ISSN 1022-8594
JUJS


Vol. 41, No. 2, pp. 87-102

# Effects of Climate Variable on Aus Rice Production at Selected Districts of Bangladesh

**Nahyatul Marjan[1] and Md. Moyazzem Hossain[2,*]**
[1] Department of Mathematics and Statistics, BUBT, Mirpur-2, Dhaka-1216
[2] Department of Statistics, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh

**Abstract**

The production of rice is sensitive to the climatic variables. So, any changes in climate variables have harmful effects on rice production. Keeping the above view in mind, this study is undertaken to investigate the impacts of climate change on Aus rice production at selected districts of Bangladesh and modeling the climate variable to predict future situations. In this study, multiple regressions and correlation analysis were carried out and observed that the maximum temperature has a significantly negative effect on Aus rice production at Dhaka, Jessore and Kushtia districts of Bangladesh. Moreover, the behavior of the time series of maximum temperature is observed and it can be seen that the series is stationary with some seasonal variation. Finally, the authors fit different order of the SARIMA model and forecast the maximum temperature of selected districts using the fitted model. It is found that the forecasted value has a similar pattern to the original data series and has an increasing tendency which is harmful for Aus rice production in selected districts of Bangladesh.

**Keywords:** Climate Variables, Regression Analysis, Maximum Temperature, SARIMA, and Forecasting.

## Introduction

Bangladesh is an agricultural based country and rice is the main agricultural products which contribute about 71% of total production in Bangladesh [1]. There are different varieties of rice cultivated in Bangladesh such as Aus, Amon, and Boro [2]. The second harvest agricultural product is Aus rice which is cultivated during the summer season mainly April to June [3]. The production of Aus rice is immensely dependable on the existing change of climatic variables.

Climate change in Bangladesh is an extremely crucial issue and Bangladesh ranks first as the nation most vulnerable to the impacts of climate change in the coming decades. Bangladesh is highly vulnerable to

E-mail of correspondence: mmhmm.justat@gmail.com

severe weather events; floods, droughts, cyclones and heavy rainfalls have a grave impact on the agriculture of the country. Due to Global climate change, the frequency of these natural disasters is increasing [4]. It can have an important effect on crop growth, development, and yield by increasing temperature, uncertainty in rainfall, humidity and wind speed [5]. The impact of climate change on rice production is of interest due to its importance as a food source all over the world, especially in Asia [6]. So, predicting the effect of climatic variables on rice production is important as it should be addressed properly to the farmers so that they can take proper adaptation measures to mitigate the adverse effect of climate change during the cultivation period.

Different studies have been used in different research design and analytical techniques. Some of those studies have used time series model to predict the effect of climatic variables on rice production in Bangladesh. Most of the studies dealt with three varieties of rice, such as Aus, Amon, and Boro [1, 7, 8, 9]. These studies identified the effect of climate change by means of the dominant climatic parameters which includes rainfall, maximum temperature and minimum temperature on rice production in Bangladesh. Many authors have been found the significant effect of maximum and minimum temperature on rice production to a different extent [10]. Some of the studies revealed that maximum temperature positively influenced the production of Aus and Amon rice [11] whereas it had a negative effect on Boro rice production [12]. Also, the climatic variable rainfall had an effect on Aus and Amon rice production but rainfall had no significant effect on Boro rice production [1, 11]. The regression model revealed that maximum temperature had a negative effect on rice production whereas the minimum temperature had a significantly positive effect [13]. So the production of rice increased with the increase in temperature [14].

In another study conducted using stochastic data analysis on climate variables which includes the effect of rainfall, temperature and humidity on rice production in Bangladesh and found that climatic variables had no effect on Boro rice production whereas they had the negative effect of temperature on Aus and Amon rice production [15]. Thus, this paper tries to identify the effects of the climate variables on the Aus rice production of some selected districts in Bangladesh. This paper also forecasts the significant climate variable of the selected districts.

**Methodology**

To determine the impact of climate variables such as Temperature (maximum or minimum), Rainfall, Sea level pressure, Humidity, Visibility and Wind speed on rice production the authors mainly use the regression analysis which describes how a dependent variable relates to two or more explanatory variables. A population model for a multiple regression model that relates the dependent variable to predictor variables is written as

$$y_t = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_p x_p + \varepsilon_t$$

where $y_t$ is the Aus rice production works as a dependent variable, $x_t$ is the climate variables work as independent variables, $\alpha$ is called the intercept, $\beta$ is the slope and $\varepsilon$ is the random error term [16].

