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Studying of Drought, Modeling and Forecasting the Precipitation of Shiraz City

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ABSTRACT

Forecasting climate processes makes available appropriate tools to managers at different fields, given these projections, they should design future policies in order to optimize costs and maximize productivity features. Precipitation forecast is very important for various purposes as, flood, drought, catchment management, agriculture, etc. The main aim of this study is to investigate changes in the time of precipitation using time models in the study area and forecasting these elements as well as studying drought and wet years for water management. In this study, three models, namely Box Jenkins, Decomposition and Healt Winterz models were used for the period 1977 to 2010 in Shiraz station and finally, regarding the comparison of error between the three methods, the Box Jenkins approach was chose as was the most appropriate method for forecast and then the monthly and seasonal precipitation forecast from 2010-2013 years have been investigated. Studying annual rainfall of this station using Hiem and Koutil Tables, it was found that Shiraz pre-province have been in drought period 20 years out of 33 years with 51.51% weak drought and 9% severe drought and these droughts have been occurred especially in these years. The recent drought has had an impact on lakes and underground water sources and causes a shortage of water and declining groundwater for agriculture.

Keywords: Modeling, Shiraz, Precipitation Forecast, Time Series, Drought

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INTRODUCTION

Two thirds of Iran, is located in arid and semi-arid zone, around 450,000 square kilometers of which constitute deserts [1]. Climate change is a global crisis, latest estimate by the Inter-governmental Panel on 2

Climate Change (IPCC, 2002) shows that a business as usual scenario will lead to an increase in global mean temperature of about 1°C above the present value by the year 2025 and 3°C before the end of the next century. The debate on climate change has been generating a lot of interest at both the national, regional and international level [2]. Drought occurrence as an extended period of anomalously low soil moisture [3] and drought is a normal recurrent feature of climate and causes a serious hydrological imbalance. Virtually, it occurs in all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration, which is restricted to low rainfall [4]. All aspects of human life are affected by climate processes and these influences can be seen in areas such as agriculture, irrigation, economy, transportation and military industries [5]. Drought and famine are two separate phenomena in that drought is the inherent characteristics of an area, but famine is a random phenomenon that is occurred in an area that is usually dry [6]. The effects of drought is much more than being dry and may cause losses, migrations, … as well as the extinction of many species of flora and fauna [7]. In recent years the drought has caused a lot of damage. Phenomenon of drought in 2000 and 2001 has brought 3.5 and 2.6

billion dollars of damage, respectively [8]. Khosh Akhlagh performed a study on drought in rainfall year of 2007-2008 as well as the effects of water on water resources and agriculture of Marvdasht pre-province and came to this conclusion that the drought in the rainfall weather of 2007-2008 was very intensive and also severe negative effects over water resources and agriculture of Marvdasht pre-province [9]. This study aims to investigate the drought years and rainfall season in Shiraz pre-province and also the table for frequency percentage of each rainfall and drought periods was provided.

2. Literature Review

Time series approach to study the climate, particularly temperature and precipitation has been used in countless articles. Borlando et.al [10] used ARIMA models to forecast hourly precipitation in the time of their fall and the amounts obtained were compared with the data to measure rain. They came to this conclusion in their study that with increasing duration of rainfall, the predictions were more accurate, and shorter duration of rainfall, rain rate difference will be more than the actual corresponding value. 3

Azizi and Roushan [11] using the character of the model predicts negative values of Health Net Winters converted the standardized scores and directly studied and predicted the amounts of drought and rainfall seasons in Hormozgan province. Zahedi et.al [12] creates a model for the rainfall of Urmia and Tabriz stations. In this study, they studied monthly rainfall of Urmia and Tabriz using 50-year data and finally predicted the amounts of precipitation in the years 2001 and 2002. Sharifian and Ghahreman [13] analyzed the precipitation forecast using SARIMA model in Golastan province. The purpose of conducting this study was to find the best model for evaluating the amount of rainfall, in that it was recommended after the required investigation for the estimation of 10-day rains. Falah Ghaheri and Khoshhal [14] predicted the spring precipitation of Khorasan Razavi province. Fatehi and Mahdian [15] studied the amount of autumn precipitation in Urmia River and came to this conclusion that non-linear models using climatic indices predicted more accurately the winter precipitation.

