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Forecasting of Humidity of Some Selected Stations from the Northern Part of Bangladesh: An Application of SARIMA Model

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Abstract: Community risk from natural hazards and climate change depends largely on physical and climatic settings of an area, socio-economic condition of a community and the magnitude, duration and consecutiveness of the hazard or change itself. Impacts of climate change can be characterized by increasing temperatures, rainfall, humidity changes and climate related extreme events such as floods, cyclone, droughts, sea level rise, salinity and soil erosion etc. Humidity affects crops through evaporation, transpiration and condensation. Crop agriculture is highly influenced by climatic change and majority of population is dependent on agricultural crop in Bangladesh. Any unfavorable change in future climate could have a devastating impact on agriculture and the economy of the country. It is needed to know the socio-economic settings of the rural community, their agricultural practices, anticipated changes in climatic parameters and the link between the climatic variables and crop growth and productivity. Time Series analysis and forecasting has become a major tools in different applications in meteorological phenomena, such as rainfall, humidity, temperature, draught etc. and environmental management fields. Among the most effective approaches for analyzing time series data is the Autoregressive Integrated Moving Average (ARIMA) model introduced by Box and Jenkins. In this study, we used Box-Jenkins methodology to build seasonal ARIMA model for monthly Humidity data taken from Bogra, Dinajpur, Rajshahi and Rangpur stations over the period January, 2001 to October, 2014. In this study, *ARIMA* $(2,0,2)(2,1,2)_{12}$, *ARIMA* $(0,1,2)(1,1,1)_{12}$, *ARIMA* $(1,0,2)(2,1,1)_{12}$ and *ARIMA* $(1,0,2)(2,1,2)_{12}$ model respectively are found to be suitable models for Dinajpur, Rajshahi, Bogra and Rangpur stations respectively and these models are used to forecasting the monthly humidity for the upcoming two years to help decision makers to establish priorities in terms of water demand management.

Keywords: Humidity, Forecasting, Box-Jenkin's Methodology, SARIMA Model

Introduction

Climate may be defined as a complex of meteorological conditions, which exists in any given area. Climate of a place plays important role in water resources management, crop management, operations of dams and generation of hydroelectricity planning of location of industrial sites, defense planning, tourism and transport, air pollution studies and in fact almost all spheres of human activity. Bangladesh occupies an area of 144,430 sq. kilometers between latitudes 20°35'N and 26°75'N longitudes 88°3'E and 92°75' E. Climatology deals with the spatial distribution of average values of climatic elements, e.g., temperature, rainfall, pressure and winds, humidity, evapotranspiration and evaporation etc. and their relation to man's activities. Community risk from natural hazards and climate change depends largely on

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physical and climatic settings of an area, socio-economic condition of a community and the magnitude, duration and consecutiveness of the hazard or change itself. Assessment of such risk must require credible information on existing climate and its trend and the future climate and its variability. The information on future climate and its variability is usually obtained from general circulation and regional climate model projection. However, the information on existing climate and its trend is derived either from the analysis of the observed historical data or from the community perception and experience (Mondal *et al.*, 2012). Bangladesh is confronted with a big challenge to mitigate the significant impact of climate change. Due to the climate change, Bangladesh has already experienced average maximum temperature rising, minimum temperature decreasing, rainfall, relative humidity and cloud coverage decreasing resulting frequent and severe floods, tropical cyclone, extensive river bank erosion and drought. Impacts of climate change can be characterized by increasing temperatures, rainfall, humidity changes and climate related extreme events such as floods, cyclone, droughts, sea level rise, salinity and soil erosion etc (Asaduzzaman *et al.*, 2010; Yu *et al.*, 2010).

Humidity is the amount of Water vapor in the air and relative humidity considers the ratio of the actual vapor pressure of the air to the saturated vapor pressure which is usually expressed in percentage. Atmospheric water vapor is a complex meteorological element. It is a fundamental component in the climate system as the most significant greenhouse gas and a key driver of many atmospheric processes. Water vapor and its transport around the atmosphere is a fundamental component of the hydrological cycle. The vapor plays a key role in determining the dynamic and radioactive properties of the climate system. Atmospheric water vapor accounts for only about 1/10,000th of the total amount of water in the global hydrological cycle. Nevertheless, atmospheric water vapor is one of the most important factors in determining Earth's weather and climate, because of its role as a greenhouse gas and because of the large amounts of energy involved as water changes between the gaseous (vapor) phase and liquid and solid phases. Humidity is very important as an environmental condition which influences the growth of the plants, health, pollution etc. For example, plants also respond to changes in humidity. Humidity affects crops through evaporation, transpiration and condensation. Crop agriculture is highly influenced by climatic change and majority of population is dependent on agricultural crop in Bangladesh. Crop agriculture is the mainstay of Bangladesh and will continue to be so in the foreseeable future. About 60.1% of the area is presently under agriculture and the sector contributes about 22% to the GNP. Any unfavorable change in future climate could have a devastating impact on agriculture and the economy of the country. It is needed to know the socio-economic settings of the rural community, their agricultural practices, anticipated changes in climatic parameters and the link between the climatic variables and crop growth and productivity. The cropping practices again vary according to geographical locations- the practices are different in haors, coasts, central floodplains and uplands. Field level information is necessary to identify the vulnerability of different crops in different locations at different times (Mondal *et al.*, 2012). High humidity in tropics, particularly during the rainy season is likely to affect the plant growth by reducing the transpiration cooling of the plant. The lowering of the yield with the increase in maximum and minimum daily relative humidness may be related to this effect. This hypothesis is further supported by the fact that low humidity is one of the important agrometeorological environmental factors for maximum rice production (De Datta and Zarate, 1970).

