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Variability of Rainfall by Some Others Climatic Phenomena in the Northern Part of Bangladesh

Md Rokonuzzaman[1] and Md Shakhawat Hossain[1]
[1]Associate Professor, Department of Statistics, University of Chittagong, Bangladesh
Correspondence Email: rokonuzzaman@cu.ac.bd

Abstract
The main objectives of this study are to find the seasonal variations of rainfalls and it's related some others climatic variables in the northern part of Bangladesh. Also a suitable panel regression model of rainfalls on these climatic variables is fitted. In this study, climatic data for different phenomena i.e. total monthly rainfall in millimeters, humidity in percentage, cloud covers in hour per day, average temperature per day in degree Celsius, bright sunshine in hour per day from 1981 to 2017 are collected from Bangladesh Meteorological Department. The selected explanatory variables humidity, temperature, cloud cover and bright sunshine are considered in this analysis. For the availability of data for all of these variables considered in this study, the weather stations of Bogura, Rajshahi and Rangpur are considered which are situated in the northern part of Bangladesh. Among these three cities, the overall average monthly rainfall is the highest in Rangpur with high variability and the lowest is in Rajshahi with low variability. For all these three cities seasonal effect of rainfall is the highest for the month of July, seasonal effect of sunshine is the highest for the month of March, and that of cloud cover is the highest for the month of July. But for humidity variable, the seasonal effects of Bogura and Rajshahi stations are the highest for the month of July but that for Rangpur station is in September. Since all of these time series data have seasonal variations and non-stationary so to run panel data regression model it is needed to be made transformation for getting stationary time series data. For rainfall data it is needed two times transformation to get stationary form. Firstly, using fourth root power transformation and the secondly make a twelve periods lag difference transformation to obtain stationary form. But for all other climatic variables only twelve periods lag difference transformation is sufficient for getting stationary form. Insignificant Cook-Weisberg test statistic suggests the homoskedasticity and lowest variance inflating factor conferred the absent of multicollinearity among explanatory variables. A panel regression model is employed to check the effect of humidity, temperature, cloud cover and bright sunshine on rainfall which is conferred by Lagrange multipliers test statistic. Since hausman test statistic is insignificant hence the random effect panel regression model is considered. Coefficient of non-determination is 0.66, implies that about 34% variation of rainfall can be explained by these explanatory variables. Cloud cover, humidity and sunshine have significant positive effects on rainfall whereas average temperature has significant negative effect on rainfall. One can try to fit a dynamic panel regression model such as GMM with Arellano Bond correction or two steps analysis of panel data models for further study.

Key Words: Rainfall, Variability, Hausman Test Statistic, Cook-Weisberg Test Statistic, Random Effect Panel Model.

1. Introduction:

Variation of climate is a continuous process which frequently observed through rainfall and temperature inconsistency (Audu, E.B. and Rizama, D.S., 2012). It was (Oyewole, J.A. *et al*., 2014) stated that rainfall variability in space and time is one of the most relevant characteristics of climate that has socio economic and ecological implications. Extreme rainfall variability causes environmental problems such as flood, gully erosion, drought and desertification, which have serious effect on the yield of rice (Ogbuene, E.B., 2010). It was also observed (Madu, I.A. and Ayogu, C.N., 2010) that rainfall variability has generated a lot of influence in the level of agricultural products. Rainfall variability and trends largely impact the economic, social and biophysical conditions of a country (Gallant *et al*., 2007). Changes in the mean rainfall have direct effects on agriculture, fisheries, ecosystem and hydrological condition. Hence, it is essential to know the variability of rainfall pattern and intensity to study the impacts of climate change.

Geographical location and physical settings govern the climate of any country. Bangladesh extends from 20°34'N to 26°38'N latitude and from 88°01'E to 92°41'E longitude, surrounded by the Assam Hills in the east, the Meghalaya Plateau in the north, the lofty Himalayas lying farther to the north. To its south lies the Bay of Bengal, and to the west lie the plain land of west Bengal. It is located in the tropical monsoon region and its climate is characterized by high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations. Due to its geographic location and dense population, Bangladesh has been identified as one of the most vulnerable countries to climate change. There is mounting evidence that natural hazards such as floods, cyclones and droughts increase in frequency and their creeping processes such as river erosion, sea-level rise and salinity ingress continue unabated.