3. The Geographical Location of the Study Area

City of Shiraz is located in southwest Iran, at an altitude of 1486 meters above sea level on the slopes of the Zagros Mountains. It is the capital of Fars Province. Shiraz city, with geographic coordinates of 29° 32´ north latitude and 52 º 36´ east longitudes with an area equivalent to 10688.8 sq. km, allocated 6.8% of the total area of the province [16]. In the northern city of Shiraz, Marvdasht and Sepidan cities are located, and in the south of the city, Firoozabad and Jahrom cities are located. Cities of Neiriz, Estahban and Fasa are located at the east of this province and Kazeroun city is located at the west of this pre-province [17] Shiraz city has Mediterranean climate. The annual average temperature is 18 degrees Celsius. Annual rainfall in Shiraz is 337.8 mm.

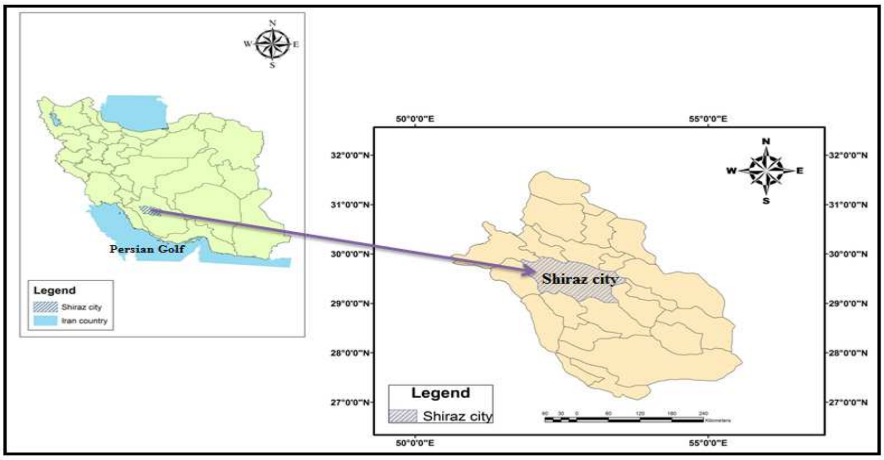

Figure 1: The Geographical Location of the Study Area

4. Materials and Research Method

According to what have been mentioned above, our study is based on a statistical approach and is based on the use of time series models. Because climatic factors such as rainfall occurs based on a specific time and the evidences showed that there is a relationship (correlation) between the previous data and subsequent ones, therefore, the best method for analyzing data is using time series approach [18]. The data used in this study, are the ones on monthly and seasonal rainfall stations in Shiraz, Lamerd, Fasa and Abadeh. The duration of statistical period covers from April 1977 to December 2010. In this study, the statistical data from the last year (2010) was not considered for investigating the amount of forecast error with the actual values, and after the forecast, a model with the lowest error was selected as the best method. Three models of Healt Winters, Decomposition and Box Jenkins models were used. The accuracy and precision of the predicted model was selected through three parameters namely mean absolute deviation, mean squared absolute deviation and finally the best method was selected. The precipitation between 2011 and 2012 years were predicted using the selected model.

Box-Jenkins's models are composed of two general forms as ARIMA *(p, d, q)* and multipliable ARMA ($SARIMA\ (p,d,q)(P,D,Q)_S$). In general, multipliable ARIMA have six coefficients, one of the main requirements of the statistical model of Box-Jenkins is to identify time series component to determine the six required coefficients. Because, if these components are not well-identified, the 5 determined coefficients will not be correct and, as a result, the prediction will be wrong. Coefficient d (non- seasonal time differencing) is related to non-static average (process) and D (degree of seasonal differencing) is related to non-static variance (rotation) and S is the seasonal period, which is determined 12. Other coefficients are achieved from the autocorrelation Function (ACF) (Auto Correlation Function) and Partial Autocorrelation Function (PACF) (Partial Auto Correlation Function). By drawing the autocorrelation coefficients against partial delay, autocorrelation table is created, which is used to interpret correlation coefficients data. In ARIMA model, autocorrelation and partial autocorrelation tables are vacillate in sinusoidal and exponential methods [19].

5. Decomposition by the Percentage Moving Average Method

The kind of decomposition used for prediction in this study is quantitative and point methods and follows time series equation as follows:

$$Y_t = T \times S \times E \qquad (1)$$

In the above equation, Y_t is predicted time series, T is the process of this series during the statistical period, S is seasonal changes of time series and E is the irregular changes of this series.