Bangladesh is predominantly an agricultural country. The cultivation mainly depends on natural calamities like rainfall, humidity and temperature. But in-depth statistical analysis did not carry out yet on humidity and its relationship with other atmospheric components like temperature and rainfall. Humidity is one of the most valuable components of air, which is very important for tree plantation as the atmospheric moisture levels do significantly influence on plant growth and development. The prediction of atmospheric parameters is essential for climate monitoring, drought detection, severe weather prediction, agriculture and production, planning in energy and industry, communication, pollution dispersal etc. Accurate prediction of Humidity is a difficult task due to the dynamic nature of the atmosphere. It is very much essential to know the nature of changes of Humidity. Purposively we select four stations for this study from the northern part of Bangladesh namely Dinajpur, Rajshahi, Rangpur and Bogra stations over the period January, 2001-October, 2014. Box-Jenkin's Methoology is used to identify the appropriate ARIMA model for the humidity of the selected stations and the selected model is used to forecast the humidity of the selected stations. The necessary secondary data have been taken from the website of "Bangladesh Agricultural Research Council (BARC)". This analysis has completely done by statistical programming based open source Software named as *R* with the version 3.1.2.

Literature Review

Bangladesh is predominantly an agricultural country. Since the irrigation system in Bangladesh has not yet been implemented vigorously, the cultivation mainly depends on natural calamities like rainfall, humidity and temperature. But in-depth statistical analysis did not carry out yet on humidity and its relationship with other atmospheric components like temperature and rainfall. Humidity is one of the most valuable components of air, which is very important for tree plantation as the atmospheric moisture levels do significantly influence on plant growth and development (Tibbitts, 1979). Islam (2014) carried out a study to find Trends, periodicities and frequency distribution of the annual average humidity by using the standard statistical techniques. He considered the annual average humidity of 30 meteorological stations of Bangladesh over the period (1981-2008). He has done the test of normality of the frequency distribution of the annual average humidity using the method suggested by Geary (1935, 1936). He found that the frequency distribution of most of the stations of Bangladesh follow normal distribution. Positive trends are shown for the data of Dinajpur, Rajshahi, Mymensingh, Ishurdi, Jessore, Madaripur, Satkhira, Hatiya, Sitakunda, Teknaf and Patuakhali, while Dhaka the capital of Bangladesh has negative trend. The periodigram analyses of the annual average humidity of most of the stations show a significant cycle of range 8 to 12 years. Abu-Taleb *et al.* (2007) examines the recent changes in annual and seasonal relative humidity variations in Jordan. Their analysis indicates an increasing trend in relative humidity at different stations. Their analysis also shows a significant increasing trend at Amman Airport Meteorological (AAM) station with a rate of increase 0.13% per year. These increasing trends are statistically significant during summer and autumn seasons. Finally, they found that a major change point in the annual relative humidity occurred in 1979 at AAM station. Syeda (2012) investigates the trend and variability pattern for decadal, annual and seasonal (three crop seasons) Average Relative Humidity (ARH) of six divisional stations in Bangladesh: Dhaka, Rajshahi, Khulna, Barisal, Sylhet and Chittagong. She examined the rates of Linear Trend (LT) for minimum, maximum and range humidity. To forecast the monthly ARH for 2009-2012 she used the univariate Box-Jenkin's Autoregressive Integrated Moving Average (ARIMA) modelling technique. The findings of her research were as follows: The rates of LT for annual ARH were found negative for Dhaka and Chittagong but positive for others. The rates were found negative for all the Coefficient of Variations (CVs). The rate for annual minimum humidity was positive for Dhaka but negative for others. The rates for annual maximum and range humidity were negative for Dhaka and Chittagong but positive for others. The rates for seasonal ARH were negative for Dhaka while positive for Rajshahi and Barisal in all the three seasons. It was negative for Kharif season, whereas positive for Prekharif and Rabi seasons for Khulna and Sylhet. It was negative for Kharif and Prekharif seasons, as the same time as positive for Rabi season for Chittagong. Chowdhury and Hossain (2011) were carried out a study during 2005-08 to find the effect of weather prevalence of seedling diseases of jackfruit in different areas of Bangladesh and develop an environment friendly disease management practice. They found that Occurrence of seedling diseases was significantly influenced by temperature, rainfall and relative humidity. Keka *et al.* (2013) found the characteristics of different climatic parameters and the recent climatic trends in Bangladesh by using the surface climatological data at 30 stations for the period of 34 years from 1971 to 2004. Mondal *et al.* (2013), shown that the relative humidity at Khulna has increasing trends of 2.3, 1.3 and 0.3% per decade in the winter, post-monsoon and pre-monsoon seasons, respectively.

