Environmental Engineering and Management Journal November 2019, Vol. 18, No. 11, 2377-2386
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

PRECIPITATION AND CLIMATE VARIABLES: A STUDY OF ISLAMABAD CITY

Dalia Streimikiene[1]*, Rizwan Raheem Ahmed[2], Saghir Pervaiz Ghauri[3], Jolita Vveinhardt[4]

[1]*Institute of Sport Science and Innovations, Lithuanian Sports University, Sporto str. 6, 44221, Kaunas, Lithuania*
[2]*Faculty of Management Sciences, Indus University, Block-17, Gulshan, Karachi-7550, Pakistan*
[3]*Faculty of Management Sciences, DHA Suffa University, DG-78, Off Khayaban-e-Tufail, Phase-7, Ext-DHA, Karachi-75500, Pakistan*
[4]*Faculty of Economics and Management, Vytautas Magnus University, Daukanto str. 28, 44248, Kaunas, Lithuania*

Abstract

The objective of this paper is to investigate the short and long run association, and causality among precipitation (dependent variable), and other climate parameters such as minimum and maximum temperature, wind speed, relative humidity, and atmospheric pressure (independent variables) for Islamabad city. The authors have considered the data set from July 2001 – December 2017, and applied several econometrics techniques such as Augmented Dickey-Fuller, Vectors Auto regression, Multivariate cointegration, and Granger causality techniques to analyze the data. The findings of the study demonstrated a long-term association between precipitation, and minimum temperature, atmospheric pressure, relative humidity, and wind speed. Finally, the Granger causality revealed the one-way causal relationship from atmospheric pressure to the rainfall, rainfall to relative humidity, and atmospheric pressure to rainfall. However, the authors have observed two-way causality between precipitation and minimum temperature.

Key words: atmospheric pressure, precipitation, relative humidity, temperatures, wind speed

Received: January, 2019; Revised final: March, 2019; Accepted: April, 2019; Published in final edited form: November, 2019

1. Introduction

The global warming is the major cause of growing CO_2 concentration in the atmosphere that enhances the pollution, and also the cause of climate change (Lee et al., 2017; Stocker et al., 2013; Shifteh et al., 2012). The first decade of 21st century has been recorded the warmest for last 100 years (Feyissa et al., 2018; Hansel et al., 2016; Rahman and Lateh, 2017). According to Dell et al. (2012), Hanif et al. (2013), and Pachauri and Reisinger (2007), it is also projected that there might be a rise of 2ºC in global temperature in the near future, and 4–6ºC increase of global temperature in a long run. Costa and Soares (2009), Hansen et al. (2016), Tye et al. (2019), and Yue and Hasino (2003) demonstrated that the climate changes tend to alter the meteorological parameters such as temperature and precipitation. According to Dai et al. (2018), Khan (2004), and Modarres and da Silva (2007), the shift in meteorological changes are not uniform across the globe; it experiences varying degree in different regions of the world.

The alteration in precipitation pattern is one of the major parameters of climate variation, the systemic shift in the state of average climatic parameters for instance precipitation, temperature, air pressure, and wind speed has been recorded. The variation in the climatic variables, particularly, alteration in atmospheric CO_2 is the major effect of climate change that leads to heat strain, succeeding the

* Author to whom all correspondence should be addressed: e-mail: dalia.streimikiene@lei.lt; Phone: +370 614 03424

pattern of change of rainfall that could lead either drought or flooding (Bahrami et al., 2018; Kueh and Kuok, 2018; Liu et al., 2018). The natural hydrocarbon cycle of the world is being changed due to the climate change, according to Philander (2008), climate change has an imperative influence on the precipitation, and evapotranspiration in several parts of the globe, and the ecosystem is exhibiting numerous substantiations that portray the effect of climate variation on it.

According to Li et al. (2018), Stocker et al. (2013), Shahid (2010), and Tabari and Talaee (2011), the long-run variation in the temperature and precipitation (rainfall) are imperative for sustainable land resource planning, and water resources management, particularly, under the certain climate change and variability. For any significant research regarding the climate change and variability, the meteorological parameters may not be ignored, and researchers have given considerable attention to examining the influences of climate change and variability for long-run trends in temperature and precipitation (Giorgi and Lionello, 2008; Kenabatho et al., 2012; Lionello and Scarascia, 2018; Menzel et al., 2006; Partal and Sezen, 2018). Several research studies were conducted regionally and globally to examine the affect of climate change and variability by using time series econometrics modeling (Shifteh et al., 2012; Tabari and Talaee, 2011). The outcomes of these studies have demonstrated that both decreasing and increasing trends in meteorological parameters have been observed during the winter season.

According to Akinsanola and Ogunjobi (2015), Rosenzweig et al. (2002), the influence of climatic variability is dissimilar and specific to region-wise. The climate variability is anticipated to result in shortages of water and other resources, rise in sea level, bug eruption and disease on livestock and crops (Gocic and Trajkovic, 2013; Hocke, 2017; Huang et al., 2016). The global prosperity vicissitudes in agricultural sector, and it was estimated the losses of $61.2 billion, however, the increases of only $ 0.1 billion (Reilly et al., 1994). Similarly, Adams et al. (1998), Adams and Hurd (1999), Darwin et al. (1995), Rosenzweig and Parry (1994), and Yacoub and Tayfur (2018) have established that under the stern circumstances of climate variability and change, the losses are pervasive. These studies further predicted that due to shortages of water there would be losses of 24% in developed countries, and 16% in developing countries in agriculture. Very few studies have been carried out on the developing countries regarding the consequences of climatic variability; the developing countries are more affected than the developed economies (Edossa et al., 2014; Wu, 2019; Yin and Sun, 2018).