6. Mass Seasonal Healt-Winters Method

Another prediction method is Healt- Winters method. Using this method, we can easily extend exponential trend to the series containing seasonal trend and changes. Healt -Winters method can be used for short-term and medium-term predictions. This procedure provides dynamic estimates of trend component, level component and seasonal component.

7. Investigating Drought

Standard score of annual precipitation was obtained by SPSS software and then was categorized according to Haim and Koutil Tables [8].

Table 1: Haim and Koutil Classification

Drought period	Z Standard score	Humid period	Z Standard score
Severe drought	$z<-1.5$	Severe humidity	$1.5<z$
Medium drought	$-0.5\leq z\leq -1.5$	Medium humidity	$0.5\leq z\leq 1.5$
Weak drought	$-0.5<z<0$	Weak humidity	$0<z<0.5$

RESULTS AND DISCUSSION

Run Test was first conducted on time series and it was found that the series is not randomly, and then time series graphs were plotted. Time series graph related to monthly and seasonal precipitation for 1977-2009 were drawn in three methods. According to forecast error and forecast precipitation, the most appropriate method was selected and the precipitation was determined and finally drought and rainfall season was studied.

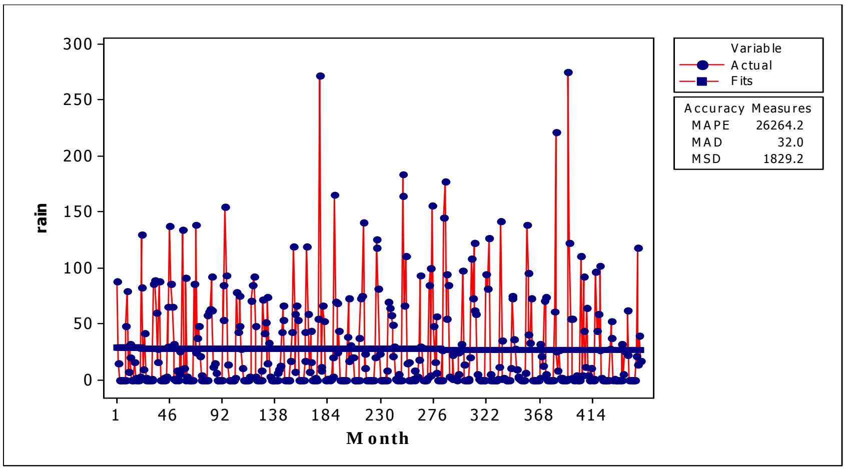

Figure 2: time series of monthly precipitation

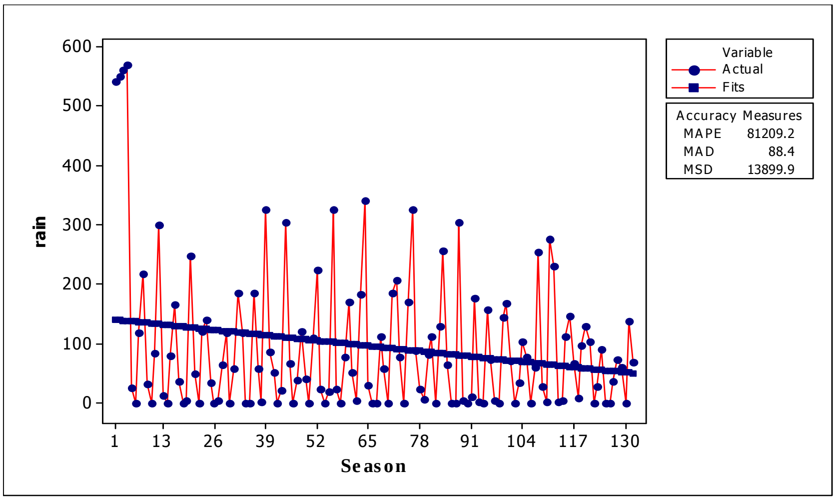

Figure 3: time series of seasonal precipitation

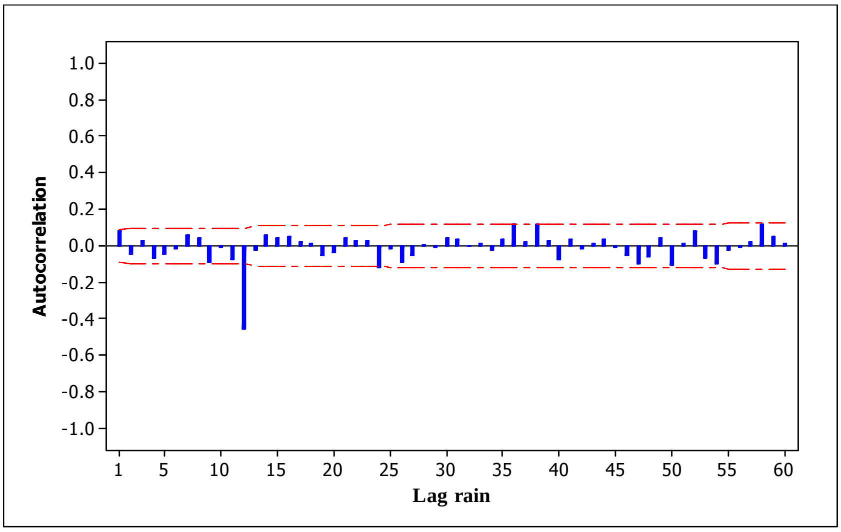

Figure 4: time series related to monthly precipitation autocorrelation

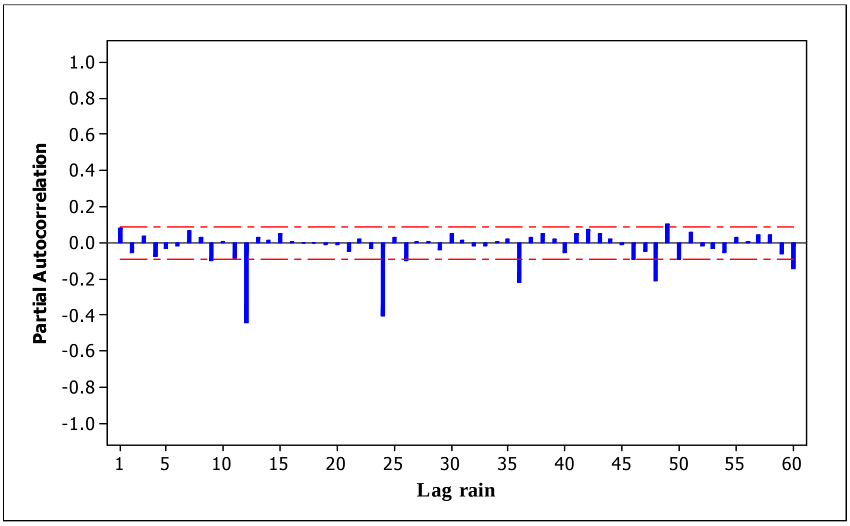

Figure 5: time series related to Partial Autocorrelation annual precipitation

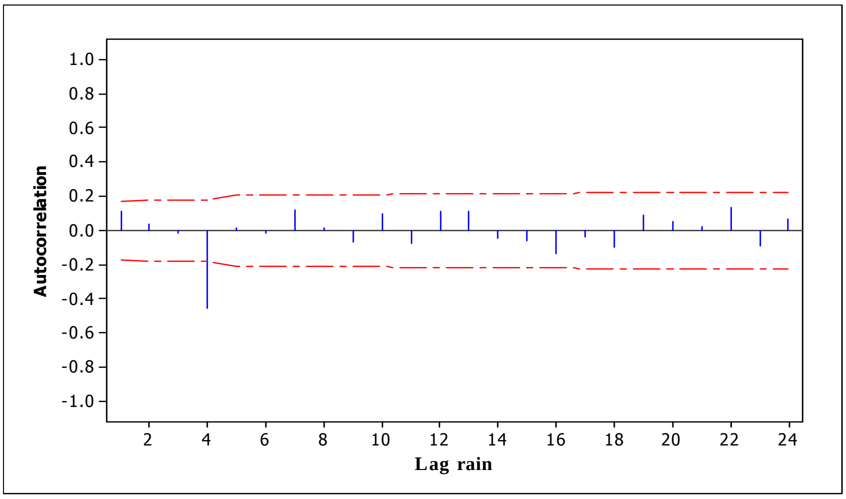

Figure 6: time series related to seasonal precipitation autocorrelation

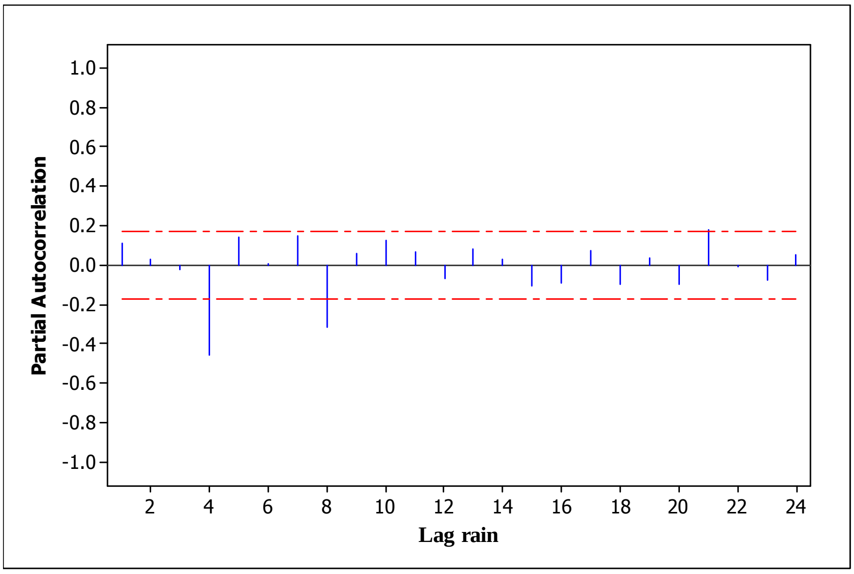

Figure 7: time series related to Partial Autocorrelation of seasonal precipitation

According to Figures 4 and 5, appropriate seasonal models will be$\mathrm{SARIMA}(0,0,0)(5,1,1)_{12}$, in which after processing and removing non-significant terms, the final model was determined as$\mathrm{SARIMA}(1,0,1)(0,1,1)_{12}$.

Based on the model, 2010 forecast was calculated and then compared with the real data that was provided. Accordingly, the mean square error of the forecast was achieved 582.11. In addition, mean square error of the model is 0.0675. The processed SARIMA model is as follows in which $X_t = \ln(Y_t)$.

