Punjab University
Journal of Mathematics (ISSN 1016-2526)
Vol. 50(4)(2018) pp. 119-132

Forecasting Rainfall in Potohar Region of Pakistan in the Perspective of Drought

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Received: 18 July, 2017 / Accepted: 31 October, 2017 / Published online: 05 September, 2018

Abstract. In this study, we have analyzed rainfall data from 2000 to 2014 for Potohar region that is, Chakwal, Jhelum and Rawalpindi. Importance of this region cannot be denied as this region is rich in agriculture. Crop situation in the region depends completely on rainfall on suitable timings. Absence of or untimely rainfall lead to drought situation in Potohar. The region has faced severe to moderate drought condition in the history. Therefore, study of pattern of rainfall in the region is beneficial for agriculture sector in Pakistan. Seasonal autoregressive integrated moving average (SARIMA) model has been applied in order to study the rainfall pattern from 2000 to 2014. Furthermore, validation of the model is done on the data from 2015 to 2016. Afterwards, future prediction has also been done using parameters obtained from historical data. Forecasted values obtain from the suggested model of rainfall will help farmers and decision makers for sowing crop on appropriate time.

AMS (MOS) Subject Classification Codes: 97k80; 00A69
Key Words: Rainfall pattern, Potohar region, SARIMA, drought.

1. Introduction

Drought is a slow-onset hazard of nature, commonly referred to as a ”creeping phenomenon” whose impacts vary from region to region. During this period, rainfall remains lower than average, thus affecting agriculture and ecology of the region. Prolonged absence of rain affects rain-fed crops, livestock and community associated with agriculture, agro-industries and ultimately economy of the country. Besides rainfall, there are many parameters increase the severity of drought situation such as high temperatures, low soil moisture, limited availability of ground water and increased evapotranspiration [4]. Generally, the most prominent types of drought are meteorological, agricultural, and hydrological droughts [17, 16]. Meteorological drought is usually defined according to the degree of dryness in comparison to the "normal"or average amount of precipitation of the region and the duration of the dry period at a particular place and at a particular time. Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on the surface or subsurface water supply (i.e., stream flow, reservoir and lake levels, and ground water) [4]. Hydrological drought is associated with the effects of low rainfall on the water levels of rivers, reservoirs, lakes and aquifers. Agricultural drought links various characteristics of meteorological and hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced ground water or reservoir levels [17].

Pakistan has a diverse climate, ranging from arid and semi-arid to hyper arid. Pakistan lies in the western end of summer monsoon belt. It receives least amount of precipitation among the summer monsoon countries of Asia. Often occurrence of severe droughts is familiar in different areas of Pakistan. The worst drought in Punjab province occurred in 1899, 1920, 1935. In 1902, 1951 Khyber Pakhtunkhwa faced severe drought and people of Sindh experienced the same in 1871, 1881, 1899, 1931, 1947 and 1999 [17].

In the recent past, 1998, 1999 and 2000 were drought years for the whole country. The drought situation caused devastation to 58 districts of the country, specifically affecting Southern Punjab, Khyber Pakhtunkhwa and Sindh. It affected rain-fed areas and their ecology to the larger extent. Most of the areas of the Punjab especially the eastern and southern regions are vulnerable to disaster and continuously suffer from drought situation. Agricultural crops and cattle and fruit orchards were badly affected resulting in economic assets losses, environment damage and decline in health conditions of residents of drought affected districts [14, 10, 17].

There are two major seasons of rainfall in Pakistan; one is monsoon which brings rain during July to September in summer and second is winter which prevails from December to March [17]. The monsoon rains are caused by south westerly system in Arabian Sea or by south easterly system in Bay of Bengal.

In winter, the westerly winds bring rains to the country during December to March. This westerly system originates in Mediterranean Sea or Atlantic Ocean and travels eastward between 30N to 60N, and brings heavy rains to northern and central regions of Pakistan, leaving South Punjab, central and eastern Sindh dry [16].

In the northern region of Pakistan, the Potohar region covers an area of about 13,000 square km. and situated at an elevation of around 350 to 575 meters. Potohar region receives rainfall both in winter and summer monsoon making the crops run by the rains [1]. If any of the seasons fails to bring rains in this rain-fed area, then soil gets affected resulting drought and crop damage. Ultimately, the drought affects the agriculture and consequently influences the economy due to shortage of food. The Region is adversely affected by significant variation in the precipitation pattern resulting in mild drought or damage to agriculture due to prolonged rain [10].

Forecasting of rainfall could be done using numerous methods such as: fourier transform, Autoregressive Integrated Moving Average (ARIMA) model, SARIMA model, simple regression model, Neural network model, Autoregressive (AR) model and simple exponential smoothing model etc [19, 3, 6, 11, 14, 18]. In this study we have selected SARIMA model due to seasonality in the data and discussed it in detail in Methodology section.

2. Study Area

The Potohar region is surrounded by the Jhelum River in the east, by the Kala-Chitta and the Margalla ranges in the north, by the Salt Range in the south and by the Indus River in the west [12]. The drought study area includes Chakwal, Rawalpindi and Jhelum.