According to Bhandari et al. (2018), Chowdhury et al. (2011), Farooqi et al. (2005), and Salma et al. (2012), the overall system of worldwide climate has developed more atypical than ever before, Pakistan, Bangladesh, and India have been experiencing severe global warming effect that has its consequences in the summer monsoon rainfall. According to Attanasio et al. (2013), He and Zhai (2018), George (2008), Karfakis et al. (2012), Kodra et al. (2011), and Maslin (2004), during the last 50 years, the northern hemisphere has become squallier, according to the simulations' model for the future of mid-latitude is anticipated to vary extensively for next 100 years, which will amplify the climate alteration happenings.

The precipitation effective index has exhibited an alarming depiction regarding the spatiotemporal changes in the pattern of normal rainfall in Pakistan; the zonation readings display a huge change in the precipitation pattern in the plateau of upper Indus (Afzal and Zaman, 2010; Faisal and Sadiq, 2011; Hanif et al., 2013; Mishra et al., 2018). According to the German Watch, in a perspective of climate change effects, Pakistan has frequently been contemplated among the top 100 most vulnerable nations, whereas, ranked 135 being a low carbon emitter (Khan et al., 2016). However, Pakistan is continually exposed to several natures of extreme incidents such as drought, flood, heat waves, glacier lake outburst floods, and other non-traditional severe events (Khalid and Zameer, 2013; Khan, 2004; Rahman and Lateh, 2017; Rasul, 2010).

The increase in temperature has its impact on the rainfall and socio-economic sectors, decrease in rainfall directly effect on drinking water, agriculture and environment of Pakistan. The residents of Islamabad city are facing the important challenges in the climate change that includes shortage of water, shortage of forests, shortage of food etc. Thus, there is dire need to examine the association of climate parameters, and its impact on the inhabitants of Islamabad city. In this research work, monthly weather data of Islamabad city has been modeled for the period of 16 years (2001–2017). The total covered area of Islamabad is 906 km^2 with elevation of 507 meters, and situated at 33.43 ^{0}N and 73.04 ^{0}E, it has three artificial reservoirs: Rawal, Simli, and Khanpur Dams. The Islamabad has subtropical humid weather with cold winter and hot summer. It has a minimum temperature (1^0C), maximum temperature (42^0C), median cloud cover (12%), highest average wind speed (5 m/s), and maximum rainfall occurred in July 2001 (647 mm) and August 2013 (620 mm).

The significance and objectives of this study is multifaceted as it is the first research that considered the Islamabad city; three deferent zones such as the provinces of Punjab and KPK, and Kashmir surround the Islamabad. The undertaken research examines the spatial-temporal extent of climate changes, and long-run causal relationship between rainfall (precipitation), and minimum & maximum temperatures, relative humidity, wind speed, and an atmospheric pressure. The authors have used more robust econometrics modeling to carry out the undertaken study, whereas, previous literature used multiple regression and OLS regression models. The results of the undertaken research could be a valuable contribution in current literature regarding climate change, and variability in case of Pakistan.

The rest of the paper comprises of four parts such as, (2) the second section deals with the research methodology, (3) the third section comprises of results and discussions, and (4) fourth section demonstrates the conclusions, policy implications, and limitations of the undertaken study.

2. Material and methods

2.1. Data collection

The monthly data of climate parameters such as rainfall (precipitation) (mm), and other climate parameters such as minimum & maximum temperatures (ºC), wind speed (knots), atmospheric pressure (hpa/gpm), and relative humidity (%) for the period from July 2001 – December 2017 has been considered for the undertaken study. We used computerized data processing center (CDPC), which is the part of Pakistan metrological department, Karachi for obtaining the monthly data, the month-to-month data of Islamabad city, the capital of Pakistan, was taken for the mentioned period.

2.2. Climate statistics

The aim of the undertaken research is to ascertain a long run causal association amid rainfall (precipitation), and minimum & maximum temperatures, atmospheric pressure, wind speed, and relative humidity for the period July 2001 – December 2017. This research study also mapping the changing pattern of rainfall and investigates the connection of the precipitations anomalies during the considered time period for the Islamabad city. Statistics of the selected parameters are given as follows:

2.3. Precipitation (R_f: mm)

It is the important parameter of the weather; sometimes it is known to be a function of all other parameters. During the considered data period, the minimum precipitation was recorded 0.0 mm, maximum precipitation was recorded 647 mm, an average value was 107.50 mm, and standard deviation was recorded 126.63 mm. However, maximum rainfall was recorded in July 2001 (647 mm). However, the pattern of precipitation during July 2001 - December 2017 has variations (Fig. 1).

2.4. Minimum temperature (T_{min}: ^0C)

During the monthly data from July 2001 – December 2017, minimum temperature has a minimum value of 1.8 ºC, however, the maximum value of 26 ºC of minimum temperature was recorded, and an average value of minimum value of 15.77 ºC was recorded. However, the standard deviation of minimum temperature of (7.78) was recorded during the seasonal variation in the data sample period (Fig. 2).

