMA model forecasted annual rainfall in 112 different synoptic stations in Iran and critical areas were determined. After publishing the paper of Box and Jenkins [1], Box-Jenkins models became one general time series model of hydrological forecasting. These models include Auto Regressive Integrated Moving Average (ARIMA), Auto Regressive Moving Average (ARMA), Auto Regressive (AR), and Moving Average (MA). Access to basic information requires integration from the series (for a continuous series) or calculating all of differences the series (for a continuous series). Since the constant of integration in derivation or differences deleted, the probability of using these amount or middle amount in this process is not possible. Therefore, ARIMA models are non-static and cannot be used to reconstruct the missing data. However, these models are very useful for forecasting changes in a process. Models of time series analysis (Box-Jenkins models) and drought periods study in various fields of hydrology and rainfall forecasting in irrigation schedule are widely applied, which some of them will be described in the following.

Mishra and Singh [2] did a review about drought modeling. Smakhtin and Hughes [3] described a new software package for automated estimation, display, and analyses of various drought indices–continuous functions of precipitation that allow quantitative assessment of meteorological drought events to be made. Yurekli and Kurunc [4] simulated agricultural drought periods based on daily rainfall and crop water consumption. Constituted monthly time series of drought durations of each hydrologic homogeneous section was simulated using ARIMA model. No linear trend was observed for the time series except one section. In general, the predicted data from the selected best models for the time series of each section represented the actual data of that section. Serinaldi and Kilsby [5] presented a modular class of multisite monthly rainfall generators for water resource management and impact studies. The results of the case study point out that the model can capture several characteristics of the rainfall series. In particular, it enables the simulation of low and high rainfall scenarios more extreme than those observed as well as the reproduction of the distribution of the annual accumulated rainfall, and of the relationship between the rainfall and circulation indices such as North Atlantic Oscillation (NAO) and Sea Surface Temperature (SST), thus making the framework well-suited for sensitivity analysis under alternative climate scenarios and additional forcing variables. Luc *et al.* [6] studied an application of artificial neural networks for rainfall forecasting successfully. Wei *et al.* [7] using weather satellite imagery forecasted rainfall in Taiwan. Andrieu *et al.* [8] studied Adaptation and application of a quantitative rainfall forecasting model in a mountainous region. This work shows that a limit on forecast lead-time may be related to the response time of the precipitating cloud system. Burlando *et al.* [9] using ARMA models forecasted short-term rainfall. Hourly rainfall from two gaging stations in Colorado, USA, and from several stations in Central Italy been used. Results showed that the event-based estimation approach yields better forecasts. Hu *et al.* [10] studied rainfall, mosquito density and the transmission of Ross River virus using a time-series forecasting model. Their results showed that both rainfall and mosquito density

*Address correspondence to this author at the Young Researchers and Elite Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran; Tel: +989124369096; Fax: +982126300812;
E-mail: mohammadvalipour@gmail.com

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were strong predictors of the Ross River virus transmission in simple models. Ramírez *et al.* [11] used artificial neural network technique for rainfall forecasting applied to the São Paulo region. The results showed that ANN forecasts were superior to the ones obtained by the linear regression model thus revealing a great potential for an operational suite. Han *et al.* [12] forecasted drought based on the remote sensing data using ARIMA model successfully. Chattopadhyay and Chattopadhyay [13] compared ARIMA and ARNN models using Univariate modelling of summer-monsoon rainfall time series. Jia and Culver [14] using bootstrapped artificial neural networks suggested that even a small set of periodic instantaneous observations of stage from a staff gauge, which can easily be collected by volunteers, can be a useful data set for effective hydrological modeling. Baareh *et al.* [15] used the artificial neural network and Auto-Regression (AR) models to the river flow forecasting problem. A comparative study of both ANN and the AR conventional model networks indicated that the artificial neural networks performed better than the AR model. They showed that ANN models can be used to train and forecast the daily flows of the Black Water River near Dendron in Virginia and the Gila River near Clifton in Arizona. Xiong and O'connor [16] used four different error-forecast updating models, autoregressive (AR), autoregressive-threshold (AR-TS), fuzzy autoregressive-threshold (FU-AR-TS), and artificial neural network (ANN) to the real-time river flow forecasting. They found that all of these four updating models are very successful in improving the flow forecast accuracy. Chenoweth *et al.* [17] estimated the ARMA model parameters using neural networks. Their results showed that the ability of neural networks to accurately identify the order of an ARMA model was much lower than reported by previous researchers, and is especially low for time series with fewer than 100 observations. Using forecasting of hydrologic time series with ridge regression in feature space, Yu and Liong [18] showed that the training speed in data mining method was very much faster than ARIMA model. See and Abrahart (2001) used of data fusion for hydrological forecasting. Their results showed that using of data fusion methodologies for ANN, fuzzy logic, and ARMA models accuracy of forecasting would increase. Using hybrid approaches, Srinivas and Srinivasan [19] improved the accuracy of AR model parameters for annual stream flows. Using the Fourier coefficients, Ludlow and Enders [20] estimated the ARMA model parameters with a relatively good accuracy. Chenoweth *et al.* [21] estimated the ARMA model parameters using the Hilbert coefficients. Their results showed that the Hilbert coefficients are considered a useful tool for estimating ARMA model parameters. Balaguer *et al.* [22] used the method of time delay neural network (TDNN) and ARMA model to forecast asking for help in support centers for crisis management. The obtained correlation results for TDNN model and ARMA were 0.88 and 0.97, respectively. This study confirmed the superiority of ARMA model to the TDNN. Toth *et al.* [23] used the artificial neural network and ARMA models to forecast rainfall. The results show the success of both short-term rainfall-forecasting models for forecast floods in real time. Mohammadi *et al.* [24] forecast Karaj reservoir inflow using data of melting snow and artificial neural network and ARMA methods, and regression analysis. 60% of inflow in dam happens between Aprils until June, so forecasting the inflow in this season is very important for dam's performance. The highest inflows were in the spring due to the snow melt caused by draining in threshold winter. The results showed that artificial neural network has lower significant errors as compared with other methods. Mohammadi *et al.* [25] in other research estimated parameters of an ARMA model for river flow forecasting using goal programming. Their results showed that the goal programming is a precise and effective method for estimating ARMA model parameters for forecasting inflow. Valipour [26-32] estimated parameters of ARMA and ARIMA models and compare their ability for inflow forecasting. By comparing root mean square error of the model, it was determined that ARIMA model can forecast inflow to the Dez reservoir from 12 months ago with lower error than the ARMA model. Valipour [32-40] studied number of required observation data for rainfall forecasting according to the climate conditions. By comparing R^2 of the models, it was determined that time series models were better appropriate to rainfall forecasting in semi-arid climate. Numbers of required observation data for forecasting of one next year were 60 rainfall data in semi-arid climate.