$$\nabla_{12}X_t = -0.0028 - 0.5672X_{t-1} + Z_t - 0.6572\ Z_{t-1} + 09397\ Z_{t-12} \qquad (2)$$

According to Figures 6 and 7, appropriate seasonal model for seasonal precipitation data will be $\text{SARIMA}(0,0,1)(2,1,1)_4$. based on the forecast model; seasonal precipitation in 2010 was calculated and then compared with the provided real data. Accordingly, mean square error will be 2131.67. Furthermore, the mean square error of the model is 0.1003. The processed SARIMA model will be as follows:

$$\nabla_{12}X_t = -0.0072 + Z_t - 0.2198\ Z_{t-1} + 0.9480\ Z_{t-4}(3)$$

Summarizing and comparing of the accuracy of three methods used for forecasting monthly precipitation is given in the following table(Table2).

Table (2): Comparison ofthree methods foraccuratepredictionof monthly precipitation

Forecasting Method	Model MSD	Forecast MSD
SARIMA	0.0675	582.11
DECOMPOSITION	0.0694	628.78
HOLT-WINTERS	0.0933	661

Based on the mean square error, prediction error of Box Jenkins methods have the lowest error. Due to the significance of predictions, the Box Jenkins method is generally recommended for the prediction of monthly precipitation.

In the table below, the real value of monthly precipitation with predicted values have been done with three methods (Table 3).