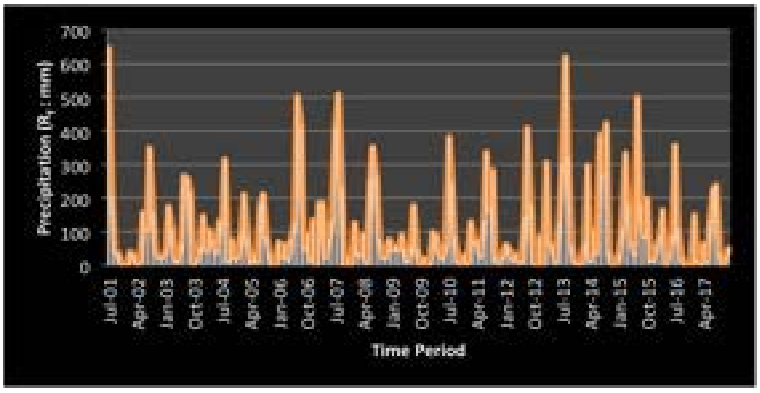

Fig. 1. Precipitation (Rainfall) of Islamabad

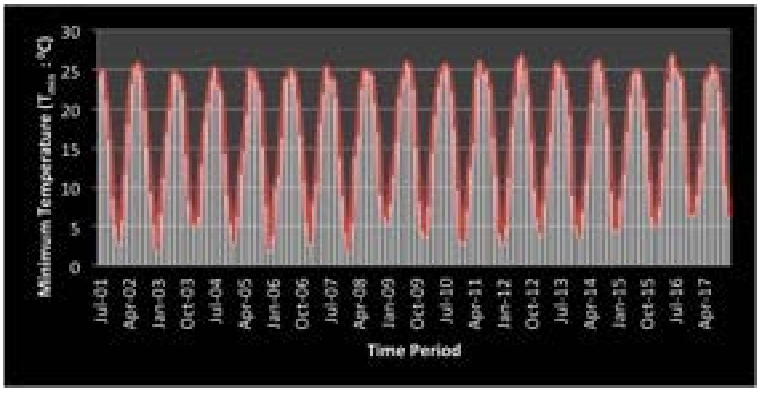

Fig. 2. The minimum temperature of Islamabad

2.5. Maximum temperature (T_{max}: ^{0}C)

For the monthly data from July 2001 - December 2017, the maximum temperature has a minimum value of 14.8ºC, and the maximum value of 41.1ºC was recorded. The average value of maximum temperature was 29.7 ºC, and standard deviation of 6.86 was recorded during the seasonal variation in the data (Fig. 3).

2.6. Wind speed (W_s: Knots)

During the monthly data from July 2001 - December 2017, the wind speed has a minimum value of 2.5 knots, and the maximum value of 18.4 knots was recorded. However, the average value of 10.93 knots of wind speed has been observed, and standard deviation (3.15) was calculated during the seasonal variation in the data (Fig. 4).

2.7. Relative humidity (R_h: %)

For the monthly data from July 2001 - December 2017, the relative humidity has a minimum value of 18%, the maximum value was 67.2%, however, an average value was 43.51%, and standard deviation was recorded 11.23. There is a seasonal variation in the data (Fig. 5).

2.8. Atmospheric pressure (A_p: hpa/gpm)

For the monthly-to-month data from Jul 2001 – December 2017, the atmosphere pressure has a minimum value of 992 hpa/gpm, however, the maximum value was 1019.7 hpa/gpm, the average value was 1006.53 hpa/gpm, and standard deviation was recorded 7.83. There is a seasonal variation in the data (Fig. 6).