Bangladesh is predominantly an agricultural country with most of the cultivated area under rain fed condition. Rainfall plays an important role in the agro-economy of Bangladesh. Moreover to irrigation and crop planning, rainfall information is also very useful. The variability in rainfall is very important for agriculture as well as the economy of the country. Bangladesh is one of the most flood-prone countries in the world due to its geographic position (Banglapedia, 2003). Forecasting and estimation of rainfall plays an important role particularly in regions where most of the cropped area is unirrigated (Kumara and Kulkari, 2000). Agriculture-dependent rural livelihoods, in particular small-scale farmers and landless labourers, are most sensitive to climatic risks as these pose an additional burden besides chronic poverty and food insecurity (cf. CARE, 2005; GOB & WFP, 2004). The high-intensity rainfall has become more frequent in Bangladesh in the recent years, which is evident from the events like 341mm of rainfall in 8 hours in September, 2004 and 333mm of rainfall in July, 2009 in Dhaka, and 408mm of rainfall in June, 2007 in Chittagong (Uddin, 2009). These rainfall events indicate a change in rainfall characteristics in Bangladesh.

The research focused on the northern part of Bangladesh. The majority of the population in this area is still dependent on agriculture, and the agriculture there is largely dependent on the available rainfall. Drought in northwestern part of the country is also a common phenomenon (Shahid, 2008). Moreover, the region is known for a high incidence of poverty and seasonal food insecurity during the so called “Monga period”. The local people are very aware of seasonal weather patterns, extreme events and variation in rainfall. This is no surprise because their livelihoods and food security reflect a seasonal rhythm. Erratic rainfall patterns have brought in a different dimension to people’s vulnerability, as they complicate and exacerbate existing livelihood problems of people living in poverty. Therefore all local people are highly exposed to rainfall variability.

The overall objective of this research is to known the effect of different climatic variables on rainfall pattern and intensity. The specific objectives are-

(i) to assess the rainfall trend and pattern in different months of the year.
(ii) to assess the present trend of high intensity rainfall and compare it with the predicted future trend, and
(iii) to determine the relationship between climatic variables and rainfall characteristics.

2. Literature Review:

Shahid, S. (2010) assessed the spatial patterns of annual and seasonal rainfall trends of Bangladesh over the time period 1958-2007 using Mann-Kendall trend test and the Sen’s slope method. They observed a significant increase in the average annual and pre-monsoon rainfall of Bangladesh. Etzol, B. at. al (2014) have conducted an empirical study on changing rainfall patterns in Kurigram district in northern Bangladesh. The study showed that there are clear links between rainfall variability, agricultural-based livelihoods, people’s food security and their migration. They also observed a distinct seasonality and thus rainfall dependency of rural livelihoods. Moreover they found rainfall variability and food security are closely intertwined. Rahman, M.A. et al. (2016) investigated temporal variability of rainfall linear trend models on the North-West part of Bangladesh over the period of 1975-2014. They estimated mean, standard deviation, cross-correlation and least squares estimate of linear trend models. They found that the annual and monsoon rainfall was in decreasing trends. In some areas in the North-Western part of the country, the amount of annual and monsoon mean rainfall may be decreased abruptly comparing with average normal rainfall all over the country.

Zafor, M.A. et. al (2016) studied to identify rainfall trend and variability by applying various numerical techniques and found a significant trend in rainfall in the entire Sylhet district of Bangladesh. From this analysis a high variability in rainfall exhibited in Sylhet region. Dash, S.S. and Kumar, H.V.H. (2017) analyzed daily rainfall, relative humidity, maximum and minimum temperature data of 20 years. They computed standard deviation and coefficient of variation. The regression and correlation analysis was used in determining trend. Their result showed a very high intensity of rainfall and relative humidity that is the rainfall increased as the relative humidity increased. Rahman, M.A. et al. (2017) used a linear regression model to analyze the data for a period of 40 years (1975-2014) to understand the variation, trend and prediction of rainfall for annual and various climatic seasons in Bangladesh. They also estimated mean rainfall with standard deviation. Their findings revealed that the trends of mean rainfall of annual, pre-monsoon and wither have decreased, whereas rainfall remained unchanged in monsoon season and has increased in post-monsoon. Most of the aforementioned researches were done using some simple statistical tools like measures of dispersion, correlation, least squares linear trend, numerical method, statistical tests etc. But in this study we have used some advanced statistical tools such as panel model to analyze the data.