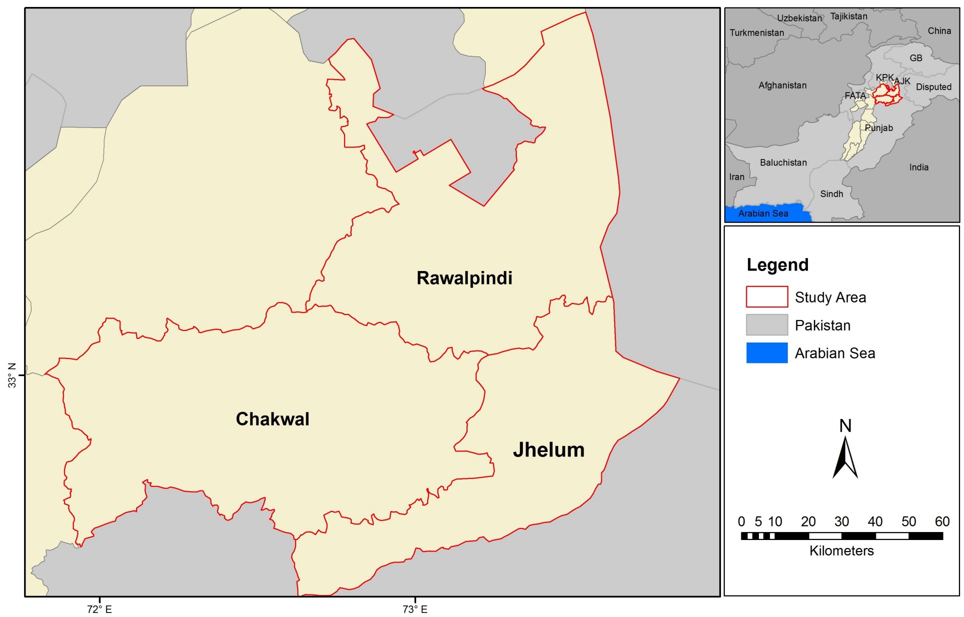


FIGURE 1. Study Area

These districts are highly dependent on rainfall for agriculture and are called barani areas [16]. There are two cropping seasons in the study area. One is related with winter crops and the other with summer crops. Major crops in this region comprise of Wheat, Rice, Barely, Jawar, Bajra, and Maize [16]. Crop in these area depends on moonsoon rains in summer and on westernly rains in winter [12]. If summer season fails to bring rains in the area, less crops yield in the year are expected. If westerly system also fails to bring rains in the area crops are affected badly, resulting in severe drought.

3. Method

Seasonal Autoregressive Integrated Moving Average Model (SARIMA)

If X_t is a time-series (TS) variable then the AR model of order p, denoted by AR(p), can be written in terms of past lagged values of the explanatory variables in X as,

$X_t = \theta_o + \sum_{i=1}^{p} \theta_i \;\; X_{t-i} + \varepsilon_t$.
A moving average process MA(q) of order q uses past errors as explanatory variables and is formulated as,
$X_t = \phi_o + \sum_{j=1}^{q} \phi_j \;\; \varepsilon_{t-j} + \varepsilon_t$.
A combination of both AR(p), and MA(q) is called ARMA(p, q) developed by Box-Jenkins [5, 13]. Some other authors have also discussed these models especially for rainfall seasonal pattern [7, 8, 9, 15]. Box and Jenkins developed ARIMA for forecasting conditional first moment, in which variance is constant. ARMA(p, q) process is described as,
$X_t = \mu + \sum_{i=1}^{p} \theta_i \;\; X_{t-i} + \sum_{j=1}^{q} \phi_j \;\; \varepsilon_{t-j} + \varepsilon_t$,
Where θ_i, ϕ_j and μ are constants (parameters), ε_t is independent and identically distributed random variable having mean zero and variance σ^2.
Extension to the ARMA (p, q) process is the ARIMA process. Non-stationary TS processes can be transformed, by differencing the series once or more, to make them stationary. The number of times 'd' that the integrated process must be differenced to make a TS stationary is denoted by ARIMA(p, d, q).
Another extension of ARIMA model that describe the seasonal behavior of the TS data is the SARIMA model.
Let $X_t = (x_1, x_2, ..., x_n)$ be non-stationary TS data then from ARIMA process:
$\theta(\beta)\Delta^d X_t = \phi(\beta)\varepsilon_t$
The general model of SARIMA (p,d,q) $(P,D,Q)_s$ is given by

$$\eta(\beta^s)\phi(\beta)(1-\beta)^d(1-\beta)^D X_t = \alpha(\beta^s)\theta(\beta)\varepsilon_t \tag{3. 1}$$

In equation (3.1), $\eta(\beta^s)$, $\phi(\beta)$, $\alpha(\beta^s)$ and $\theta(\beta)$ are the polynomial.
$\eta(\beta^s) = 1 - \eta_1(\beta^s) - \eta_2(\beta^{2s}) - \eta_3(\beta^{3s}) - ... - \eta_P(\beta^{Ps})$
$\alpha(\beta^s) = 1 - \alpha_1(\beta^s) - \alpha_2(\beta^{2s}) - \alpha_3(\beta^{3s}) - ... - \alpha_Q(\beta^{Qs})$
$\theta(\beta) = 1 - \theta_1(\beta) - \theta_2(\beta^2) - \theta_3(\beta^3) - ... - \theta_q(\beta^q)$
$\phi(\beta) = 1 - \phi_1(\beta) - \phi_2(\beta^2) - \phi_3(\beta^3) - ... - \phi_p(\beta^p)$
Where, β is back shift operator, p and P represent order of the non- seasonal and seasonal AR, q and Q MA part of the model respectively, d and D denotes differenced of the series to make the process stationary. ε_t is is a sequence of white noise follows $N(0, \sigma^2)$ distribution.
Moreover, the model building process of SARIMA is same as ARIMA model. The objective of this study is to forecast the monthly rain fall of the Potohar region using SARIMA model.

4. Data Analysis

Rainfall Data Analysis (Ground based rainfall data)
The monthly rainfall data from 2000 -2016 is acquired from Pakistan Meteorological Department (PMD), totaling two hundred and four (204) observations. Data values are first converted into inches from mm in order to stabilize high and low peeks in the graphs and this conversion of unit does not affect model building. It has been observed that seasonal pattern is strong and stable, as shown in figure 2, 3 and 4, showing monthly rain fall data of Rawalpindi, Jhelum and Chakwal regions, respectively.