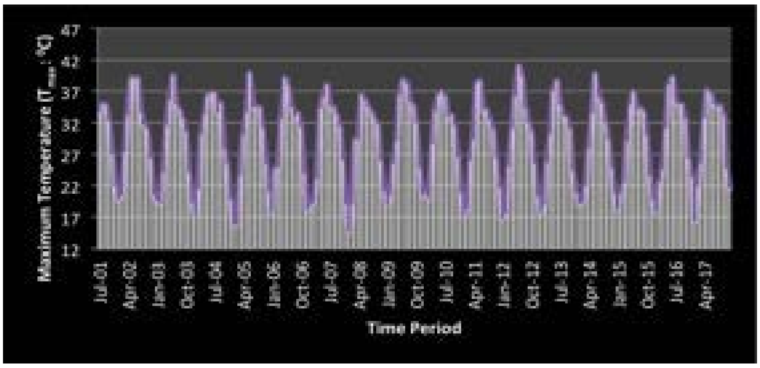

Fig. 3. The maximum temperature of Islamabad

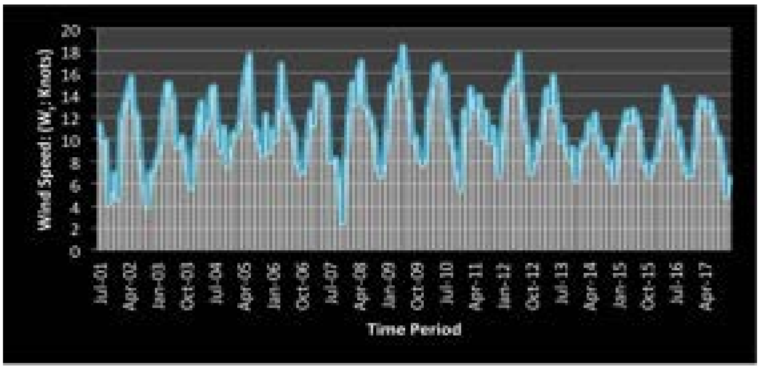

Fig. 4. Wind speed of Islamabad

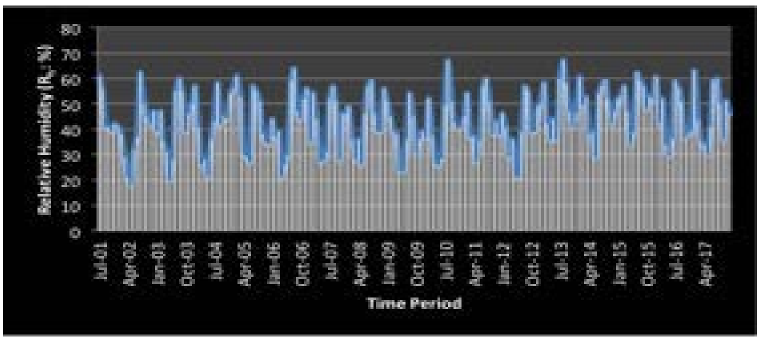

Fig. 5. Relative humidity of Islamabad

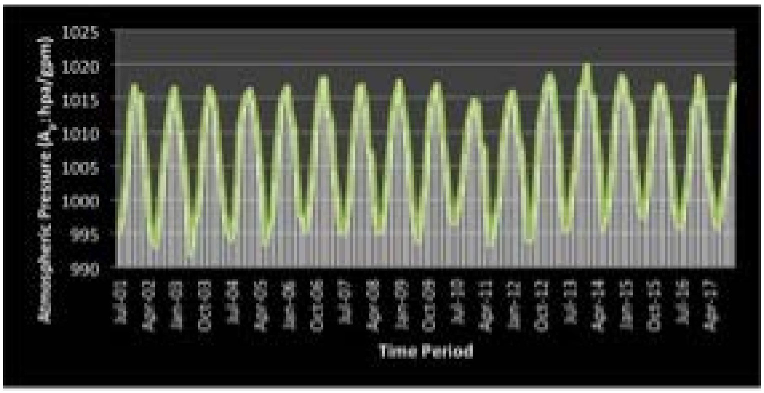

Fig. 6. The atmospheric pressure of Islamabad

2.9. Estimation techniques

This research is employed several econometrics techniques in order to analyze the data, which is more robust modeling techniques for time series analysis. For the correlation analysis we used Pearson correlation method to check the association amongst the climatic variables; we have employed unit root test (ADF) to check the existence of unit root and stationarity in data time series. By using the VAR model, we identify the lag length, and on the base of lag length, we find a long run association between dependent, and independent parameters by using Johansen cointegration technique, the precipitation is used as a dependent variable. Further, we employed the ECM model to measure the short run relationship. Finally, we have employed Granger causality approach to investigate the causality between the pair of parameters.

2.10. Augmented Dickey-Fuller method

We employed Augmented Dickey and Fuller (1979); (1981) approach to check the presence of unit root and stationarity in the data series. The expression of ADF could be written (Eq. 1):

$$\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \sum_{i=1}^{n} \alpha \Delta y_t + e_t \quad (1)$$

where: y - the data series; t - time period; n - the optimum lags; αo - the constant value; e - the white noise error.

2.11. Vector auto regression (VAR) technique

The next phase is to investigate the cointegrating association amongst the variables, whether they have a non-spurious and established relationship. We have used Schwartz Bayesian Criterion for selecting the lag order and then employed Johansen cointegration approach to ascertain a long-term association amid precipitation, and atmospheric pressure, wind speed, minimum & maximum temperatures, and relative humidity. We have derived the Johansen cointegration approach from the following form of Vector auto regression (VAR) model (Eq. 2):

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + U_t \quad (2)$$

where: Y_{t-1}, Y_{t-2} + ………+ Y_{t-p} – vectors; A_1, A_2+ ………+ A_p – matrices; Y_t – n number of vectors of parameters for I(1).

2.12. Johansen cointegration testing approach

We used the Johansen cointegration testing approach when an order of integration of different variables has been classified identical after employing unit root test for stationarity. We employed the Johansen technique to ascertain a long run association amid the rainfall, and other climate parameters. If there will be an existence of *p-lag* vectors autoregression alongside the Gaussian error for Y_t vector of *n* stochastic components (Eq. 3):

$$\Delta Y_t = \beta_1 Y_{t-1} + \sum_{j=2}^{p} \beta_j \Delta Y_{t-j+1} + U_t \quad (3)$$

where: j - *2,3,…….p;* ΔY_t........ ΔY_{t-p+1} *are I(0);* ΔY_{t-1} *are I(1).*

We use VAR by maximum likelihood technique, obtained by solving the Eigenvalue problem. Here all the parameters are integrated at the same level.

2.13. Trace test and Maximum Eigenvalue test

We employed Johansen (1988) approach for separating the values of cointegration vectors; the objective of the Johansen cointegration approach is to calculate two tests statistics. The first test is called the trace test (Eq. 4):

$$\lambda_{trace} = -N \sum_{i=y+1}^{n} ln\left(1-\lambda\right)^{-} \quad (4)$$

The subsequent test is recognized as the Maximum Eigenvalues rank test (Eq. 5):

$$\lambda_{\max}(r,r+1) = -N\ln\left(1-\lambda\right)^{\sim} \quad (5)$$

where: $\lambda_1 > \lambda_2 > \lambda_3 \ldots\ldots \lambda_\gamma > \lambda_{\gamma+1} > \ldots\ldots > \lambda n$; λ_{max} test (Eq. 5) is more powerful than λ_{trace} test (Eq. 4).