***Seasonal ARIMA Model***

When the seasonal fluctuations exhibit in data series then we used seasonal autoregressive integrated moving average (SARIMA) model which belongs to a family of flexible linear time series models. The multiplicative seasonal ARIMA model can be expressed as shorthand notation with both non-seasonal and seasonal factors is

$$ARIMA\ (p,d,q)\times(P,D,Q)S \qquad (1)$$

where, $p$ , $d$ and $q$ represent the non-seasonal auto regressive, differencing and moving average order respectively. Also, $P$ , $D$ *and* $Q$ represents seasonal auto regressive, differencing, and moving average order respectively and $S$ represent seasonal order ( $S = 12$ for monthly data). The model $(1)$ could be written more formally without differencing operations as

$$\Phi(B^S)\varphi(B)(x_t - \mu) = \Theta(B^S)\theta(B)w_t$$

where, $B$ represent backward shift operator $\left(B^k x_t = x_{t-k}\right)$, $x_t$ represents time series data at period $t$ and $w_t$ represents Gaussian white noise process (random shock) at period $t$.

Box and Jenkins expressed the non-seasonal components of the model as

$$AR: \varphi(B) = 1 - \varphi_1 B - \ldots - \varphi_p B^p$$

$$MA: \theta(B) = 1 + \theta_1 B + \ldots + \theta_q B^q$$

and seasonal components are [17]:

$$Seasonal\ AR: \Phi\left(B^S\right) = 1 - \varphi_1 B^S - \ldots - \varphi_p B^{pS}$$

$$Seasonal\ MA: \theta\left(B^S\right) = 1 + \theta_1 B^S + \ldots + \theta_q B^{qS}$$

***Sources of Data***

In Bangladesh, there are different weather stations to collect the data of climate variables. The data are available in the web sitehttp://en.tutiempo.net/climate/ws-419230.html. To assess the impact of climate variables on production of Aus we consider the median of cultivation period (April to June) in each year from 1982 to 2017 because for the skewed data median is the best measure. The production of Aus is collected from "Economic Trend monthly" publications of Bangladesh Bank.

**Results and Discussion**

The authors first observe the relationship between the climate variables and the production of Aus rice. Therefore, this section starts with the regression analysis for investigating and modeling the relationship between variables that are used in the study.

***Regression Analysis***

Generally, it is known that regression analysis cannot apply for the non-stationary series. The production of Aus series is stationary so one can apply directly regression analysis. For performing the regression analysis, we consider the production of Aus as the dependent variable and the climate variables work as the independent variable. Table 1 containts the summary results.

**Table 1:** Regression results of Climate variables at selected districts for Aus

| Variables | Jessore | | Kushtia | | Dhaka | |
|---|---|---|---|---|---|---|
| | Coefficients | P-value | Coefficients | P-value | Coefficients | P-value |
| Intercept | 541523.2 | 0.529 | 599328.5 | 0.410 | 548467 | 0.37 |
| Avg. temp. | 34085.52 | 0.026 | 51186.72 | 0.028 | 19787.06 | 0.15 |
| **Max. temp.** | **-21163.80** | **0.042*** | **-27721.61** | **0.009*** | **-6428.93** | **0.04*** |
| Min. temp. | -16862.57 | 0.164 | -17338.94 | 0.099 | -7806 | 0.24 |
| Sea level pressure | -5143.27 | 0.540 | -5937.00 | 0.415 | -5974.63 | 0.34 |
| Humidity | -244.19 | 0.920 | -678.47 | 0.582 | 4845.234 | 0.24 |
| Rainfall | 183.11 | 0.146 | 222.05 | 0.041 | -181.069 | 0.11 |
| Visibility | 6913.60 | 0.0547 | 6553.56 | 0.037 | 3223.28 | 0.084 |
| Wind speed | 2238.87 | 0.526 | 6812.63 | 0.236 | 7024.84 | 0.04 |

*indicate $P$-value $< 0.05$ and $R^2$ is 0.591 (Jessore), 0.829 (Kushtia) and 0.8092 (Dhaka)

From the above table, it is evident that the maximum temperature has a negative linear influence on the production of Aus in almost all study areas. The coefficient of determination ($R^2$) indicates 59.1%, 82.9% and 80.92% variation in production of Aus can be explained by the variation in Climate variables of Jessore, Kushtia and Dhaka districts respectively. The correlations also show that the production of Aus has a negative significant relationship with the maximum temperature of selected districts (Table 2).