Therefore, considering the above mentioned performed researches, we can know the efficacy of ARIMA model in forecasting field and hydrologic sampling. Although there are a lot of investigations on different aspect of hydrological analysis [41-59], effect of annual rainfall forecasting has not been done in previous researches for agriculture water management and critical areas determining. This study aims to forecast annual rainfall using ARIMA model and determine areas that chance of drought in those is more than other areas of Iran.

2. MATERIALS AND METHODS

In this study to forecasting of annual rainfall used from 112 synoptic stations data in Iran. In order to rainfall forecasting at the annual scale, rainfall data period from 1951-2000 has been gathered. Actually, the used data involved 5600 data (all stations). In this study, ARIMA model were used for forecast annual rainfall. In each station 250 structure of ARIMA model were used. For this purpose used MINITAB software to run of all ARIMA structures. In this research used from 49 years data (1951-1999) for calibration of ARIMA model and forecasted amount of annual rainfall for year 2000. Finally, by two methods critical areas of Iran for water management were specified and used relative error to compare stations. In first method, areas that amount of their relative error were more than 20% were introduced as critical areas. In second method, areas that amount of their rainfall in some years were less than half of average rainfalls in 50 years periods were specified as areas that chance of drought in these were more that other areas.

3. RESULTS AND DISCUSSION

Tables **1** to **5** shows obtained relative error for 112 different stations with stations information and best structures of ARIMA models. Figure **1** represents ability of ARIMA model in annual rainfall forecasting. Figures 2 and 3 shows critical areas of Iran for agriculture water management according to first and second methods, respectively.

After running 28000 ARIMA structures for all stations, according to obtained results from relative error in Tables **1** to **5**, five stations include IRANSHAHR, SIRJAN, NAEIN, ZAHEDAN, and KISH, were in critical condition. In these areas due to very low rainfalls in 2000, ARIMA model do not give a good forecasting and relative error was more than 20%. Therefore, in these areas due to lack of accurate forecasting, agriculture water management and crop pattern presenting must be done very carefully. As the Figure **1** in 65% from forecasted annual rainfalls by ARIMA model amount of relative error was less than 0.1 (10%). These areas were in the safe range. 35% of forecasting had a relative error between 0.1-0.2 (10-20%) and these areas were in the alarm range. Finally only 5% of all ARIMA forecasting occurred in the critical range. This showed a high ability of ARIMA model in annual rainfall forecasting.

In addition five areas marked in the first method, can be determined 45 areas as critical areas of Iran due to occurred amount of their rainfall in some years were less than half of average rainfalls in 50 years periods. In these areas because observed very low rainfall in some cases, drought in the coming years is not unexpected. Thus, how agriculture water management should be performed with high accuracy and proposed crop pattern to be applied with adequate safety factors else there is the possibility of being trapped in periods of drought. To support of sustainable agriculture and management of required water can be prevented from future damage.

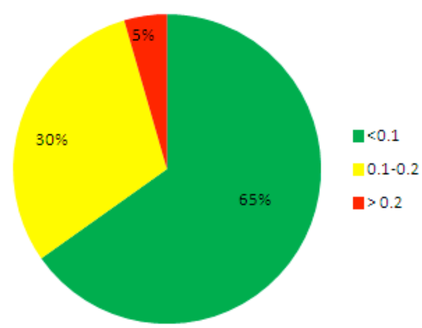

Figure 1: Ability of ARIMA model in rainfall forecasting according to the relative error.

Table 1: **Obtained Relative Error for 112 Different Stations with Stations Information and Best Structures of ARIMA Models (0-3%)**

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
MESHKINSHAR	40705	38 23 N	47 40 E	1568.5	289.4	289.0	0.1	ARIMA(1,0,0)
BABOLSAR	40736	36 43 N	52 39 E	-21.0	968.4	964.5	0.4	ARIMA(5,1,3)
RAMHORMOZ	40813	31 16 N	49 36 E	150.5	292.8	291.4	0.5	ARIMA(4,1,0)

(Table 1) Contd…..