First, γ values are significant and γ_{-1} is insignificant i.e. there are γ cointegrating vectors. Trace value capture $\lambda_{\gamma+1}, \lambda_{\gamma+2}, \ldots\ldots \lambda_n$, whereas, Max. Eigenvalue test captures only $\lambda_{\gamma+1}$. Johansen (1992), and Perron and Campbell (1993) extended the Johansen test to include trends, and thus cover the case of stochastic co-integration. In case of no drift and trend (Eq. 6):

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum_{j=2}^{p} \beta_j \Delta Y_{t-i+1} + \Psi_t + \varepsilon_t \quad (6)$$

2.14. Vector error correction model (VECM)

For ascertaining a short-term relationship, we have used the VECM approach to investigate the presence of at least one cointegrating vector that confirms the association amongst the parameters. The VECM suggests the information about the rate of change of equilibrium in a long-term and avoids the problem of spurious regression. The illustration of the regression for the error correction model (Eq. 7):

$$\Delta Y_t = \alpha + \beta\Delta X_t + \beta U_{t-1} + \varepsilon_t \quad (7)$$

where: U - the one period lagged residual value in which the ECM examined the rate at which the previous deviation from the equilibrium is adjusted; Δ - the operator of first difference.

2.15. Granger causality technique

According to Granger (1969), the causality is imperative to ascertain the causation of one variable to another variable in different time series. For the Granger causality, we have used two data time series X and Y for a pairwise testing (Eq. 8 and Eq. 9):

$$Y_t = \sum_{n=1}^{p} A_n X_{(t-p)} + \sum_{n=1}^{p} B_n Y_{(t-p)} + CZ_t + E_t \quad (8)$$

$$Y_t = \sum_{n=1}^{p} A_n X_{(t-p)} + \sum_{n=1}^{p} B_n Y_{(t-p)} + CZ_t + E_t \quad (9)$$

where: X & Y - two data series; T - time period; E - white noise errors are non-correlated.

It is assumed that the first regression (Eq. 8) in which the existing values of Y are connected with the previous values of X data series. However, the second regression (Eq. 9) suggested, an existing value of X is connected with the previous values of Y data series.

3. Results and discussion

3.1. Correlation analysis

The results of correlation analysis reveal that the relative humidity is significant and positively related to the precipitation, however, maximum temperature, and atmospheric pressure is significant but negatively correlated to the precipitation (Table 1). These results are consistent with the previous literature (Hocke 2017; Mishra et al., 2018).

3.2. Outcomes of the ADF unit root test

In this study climate data from July 2001 to December 2017 for different variables such as precipitation (rainfall), wind speed, atmospheric pressure, relative humidity, and maximum & minimum temperature are employed for the Islamabad city. All the selected parameters are non-stationary (Figs. 1-6) except the maximum temperature that is stationary at level. By using the ADF test (Table 2), we transformed other climate variables into stationary by taking the first difference.

3.3. Trace and Maximum Eigenvalues tests (unrestricted cointegration rank tests)

The lag selection for the Johansen cointegration test, the VAR model is estimated for the variables at the first difference in which precipitation (mm), minimum temperature (^{0}C), wind speed, relative humidity (knots), atmospheric pressure (%), and maximum temperature (^{0}C) are not included because of the integrating order of these variables.

Table 1. Correlation analysis

Parameters		***dTmin_i***	***dTmax_i***	***dRh_i***	***dWs_i***	***dAp_i***	***dRf_i***
Minimum Temperature	Pearson Correlation	1	.852**	-.044	.248**	-.891**	.140
	Sig. (2-tailed)		.000	.536	.000	.000	.051
Maximum Temperature	Pearson Correlation		1	-.488**	.230**	-.805**	-.212**
	Sig. (2-tailed)			.000	.001	.000	.003
Relative Humidity	Pearson Correlation			1	-.261**	.105	.685**
	Sig. (2-tailed)				.000	.141	.000
Wind Speed	Pearson Correlation				1	-.282**	-.057
	Sig. (2-tailed)					.000	.425
Atmospheric Pressure	Pearson Correlation					1	-.149*
	Sig. (2-tailed)						.036
Precipitation	Pearson Correlation						1
	Sig. (2-tailed)						

*** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed)*

Table 2. Augmented Dickey-Fuller unit root test

Variables	*Augmented Dickey-Fuller Test*			
	At Level		*At 1st Difference*	
	t-stat	*Prob.*	*t-stat*	*Prob.*
Tmin_i	-1.6412	0.4595	-15.4159	0.0000
Tmax_i	-3.1192	0.0268		
Rh_i	-2.3086	0.1704	-12.7129	0.0000
Ws_i	-2.0185	0.2788	-12.0381	0.0000
Ap_i	-1.5495	0.8088	-12.7186	0.0000
Rf_i	-2.3762	0.1499	-13.2917	0.0000
lfv_i	-0.6725	0.8497	-7.4692	0.0000
lff_i	-0.8690	0.7962	-5.5215	0.0000

VAR is estimated by using 12 lags, after that Wald exclusion test is applied to identify the lags, the identified lags are 1 to 7 and 9 to 12. For establishing a long run association between precipitation, and other climate parameters, we have employed the Johansen cointegration technique. Both Trace and Maximum Eigenvalues tests indicate one co-integration relationship between variables (Tables 3 - 4), which confirmed a long run relationship amid precipitation (rainfall) and climate parameters. Similar results were demonstrated the previous literature (Bhandari et al., 2018; Wu, 2019).

3.4. Granger causality approach

To ascertain the causal association between precipitation, and all other climate parameters, the Granger causality model was used. There is one-way causal relationship from atmospheric pressure to the rainfall, rainfall to relative humidity, and atmospheric pressure to rainfall in lag 1 and lag 2 (Dai et al., 2018; Li et al., 2018). However, there is a two-way causal relationships was ascertained between precipitation and minimum temperature in both lag 1 and lag 2. The atmospheric pressure has a causative impact on the precipitation; similarly, relative humidity has a causative influence on the precipitation in lag 1 and lag 2 (Table 5). These results are consistent with the previous literature (Feyissa et al., 2018; Tye et al., 2019).