Methods and Materials

Seasonal ARIMA

Box and Jenkins (1976) suggested the use of Seasonal Autoregressive (SAR) and Seasonal Moving Average (SMA) terms for monthly or quarterly data with systematic seasonal movements. The Box-Jenkins approach for modeling and forecasting has the advantage in analyze the seasonal time series data. In this case the seasonal components are included and the model is called seasonal ARIMA model or SARIMA model. A seasonal ARIMA model is classified as:

$$ARIMA(p,d,q)\times(P,D,Q)_m \text{ model}$$

Where:

p = The order of the Autoregressive (AR) term
d = The degree of differencing
q = The order of the Moving-Average (MA) term
P = The number of Seasonal Autoregressive (SAR) terms
D = The number of seasonal differences
Q = The number of Seasonal Moving Average (SMA) terms
m = The number of time periods until the pattern repeats again

In the Seasonal ARIMA model the lowercase for non-seasonal part meanwhile the uppercase for seasonal part can be written in form of:

$$\Phi_P\left(B^S\right)\phi_p\left(B\right)\nabla_S^D\nabla^d y_t = \Theta_Q\left(B^S\right)\theta_q\left(B\right)u_t$$

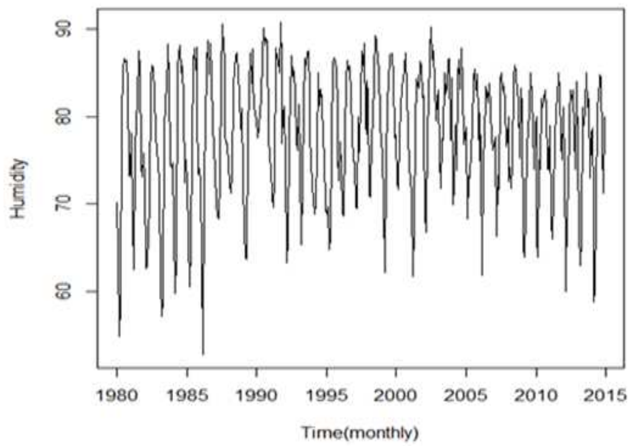
Where:

$$\Phi_P\left(B^S\right) = 1 - \Phi_1 B^S - \Phi_2 B^{2S} - \ldots - \Phi_P B^{PS},$$
$$\Theta_Q\left(B^S\right) = 1 - \Theta_1 B^S - \Theta_2 B^{2S} - \ldots - \Theta_Q B^{QS},$$
$$\phi_p\left(B\right) = 1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p,$$
$$\theta_q\left(B\right) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q, \nabla_S = 1 - B^S$$

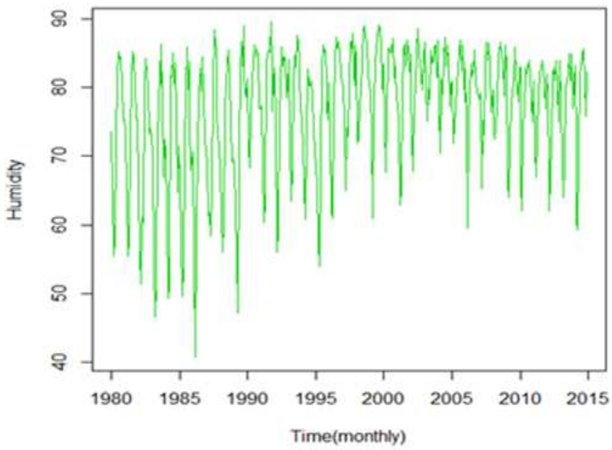
Results

Four stations namely Bogra, Dinajpur, Rajshahi and Rangpur district were considered in this study from the northern part of Bangladesh. The first step of time series analysis is to make the time series plot of the data. Such a plot gives preliminary idea about the nature of the time series. Time series plot can also be used to find the Seasonality, Cyclical variation, trend or irregular pattern of the series.

From Fig. 1a-d it appeared that the series is stationary; that is, mean is constant as time increases and we do not take any additional difference. In this study Augmented-Dickey-Fuller (ADF) unit root test was used to check whether the data series is stationary or not. The Augmented Dickey-Fuller (ADF) test with $\Pr\left(\left|\tau\right| \geq -8.7302\right) < 0.01$ for Bogra, $\Pr\left(\left|\tau\right| \geq -8.6293\right) < 0.01$ for Dinajpur, $\Pr\left(\left|\tau\right| \geq -8.5034\right) < 0.01$ for Rajshahi and $\Pr\left(\left|\tau\right| \geq -9.6137\right) < 0.01$ for Rangpur district at 5% level of significance adequately declared that the data series is stationary and suggest that there is no unit root, however may have a seasonal variation for all stations considered in this study. The seasonal index of Humidity in Bogra, Dinajpur, Rajshahi and Rangpur district are obtained using the moving average method and given in Table 1.



(a)



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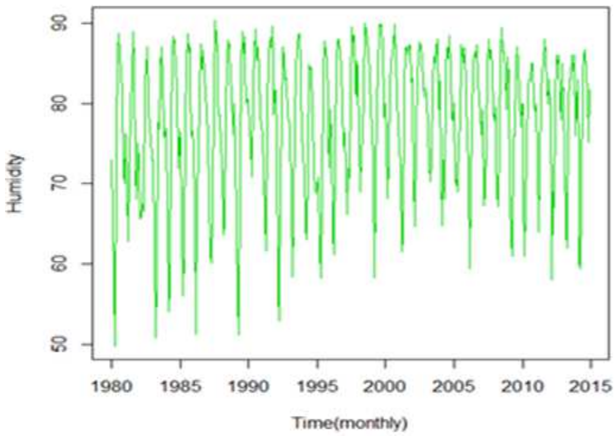

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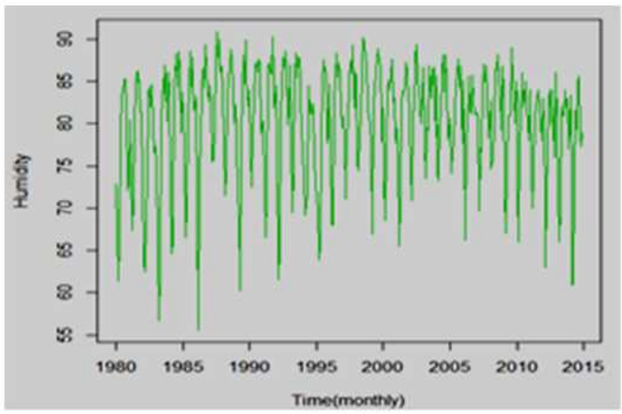