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
TORBATE JAM	40806	35 15 N	60 35 E	950.4	111.6	111.0	0.6	ARIMA(1,3,0)
ABADAN	40831	30 22 N	48 15 E	6.6	155.5	156.7	0.8	ARIMA(5,1,0)
MAKOO	40701	39 20 N	44 26 E	1411.3	185.7	184.2	0.8	ARIMA(0,0,2)
SHOSHTAR	99446	32 3 N	48 50 E	67.0	296.3	298.7	0.8	ARIMA(1,1,0)
ZANJAN	40729	36 41 N	48 29 E	1663.0	309.7	312.7	1.0	ARIMA(5,1,0)
NOUSHAHR	40734	36 39 N	51 30 E	-20.9	1227.2	1239.4	1.0	ARIMA(1,1,0)
ARDESTAN	40799	33 23 N	52 23 E	1252.4	129.2	130.5	1.0	ARIMA(5,1,1)
ALIGOODARZ	40783	33 24 N	49 41 E	2034.0	415.1	409.1	1.4	ARIMA(1,1,3)
KANGAVAR	40771	34 30 N	48 0 E	1460.0	346.8	352.0	1.5	ARIMA(1,1,0)
SHIRAZ	40848	29 36 N	52 32 E	1488.0	358.0	351.7	1.8	ARIMA(4,1,0)
KARAJ	40752	35 55 N	50 54 E	1312.5	240.0	244.3	1.8	ARIMA(1,1,0)
ARAK	40769	34 6 N	49 46 E	1708.0	343.7	337.5	1.8	ARIMA(5,1,0)
BOJNURD	40723	37 28 N	57 19 E	1091.0	309.1	301.6	2.4	ARIMA(3,3,4)
KHOY	40703	38 33 N	44 58 E	1103.0	207.1	212.2	2.5	ARIMA(4,1,0)
YASOUJ	40836	30 40 N	51 35 E	1837.0	619.5	635.2	2.5	ARIMA(0,0,2)
YAZD	40821	31 54 N	54 24 E	1230.2	44.9	46.1	2.6	ARIMA(1,1,0)
OROOMIEH	40712	37 32 N	45 5 E	1313.0	230.6	236.7	2.6	ARIMA(5,1,1)
KERMAN	40841	30 15 N	56 58 E	1753.8	86.9	89.2	2.6	ARIMA(0,0,1)
ILAM	40780	33 38 N	46 25 E	1363.4	504.0	489.3	2.9	ARIMA(5,1,2)
BOROOJEN	99459	31 57 N	51 18 E	2197.0	175.1	180.4	3.0	ARIMA(5,1,0)

Table 2: Obtained Relative Error for 112 Different Stations with Stations Information and Best Structures of ARIMA Models (3.1-5.5%)

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
GORGAN	40738	36 51 N	54 16 E	13.3	579.0	561.0	3.1	ARIMA(1,1,0)
AHWAZ	40811	31 20 N	48 40 E	22.5	234.8	227.4	3.1	ARIMA(1,0,1)
SARDASHT	40725	36 9 N	45 30 E	1670.0	689.1	712.0	3.3	ARIMA(1,1,0)
KHORRAMABAD	40782	33 29 N	48 22 E	1125.0	423.8	438.6	3.5	ARIMA(5,1,2)
SARAKHS	40741	36 32 N	61 10 E	235.0	99.3	95.8	3.6	ARIMA(5,3,2)
TABRIZ	40706	38 5 N	46 17 E	1361.0	205.0	197.6	3.6	ARIMA(5,1,0)
KHALKHAL	40717	37 38 N	48 31 E	1796.0	340.7	353.1	3.6	ARIMA(5,1,1)
GHOOCHAN	40740	37 4 N	58 30 E	1287.0	271.5	281.4	3.6	ARIMA(4,1,0)
BANDAR ANZALI	40718	37 28 N	49 28 E	-26.2	2009.8	1934.1	3.8	ARIMA(5,1,4)
BIJAR	40748	35 53 N	47 37 E	1883.4	309.4	321.3	3.9	ARIMA(5,1,4)
ABADEH	40818	31 11 N	52 40 E	2030.0	95.1	99.2	4.3	ARIMA(5,1,1)
MALAYER	40775	34 17 N	48 49 E	1725.0	327.4	313.4	4.3	ARIMA(4,1,0)
SAVEH	99372	35 3 N	50 20 E	1108.0	239.2	228.4	4.5	ARIMA(1,2,0)
KERMANSHAH	40766	34 17 N	47 7 E	1322.0	352.4	335.8	4.7	ARIMA(1,1,0)

(Table 2) Contd…..

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
SHAHROUD	40739	36 25 N	54 57 E	1345.3	166.9	158.9	4.8	ARIMA(1,1,0)
MASJED SOLEYMAN	40812	31 56 N	49 17 E	320.5	372.2	390.4	4.9	ARIMA(1,1,0)
ESLAMABAD GHARB	40779	34 8 N	46 26 E	1346.0	354.4	336.3	5.1	ARIMA(4,1,2)
SABZEVAR	40743	36 12 N	57 43 E	977.6	147.4	155.2	5.3	ARIMA(3,1,3)
SEMNAN	40757	35 33 N	53 23 E	1171.0	140.5	148.0	5.4	ARIMA(1,1,0)
GHAZVIN	40731	36 15 N	50 0 E	1278.3	311.0	294.2	5.4	ARIMA(1,1,0)
GHORVEH	40772	35 10 N	47 48 E	1906.0	317.3	334.6	5.5	ARIMA(1,1,0)
SANANDAJ	40747	35 20 N	47 0 E	1373.4	329.5	311.5	5.5	ARIMA(1,1,0)

Table 3: Obtained Relative Error for 112 Different Stations with Stations Information and Best Structures of ARIMA Models (5.6-9.1%)