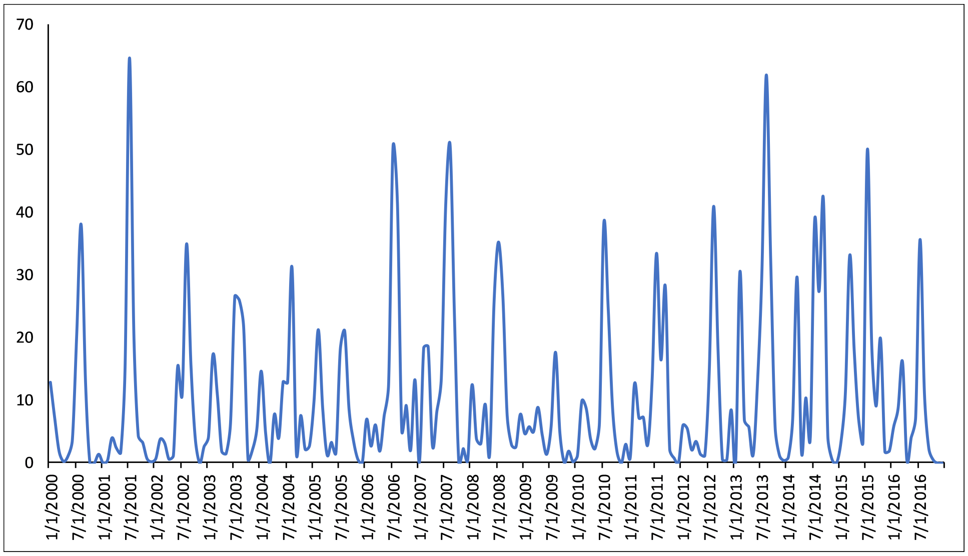


FIGURE 2. Time series plot of Rawalpindi monthly Rain fall

Figure 2 shows graph of actual rainfall of Rawalpindi. Highest rainfall is observed in summer monsoon of 2001 i.e. 65 inches. Furthermore, rapidly changing behavior is observed from 2002 to 2011. Whereas, stability in the pattern has been observed in the data from 2012 and onwards.

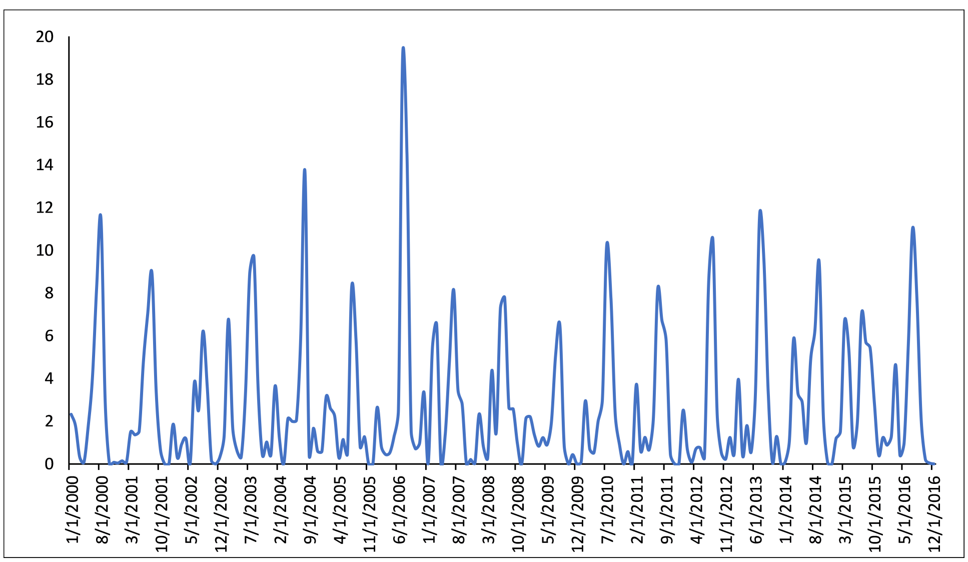


FIGURE 3. Time series plot of Jhelum monthly Rain fall

Figure 3 shows graph of actual rainfall of Jhelum. Highest rainfall is observed in summer monsoon of 2006 i.e. 19 inches. Unlike Rawalpindi and Chakwal, rainfall pattern has rapidly changing behavior throughout.