**Table 2:** Correlation between production of Aus and climate variables

| | Districts | Avg. temp. | Max. temp | Min. temp | Sea Level pres. | Hum. | Rainfall | Wind speed | Vis. |
|---|---|---|---|---|---|---|---|---|---|
| **Production of Aus** | **Jessore** | 0.11<br>(0.15) | -0.72**<br>(0.001) | 0.11<br>(0.48) | -0.11<br>(0.48) | 0.03<br>(0.92) | -0.12<br>(0.25) | 0.067<br>(0.77) | 0.11<br>0.12 |
| | **Kushtia** | 0.01<br>(0.8) | -0.74**<br>(0.004) | 0.10<br>(0.84) | -0.1<br>(0.58) | 0.02<br>(0.26) | -0.03<br>(0.55) | 0.24<br>(0.47) | 0.11<br>(0.21) |
| | **Dhaka** | -0.16<br>(0.47) | -0.66**<br>(0.001) | 0.14<br>(0.38) | -0.12<br>(0.59) | 0.03<br>(0.19) | -0.33<br>(0.13) | 0.077<br>(0.727) | 0.18<br>(0.4) |

** Correlation is significant at 0.01 level

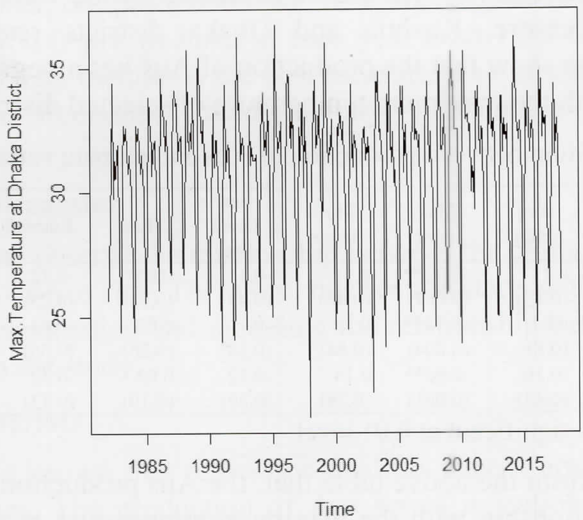
It can be seen from the above table that, the Aus production has a negative significant relationship with the maximum temperature in all study areas. In Bangladesh, the Aus production decreased while the maximum temperature increased. Now, the authors analyze the temperature series and make a prediction for future values.

## *Modelling and Forecasting*

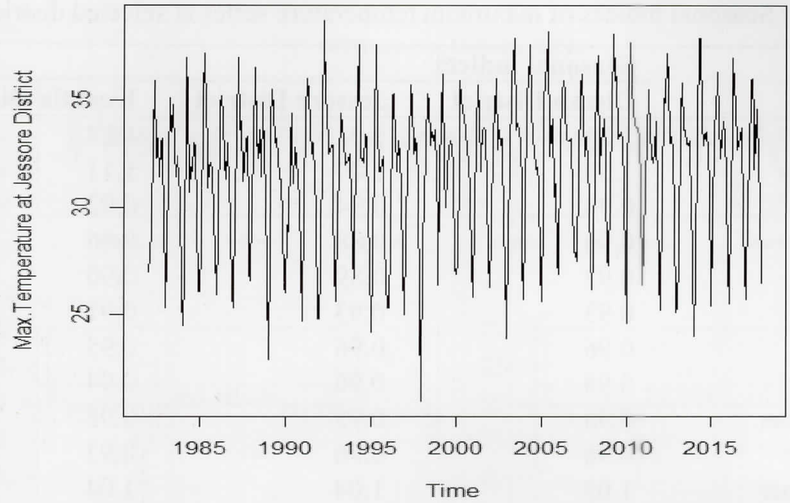
In this section, modeling and forecasting with the maximum temperature series are described incorporating with the model diagnosis.