4. Conclusions

The results of the study concluded that the humidity directly correlated to the precipitation, however, precipitation (rainfall) is inversely related to the maximum and minimum temperatures, and atmospheric pressure. The results of this research further concluded a long-term relationship between precipitation, and wind speed, relative humidity, atmospheric pressure, and minimum & maximum temperature.

There is a one-way causal relationship from atmospheric pressure to rainfall, and relative humidity to rainfall. Thus, it is concluded that the rainfall is dependent on atmospheric pressure and relative humidity. However, precipitation and minimum temperature have two-way causal association. The outcomes of this study concluded that the climatic shift might change the abrupt behavior of precipitation in the study area that concluded a favorable impact of climatic shift on the precipitation.

Table 3. Trace test

Hypothesized		*Trace*	*0.05*	
No. of CE(s)	*Eigenvalue*	*Statistic*	*Critical Value*	*Prob.***
None *	0.2761	105.2366	69.8189	0.0000
At most 1	0.0917	45.4649	47.8561	0.0824
At most 2	0.0833	27.6753	29.7971	0.0862
At most 3	0.0508	11.5877	15.4947	0.1778
At most 4	0.0105	1.9519	3.8415	0.1624

*Trace test indicates 1 cointegrating eqn(s) at the 0.05 level; *Denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values*

Table 4. Maximum Eigenvalue test

Hypothesized		*Max-Eigen*	*0.05*	
No. of CE(s)	*Eigenvalue*	*Statistic*	*Critical Value*	*Prob.***
None *	0.2761	59.7717	33.8769	0.0000
At most 1	0.0917	17.7896	27.5843	0.5127
At most 2	0.0833	16.0876	21.1316	0.2198
At most 3	0.0508	9.6357	14.2646	0.2370
At most 4	0.0105	1.9519	3.8415	0.1624

*Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level; *Denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values*

Table 5. Outcomes of Granger causality test

Lags: 1			
Null Hypothesis	***Obs.***	***F-Statistic***	***Prob.***
DAP_I does not Granger Cause DRF_I	196	27.6955	0.0000
DRF_I does not Granger Cause DAP_I		0.3079	0.5796
DRH_I does not Granger Cause DRF_I	196	0.0148	0.9034
DRF_I does not Granger Cause DRH_I		3.8863	0.0501
DTMIN_I does not Granger Cause DRF_I	196	3.9859	0.0473
DRF_I does not Granger Cause DTMIN_I		8.0485	0.0050
DWS_I does not Granger Cause DRF_I	196	0.3644	0.5468
DRF_I does not Granger Cause DWS_I		1.8564	0.1046
Lags: 2			
DAP_I does not Granger Cause DRF_I	195	17.0261	0.0000
DRF_I does not Granger Cause DAP_I		0.5662	0.5686
DRH_I does not Granger Cause DRF_I	195	2.4208	0.0916
DRF_I does not Granger Cause DRH_I		0.9574	0.3857
DTMIN_I does not Granger Cause DRF_I	195	3.8712	0.0225
DRF_I does not Granger Cause DTMIN_I		4.1311	0.0175
DWS_I does not Granger Cause DRF_I	195	0.9290	0.3967
DRF_I does not Granger Cause DWS_I		0.9361	0.0940

Thus, the government of Pakistan should take the climate shift as serious business, and formulate the effective strategies in order to cope up the future challenges of a climate shift for Islamabad city. The short-run shocks will convergence towards the long run by maximum value adjustment. Thus, incremental adaptation policies and strategies are required to prevent from the flooding catastrophes, and to convert the challenge of extra precipitation into benefits.

The undertaken study has certain limitations such as it is confined to the one city only, thus, the results may not be generalizable to the entire region, future studies may address this limitation. Moreover, additional climate variables may be taken into account for future studies for better results. For more precision in results, the atmospheric ocean general circulation models (AOGCMs) may be employed in future studies.

References

Adams R.M., Hurd B.H., (1999), Climate change and agriculture: some regional implications, *Choices*, **14**, 22-23.

Adams R.M., Hurd B.H., Lenhart S., Leary N., (1998), Effects of global climate change on world agriculture: an interpretive review, *Climate Research*, **11**, 19-30.

Afzal M., Zaman Q.U., (2010), Case study: heavy rainfall event over Lai Nullah catchment area, *Pakistan Journal of Meteorology*, **6**, 39-48.

Akinsanola A.A., Ogunjobi K.O., (2015), Recent homogeneity analysis and long-term spatio-temporal rainfall trends in Nigeria, *Theoretical and Applied Climatology*, **128,** 275-289.

Attanasio A., Pasini A., Triacca U., (2013), Granger causality analyses for climatic attribution, *Atmospheric and Climate Sciences*, **3**, 515-522.

Bahrami M., Bazrkar S., Zarei A.R., (2018), Modeling, prediction and trend assessment of drought in Iran using standardized precipitation index, *Journal of Water and Climate Change*, **10**, 181-196.

Bhandari S., Kalra A., Tamaddun K., Ahmad S., (2018), Relationship between ocean-atmospheric climate variables and regional stream flow of the conterminous United States, *Hydrology*, **5**, 1-24.

Chowdhury A.F.M.K., Chowdhury M.A.I., Ahmmed S., (2011), *Urban Heat Island: Micro Climatic Evidence in Bangladesh*, Lap-Lambert Academic Publishing, Germany.