3. Data and Methodology:

Data: The factors that govern the climate are called climatic variables. The most important factors among them are rainfall, atmospheric pressure, wind, humidity, temperature, sunshine, cloud cover etc. In this study monthly climatic data of 37 years from 1981 to 2017 are collected from Bangladesh Meteorological Department (BMD). Some climatic phenomena rainfall, cloud cover, bright sunshine, temperature and humidity are considered in this analysis. For the availability of data for all of these variables considered in this study only three weather stations Bogura, Rajshahi and Rangpur , situated in the northern part of Bangladesh, are selected.

Dependent Variable: Total monthly rainfall in millimeters (**rain**).

Independent Variables: Humidity in percentage (**hum**), Cloud covers in hour per day (**cloud**), Temperature in degree celsius (**temp**), Bright sunshine in hour per day (**sunshine**)

Methodology: Since all of these time series data have seasonal variations and non-stationary so to run panel data regression model it is needed to be made transformation for getting stationary time series data. For rainfall data it is needed two times transformation to get stationary form. Firstly, using fourth root power transformation and the secondly make a twelve periods lag difference transformation to obtain stationary form. But for all other climatic variables only twelve periods lag difference transformation is sufficient for getting stationary form.

Some descriptive statistics are computed to see the variation of variables in the study period. Cook-Weisberg test is conducted to detect heteroskedasticity of data and variance inflating factors (VIF) are calculated to observe the multicollinearity among independent variables. We have fitted different regression models: OLS, OLS-dummy, Fixed Effect Panel and Random Effect Panel to choose the suitable one using Breusch and Pagan Lagrangian multiplier test and Hausman test. All these analyses are done using computer software STRATA and MS-Excel.

4. Results and Discussion:

Non-stationary patterns are exhibited for the extracted time series data in Figure 1.