### Data Description and Screening

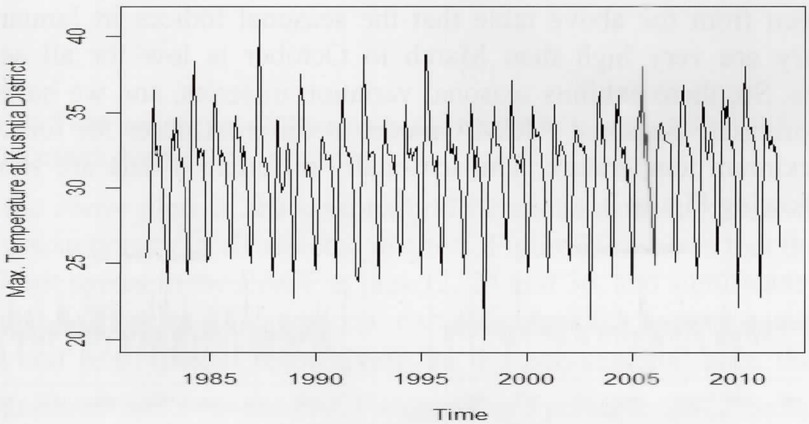
The authors first observe the time series plot of maximum temperature at selected districts which gives a preliminary idea about the nature of time series. Time series plot of maximum temperature at selected districts are shown in the following Figure 1. From Figure 1(a)-(c), it appears that the series looks like stationary. The Augmented-Dickey-Fuller (ADF) test was used to check whether the series is stationary or not. The ADF test with maximum temperature $\Pr(|\tau| \geq -9.3442) < 0.01$ for Dhaka district, $\Pr(|\tau| \geq -9.1483) < 0.01$ for Jessore district and $\Pr(|\tau| \geq -8.3276) < 0.01$ for Kushtia district indicate that the series is stationary at 5% level of significance and there is no unit root.




(a)




(b)




(c)

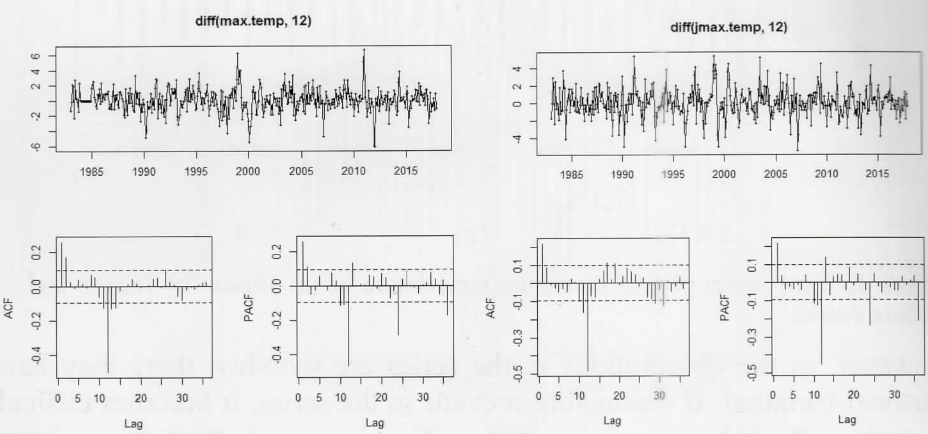
**Figure 1:** Time series plot of maximum temperature at (a) Dhaka (b) Jessore and (c) Kushtia district

However, as the observations in the series are monthly, there may have seasonal variation. If seasonality prevails in the series, it becomes difficult to analyze the behavior of time series. The seasonal indices of maximum temperature series are calculated using the moving average method in the following Table 3.