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
ABALI	40755	35 45 N	51 53 E	2465.2	440.9	416.1	5.6	ARIMA(0,0,2)
DOGONBADAN	40835	30 26 N	50 46 E	699.5	336.5	316.5	5.9	ARIMA(1,3,0)
KASHMAR	40763	35 12 N	58 28 E	1109.7	145.7	154.4	5.9	ARIMA(5,1,0)
TEHRAN	40754	35 41 N	51 19 E	1190.8	195.6	183.9	6.0	ARIMA(5,1,1)
KHORRAMDAREH	40730	36 11 N	49 11 E	1575.0	247.9	262.8	6.0	ARIMA4,1,0)
MARIVAN	40750	35 31 N	46 12 E	1287.0	741.5	694.3	6.4	ARIMA(1,1,0)
GARMSAR	40758	35 12 N	52 16 E	825.2	115.1	122.8	6.7	ARIMA(1,1,0)
NEYSHABOOR	40746	36 16 N	58 48 E	1213.0	15.8	16.9	6.7	ARIMA(1,1,0)
IZEH	99455	31 51 N	49 52 E	767.0	600.6	641.5	6.8	ARIMA(5,1,0)
KASHAN	40785	33 59 N	51 27 E	982.3	136.9	146.5	7.0	ARIMA(4,1,0)
SHAHRE KORD	40798	32 20 N	50 51 E	2061.4	242.6	260.0	7.2	ARIMA(1,1,0)
NATANZ	99421	33 32 N	51 54 E	1684.9	194.1	208.5	7.4	ARIMA(1,1,0)
BEHBAHAN	40834	30 36 N	50 14 E	313.0	188.1	202.2	7.5	ARIMA(0,0,1)
BAFGH	40820	31 36 N	55 26 E	991.4	32.2	34.7	7.6	ARIMA(3,1,0)
MARAGHEH	40713	37 24 N	46 16 E	1477.7	175.5	189.0	7.7	ARIMA(1,1,0)
MANJIL	40720	36 44 N	49 24 E	333.0	196.9	212.1	7.7	ARIMA(1,3,0)
TAKAB	40728	36 23 N	47 7 E	1765.0	296.5	272.8	8.0	ARIMA(3,1,2)
GHAEN	40793	33 43 N	59 10 E	1432.0	124.3	134.4	8.1	ARIMA(0,0,1)
BIRJAND	40809	32 52 N	59 12 E	1491.0	94.1	86.4	8.2	ARIMA(0,0,2)
FASSA	40859	28 58 N	53 41 E	1288.3	243.7	264.3	8.5	ARIMA(1,1,0)
KAHNOUJ	40877	27 58 N	57 42 E	469.7	241.3	262.8	8.9	ARIMA(1,5,0)
BUSHEHR	40858	28 59 N	50 50 E	19.6	263.3	287.2	9.1	ARIMA(1,0,1)
GONBADE GHABOOS	99240	37 15 N	55 10 E	37.2	514.7	467.7	9.1	ARIMA(1,1,0)

Table 4: Obtained Relative Error for 112 Different Stations with Stations Information and Best Structures of ARIMA Models (9.2-13%)

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
TABASS	40791	33 36 N	56 55 E	711.0	61.2	66.9	9.2	ARIMA(1,0,0)
BANDAR DAIER	40872	27 50 N	51 56 E	4.0	203.7	183.8	9.8	ARIMA(1,1,0)
JOLFA	40702	38 45 N	45 40 E	736.2	129.2	141.8	9.8	ARIMA(0,0,1)
ZABOL	40829	31 2 N	61 29 E	489.2	26.8	29.4	9.9	ARIMA(0,0,1)
SARAB	40710	37 56 N	47 32 E	1682.0	200.8	220.8	9.9	ARIMA(1,1,0)
GONABAD	40778	34 21 N	58 41 E	1056.0	99.3	89.2	10.1	ARIMA(5,1,0)
MASHHAD	40745	36 16 N	59 38 E	999.2	168.9	151.6	10.3	ARIMA(0,0,3)
FERDOUS	40792	34 1 N	58 10 E	1293.0	101.0	90.4	10.5	ARIMA(5,0,4)
GHOM	40770	34 42 N	50 51 E	877.4	175.1	156.1	10.9	ARIMA(1,0,0)
BOSTAN	40810	31 43 N	48 0 E	7.8	206.2	228.9	11.0	ARIMA(3,1,1)
MIANEH	40716	37 27 N	47 42 E	1110.0	274.6	243.6	11.3	ARIMA(1,1,0)
MAHABAD	40726	36 46 N	45 43 E	1385.0	313.3	277.5	11.4	ARIMA(4,1,0)
CHAHBAHAR	40898	25 17 N	60 37 E	8.0	44.4	49.6	11.7	ARIMA(2,0,0)
ESFAHAN	40800	32 37 N	51 40 E	1550.4	88.1	77.8	11.7	ARIMA(0,0,2)
BANDAR MAHSHAHR	40832	30 33 N	49 9 E	6.2	146.2	128.9	11.8	ARIMA(0,0,2)
SAR POL ZOHAB	40765	34 27 N	45 52 E	545.0	379.5	333.6	12.1	ARIMA(1,1,0)
BAM	40854	29 6 N	58 21 E	1066.9	47.7	53.5	12.1	ARIMA(5,1,1)
GOLPAIGAN	99417	33 28 N	50 17 E	1870.0	184.1	206.9	12.4	ARIMA(1,0,0)
MINAB	40876	27 7 N	57 6 E	27.0	199.0	224.0	12.6	ARIMA(1,2,0)
JASK	40893	25 38 N	57 46 E	4.8	16.4	18.5	12.7	ARIMA(1,3,2)
PIRANSHAHR	40724	36 40 N	45 8 E	1455.0	577.2	503.4	12.8	ARIMA(3,0,3)
ARDEBIL	40708	38 15 N	48 17 E	1332.0	302.8	264.0	12.8	ARIMA(4,1,1)