Table 3: real value of prediction of monthly precipitation (2010-2013)

Year	Month	Real values	Box-Jenkins	Decomposition	Healt-Winters
2010	April	25.90	23.79	30.85	31.36
	May	7.90	6.06	4.21	3.07
	June	0.50	0	0.44	1.14
	July	0	0	0.33	1.36
	August	0	0.18	0.61	1.75
	September	2.60	0	0.51	0.74
	October	0.10	0.37	0.77	1.15
	November	0	9.33	4.42	12.45
	December	0.20	37.55	48.60	43.20
	January	34.70	53.51	79.74	47.54
	February	102.30	41.40	51.21	40.93
	March	65.20	27.48	42.83	21.21
2011	April		26.58	30.85	31.15
	May		5.25	4.21	3.02
	June		0	0.44	1.11
	July		0	0.33	1.32
	August		0.23	0.61	1.72
	September		0	0.51	0.70
	October		0.36	0.77	1.12
	November		9.21	4.42	12.35
	December		37.40	48.60	42.92
	January		53.21	79.74	47.23
	February		41.21	51.21	40.66
	March		27.33	42.83	21.07
2012	April		26.43	30.85	30.95
	May		5.19	4.21	2.98
	June		0	0.44	1.07
	July		0	0.33	1.28
	August		0.18	0.61	1.68
	September		0	0.51	0.67
	October		0.32	0.77	1.08
	November		9.13	4.42	12.26
	December		37.20	48.60	42.64
	January		52.95	79.74	46.92
	February		40.99	51.21	40.40
	March		27.16	42.83	20.93
2013	April		26.28	30.85	30.75
	May		5.12	4.21	2.93
	June		0	0.44	1.04
	July		0	0.33	1.25
	August		0.14	0.61	1.64
	September		0	0.51	0.64
	October		0.27	0.77	1.05
	November		9.05	4.42	12.17
	December		37	48.60	42.36
	January		52.69	79.74	46.61
	February		40.78	51.21	40.13
	March		27.01	42.83	20.78
	MSD	-	582.11	628.78	661.08

Summarizing the comparison of the accuracy of three methods for the prediction used for seasonal precipitation has been presented in the following table (Table 4).

Table 4: the comparison of the accuracy of three methods for the prediction of seasonal precipitation

Forecasting Method	Model MSD	Forecast MSD
SARIMA	0.1003	2131.67
DECOMPOSITION	0.1208	2495.86
HOLT-WINTERS	0.1518/	2955.4

Based on the model mean square error and also the mean square error of prediction method, Box and Jenkins method have the lowest rate of error. Therefore, Box-Jenkins is generally recommended for the prediction of seasonal precipitation. In the following table, the real values of seasonal precipitation with the predicted values by the three methods have been presented (Table 5).

Table (5): real values with the prediction values of seasonal precipitation (2010-2013)

Season	Real data	Box Jenkins	Decomposition	Holt winter
Spring	34.30	21.34	35.11	26.72
Summer	2.60	0	0	0.27
Fall	0.30	46.77	49.36	48.72
Winter	202.2	123.52	115.20	105.17
Spring		26.35	34.37	25.11
Summer		0	0	0
Fall		45.83	48.32	45.81
Winter		121.31	112.61	98.52
Spring		25.75	33.65	23.58
Summer		0	0	0
Fall		44.91	47.31	43
Winter		119.15	110.08	92.25
Spring		25.16	32.94	22.11
Summer		0	0	0
Fall		44	46.31	40.41
Winter		117.01	107.61	86.34
MSD		2131.67	2495.86	2955.4

Finally, given the real values of monthly precipitation and the predicted values by three methods, Box-Jenkins method is the most appropriate method for prediction,and Box-Jenkins is the most appropriate method about the seasonal precipitation. Prediction and confidence amount is 95% for two years (2012 and 2013) based on Box-Jenkins model as follows (Table 6).

Table 6: confidence amount of 95% for the years (2011-2012) by Box-Jenkins method

Season	Low boundaries	Forecast	high boundaries
Spring	0	25.75	145.13
Summer	0	0	30.139
Fall	2.65	44.91	228.25
Winter	19.76	119.15	550.36
Spring	0	25.16	142.87
Summer	0	0	29.55
Fall	2.42	44	224.78
Winter	19.21	117	542.20

Prediction based on Box-Jenkins method is based on seasonalmass structure for monthly precipitation (Figure 8) and seasonal precipitation (Figure 9) is as follows:

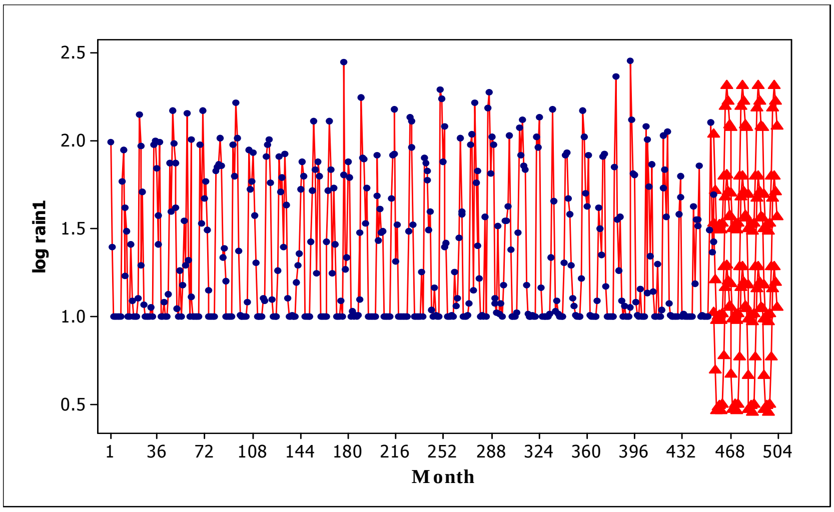

Figure8:Actualand predicted values of precipitation for 12 months using Box Jenkins method in Shiraz

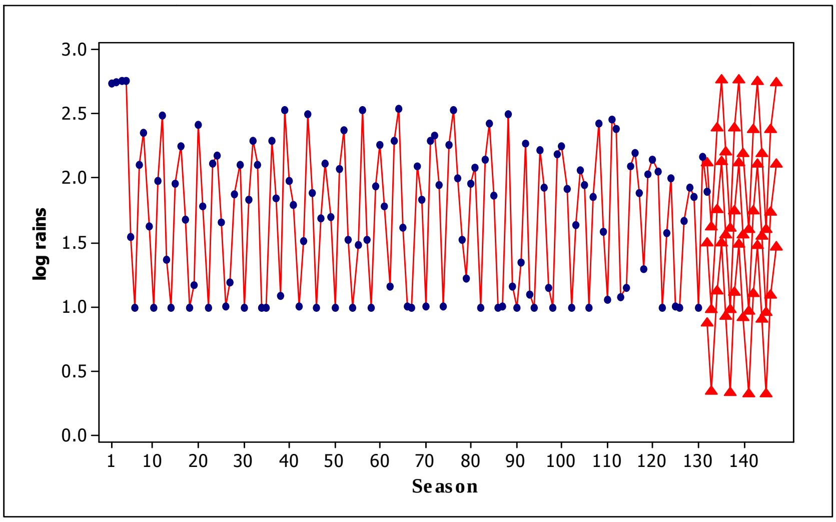

Figure 9:The actual and predicting amounts seasonal rain fall by Box Jenkins method in Shiraz

9. Investigating Precipitation and Drought

Studying the phenomenon of drought in Shiraz due to its important role in the country's agricultural sector is important and can lead to heavy and irreparable damages. Hence, determining and separating precipitation and drought periods and also investigating statistical characteristics of precipitation can plays a main role in the recognition of drought periods and appropriate management of water resources.

To determine drought and precipitation periods, having been calculated the standard score using SPSS software from Table (1), the amount of drought and precipitation in Shiraz station was extracted and the precipitation and drought periods are as follows:

The years 1977,1979,1997,2003, it was in the medium amount of humidity. The years 1978, 1984,1989,1990,1998, it was in the branch of weak humid according to Z score. In the years 1980,1981,1982,1985,1987,1988,1991,1996,1999,2000,2001,2002,2005,2006,2007,2009, it was in the weak drought branch. In the years 1983, 1993, 2008, it was in the severe drought group. In the years 1992,1994,1995,2004, it was in the severe humid branch.

In Figure(10),Z standardized scores of annual rain fall stations in Shiraz is plotted.