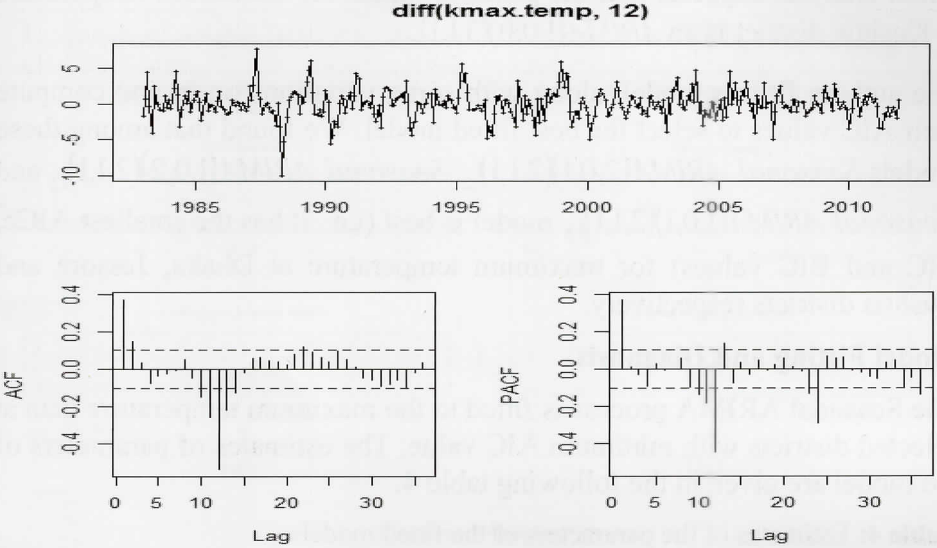
**Table 3:** Seasonal indices of maximum temperature series at selected districts

| Month | Seasonal indices | | |
|---|---|---|---|
| | **Dhaka District** | **Jessore District** | **Kushtia District** |
| January | 1.22 | 1.23 | 1.27 |
| February | 1.08 | 1.09 | 1.11 |
| March | 0.94 | 0.94 | 0.92 |
| April | 0.90 | 0.88 | 0.86 |
| May | 0.92 | 0.89 | 0.90 |
| June | 0.93 | 0.93 | 0.91 |
| July | 0.96 | 0.96 | 0.95 |
| August | 0.95 | 0.96 | 0.94 |
| September | 0.95 | 0.95 | 0.95 |
| October | 0.96 | 0.96 | 0.97 |
| November | 1.03 | 1.04 | 1.04 |
| December | 1.15 | 1.17 | 1.18 |

It is seen from the above table that the seasonal indices in January and February are very high than March to October is low for all selected districts. So, there exhibits seasonal variation in series, and we have to fit the appropriate Seasonal ARIMA model at different order for forecasting the maximum temperature. The seasonally differenced data are shown in the following Figure 2.




(a) (b)




(c)

**Figure 2:** Time series plot of seasonally differenced data at (a) Dhaka (b) Jessore and (c) Kushtia district

From the above plots of the seasonally differenced data, it is clear that the series are stationary in all selected districts. Figure 2(a) shows that there are significant spikes in the PACF at lags 12, 24 and 36, and significant spikes are in the ACF at lag 12 in seasonal part. These results suggest considering $AR(3)$ and $MA(1)$ model respectively. In the non-seasonal lags, there are two significant spikes in the PACF suggesting a possible $AR(2)$ model. The pattern in the ACF is not indicative of any simple model. This initial analysis suggests that $ARIMA(2,0,0)(3,1,1)_{12}$ model for maximum temperature at Dhaka district and similar model suggests for the Jessore districts maximum temperature series which shown in Figure 2(b). Figure 2(c) shows that there are significant spikes in the PACF at lags 12, 24 and 36, and significant spikes are in ACF at lag 12 in seasonal part. These results suggest considering $AR(3)$ and $MA(1)$ model. In the non-seasonal lags, there is one significant spike in the PACF suggesting a possible $AR(1)$) model. The pattern in the ACF does not indicate any simple model. This initial analysis suggests that the possible model for maximum temperature at Kushtia district is an $ARIMA(1,0,0)(3,1,1)_{12}$.

The authors fit this model, along with some variations on it, and compute their AIC values to select the best fitted model. We found that among these models *Seasonal* $ARIMA(2,0,1)(2,1,1)_{12}$ *Seasonal* $ARIMA(1,0,2)(2,1,1)_{12}$ and *Seasonal* $ARIMA(1,0,1)(2,1,1)_{12}$ model is best (i.e., it has the smallest AICc, AIC and BIC values) for maximum temperature at Dhaka, Jessore and Kushtia districts respectively.

## Model Fitting and Diagnosis

The Seasonal ARIMA process is fitted to the maximum temperature data at selected districts with minimum AIC value. The estimates of parameters of the model are given in the following table 4.