Table 5: Obtained Relative Error for 112 Different Stations with Stations Information and Best Structures of ARIMA Models (>13%)

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
RAVANSAR	40764	34 43 N	46 40 E	1362.7	399.4	451.6	13.1	ARIMA(5,1,0)
DEHLORAN	40796	32 41 N	47 16 E	232.0	205.5	232.7	13.2	ARIMA(1,0,0)
LAR	40873	27 41 N	54 17 E	792.0	102.1	116.4	14.0	ARIMA(1,0,0)
LORDEGAN	40814	31 31 N	50 49 E	1580.0	466.4	533.9	14.5	ARIMA(3,1,0)
KHASH	40870	28 13 N	61 12 E	1394.0	40.0	45.8	14.5	ARIMA(5,1,0)
RAMSAR	40732	36 54 N	50 40 E	-20.0	802.8	920.0	14.6	ARIMA(1,1,0)
BANDAR ABASS	40875	27 13 N	56 22 E	10.0	213.6	245.3	14.8	ARIMA(5,1,0)
KOOHRANG	40797	32 26 N	50 7 E	2285.0	1077.9	1238.5	14.9	ARIMA(1,3,0)
HAMEDAN	40768	34 51 N	48 32 E	1749.0	318.9	271.4	14.9	ARIMA(1,1,0)

(Table 5) Contd…..

Station	Code	Altitude	Longitude	Elevation (m)	Actual rainfall (mm/year)	Forecasted rainfall (mm/year)	Relative error (%)	Best model
DEZFUL	40795	32 24 N	48 23 E	143.0	429.7	494.9	15.2	ARIMA(4,1,0)
RAFSANJAN	99502	30 25 N	55 54 E	1580.9	52.5	44.5	15.2	ARIMA(3,1,0)
RASHT	40719	37 12 N	49 39 E	36.7	1438.3	1211.7	15.8	ARIMA(2,1,0)
SHAHREZA	40815	31 59 N	51 50 E	1845.2	98.2	115.3	17.4	ARIMA(2,1,0)
TORBATE HEYDARIEH	40762	35 16 N	59 13 E	1450.8	220.2	259.3	17.8	ARIMA(2,5,3)
BANDAR LENGEH	40883	26 35 N	54 50 E	14.2	132.1	157.0	18.9	ARIMA(1,1,0)
AHAR	40704	38 26 N	47 4 E	1390.5	243.5	289.6	18.9	ARIMA(5,1,0)
ABOMOOSA	40890	25 50 N	54 50 E	6.6	52.2	62.6	19.8	ARIMA(5,1,0)
KISH	40882	26 30 N	53 59 E	30.0	113.3	136.7	20.7	ARIMA(1,0,0)
ZAHEDAN	40856	29 28 N	60 53 E	1370.0	40.7	49.9	22.6	ARIMA(0,0,2)
NAEIN	40801	32 51 N	53 5 E	1549.0	66.2	91.6	38.3	ARIMA(5,1,0)
SIRJAN	40851	29 28 N	55 41 E	1739.4	66.7	98.9	48.2	ARIMA(3,1,3)
IRANSHAHR	40879	27 12 N	60 42 E	591.1	20.0	33.3	66.4	ARIMA(0,0,3)

Figure 2: Critical areas of Iran for agriculture water management according to first method.