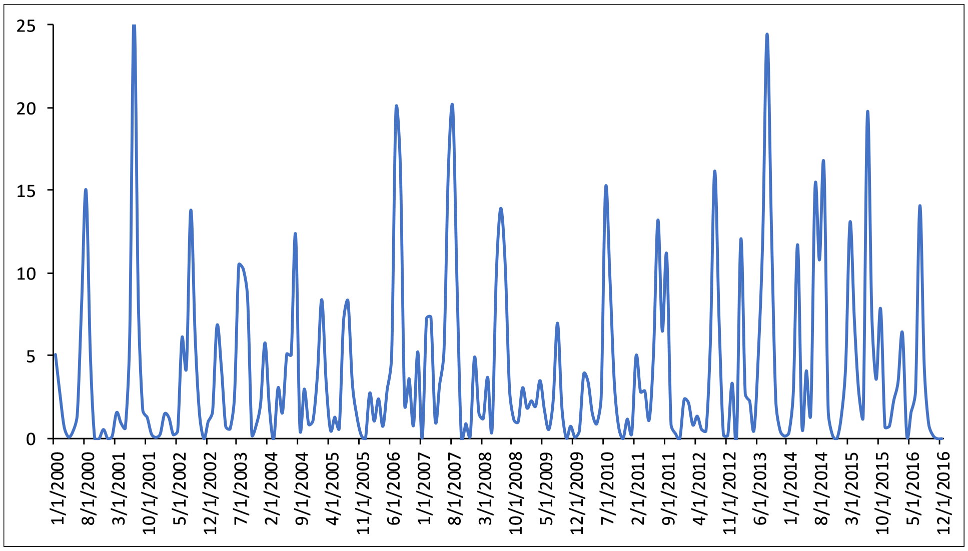


FIGURE 4. Time series plot of Chakwal monthly Rain fall

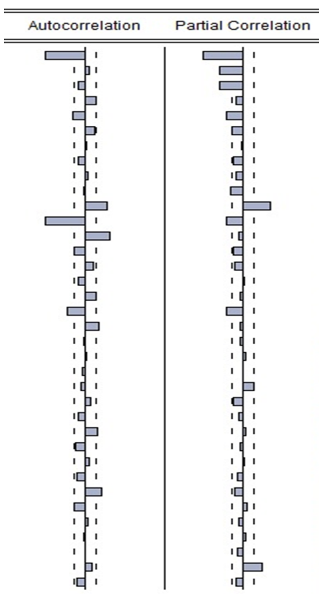
Figure 4 shows graph of actual rainfall of Chakwal. Highest rainfall is observed in summer monsoon of 2001 i.e. 25 inches. Furthermore, rapidly changing behavior is observed from 2002 to 2011. Whereas, stability in pattern has been observed in the data from 2012 and onwards.

From above figures, it is concluded that Rawalpindi and Chakwal show similar behavior towards rainfall. On the other hand, Jhelum has unpredictable pattern. This is because of the reason that crop in Jhelum does not depends completely on rainfall. In Table 1 we give the basic statistics for the data after taking first differences in order to achieve stationarity.

Values	**D(CHAKWAL)**	**D(JHELUM)**	**D(PINDI)**
Mean	-0.00081	-0.01142	-0.02502
Median	-0.00787	-0.05118	-0.19685
Maximum	7.22835	16.58662	19.44883
Minimum	-6.17717	-13.248	-17.3228
Std. Dev.	1.54945	3.440373	5.561568
Skewness	1.355365	0.076314	0.194729
Kurtosis	11.49588	6.887286	4.567835‘

TABLE 1. Descriptive Statistic of Rain fall data

All the mean values of differenced data indicate low rain fall. Furthermore, standard deviation of the data for Rawalpindi is very high (5.562) but Chakwal has least value that is 1.54945. Therefore, high variability occurs in the Rain Fall pattern of Rawalpindi and less in Chakwal. Most importantly, all the data is positively skewed which indicates that average rainfall is greater than the frequently occurred rainfall.
Seasonal pattern of data motivates us to apply SARIMA model for future forecast. For the purpose, we plotted Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF). It is observed that there are significant spikes in the plot of ACF at lags 12, 24, and so on, as seen in figure 5, 6 and 7. Therefore, seasonal difference of 12 is considered for model building.

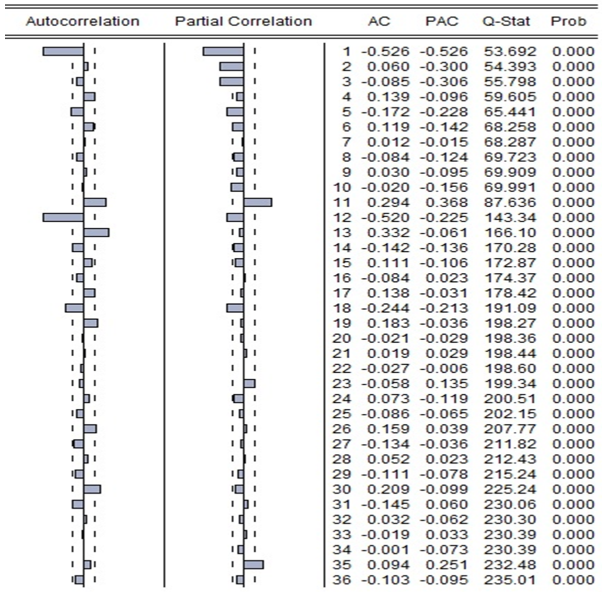


	AC	PAC	Q-Stat	Prob
1	-0.526	-0.526	53.692	0.000
2	0.060	-0.300	54.393	0.000
3	-0.085	-0.306	55.798	0.000
4	0.139	-0.096	59.605	0.000
5	-0.172	-0.228	65.441	0.000
6	0.119	-0.142	68.258	0.000
7	0.012	-0.015	68.287	0.000
8	-0.084	-0.124	69.723	0.000
9	0.030	-0.095	69.909	0.000
10	-0.020	-0.156	69.991	0.000
11	0.294	0.368	87.636	0.000
12	-0.520	-0.225	143.34	0.000
13	0.332	-0.061	166.10	0.000
14	-0.142	-0.136	170.28	0.000
15	0.111	-0.106	172.87	0.000
16	-0.084	0.023	174.37	0.000
17	0.138	-0.031	178.42	0.000
18	-0.244	-0.213	191.09	0.000
19	0.183	-0.036	198.27	0.000
20	-0.021	-0.029	198.36	0.000
21	0.019	0.029	198.44	0.000
22	-0.027	-0.006	198.60	0.000
23	-0.058	0.135	199.34	0.000
24	0.073	-0.119	200.51	0.000
25	-0.086	-0.065	202.15	0.000
26	0.159	0.039	207.77	0.000
27	-0.134	-0.036	211.82	0.000
28	0.052	0.023	212.43	0.000
29	-0.111	-0.078	215.24	0.000
30	0.209	-0.099	225.24	0.000
31	-0.145	0.060	230.06	0.000
32	0.032	-0.062	230.30	0.000
33	-0.019	0.033	230.39	0.000
34	-0.001	-0.073	230.39	0.000
35	0.094	0.251	232.48	0.000
36	-0.103	-0.095	235.01	0.000