**Table 4:** Estimates of the parameters of the fitted models

| | | | | | |
|---|---|---|---|---|---|
| Maximum Temperature at Dhaka District | | | | | |
| ar1 | ar2 | ma1 | sar1 | sar2 | sma1 |
| 1.1441 (0.0072) | -0.1782 (0.0609) | -0.8674 (0.0463) | -0.0966 (0.0545) | -0.0046 (0.0512) | -0.9998 (0.0713) |
| Maximum Temperature at Jessore District | | | | | |
| ar1 | ma1 | ma2 | sar1 | sar2 | sma1 |
| 0.5965 (0.0688) | -0.3204 (0.0702) | -0.0805 (0.0539) | 0.0126 (0.057) | 0.0122 (0.061) | -0.924 (0.056) |
| Maximum Temperature at Kushtia District | | | | | |
| ar1 | ma1 | sar1 | sar2 | sma1 | |
| 0.3177 (0.1746) | 0.0067 (0.1848) | -0.1029 (0.0631) | -0.0316 (0.0626) | -0.9214 (0.0435) | |

**Note:** Values in parenthesis indicates standard error

Now the diagnostic checks of fitted model at selected districts are in the following Figure 3.

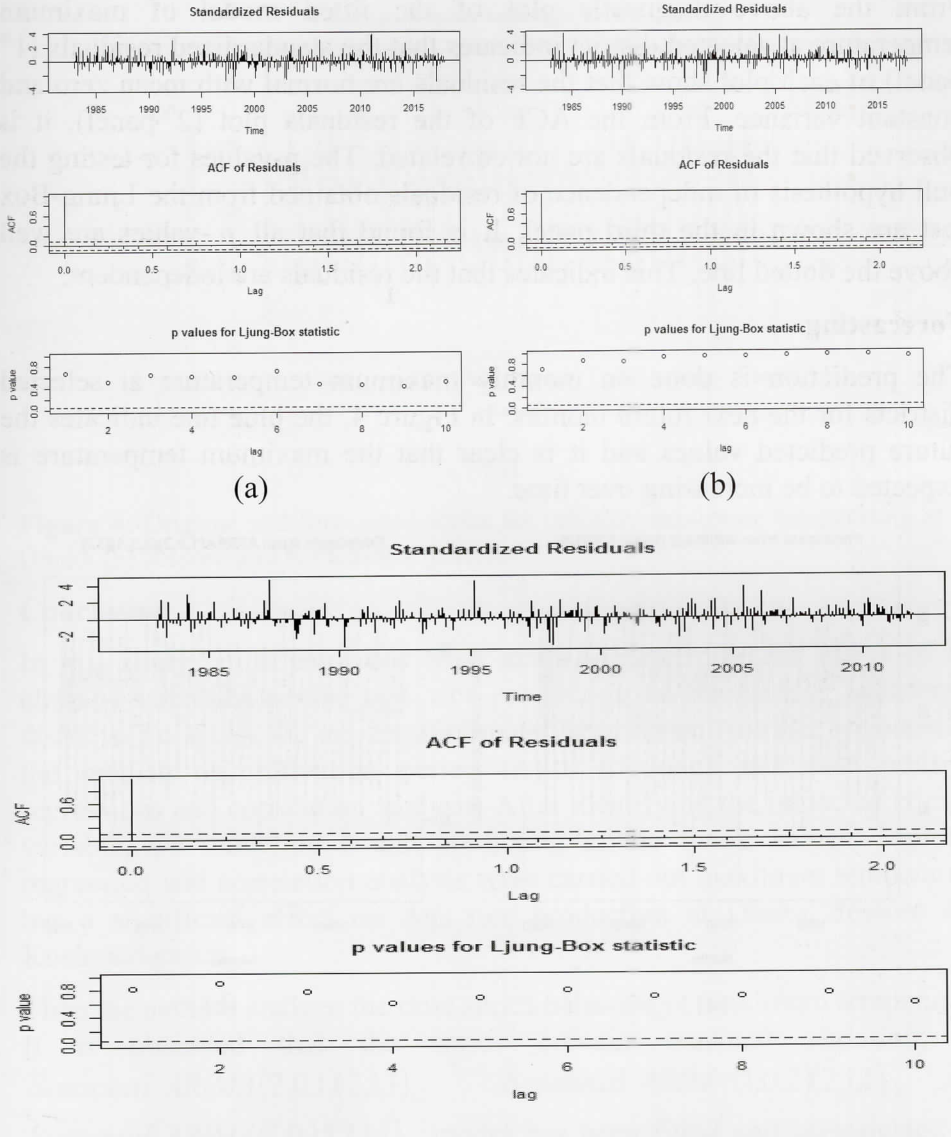
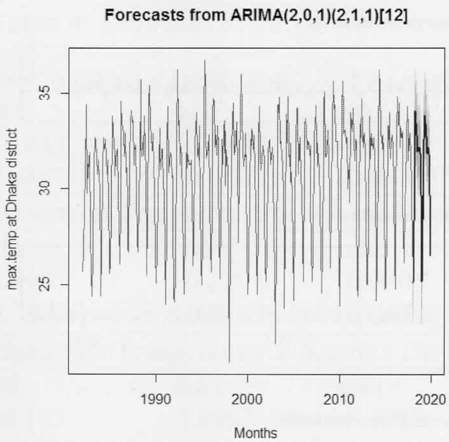