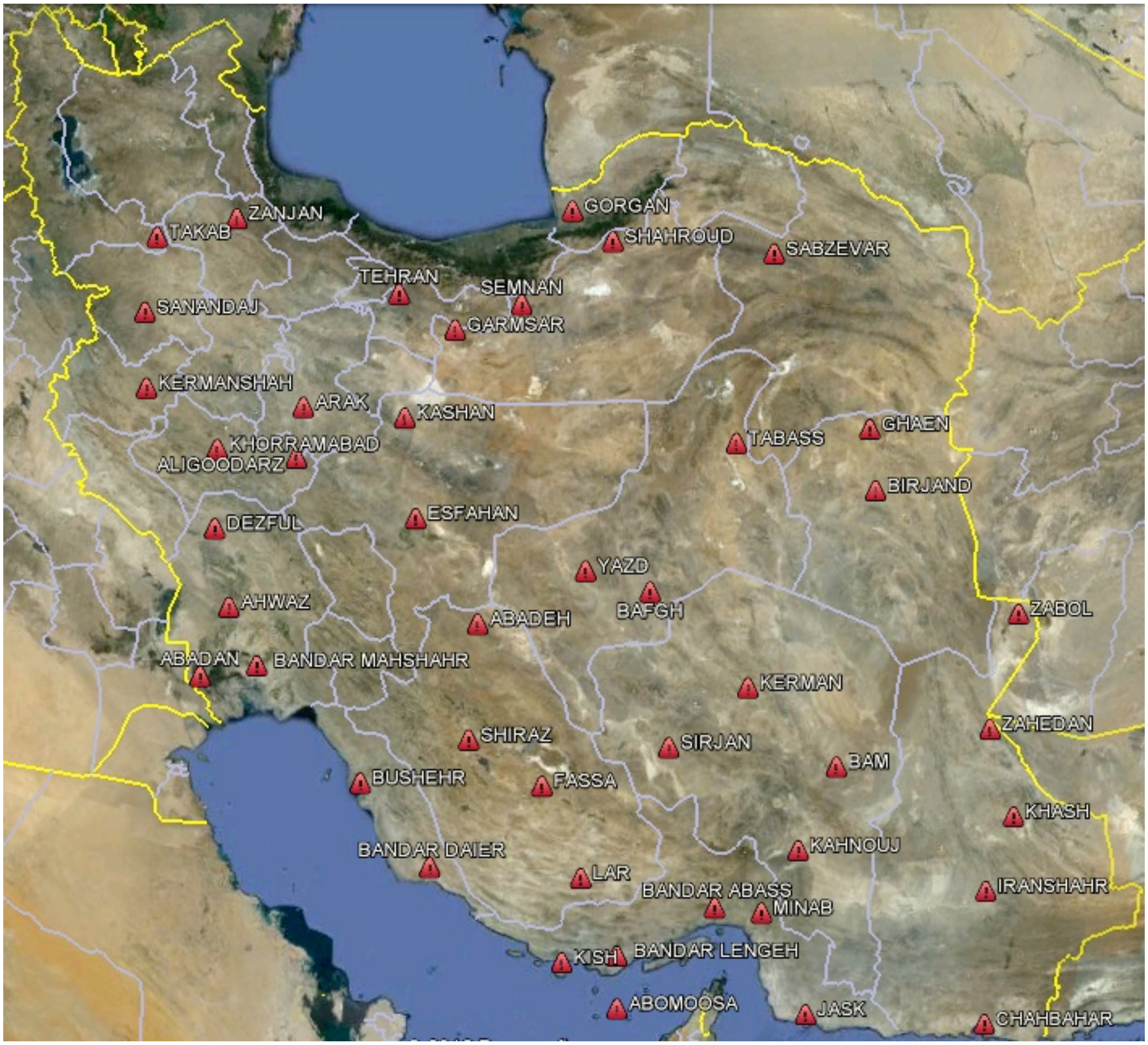

Figure 3: Critical areas of Iran for agriculture water management according to second method.

4. CONCLUSION

In this paper, using 50 years of rainfall data and ARIMA model, critical areas of Iran were determined. For this purpose, annual rainfall data of 112 different synoptic stations in Iran was gathered. To summarize, it could be concluded that:

ARIMA model was an appropriate tool to forecasting annual rainfall.

According to obtained results from relative error, five stations include IRANSHAHR, SIRJAN, NAEIN, ZAHEDAN, and KISH, were in critical condition.

In 45 stations accrued rainfalls with amounts of less than half of average in 50 years period. Therefore, in these 45 areas chance of drought is more than other areas of Iran.

REFERENCES

[1] Box GEP, Jenkins GM. Series Analysis Forecasting and Control. Prentice-Hall Inc. London 1976.

[2] Mishra AK and Singh VP. Drought modeling – A review. Journal of Hydrology 2011; 403(1-2): 157–175. DOI: http://dx.doi.org/10.1016/j.jhydrol.2011.03.049

[3] Smakhtin VU and Hughes DA. Automated estimation and analyses of meteorological drought characteristics from monthly rainfall data. Environmental Modelling & Software 2007; 22(6): 880–890. DOI: http://dx.doi.org/10.1016/j.envsoft.2006.05.013

[4] Yurekli K and Kurunc A. Simulating agricultural drought periods based on daily rainfall and crop water consumption. Journal of Arid Environments 2006; 67(4): 629–640. DOI: http://dx.doi.org/10.1016/j.jaridenv.2006.03.026

[5] Serinaldi F and Kilsb CG. A modular class of multisite monthly rainfall generators for water resource management and impact studies. Journal of Hydrology 2012; 464-465: 528-540. DOI: http://dx.doi.org/10.1016/j.jhydrol.2012.07.043

[6] Luc KC, Ball JE and Sharma A. An application of artificial neural networks for rainfall forecasting. Mathematical and

Computer Modelling 2001; 33(6-7): 683–693.
DOI: http://dx.doi.org/10.1016/S0895-7177(00)00272-7

[7] Wei C, Hung WC and Cheng KS. A multi-spectral spatial convolution approach of rainfall forecasting using weather satellite imagery. Advances in Space Research, 2006; 37(4), pp: 747–753.
DOI: http://dx.doi.org/10.1016/j.asr.2005.08.017

[8] Andrieu H, French MN, Thauvin V and Krajewsk WF. Adaptation and application of a quantitative rainfall forecasting model in a mountainous region. Journal of Hydrology 1996; 184(3-4): 243–259.
DOI: http://dx.doi.org/10.1016/0022-1694(95)02977-X

[9] Burlando, C., R., Rosso, L. G., Cadavid and J. D., Salas, 1993. "Forecasting of short-term rainfall using ARMA models", Journal of Hydrology, 144(1-4), pp: 193–211.
DOI: http://dx.doi.org/10.1016/0022-1694(93)90172-6

[10] Hu, W., S., Tong, K., Mengersen and B., Oldenburg, 2006. "Rainfall, mosquito density and the transmission of Ross River virus: A time-series forecasting model", Ecological Modelling, 196(3-4), pp: 505–514.
DOI: http://dx.doi.org/10.1016/j.ecolmodel.2006.02.028

[11] Ramírez, M. C. V., H. F. D. C., Velho and N. J. Ferreira, 2005. "Artificial neural network technique for rainfall forecasting applied to the São Paulo region", Journal of Hydrology, 301(1-4), pp: 146–162.
DOI: http://dx.doi.org/10.1016/j.jhydrol.2004.06.028