FIGURE 5. ACF/PACF for Rawalpindi

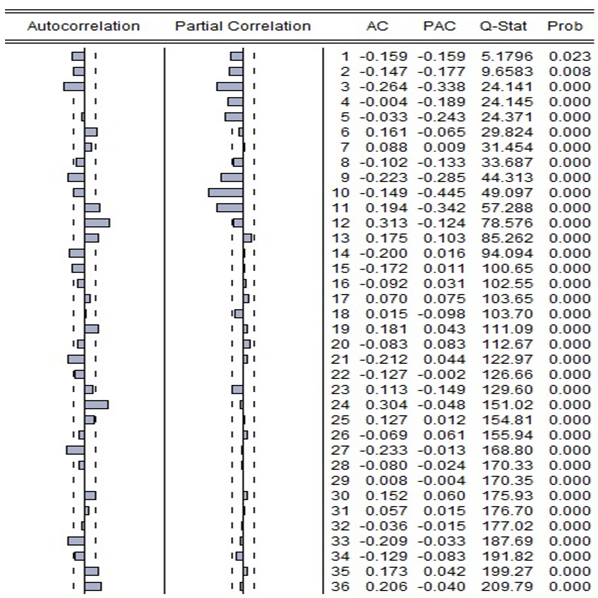
Figure 5 shows plot of ACF/PCF for Rawalpindi. First spike is found at 12. The ACF dies down after lag 1 and the PACF also tails off after lag 1. So, p=1 and q=1 would be needed to describe these data for non-seasonal autoregressive and moving average processes, respectively.

Figure 6 shows plot of ACF/PCF for Jhelum. First spike is found at 12. The ACF dies down after lag 1 and the PACF also tails off after lag 1. So, p=1 and q=1 would be needed to describe these data for non-seasonal autoregressive and moving average processes, respectively.



Lag	AC	PAC	Q-Stat	Prob
1	-0.526	-0.526	53.692	0.000
2	0.060	-0.300	54.393	0.000
3	-0.085	-0.306	55.798	0.000
4	0.139	-0.096	59.605	0.000
5	-0.172	-0.228	65.441	0.000
6	0.119	-0.142	68.258	0.000
7	0.012	-0.015	68.287	0.000
8	-0.084	-0.124	69.723	0.000
9	0.030	-0.095	69.909	0.000
10	-0.020	-0.156	69.991	0.000
11	0.294	0.368	87.636	0.000
12	-0.520	-0.225	143.34	0.000
13	0.332	-0.061	166.10	0.000
14	-0.142	-0.136	170.28	0.000
15	0.111	-0.106	172.87	0.000
16	-0.084	0.023	174.37	0.000
17	0.138	-0.031	178.42	0.000
18	-0.244	-0.213	191.09	0.000
19	0.183	-0.036	198.27	0.000
20	-0.021	-0.029	198.36	0.000
21	0.019	0.029	198.44	0.000
22	-0.027	-0.006	198.60	0.000
23	-0.058	0.135	199.34	0.000
24	0.073	-0.119	200.51	0.000
25	-0.086	-0.065	202.15	0.000
26	0.159	0.039	207.77	0.000
27	-0.134	-0.036	211.82	0.000
28	0.052	0.023	212.43	0.000
29	-0.111	-0.078	215.24	0.000
30	0.209	-0.099	225.24	0.000
31	-0.145	0.060	230.06	0.000
32	0.032	-0.062	230.30	0.000
33	-0.019	0.033	230.39	0.000
34	-0.001	-0.073	230.39	0.000
35	0.094	0.251	232.48	0.000
36	-0.103	-0.095	235.01	0.000

FIGURE 6. ACF/PACF for Jhelum



Lag	AC	PAC	Q-Stat	Prob
1	-0.159	-0.159	5.1796	0.023
2	-0.147	-0.177	9.6583	0.008
3	-0.264	-0.338	24.141	0.000
4	-0.004	-0.189	24.145	0.000
5	-0.033	-0.243	24.371	0.000
6	0.161	-0.065	29.824	0.000
7	0.088	0.009	31.454	0.000
8	-0.102	-0.133	33.687	0.000
9	-0.223	-0.285	44.313	0.000
10	-0.149	-0.445	49.097	0.000
11	0.194	-0.342	57.288	0.000
12	0.313	-0.124	78.576	0.000
13	0.175	0.103	85.262	0.000
14	-0.200	0.016	94.094	0.000
15	-0.172	0.011	100.65	0.000
16	-0.092	0.031	102.55	0.000
17	0.070	0.075	103.65	0.000
18	0.015	-0.098	103.70	0.000
19	0.181	0.043	111.09	0.000
20	-0.083	0.083	112.67	0.000
21	-0.212	0.044	122.97	0.000
22	-0.127	-0.002	126.66	0.000
23	0.113	-0.149	129.60	0.000
24	0.304	-0.048	151.02	0.000
25	0.127	0.012	154.81	0.000
26	-0.069	0.061	155.94	0.000
27	-0.233	-0.013	168.80	0.000
28	-0.080	-0.024	170.33	0.000
29	0.008	-0.004	170.35	0.000
30	0.152	0.060	175.93	0.000
31	0.057	0.015	176.70	0.000
32	-0.036	-0.015	177.02	0.000
33	-0.209	-0.033	187.69	0.000
34	-0.129	-0.083	191.82	0.000
35	0.173	0.042	199.27	0.000
36	0.206	-0.040	209.79	0.000

FIGURE 7. ACF/PACF for Chakwal

Figure 7 shows plot of ACF/PCF for Chakwal. First and second spikes are found at 12 and 24 respectively. The ACF dies down after lag 2 and the PACF also tails off after lag 1. So, p=1 and q=1 would be needed to describe these data for non-seasonal autoregressive and moving average processes, respectively.