**Figure 3:** Diagnostic check of the fitted model for monthly maximum temperature at (a) Dhaka (b) Jessore and (c) Kushtia district

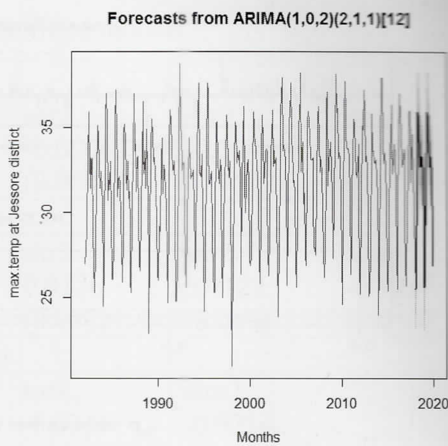
From the above diagnostic plot of the fitted model of maximum temperature at selected district indicates that the standardized residuals (1st panel) of each plot show that the residuals are normal with mean zero and constant variance. From the ACF of the residuals plot (2nd panel), it is observed that the residuals are not correlated. The p-values for testing the null hypothesis of independence of residuals obtained from the Ljung-Box test are shown in the third panel. It is found that all $p$ -values are well above the dotted line. This indicates that the residuals are independent.

## Forecasting

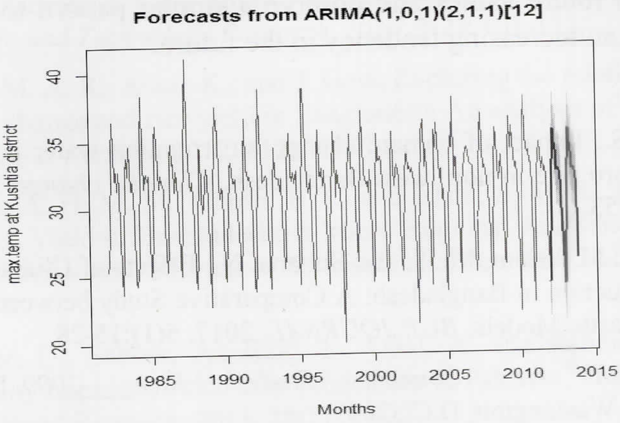
The prediction is done on monthly maximum temperature at selected districts for the next future months. In Figure 4, the blue line indicates the future predicted values and it is clear that the maximum temperature is expected to be increasing over time.




(a)




(b)




(c)

**Figure 4:** Original and forecasted series for monthly maximum temperature at (a) Dhaka (b) Jessore and (c) Kushtia district

## Conclusion

In this study, an attempt has been made to determine the effect of the climatic variables on the Aus rice production in Bangladesh at selected districts. To assess the impact of climate variables on Aus rice we consider the median of cultivation period (April to June) and used multiple regressions and correlation analysis. After identifying the impacted climate variable, we modeling it and predicting in the future values. Multiple regression and correlation analysis were carried out maximum temperature has a significant effect on Aus rice production at Dhaka, Jessore and Kushtia districts.