Costa A.C., Soares A., (2009), Trends in extreme precipitation indices derived from a daily rainfall database for the South of Portugal, *International Journal of Climatology*, **29**, 1956-1975.

Dai A., Zhao T., Chen J., (2018), Climate change and drought: a precipitation and evaporation perspective, *Current Climate Change Reports*, **4**, 301-312.

Darwin R., Marinos T., Lewandrowski J., Raneses A., (1995), World Agriculture and Climate Change: Economic Adaptations, Agricultural Economic Report 703, US Department of Agriculture, Economic Research Service, Washington, D.C., On line at: https://ideas.repec.org/p/ags/uerser/33933.html.

Dell M., Jones B.F., Olken B.A., (2012), Temperature shocks and economic growth: Evidence from the last half century, *American Economic Journal: Macroeconomics*, **4**, 66-95.

Dickey D.A., Fuller W.A., (1979), Distribution of estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association*, **74,** 427-431.

Dickey D.A., Fuller W.A., (1981), Likelihood ratio statistics for autoregressive time series with a unit root, *Econometrica*, **49**, 1057-1072.

Edossa D.C., Woyessa Y.E., Welderufael W.A., (2014), Analysis of droughts in the central region of South Africa and their association with SST anomalies, *International Journal of Atmospheric Sciences*, On line at: http://dx.doi.org/10.1155/2014/508953.

Faisal N., Sadiq N., (2011), Climatic zonation of Pakistan through precipitation effectiveness index, *Pakistan Journal of Meterology*, **6**, 51-60.

Farooqi A., Khan A.H., Hazrat M., (2005), Climate change perspective in Pakistan, *Pakistan Journal of Meteorology*, **2**, 11-21.

Feyissa G., Zeleke G., Bewket W., Gebremariam E., (2018), Downscaling of future temperature and precipitation extremes in Addis Ababa under climate change, *Climate*, **6**, 58.

George S.P. (2008), *Encyclopedia of Global Warming and Climate Change*, second edition, Thousand Oaks, California: SAGE Publications.

Giorgi F., Lionello P., (2008), Climate change projections for the Mediterranean Region, *Global and Planetary Change*, **63**, 90-104.

Gocic M., Trajkovic S., (2013), Analysis of changes in meteorological variables using Mann–Kendall and Sen's slope estimator statistical tests in Serbia, *Global and Planetary Change*, **100**, 172-182.

Granger C.W.J., (1969), Investigating Causal Relations by Econometric Models and Cross-spectral Methods, *Econometrica*, **37**, 424-438.

Hanif M., Khan A.H., Adnan S., (2013), Latitudinal precipitation characteristics and trends in Pakistan, *Journal of Hydrology*, **49**, 266-272.

Hansel S., Medeiros D.M., Matschullat J., Petta R.A., Silva I.M., (2016), Assessing homogeneity and climate variability of temperature and precipitation series in the capitals of Northeastern Brazil, *Frontiers in Earth Science*, **4**, 1-21.

Hansen J., Sato M., Ruedy R., Schmidt G.A., Lo K., (2016), *Global Temperature in 2015*, Colombia University, New York, 1-6, On line at: http://csas.ei.columbia.edu/2016/01/19/global-temperature-in-2015/.

He B.-R., Zhai P.-M., (2018), Changes in persistent and non-persistent extreme precipitation in China from 1961 to 2016, *Advances in Climate Change Research*, **9,** 177-184.

Hocke K., (2017), Relation between short-term and long-term variations of precipitation, *Climate*, **5**, 1-10.

Huang J., Ji M., Xie Y., Wang S., He Y., Ran J., (2016), Global semi-arid climate change over last 60 years, *Climate Dynamics*, **46**, 1131-1150.

Johansen S., (1988), Statistical analysis of cointegration vectors, *Journal of Economic Dynamics and Control*, **12**, 231-254.

Johansen S., (1992), Determination of co-integration rank in the presence of a linear trend, *Oxford Bulletin of Economics and Statistics*, **54**, 383-397.

Karfakis P., Lipper L., Smulders M., (2012), *The Assessment of the Socioeconomic Impacts of climate change at Household Level and Policy Implications*, In: *Building Resilience for Adaptation to Climate Change in the Agriculture Sector*, Proc. of a Joint FAO/OECD workshop 23-24 April, 2012, Meybeck A., Lankoski J., Redfern S., Azzu N., Gitz V. (Eds.), Food and Agriculture Organization of the United Nations and the Organization for Economic Co-operation and Development, Rome, 133-150.

Kenabatho P.K., Parida B.P., Moalafhi D.B., (2012), The value of large-scale climate variables in climate change assessment: The case of Botswana's rainfall, *Physics and Chemistry of Earth*, **50-52**, 64-71.

Khalid S., Zameer S., (2013), Climate change and relationship between metrological parameters, A case study of Jacobabad (Sindh) Pakistan, *International Journal of Asian Social Sciences*, **3**, 1607-1624.

Khan A.H., (2004), The influence of La Nina phenomena on Pakistan's precipitation, *Pakistan Journal of Meteorology*, **1**, 23-31.

Khan M.I., Liu D., Fu Q., Azmat M., Lou M., Hu Y., Zhang Y., Abrar F.M., (2016), Precipitation variability assessment of northern China: Songhua River Basin of China, *Journal of Earth System Science*, **125**, 957-968.

Kodra E., Chatterjee S., Ganguly A.R., (2011), Exploring Granger causality between global average observed time series of carbon dioxide and temperature, *Theoretical and Applied Climatology*, **104**, 325-335.

Kueh S.M., Kuok K.K., (2018), Forecasting long term precipitation using cuckoo search optimization neural network models, *Environmental Engineering and Management Journal*, **17**, 1283-1292.