(d)

Fig. 1. Time series plot of humidity of (a) Bogra (b) Dinajpur (c) Rajshahi (d) Rangpur district

Table 1. Seasonal Index of humidity in Bogra, Dinajpur, Rajshahi and Rangpur district

	Seasonal index			
Month	Bogra	Dinajpur	Rajshahi	Rangpur
January	98.38	100.77880	99.91274	101.53970
February	89.26	89.23660	91.16796	92.41364
March	84.19	79.68952	80.38460	84.30614
April	91.24	86.34502	84.24435	90.87938
May	99.54	98.92299	96.70370	99.78721
June	107.13	107.29470	106.88350	105.57690
July	109.75	110.67200	112.10500	106.77900
August	108.91	109.44470	111.15960	105.96280
September	109.6	110.63210	110.54880	107.59670
October	105.03	105.88720	106.30480	104.79890
November	98.08	99.76456	99.76456	99.59271
December	98.89	101.33180	101.33180	100.76690

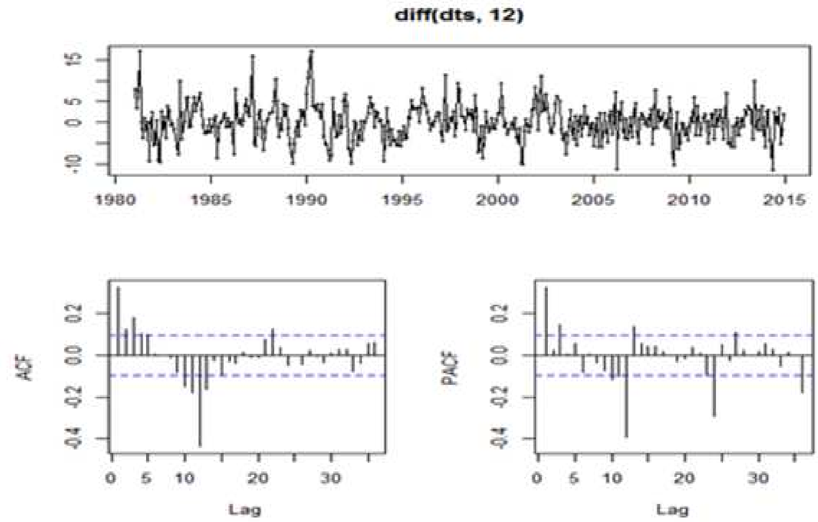
Table 1 revealed that the seasonal variation is present in humidity of Bogra, Dinajpur, Rajshahi and Rangpur district. Thus it is necessary to take a seasonal difference. However, it is clear that first seasonal differenced data series shows stable variance for all stations which implies that the data becomes stationary for all stations considered in this study. The seasonally differenced data are shown in Fig. 2.

Figure 2a shows that there are significant spikes in the PACF at lags 12 and 24, but nothing at seasonal lags in the ACF. This may suggest a seasonal AR (2) model. In the non-seasonal lags, there are three significant spikes in the PACF suggesting a possible AR (3) model. The pattern in the ACF is not indicative of any simple model. Consequently, this initial analysis suggests that the possible model for these data is an *ARIMA* $(3,0,0)(2,1,0)_{12}$. Figure 2b shows that there is a significant spike on PACF at lag 12, 24 and 36. This may be suggestive of a seasonal AR (3) term. In the non-seasonal lags, there are three significant spikes in the PACF suggesting a possible AR (3) term. This initial analysis suggests that a possible model for these data is an *ARIMA* $(3,0,0)(3,1,0)_{12}$. Again, from Fig. 2c it is clear that there are significant spikes at lag12, 24 and 36 but nothing at seasonal lags in the ACF. This may be suggestive of a seasonal AR (3) term. In the non-seasonal lags, there are one significant spikes in the PACF suggesting a possible AR (1) term. Consequently, this initial analysis suggests that a possible model for these data is an *ARIMA* $(1,0,0)(3,1,0)_{12}$. Furthermore, Fig. 2d shows that there are significant spikes at lag 12, 24 and 36 but nothing at seasonal lags in the ACF. This may be suggestive of a seasonal AR (3) term. In the non-seasonal lags, there are three significant spikes in the PACF suggesting a possible AR (3) term. Consequently, this initial analysis suggests that a possible model for these data is an *ARIMA* $(3,0,0)(3,0,1)_{12}$.