With seasonal cycle of 12 months different order (p,d,q) of SARIMA models were considered such as:$(0,1,1)(0,0,1)^{12}$, $(0,1,2)(0,0,2)^{12}$ and $(1,1,1)(0,0,1)^{12}$. Two most commonly used criteria for the model selection are: Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC) [2]. We used both AIC and BIC criterion for selection of suitable model for each region (Table 2). It is found that model order $(0,1,1)(0,0,1)^{12}$ is suitable in all.

Region	**AIC**	**BIC**	**SARIMA(p,d,q)(P,D,Q)**	R^2	**RMSE**
Chakwal	3.1	3.12	$(0,1,1)(0,0,1)^{12}$	53.7%	1.275
Rawalpindi	5.32	5.37	$(0,1,1)(0,0,1)^{12}$	73.1%	3.094
Jhelum	4.33	4.37	$(0,1,1)(0,0,1)^{12}$	68.5%	1.34

TABLE 2. Order of SARIMA model with R-squared and model RMSE

From Table 2, Rawalpindi has Highest value of R^2 which shows better accuracy of prediction and can be used in forecasting. On the other hand, Root Mean Square Error (RMSE) is minimum in Chakwal explaining that the difference between actual and the estimated values is negligible.

Region	**Value**	**Coefficient**	**Std. Error**	**t-Statistics**	**Prob.**
Rawalpindi	MA(1)	-0.9548	0.02219	-43.017	0.0000
	SMA(12)	-0.9044	0.01196	-46.04304	0.0000
Chakwal	MA(1)	-0.927967	0.030143	-30.78554	0.0000
	SMA(12)	-0.556138	0.077308	-7.193835	0.0000
Jhelum	MA(1)	-0.942926	0.025481	-37.00577	0.0000
	SMA(12)	-0.899183	0.021350	-42.11724	0.0000

TABLE 3. Parameters of SARIMA model for the study area

For model building EViews9 software has been used. All the estimated parameters are significant at 5% level of significance and have minimum standard error (See Table 3).

5. VALIDATION OF THE MODEL

Statistical models developed with the help of available data. Data from 2015 to 2016 was used in order to check the accuracy of the model. For the purpose, said data was plotted along with forecasted values based on developed model, figure 8.

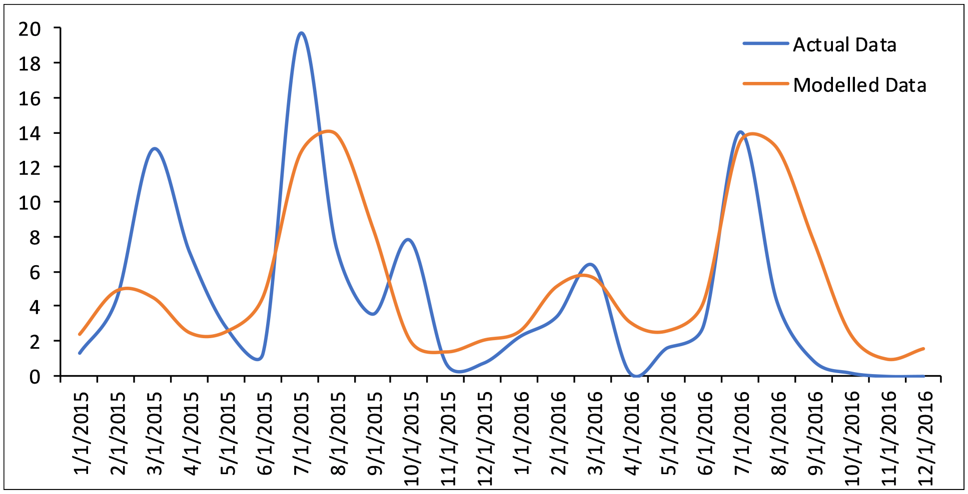


FIGURE 8. Actual and modelled values of rainfall for Rawalpindi

In figure 8 actual and modelled values of rainfall for Rawalpindi have been plotted. RMSE is found to be 4.09 Which indicates a close match in actual and modelled values. Most of the spikes in the forecasted vales matches with actual one especially both in winter and summer monsoon seasons of 2016.