Lee Y.Y., Din M.F.M., Ponraj M., Noor Z.Z., Iwao K., Chelliapan S., (2017), Overview of urban heat island (UHI) phenomenon towards human thermal comfort, *Environmental Engineering and Management Journal*, **16**, 2097-2111.

Li B.-Q., Xiao W.-H., Wang Y.-C., Yang M.-Z., Huang Y., (2018), Impact of land use/cover change on the relationship between precipitation and runoff in typical area, *Journal of Water and Climate Change*, **9**, 261-274.

Lionello P., Scarascia L., (2018), The relation between climate change in the Mediterranean region and global warming, *Regional Environmental Change*, **18**, 1481-1493.

Liu H., Wu J., Xu Y., (2018), Investigating the effects of precipitation on drought in the Hanjiang River Basin using SPI, *Journal of Water and Climate Change*, **10**, 977-992.

MacKinnon J.G., Haug A.A., Michelis L., (1999), Numerical distribution functions of likelihood ratio tests for cointegration, *Journal of Applied Econometrics*, **14**, 563-577.

Maslin M., (2004), *Global Warming: A Very Short Introduction*, Oxford University Press, New York.

Menzel A., Sparks T.H., Estrella N., Koch E., Aasa A., Ahas R., Alm-Kübler K., Bissolli P., Braslavska O., Briede A., Chmielewski F.M., Crepinsek Z., Curnel Y., Dahl A., Defila C., Donnelly A., Filella Y., Jatczak K., Mage F., Mestre A., Nordli Ø., Peñuelas J., Pirinen P., Remišova V., Scheifinger H., Striz M., Susnik A., Van Vliet A.J.H., Wielgolaski F.E., Zach S., Zust A., (2006), European phonological response to climate change matches the warming pattern, *Global Change Biology*, **12**, 1969-1976.

Mishra A.K., Nagaraju V., Rafiq M., Chandra S., (2018), Evidence of links between regional climate change and precipitation extremes over India, *Weather*, **74**, 218-221.

Modarres R., da Silva V.D.P.R., (2007), Rainfall trends in arid and semi-arid regions of Iran, *Journal of Arid Environments*, **70**, 344-355.

Pachauri R.K., Reisinger A., (2007), *IPCC Fourth Assessment Report*, The Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland, On line at: https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf.

Partal T., Sezen C., (2018), Wavelet-based analysis of global index effects in air temperature and precipitation data of the Black Sea coast, *Journal of Water and Climate Change*, **10**, 402-418.

Perron P., Campbell J.Y. (1993), A note on Johansen's cointegration procedure when trends are present, *Empirical Economics*, **18**, 777-789.

Philander S.G., (2008), *Encyclopedia of Global Warming and Climate Change*, 2nd Edition, SAGE Publications Inc., Princeton University, USA, On line at: http://dx.doi.org/10.4135/9781412963893.

Rahman M.R., Lateh H., (2017), Climate change in Bangladesh: A spatio-temporal analysis and simulation of recent temperature and rainfall data using GIS and time series analysis model, *Theoretical and Applied Climatology*, **128**, 27-41.

Rasul G., (2010), An analysis of knowledge gaps in climate change research, *Pakistan Journal of Meteorology*, **7**, 1-9.

Reilly J., Hohmann N., Kane S., (1994), Climate Change and Agricultural Trade, *Global Environmental Change*, **4**, 24-36.

Rosenzweig C., Parry M.L., (1994), Potential Impact of Climate Change on World Food Supply, *Nature*, **367**, 133-138.

Rosenzweig C.E., Tubiello F., Goldberg R., Mills E., Bloomfield J., (2002), Increased crop damage in the US from excess precipitation under climate change, *Global Environmental Change*, **12**, 197-202.

Salma S., Rehman S., Shah M.A., (2012), Rainfall trends in different climate zones of Pakistan, *Pakistan Journal of Meteorology*, **9**, 37-47.

Shahid S., (2010), Rainfall variability and the trends of wet and dry periods in Bangladesh, *International Journal of Climatology*, **30**, 2299-2313.

Shifteh B.S., Ezani A., Tabari H., (2012), Spatiotemporal trends and change point of precipitation in Iran, *Atmospheric Research*, **113**, 1-12.

Stocker T.F., Qin D., Plattner G.K., Tignor M., Allen S. K., Boschung J., Nauels A., Xia Y., Bex V., Midgley P.M., (2013), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Tabari H., Talaee P.H., (2011), Temporal variability of precipitation over Iran: 1966–2005, *Journal of Hydrology*, **396**, 313-320.

Tye M.R., Katz R.W., Rajagopalan B., (2019), Climate change or climate regimes? Examining multi-annual variations in the frequency of precipitation extremes over the Argentine Pampas, *Climate Dynamics*, **53**, 245-260.

Wu R., (2019), Summer precipitation–SST relationship on different time scales in the northern tropical Indian Ocean and western Pacific, *Climate Dynamics*, **52**, 5911–5926.

Yacoub E., Tayfur G., (2018), Trend analysis of temperature and precipitation in Trarza region of Mauritania, *Journal of Water and Climate Change*. On line at: https://doi.org/10.2166/wcc.2018.007.

Yin H., Sun Y., (2018), Characteristics of extreme temperature and precipitation in China in 2017 based on ETCCDI indices, *Advances in Climate Change Research*, **9,** 218-226.

Yue S., Hashino M., (2003), Long term trends of annual and monthly precipitation in Japan, *Journal of the American Water Resources Association*, **39**, 587-596.