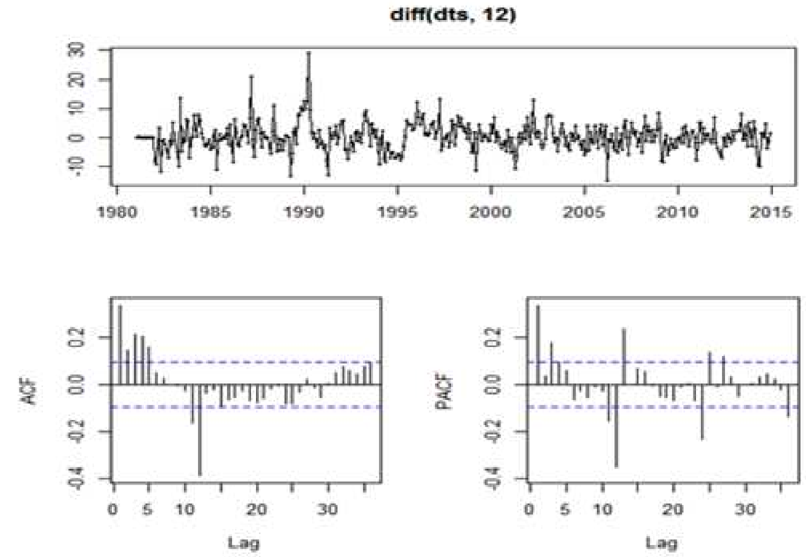
We fit these models along with some variations on it and compute their AICc values for Bogra, Dinajpur, Rajshahi and Rangpur districts. Among the fitted models, we try to find the best one for Bogra, Dinajpur, Rajshahi and Rangpur districts. On the basis of the smallest AICc value the models for Bogra, Dinajpur, Rajshahi and Rangpur districts are *ARIMA* $(2,0,2)(2,1,2)_{12}$, *ARIMA* $(0,1,2)(1,1,1)_{12}$, *ARIMA* $(1,0,2)(2,1,1)_{12}$ and *ARIMA* $(1,0,2)(2,1,2)_{12}$ model respectively along with the lowest RMSE values on the test set. The values of RMSE for Bogra, Dinajpur, Rajshahi and Rangpur districts are 4.101166, 3.541074, 3.528605 and 4.382672 respectively. We check the normality assumption using Jarque and Bera (1987) test, which is a goodness of fit measure of departure from normality, based on the sample kurtosis (k) and skewness (s). It is observed that the "Jarque-Bera" test with $\Pr\left(\left|\chi_2^2\right| \geq 27.6841\right) = 0$ for Bogra, $\Pr\left(\left|\chi_2^2\right| \geq 50.6713\right) = 0$ for Dinajpur, $\Pr\left(\left|\chi_2^2\right| \geq 66.7505\right) = 0$ for Rajshahi and $\Pr\left(\left|\chi_2^2\right| \geq 40.4687\right) = 0$ for Rangpur district strongly suggests that the residuals of the fitted model are normally distributed at 5% level of significance. The plots of the residuals of the fitted model are shown in Fig. 3.

From the diagnostic plots given in Fig. 3 of the selected models it may be conclude that the fitted models is the best suited for predicting the future humidity in Bogra, Dinajpur, Rajshahi and Rangpur district. Thus, the estimates of the parameters of the fitted models used to forecast the future humidity in Bogra district are shown in Table 2.

The graphical comparison of the original series and the forecasted series is shown in Fig. 4. It is apparent that the forecasted series (blue-color) fluctuate from the original series (pink-color) with a very small amount of variation. So the forecasted series is really better representation of the original humidity of Bogra, Dinajpur, Rajshahi and Rangpur district.


diff(dts, 12)
ACF
PACF
Lag
Lag

(a)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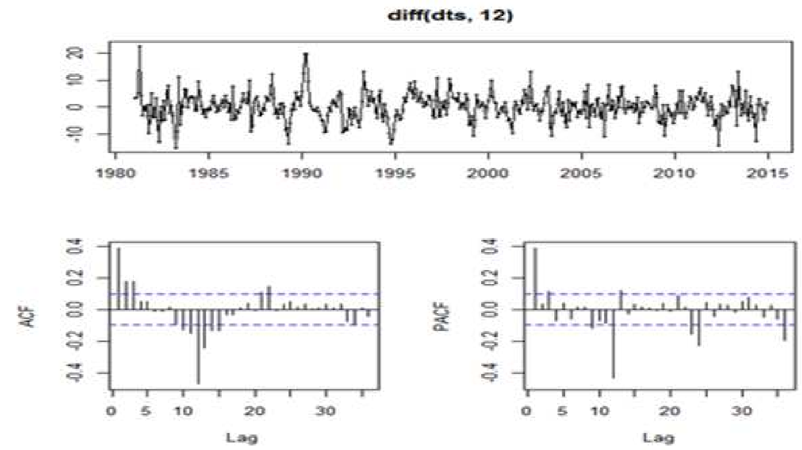
(b)


diff(dts, 12)
ACF
PACF
Lag
Lag

(c)