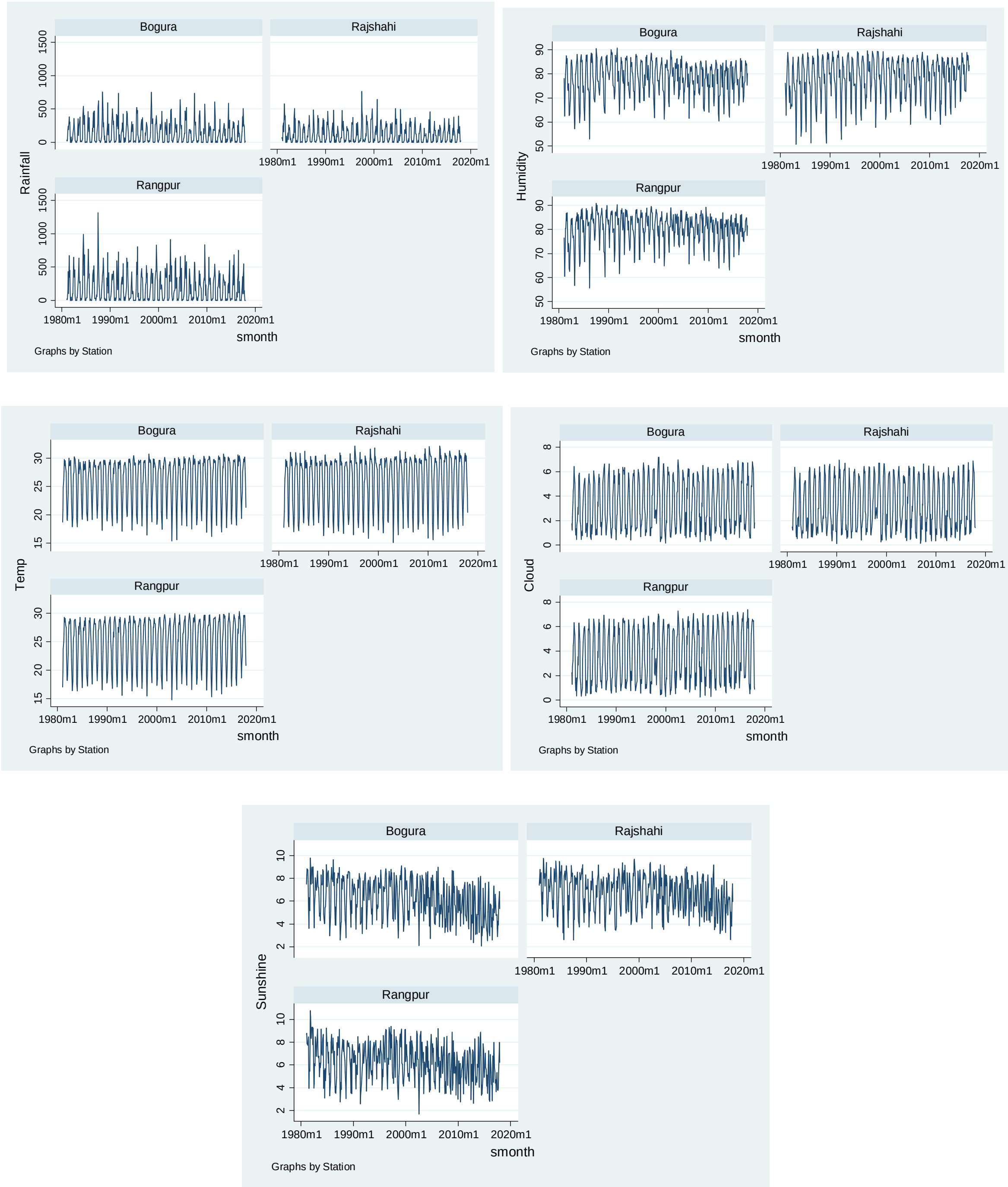

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Figure 1: Station-wise pattern of rainfall, humidity, temperature, cloud cover and sunshine before any transformation.

All the variables became stationary after necessary transformations which are exhibited in Figure 2.