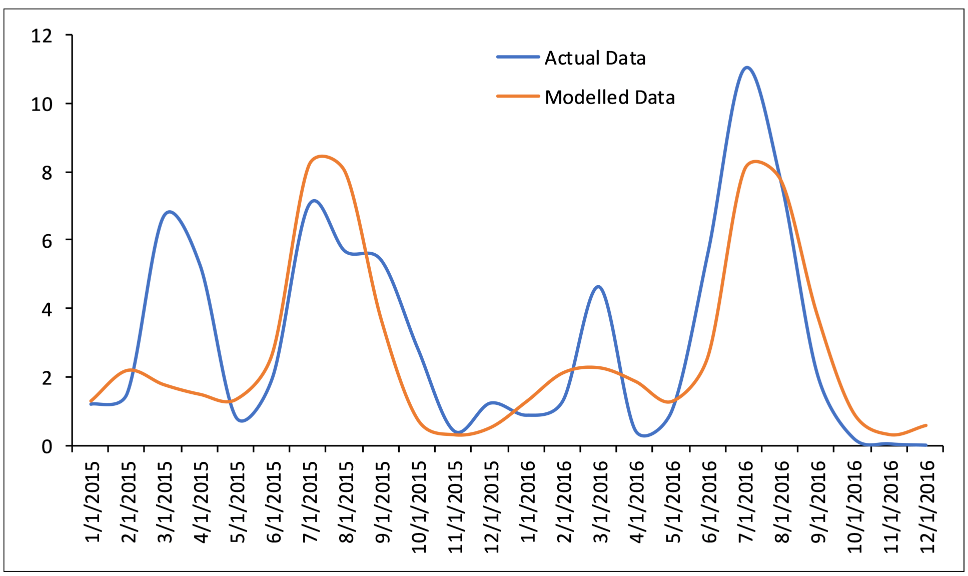


FIGURE 9. Actual and modelled values of rainfall for Jhelum

In figure 9 actual and modelled values of rainfall for Jhelum have been plotted. RMSE is found to be 1.88 Which indicates a close match in actual and modelled values. Similar to Rawalpindi, Jhelum data also shows two spikes in good harmony but in different years, that is in summer monsoon season for 2015 and 2016.

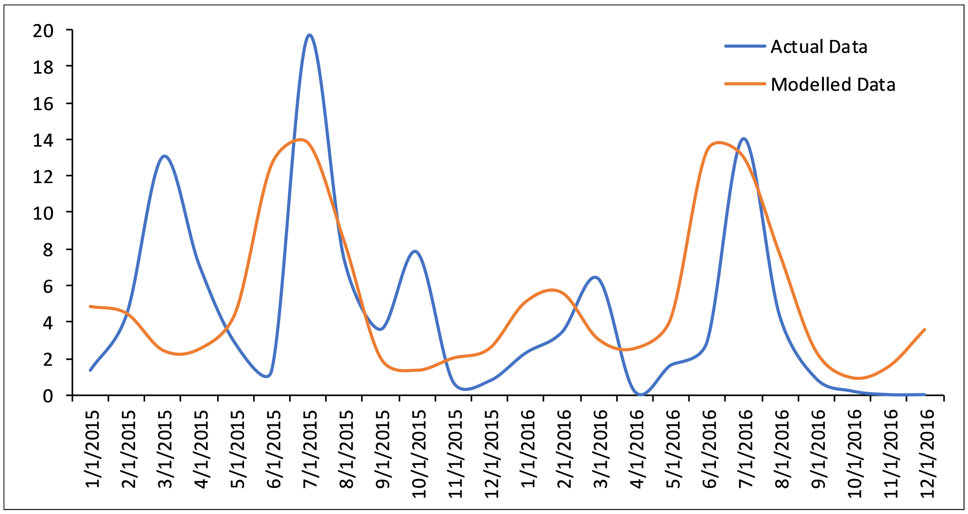


FIGURE 10. Actual and modelled values of rainfall for Chakwal

In figure 10 actual and modelled values of rainfall for Chakwal have been plotted. RMSE is found to be 2.5 Which indicates a close match in actual and modelled values. Most of the spikes in the forecasted vales matches with actual one with a slight shift.
observe that RMSE of in-sample estimated model for Chakwal, Rawalpindi and Jhelum are 1.18, 3.4 and 2.06 respectively. Whereas, out-sample forecast mean square error for Chakwal, Rawalpindi and Jhelum are 1.27, 3.09, 1.34 respectively. This shows that in-sample and out-sample forecasts are quite close. Furthermore, plots of actual and forecasted data represent that developed model with least RMSE is capable of predicting rainfall data in the selected region.

6. FORECAST

We have forecasted rainfall pattern from 2017 to 2019, figure (11-13).
Figure 11, represent actual as well as forecasted data of rainfall for Chakwal. Forecasted data may be verified with real time data in future.

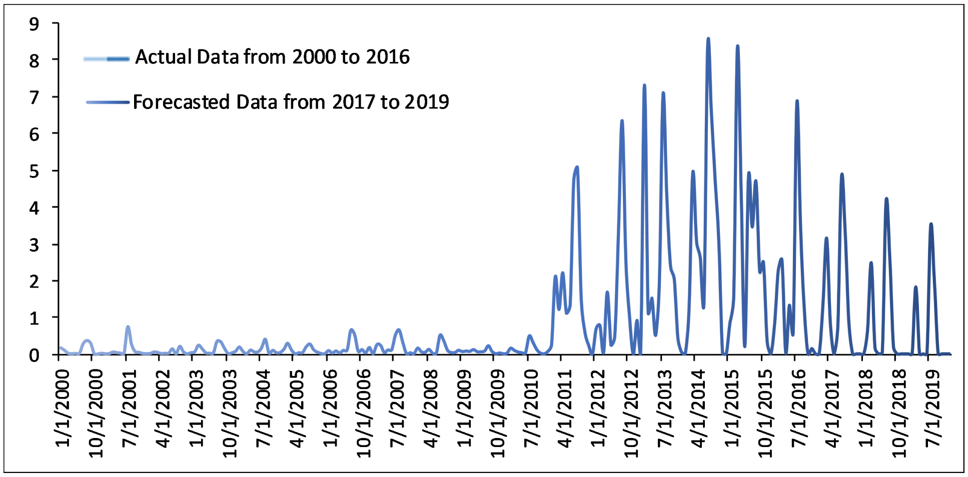


FIGURE 11. Actual and Forecasted Rainfall data for Chakwal

It is observed that the amount of rainfall from 2000 to 2010 had been very low as compared to that of remaining years. Moreover, Forecasted data for 2017 shows high amount of rainfall as compared to 2018 and 2019 in summer monsoon season. Whereas, decrease in the intensity of rainfall is expected in coming years, 2018 and 2019, indicating drought situation.