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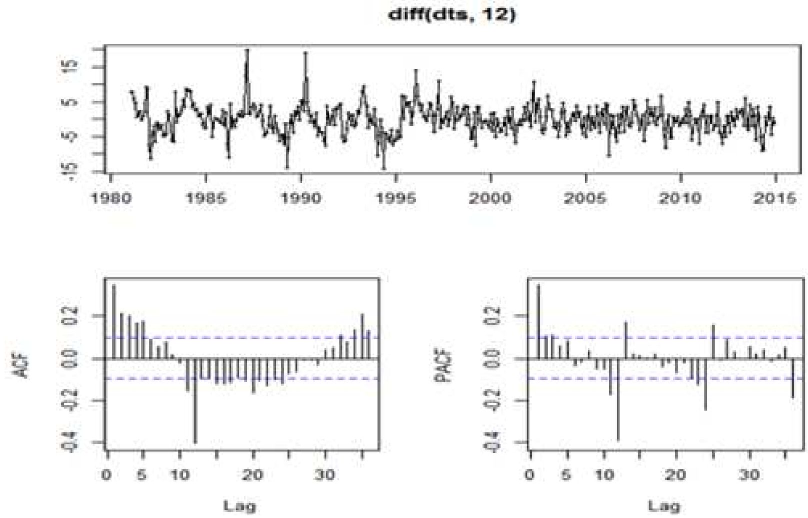
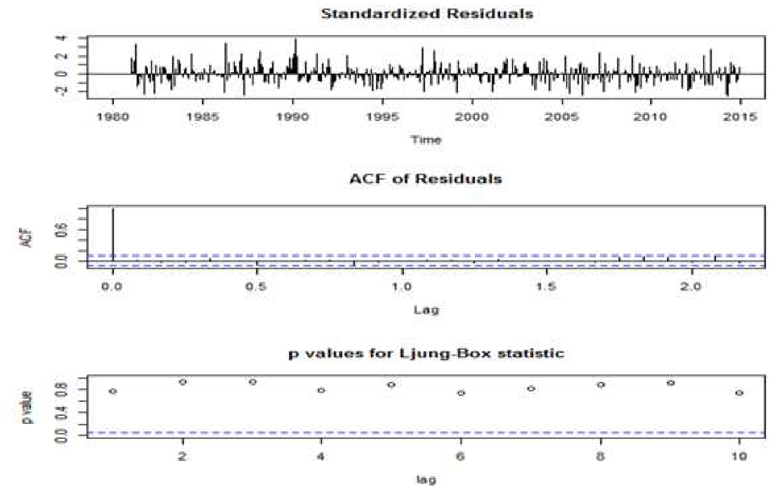
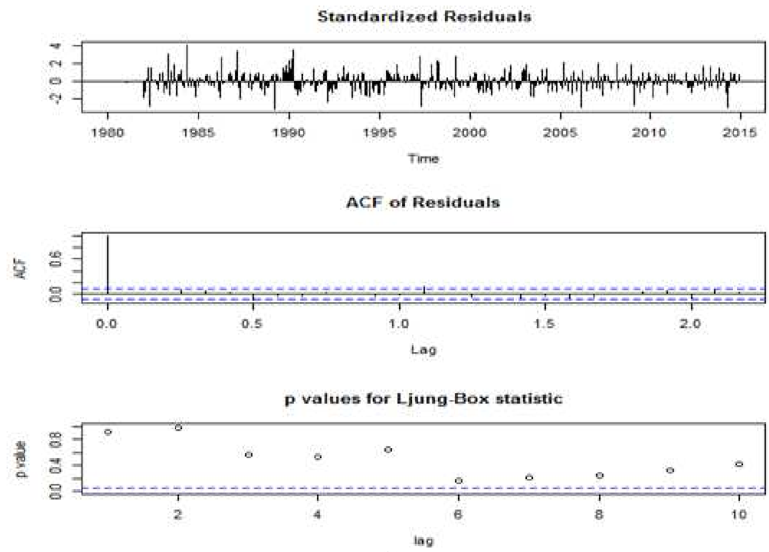


(d)

Figure 2. ACF and PACF of first seasonal differenced data in (a) Bogra (b) Dinajpur (c) Rajshahi (d) Rangpur district



(a)



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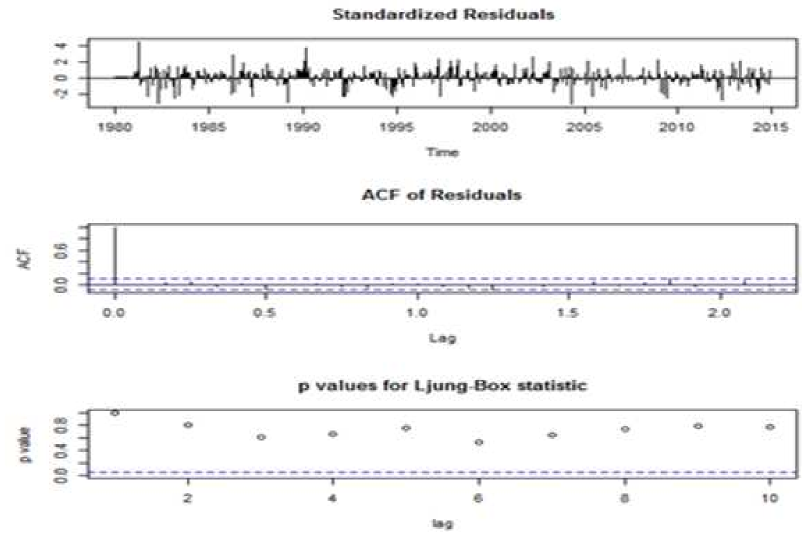