[12] Han, P., P.X., Wang, S. Y., Zhang and D. H. Zhu, 2010. "Drought forecasting based on the remote sensing data using ARIMA models", Mathematical and Computer Modelling, 51(11-12), pp: 1398–1403.
DOI: http://dx.doi.org/10.1016/j.mcm.2009.10.031

[13] Chattopadhyay, S. and G., Chattopadhyay, 2010. "Univariate modelling of summer-monsoon rainfall time series: Comparison between ARIMA and ARNN", Comptes Rendus Geoscience, 342(2), pp: 100–107.
DOI: http://dx.doi.org/10.1016/j.crte.2009.10.016

[14] Jia, Y. and Culver T. B., 2006. "Bootstrapped artificial neural networks for synthetic flow generation with a small data sample", Journal of Hydrology, 331, pp: 580– 590.
DOI: http://dx.doi.org/10.1016/j.jhydrol.2006.06.005

[15] Baareh, M.A.K., A. F. Sheta and Kh. Al Khnaifes, 2006, "Forecasting River Flow in the USA: A Comparison between Auto-Regression and Neural Network Non-Parametric Models", Journal of Computer Science, 2 (10), pp: 775-780.

[16] Xiong, L. and K. M. O'connor, 2002, "Comparison of four updating models for real-time river flow forecasting", Hydrological Sciences-Journal-des Sciences Hydrologiques, 47(4), pp: 621-639.

[17] Chenoweth, T., K. Dowling, R., Hubata and R. Louis, 2004. "Automatic ARMA identification using neural networks and the extended sample autocorrelation function: a reevaluation". Decision Support Systems, 29, pp: 21-30.
DOI: http://dx.doi.org/10.1016/S0167-9236(00)00058-0

[18] Yu, X., and S. Liong, 2006. "Forecasting of hydrologic time series with ridge regression in feature space", Journal of Hydrology, 332, pp: 290– 302.
DOI: http://dx.doi.org/10.1016/j.jhydrol.2006.07.003

[19] Srinivas, V.V., and K. Srinivasan, 2000. "Post-blackening approach for modeling dependent annual streamflows", Journal of Hydrology, 230, pp: 86–126.
DOI: http://dx.doi.org/10.1016/S0022-1694(00)00168-2

[20] Ludlow, J. and W. Enders, 2000. "Estimating non-linear ARMA models using Fourier Coefficients", International Journal of Forecasting, 16(3), pp: 333-347.

[21] Chenoweth, T., K. Dowling, R., Hubata, and R. Louis, 2004. "Distance and prediction error variance constraints for ARMA model portfolios". International Journal of Forecasting, 20, pp: 41-52.
DOI: http://dx.doi.org/10.1016/S0169-2070(03)00006-2

[22] Balaguer, E., A. Palomares, E. Sorie and J.D. Martin-Guerrero, 2008. "Predicting service request in support centers based on nonlinear dynamics, ARMA modeling and neural networks". Expert Systems with Applications, 34(1), pp. 665–672.
DOI: 10.1016/j.eswa.2006.10.003

[23] Toth, E., A. Brath, and A. Montanari, 2000. "Comparison of short-term rainfall predication models for real-time flood forecasting", Journal of Hydrology, 239, pp: 132–147.
DOI: http://dx.doi.org/10.1016/S0022-1694(00)00344-9

[24] Mohammadi, K., H.R. Eslami and S. Dayyani Dardashti, 2005. "Comparison of Regression ARIMA and ANN Models for Reservoir Inflow Forecasting using Snowmelt Equivalent (A Case Study of Karaj)", Journal of Agriculture Science Technology, 7, pp. 17-30.

[25] Mohammadi, K., H.R. Eslami and R. Kahawita, 2006. "Parameter estimation of an ARMA model for river flow forecasting using goal programming", Journal of Hydrology, 331 (2), pp: 293–299.
DOI: http://dx.doi.org/10.1016/j.jhydrol.2006.05.017

[26] Valipour, M. (2012a) 'HYDRO-MODULE DETERMINATION FOR VANAEI VILLAGE IN ESLAM ABAD GHARB, IRAN', ARPN J. Agric. Biol. Sci., Vol. 7, No. 12, pp.968-976.

[27] Valipour, M. (2012b) 'Ability of Box-Jenkins Models to Estimate of Reference Potential Evapotranspiration (A Case Study: Mehrabad Synoptic Station, Tehran, Iran)', IOSR J. Agric. Veter. Sci. (IOSR-JAVS), Vol. 1, No. 5, pp.1-11.

[28] Valipour, M. (2012c) 'A Comparison between Horizontal and Vertical Drainage Systems (Include Pipe Drainage, Open Ditch Drainage, and Pumped Wells) in Anisotropic Soils', IOSR J. Mech. Civil Eng. (IOSR-JMCE), Vol. 4, No. 1, pp.7-12.

[29] Valipour, M. (2012d) 'Number of Required Observation Data for Rainfall Forecasting According to the Climate Conditions', Am. J. Sci. Res., Vol. 74, pp.79-86.

[30] Valipour, M. (2012e) 'Critical Areas of Iran for Agriculture Water Management According to the Annual Rainfall', Eur. J. Sci. Res., Vol. 84, No. 4, pp.600-608.

[31] Valipour, M. (2014a) 'Application of new mass transfer formulae for computation of evapotranspiration', J. Appl. Water Eng. Res., Vol. 2, No. 1, pp.33-46.

[32] Valipour, M. (2014b) 'Use of average data of 181 synoptic stations for estimation of reference crop evapotranspiration by temperature-based methods', Water Res. Manage., Vol. 28, No. 12, pp.4237-4255.