Then the authors analyze the time series behavior of maximum temperature. It is observed that the series contain seasonal variation, so *Seasonal* $ARIMA(2,0,1)(2,1,1)_{12}$ , *Seasonal* $ARIMA(1,0,2)(2,1,1)_{12}$ and *Seasonal* $ARIMA(1,0,1)(2,1,1)_{12}$ model has been fitted and investigated by means of some model selection and diagnostics criteria such as AIC and ACF plot of standardized residuals for the maximum temperature at Dhaka, Jessore and Kushtia districts respectively. To this end, using these models we predict the future values and observe a similar pattern to the original data also have an increasing tendency in the future.

## References


[1] Shahid, S., Impact of climate change on irrigation water demand of dry season Boro rice in northwest Bangladesh, *Climatic change*, 2011, **105(3-4)**: 433–453.

[2] Hasan, M. M., Islam, M. T. and Sultana, N., Effects of Climate Change on Rice Production in Bangladesh: A Comparative Study between Time Series and Stochastic Models, *BUP JOURNAL*, 2017, **5(1)**:15-28.

[3] *Bangladesh: A Country Study: Rice____2009*. Library of Congress, Washington, D.C., 2009.

[4] Zaman, M. A. and Biswas, A. K. M. A. A., *Application of ICT Tools for Climate Change and Disaster Management in Bangladesh*, Proceedings of AFITA, 2014.

[5] National Research Council, *Advancing the Science of Climate Change*, Washington, D.C. the National Academies Press, 2010.

[6] Hossain, M., *Sustaining Food Security in Asia: Economic, Social and Political Aspects*. In: Sustainability of Rice in the Global Food System, Dowling, N.G., S.M. Greenfield and K.S. Fischer (Eds.). International Rice Research Institute, Manila, Philippines, ISBN-13: 9789712201073, pp: 19-44, 1998.

[7] Ara, I., Lewis, M. and Ostendorf, B., Spatio-temporal analysis of the impact of climate, cropping intensity and means of irrigation: an assessment on rice yield determinants in Bangladesh, *Agriculture & Food Security*, 2016, **5**:12.

[8] Chowdhury, I. U. A. and Khan, M. A. E., The impact of climate change on rice yield in Bangladesh: A time series analysis, *Russian Journal of Agricultural and Socio-Economic Sciences*, 2015, **40(4)**: 12-28.

[9] Karim, M. R., Ishikawa, M., Ikeda, M., and Islam, M. T., Climate change model predicts 33% rice yield decreasein 2100 in Bangladesh, *Agronomy for Sustainable Development*, 2012, **32(4)**: 821-830.

[10] Zakaria, M., Aziz, M. A., Hossain, M. I. and Rahman, N. M. F., 2014. Effects of Rainfall and Maximum Temperature on Aman Rice Production

of Bangladesh: A Case Study For Last Decade, *International Journal of Scientific and Technology Research*, 2014, **3(2)**: 131-137.

[11] Sarker, M. A. R., Alam, K., and J. Gow, Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data, *Agricultural Systems*, 2012, **112**: 11-16.

[12] Mamun, A. H. M. M., Ghosh, B. C. and Islam, S. M. R., Climate Change and Rice Yield in Bangladesh: A Micro Regional Analysis of Time Series Data, *International Journal of Scientific and Research Publications*, 2015, **5(2)**: 1-8.

[13] Shakoor, U., Saboor, A., Baig, I., Afzal, A. and Rahman, A., Climate variability impacts on rice crop production in Pakistan, *Pakistan Journal of Agricultural Research*, 2015, **28(1)**: 19-27.

[14] Tuhin, S. M. S. A., *Farukh, M. A., Nahar, B. S., and Baten, M. A.,* Impacts of Some Climatic Variables on the Seasonal Productivity of Aman Rice at Dhaka Region, Central Part of Bangladesh, *Journal of Environmental Science and Natural Resources*, 2015, **8(2)**: 7-10.

[15] Auffhammer, M., Ramanathan, V., and Vincent, J. R., 2006. Integrated model shows that atmospheric brown clouds and greenhouse gases have reduced rice harvests in India, *Proceedings of the National Academy of Sciences*, 2006, **103(52)**: 19668-19672.

[16] Young, D. S., *Multiple linear regression*, stat 501, online courses.

[17] Box, G. E. P., and Jenkins, G. M., Time Series Analysis: Forecasting, and Control, Holden Day, San Francisco, CA, 1976.