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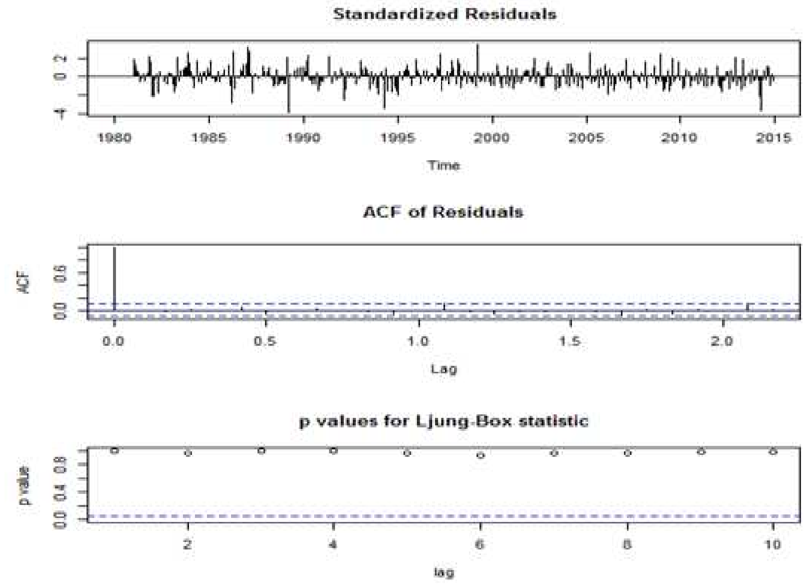
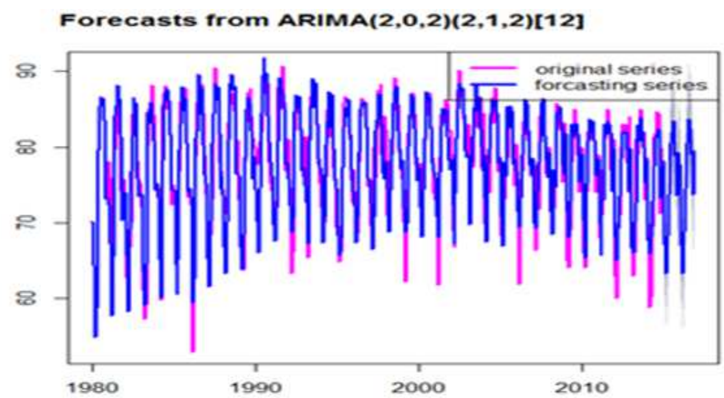


(d)

Fig. 3. Plots of the residuals of the fitted model for (a) Bogra (b) Dinajpur (c) Rajshahi (d) Rangpur district



(a)

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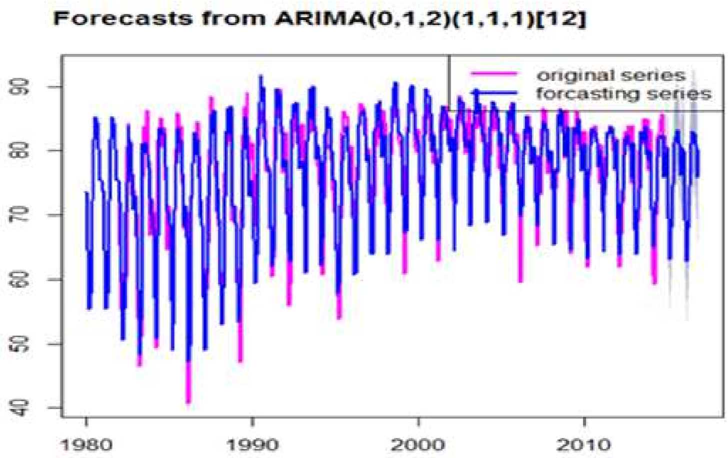

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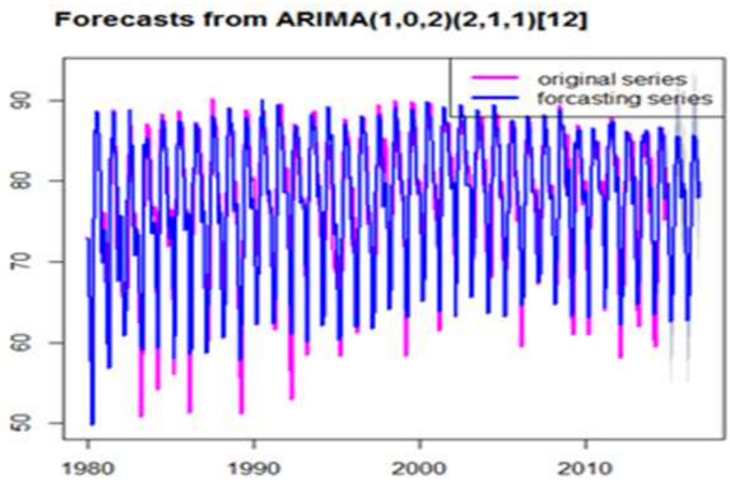

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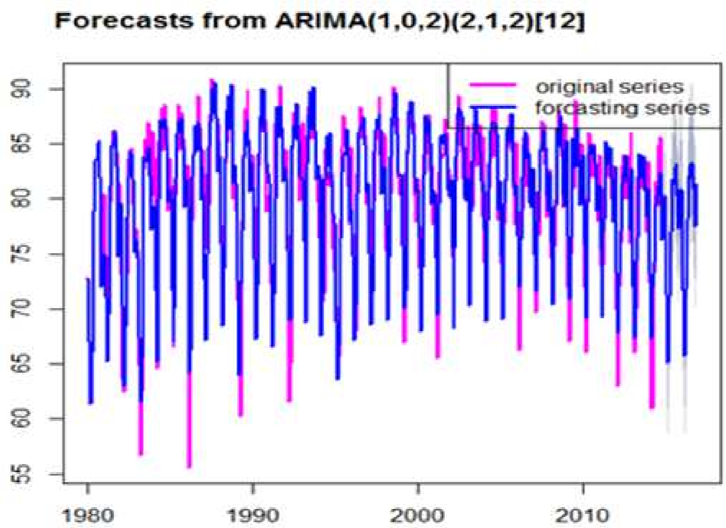

(d)

Fig. 4. Comparison of original and forecasted series for (a) Bogra (b) Dinajpur (c) Rajshahi (d) Rangpur district

Table 2. Estimates of the parameters of the fitted models for Bogra, Dinajpur, Rajshahi and Rangpur district