[33] Valipour, M. (2017a) 'Global experience on irrigation management under different scenarios', J. Water Land Develop., Vol. 32, No. 1, pp.95-102.

[34] Valipour, M. (2017b) 'Status of land use change and irrigation in Europe by 2035 and 2060', J. Water Land Develop., In Press.

[35] Valipour, M. (2017c) 'Drought analysis in different basins and climates', Taiwan Water Conservancy, Vol. 65, No. 1, pp.55-63.

[36] Valipour, M. (2017d) 'A study on irrigated area to analyze Asian water development' J. Water Land Develop., In Press.

[37] Valipour, M. (2017e) 'Analysis of potential evapotranspiration using limited weather data', Appl. Water Sci., Vol. 7, No. 1, pp.187-197.

[38] Valipour, M. (2016a) 'How Much Meteorological Information Is Necessary to Achieve Reliable Accuracy for Rainfall Estimations?', Agric., Vol. 6, No. 4, pp.53.

[39] Valipour, M. (2016b) 'Variations of land use and irrigation for next decades under different scenarios', Irriga, Vol. 1, No. 1, pp.262-288.

[40] Valipour, M., Gholami Sefidkouhi, M.A. and Raeini-Sarjaz, M. (2017a) 'Selecting the best model to estimate potential evapotranspiration with respect to climate change and

magnitudes of extreme events', Agric. Water Manage., Vol. 180, No. Part A, pp.50-60.

[41] Valipour, M., Gholami Sefidkouhi, M.A. and Khoshravesh, M., (2017b) 'Estimation and trend evaluation of reference evapotranspiration in a humid region', Ital. J. Agrometeorol., Vol. 1, pp.19-38. In Press.

[42] Valipour, M. and Gholami Sefidkouhi, M.A. (2017) 'Temporal analysis of reference evapotranspiration to detect variation factors', Int. J. Glob. Warm., In Press. http://www.inderscience.com/info/ingeneral/forthcoming.php?jcode=ijgw#63006

[43] Valipour, M. (2015a) 'Future of agricultural water management in Africa', Arch. Agron. Soil Sci., Vol. 61, No. 7, pp.907-927.

[44] Valipour, M. (2015b) 'Land use policy and agricultural water management of the previous half of century in Africa', Appl. Water Sci., Vol. 5, No. 4, pp.367-395.

[45] Valipour, M. (2015c) 'Comparative Evaluation of Radiation-Based Methods for Estimation of Potential Evapotranspiration', J. Hydrol. Eng., Vol. 20, No. 5, pp.04014068.

[46] Valipour, M. (2015d) 'Importance of solar radiation, temperature, relative humidity, and wind speed for calculation of reference evapotranspiration', Arch. Agron. Soil Sci., Vol. 61, No. 2, pp.239-255.

[47] Valipour, M. (2015e) 'Study of different climatic conditions to assess the role of solar radiation in reference crop evapotranspiration equations', Arch. Agron. Soil Sci., Vol. 61, No. 5, pp.679-694.

[48] Valipour, M. (2015f) 'Evaluation of radiation methods to study potential evapotranspiration of 31 provinces', Meteorol. Atmos. Physic., Vol. 127, No. 3, pp.289-303.

[49] Valipour, M. (2015g) 'Temperature analysis of reference evapotranspiration models', Meteorol. Appl., Vol. 22, No. 3, pp.385-394.

[50] Valipour, M. (2015h) 'Investigation of Valiantzas' evapotranspiration equation in Iran', Theoret. Appl. Climatol., Vol. 121, No. (1-2), pp.267-278.

[51] Valipour, M. (2015i) 'Long-term runoff study using SARIMA and ARIMA models in the United States', Meteorol. Appl., Vol. 22, No. (3), pp.592-598.

[52] Valipour, M. and Montazar, A.A. (2012) 'An Evaluation of SWDC and WinSRFR Models to Optimize of Infiltration Parameters in Furrow Irrigation', Am. J. Sci. Res., Vol. 69, pp.128-142.

[53] Valipour, M. (2013a) 'Increasing irrigation efficiency by management strategies: cutback and surge irrigation', ARPN J. Agric. Biol. Sci., Vol. 8, No. 1, pp.35-43.

[54] Valipour, M. (2013b) 'Necessity of Irrigated and Rainfed Agriculture in the World', Irrig. Drain. Syst. Eng., S9, e001.

[55] Valipour, M. (2013c) 'Evolution of Irrigation-Equipped Areas as Share of Cultivated Areas', Irrig. Drain. Syst. Eng., Vol. 2, No. 1, e114.

[56] Valipour, M. (2013d) 'Use of surface water supply index to assessing of water resources management in colorado and oregon, US', Adv. Agric. Sci. Eng. Res., Vol. 3, No. 2, pp.631-640.

[57] Valipour, M., Mousavi, S.M., Valipour, R. and Rezaei, E. (2013) 'A New Approach for Environmental Crises and its Solutions by Computer Modeling', The 1st International Conference on Environmental Crises and its Solutions, Kish Island, Iran.

[58] Viero, D.P. and Valipour, M. (2017) 'Modeling anisotropy in free-surface overland and shallow inundation flows', Adv. Water Resour., Vol. 104, pp.1-14.

[59] Yannopoulos, S.I., Lyberatos, G., Theodossiou, N., Li, W., Valipour, M., Tamburrino, A., Angelakis, A.N., 2015. Evolution of Water Lifting Devices (Pumps) over the Centuries Worldwide. Water. 7 (9), 5031-5060.

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