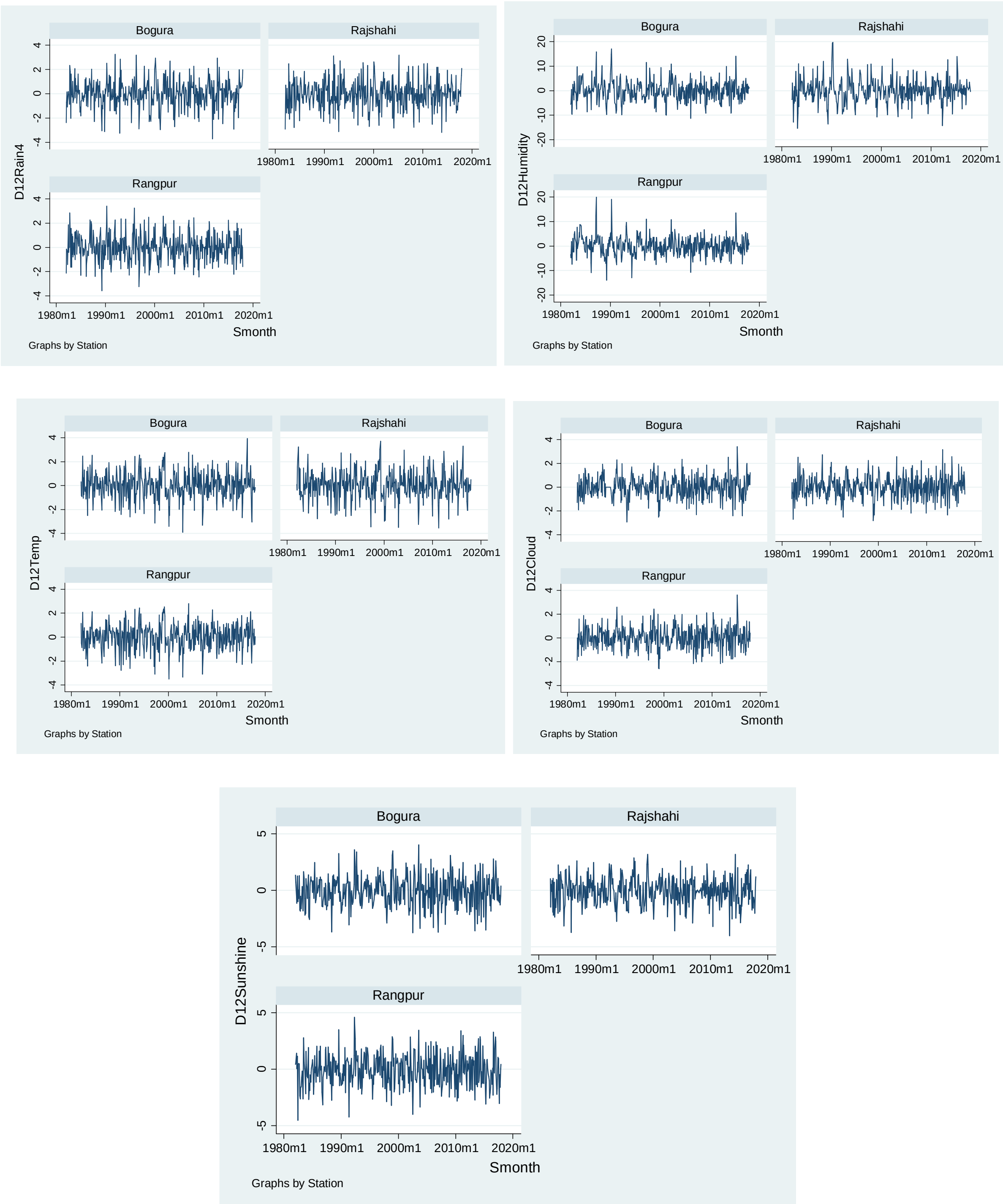

Figure 2: Station-wise pattern of rainfall, humidity, temperature, cloud cover and sunshine after transformation.

Table 1: Station wise overall mean and standard error

	Bogura		Rajshahi		Rangpur	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Rainfall	145.34	7.76	119.72	6.36	190.52	10.31
Humidity	78.20	0.33	78.25	0.40	80.42	0.30
Temperature	25.88	0.19	25.91	0.22	24.93	0.20
Cloud	3.38	0.10	3.29	0.40	3.64	0.10
Sunshine	6.21	0.08	6.68	0.08	6.27	0.08

Table 1 tells that the overall mean rainfall is the height in Rangpur (190.52mm) with higher variability and the lowest is in Rajshahi (119.72mm) with lower variability. The Table 2 reveals that for all the three cities the average monthly rainfall and cloud coverage is the highest in July while the highest average sunshine is in the month of March. In case of humidity, the average effects of Bogura and Rajshahi area are highest in the month of July whereas that of Rangpur area is in September. Average temperature is the highest in August for Bogura and Rangpur station but that of for Rajshahi is in June. From Figure 1 and Table 2, it is observed that all these time series data have seasonal variations and non-stationary. To apply the panel regression model, it is needed to make appropriate transformation for getting stationary time series data. For rainfall data it is required two times transformation to be stationary form. Firstly, using fourth root power transformation and secondly make a twelve periods lag difference transformation to obtain stationary form. But for all other variables only twelve periods lag difference transformation is sufficient for getting stationary form. After these transformations all the variables became stationary form which is observed in Figure 2 and in Table 3.

Table 2: Month and station wise mean value of rainfall, humidity, temperature, cloud cover and sunshine.

Month	Rainfall (mm)			Humidity (%)			Temperature (°C)			Cloud (hour/day)			Sunshine (hour/day)		
	Bog	Raj	Ran	Bog	Raj	Ran	Bog	Raj	Ran	Bog	Raj	Ran	Bog	Raj	Ran
Jan	7.65	8.62	9.00	77.08	78.27	81.85	18.03	17.27	16.98	1.30	1.21	1.56	6.07	6.57	6.01
Feb	14.00	13.29	11.89	69.98	71.64	74.56	21.06	20.60	19.87	1.28	1.32	1.37	7.38	7.95	7.37
Mar	20.24	23.32	29.24	66.06	63.24	68.05	25.28	25.59	23.88	1.67	1.76	1.85	7.96	8.19	7.71
Apr	82.06	64.92	114.51	71.62	66.24	73.52	28.13	29.42	26.46	3.12	2.72	3.68	7.35	8.10	6.95
May	211.16	145.02	279.43	77.71	75.68	80.24	28.75	29.81	27,58	4.37	3.95	4.99	6.52	7.22	6.46
Jun	312.92	233.32	438.76	83.42	83.11	84.59	29.42	29.99	28.71	5.67	5.50	6.16	4.63	5.36	4.72
Jul	350.97	306.03	473.51	85.58	87.24	85.59	29.25	29.40	28.97	6.18	6.23	6.56	4.03	4.39	4.23
Aug	285.89	248.70	361.93	84.86	86.47	85.01	29.49	29.59	29.27	5.89	5.91	6.17	4.69	4.99	5.03
Sep	290.59	256.19	384.75	85.49	86.13	86.52	29.07	29.23	28.52	5.33	5.36	5.65	4.89	5.39	5.09
Oct	150.16	115.14	169.24	82.00	83.07	83.88	27.72	27.42	26.81	3.12	3.02	3.19	6.99	7.27	7.06
Nov	9.70	13.24	7.11	76.71	78.69	79.89	24.26	23.38	23.01	1.44	1.39	1.36	7.59	7.87	7.97
Dec	8.76	8.81	6.92	77.88	79.23	81.36	20.08	19.14	19.07	1.14	1.09	1.13	6.46	6.77	6.65

Table 3: Seasonal indices for rainfall, humidity, temperature, cloud cover and sunshine for different stations.