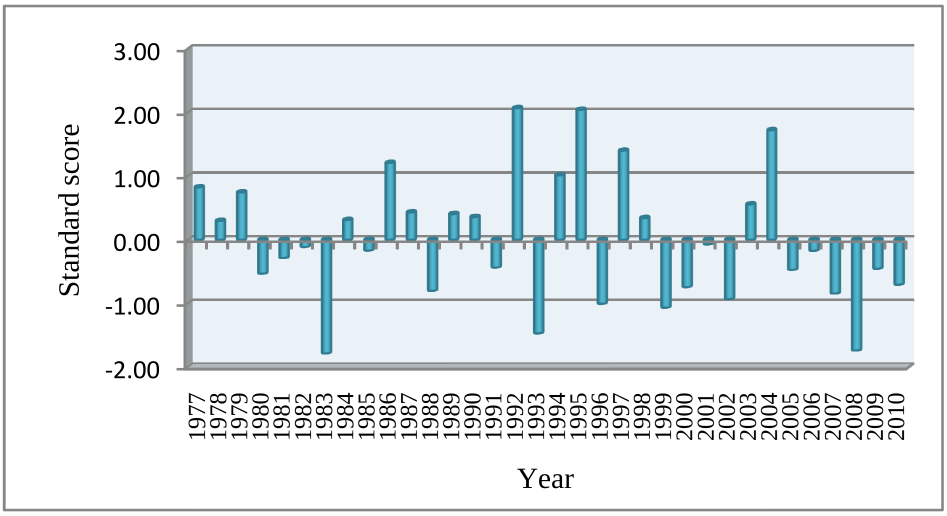

Figure 10: standardized Z scoreof annual rainfall in Shiraz station

In Figure (11), the amount of frequency percentage of each category has been specified, and according to this chart, it involves the highest percentage of drought. Weak drought percentage is 51.51. Weak humidity with 15.15% is in the second rate. Two groups of medium and severe humidity with 12.12% are both involved in the third branch in terms of frequency percentage. The last group is severe drought which comprises 9% out of 100%.

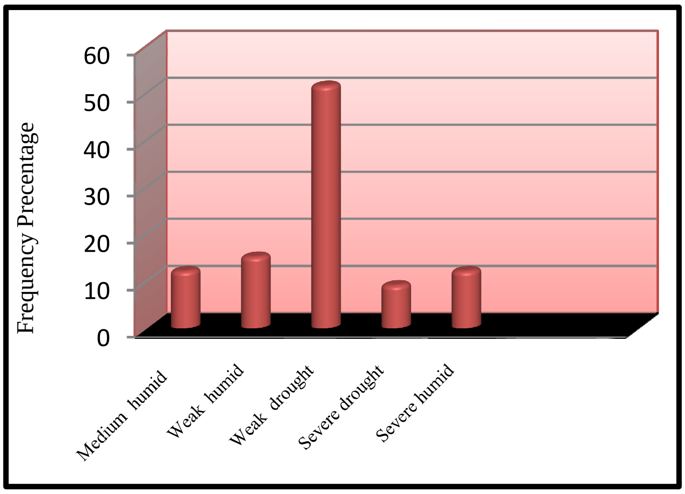

Figure 11: frequency percentage of drought in Shiraz Station

CONCLUSION

Forecasting and estimating precipitation for each climate zone and watershed is considered as one of the most important parameters is the use of water resources and enables water managers to better plan for the management and optimized operation of the network. In the first study, it is first examined and then studied the predictor and drought in Station Shiraz. According to the error rate test of different methods of time series of error prediction, Box Jenkins method has significant advantages over other methods. The appropriate model to predict monthly precipitation was $\mathrm{SARIMA}(1{,}0{,}1)(0{,}1{,}1)_{12}$and for the annual precipitation was $\mathrm{SARIMA}(0{,}0{,}1)(0{,}1{,}1)_{4}$ for this station. Drought in various fields both directly and indirectly causes detrimental effects. The most direct effect of drought is on water resources in the region. By reducing precipitation or lack of rainfall for a long period of time, pastures, forests, fields and the gardens whose water resources are provided from precipitation, as well as the soil and other natural resources directly will be damaged. Having been studied the annual rainfall in the station, it was found that Shiraz pre-province with weak drought of 51.51 and 9% severe drought that occurred in recent years, and it has negative effects on rivers, water resources and underground resources. Given that drought period exists also in this area of Shiraz, some measures should be taken to prevent water loss in order to people be not faced with drought. Protection of water resources, environmental considerations, the use of appropriate technologies, economy and maintain social acceptance are necessary for promoting the sustainable development of water resources and will be. Khosh Akhlagh et.al conducted a study entitled studying drought in the precipitation year of 2007-2008 and its effects over water and agricultural resources in Marvdasht pre-provinces and achieved similar results in that the drought in the precipitation years of 2007-2008 was very severe and had many negative effects on agriculture and water resources of Marvdasht pre-province (Fars).

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