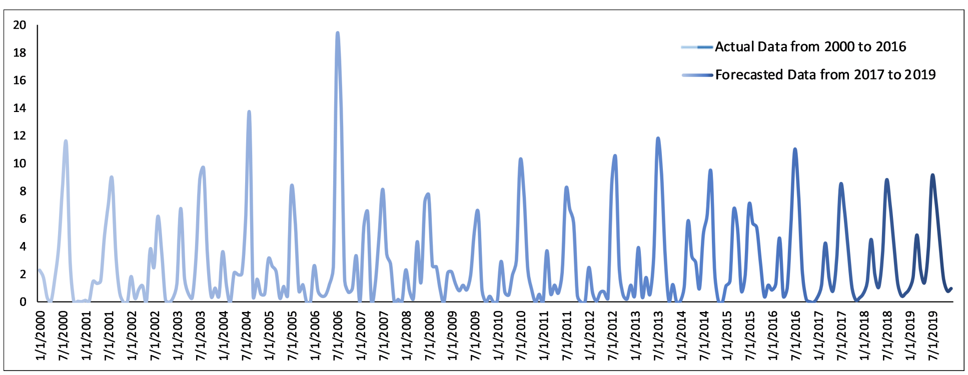


FIGURE 12. Actual and Forecasted Rainfall data for Jhelum

Figure 12, represent actual as well as forecasted data of rainfall for Jhelum. Unlike Chakwal, Jhelum has rainfall values in similar range throughout the timeline. Forecasted data for 2017, 2018 and 2019 show similar pattern. Amount of rainfall remains within the range of 9 inches, which is higher than that of winter 2001 to 2002, labeled as drought years in the past. Therefore, from this comparison we conclude that in future Jhelum may remain safe from severe drought condition.

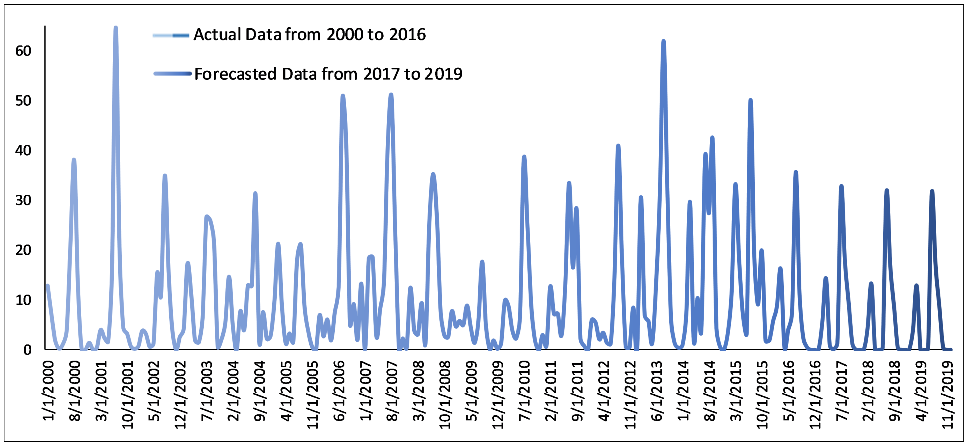


FIGURE 13. Actual and Forecasted Rainfall data for Rawalpindi

Figure 13, represent actual as well as forecasted data of rainfall for Rawalpindi. Unlike Chakwal, Rawalpindi has rainfall values in similar range throughout the timeline. Just like Jhelum, forecasted data for 2017, 2018 and 2019 show similar pattern in Rawalpindi as well. In Rawalpindi, amount of rainfall remains within the range of 32 inches, which is less than that of winter 2001 to 2002, labeled as drought years in the past. Therefore, from this comparison we conclude that in future Rawalpindi may face drought condition.
It is a known fact that SARIMA model has short memory model dependency. Therefore, it is not suitable for long time forecast. But, forecast can be continued with addition of latest data for upcoming year.

7. CONCLUSION

Crop situation in Pothohar region of Pakistan completely depends on rainfall. Importance of rainfall has been witnessed by occurrence of drought in past few years. Because of seasonality in pattern, SARIMA model was applied with different order for different regions and it was found that a model with order $(0, 1, 1)(0, 0, 1)^{12}$ is suitable for all regions. RMSE are computed, that are: for Chakwal, 2.5, for Rawalpindi, 4.08, and for Jhelum, 1.88. The RMSE show that the developed models are best suitable for each region respectively. Furthermore, forecasted vales are computed for 2017, 2018 and 2019. Through the model a decrease in rainfall in 2018 and 2019 has been predicted in Chakwal and Rawalpindi regions which is an indication of occurrence of drought. Whereas, rainfall values for Jhelum are better than that of Chakwal and Rawalpindi regions. Forecast for more years have not been computed because SARIMA model provides short term forecast. Long term forecast is possible with the help of Autoregressive Fractionally Integrated Moving Average (ARFIMA) model. However, we did not apply ARFIMA model due to insufficient availability of data. Researchers can continue this study with ARFIMA model subject to the availability of large amount of data. Furthermore, the study could be enhanced by incorporating other variables such as: humidity, temperature, evapotranspiration etc.

8. RECOMMENDATIONS

Keeping the importance of rainfall in view in crop production which may reduce or trigger drought situation in the region, it is suggested that drought early warning system should be developed. Furthermore, quality data management is questionable especially in these regions. Monitoring, managing and availability of correct data will also help in reducing frequent occurrence of drought region. Moreover, rainfall also depends on amount of forest in the region. Therefore, the forest management will also be a positive addition to the cause.

9. Acknowledgments

Authors are highly grateful to PMD for data provision. We are also thankful to review panel of CASM LUSM for their valuable comments.

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