Bogra district							
ar1	ar2	ma1	ma2	sar1	sar2	sma1	sma2
0.2296 (0.172)	0.6002 (0.11)	0.1329 (0.1702)	-0.618 (0.0857)	0.6009 (0.4404)	-0.1181 (0.0829)	-1.4044 (0.4411)	0.5379 (0.3372)
Dinajpur district							
ma1		ma2		sar1		sma1	
-0.5789 (0.0496)		-0.2651 (0.053)		0.0049 (0.0617)		-0.7823 (0.0385)	
Rajshahi district							
ar1		ma1	ma2	sar1	sar2	sma1	
0.9665 (0.0376)		-0.5512 (0.0634)	-0.3189 (0.0621)	-0.0261 (0.0609)	0.0231 (0.0606)	-0.8823 (0.0414)	
Rangpur district							
ar1		ma1	ma2	sar1	sar2	sma1	sma2
0.9414 (0.0336)		-0.5950 (0.0601)	-0.1529 (0.0574)	0.3432 (0.3713)	-0.1263 (0.0688)	-1.1876 (0.3711)	0.3534 (0.3188)

Note: Values in parenthesis indicates standard error

Conclusion

The prediction of atmospheric parameters is essential for climate monitoring, drought detection, severe weather prediction, agriculture and production, planning in energy and industry, communication, pollution dispersal etc. Accurate prediction of Humidity is a difficult task due to the dynamic nature of the atmosphere. It is very much essential to know the nature of changes of Humidity. In this study, *ARIMA* $(2,0,2)(2,1,2)_{12}$, ARIMA $(0,1,2)(1,1,1)_{12}$, *ARIMA* $(1,0,2)(2,1,1)_{12}$ and *ARIMA* $(1,0,2)(2,1,2)_{12}$ model respectively are found to be suitable models for Dinajpur, Rajshahi, Bogra and Rangpur stations respectively and these models are used to forecasting the monthly humidity for the upcoming two years to help decision makers to establish priorities in terms of water demand management.

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Author's Contributions

Md. Moyazzem Hossain: Collected and checked the analyzed data and wrote the manuscript and the final art work.

Md. Atikur Rahman: Analyzed data and wrote manuscript.

Md. Zahirul Islam: Design and coordinated the study and wrote manuscript.

Ajit Kumar Majumder: Reviewed the manuscript and contributed in interpreting data.

Ethics

The authors declare that this is an original research and do not have any ethical issues or copyrights conflict.

References

Abu-Taleb, A.A., A.J. Alawneh and M.M. Smadi, 2007. Statistical analysis of recent changes in relative humidity in Jordan. Am. J. Environ. Sci., 3: 75-77. DOI: 10.3844/ajessp.2007.75.77

Asaduzzaman, M., C. Ringler, J. Thurlow and S. Alam, 2010. Investing in crop agriculture in Bangladesh for higher growth and productivity and adaptation to climate change. Proceedings of the Bangladesh Food Security Investment Forum, May 26-27, Dhaka.

Box, G.E.P. and G.M. Jenkins, 1976. Time Series Analysis: Forecasting and Control. 1st Edn., Holden Day, San Francisco, ISBN-10: 0816211043, pp: 575.

Chowdhury, M.S.M. and I. Hossain, 2011. Effects of temperature, rainfall and relative humidity on leaf spot of jackfruit seedling and its eco-friendly management. Agriculturists, 9: 126-136. DOI: 10.3329/agric.v9i1-2.9487

De Datta, S.K. and P.M. Zarate, 1970. Environmental conditions affecting growth characteristics, nitrogen response and grain yield of tropical rice. Biometeorology, 4: 71-89.

Geary, R.C., 1935. The ratio of the mean deviation to the standard deviation as a test of normality. Biometrika, 27: 310-332. DOI: 10.1093/biomet/27.3-4.310

Geary, R.C., 1936. Moments of the ratio of the mean deviation to the standard deviation for normal samples. Biometrika, 28: 295-307. DOI: 10.1093/biomet/28.3-4.295

Islam, M.M., 2014. Regional differentials of annual average humidity over Bangladesh. ASA Univ. Rev., 8: 1-14.

Jarque, C.M. and A.K. Bera, 1987. A test for normality of observations and regression residuals. Int. Stat. Rev., 55: 163-172. DOI: 10.2307/1403192

Keka, I.A., I. Matin and D.A. Banu, 2013. Recent climatic trends in Bangladesh. Daffodil Int. Univ. J. Sci. Technol., 8: 43-50.

Mondal, M.S., A.K.M. Saiful Islam and M.K. Madhu, 2012. Spatial and temporal distribution of temperature, rainfall, sunshine and humidity in context of crop agriculture. Institute of Water and Flood Management Bangladesh University of Engineering and Technology, Bangladesh.

Mondal, M.S., M.R. Jalal, M.S.A. Khan, U. Kumar and R. Rahman *et al*., 2013. Hydro-Meteorological trends in southwest coastal Bangladesh: Perspectives of climate change and human interventions. Am. J. Climate Change, 2: 62-70. DOI: 10.4236/ajcc.2013.21007

Syeda, J.A., 2012. Variability analysis and forecasting of relative humidity in Bangladesh. J. Environ. Sci. Natural Resources, 5: 137-147. DOI: 10.3329/jesnr.v5i2.14805

Tibbitts, T.W., 1979. Humidity and plants. BioScience, 29: 358-365. DOI: 10.2307/1307692

Yu, W., A.M. Hassan, A. Khan, A.S. Ruane and A.C. Rosenzweig *et al*., 2010. Climate Change Risks and Food Security in Bangladesh. 1st Edn., Earthscan, London, ISBN-10: 1849776385, pp: 176.