Month	Rainfall			Humidity			Temperature			Cloud			Sunshine		
	Bog	Raj	Ran	Bog	Raj	Ran	Bog	Raj	Ran	Bog	Raj	Ran	Bog	Raj	Ran
Jan	5.3	7.2	4.7	98.4	99.8	101.6	69.3	66.3	67.8	37.3	35.9	41.7	95.5	96.3	93.7
Feb	9.7	11.1	6.3	89.4	91.4	92.6	81.1	79.2	79.4	37.6	39.6	37.3	116.3	116.9	115.2
Mar	14.0	19.5	15.4	84.4	80.7	84.5	97.3	98.4	95.5	49.4	53.2	50.7	125.8	120.8	121.0
Apr	56.5	54.2	60.1	91.5	84.6	91.3	108.4	113.2	105.8	90.8	81.6	99.2	116.7	119.9	109.5
May	145.2	121.1	146.6	99.3	96.7	99.7	110.9	114.8	110.4	126.8	118.0	134.3	104.1	107.5	102.2
Jun	215.1	194.7	230.2	106.6	106.2	105.2	113.5	115.6	115.0	164.3	163.4	165.6	75.0	80.6	75.7
Jul	241.3	255.4	248.4	109.4	111.5	106.4	113.0	113.5	116.1	179.2	185.2	176.9	66.0	66.8	68.6
Aug	196.6	207.6	189.9	108.6	110.5	105.7	114.0	114.3	117.4	172.0	176.8	167.4	76.9	76.1	81.4
Sep	199.9	213.9	201.9	109.4	110.1	107.6	112.5	113.0	114.6	156.8	161.7	154.5	80.4	82.3	82.7
Oct	103.4	96.3	88.9	105.0	106.3	104.4	107.4	106.2	107.9	95.6	95.0	90.9	113.7	110.1	113.7
Nov	6.9	11.3	3.9	98.3	100.7	99.5	94.3	90.8	92.9	49.0	48.7	43.4	123.4	119.2	128.2
Dec	6.2	7.6	3.8	99.8	101.4	101.3	78.3	74.6	77.3	41.3	41.0	38.1	106.2	103.5	108.2
Total	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200

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Cook-Weisberg test of heteroskedasticity is conducted and found the value of test statistic is 0.06 with p=0.8019 which is not significant. The insignificant Cook-Weisberg test statistic advocates the homoscedasticity of data.

Variance inflating factors (VIF) are calculated for each independent variable and presented in Table-4. The VIFs for all independent variables are found very low (i.e. less than 5) indicate that there is no multicollinearity exist among the independent variables.

Table-4: Variance Inflating Factor (VIF) for independent variables.

Variable	VIF	1/VIF
cloud	2.39	0.418632
hum	1.98	0.504354
sunshine	1.93	0.516945
tem	1.28	0.783706
wind	1.03	0.966806
Mean VIF	1.72	

We have conducted Breushch and Pagan Lagrangian multiplier test for random effects and its results are given in Table 5. Insignificance Breush and Pagan Lagrangian multiplier test suggests of fitting a panel regression model for the data.

Table-5: Strata output of Breusch and Pagan Lagrangian multiplier test for random effects

```
rain[Station1,t] = Xb + u[Station1] + e[Station1,t]
Estimated results:
                 |       Var     sd = sqrt(Var)
        ---------+-----------------------------
            rain |   1.200335       1.095598
               e |   .8020121       .8955513
               u |          0              0
 Test:   Var(u) = 0
                      chi2(1) =     1.42
                  Prob > chi2 =     0.2339
```

To compare the estimates we fitted OLS model and OLS dummy model with stations as dummy for the data and the results are shown in Table 6.

Table-6: Comparison of estimates of OLS model and OLS dummy model.

Variable	ols	ols_dum
hum	.05124746***	.05128244***
cloud	.53551848***	.53545354***
tem	-.10582236***	-.10579419***
sunshine	.09354611***	.09357785***
IStation1_2		-.01734295
IStation1_3		-.01287915
_cons	-.00995876	.00011481
N	1296	1296

legend: * p<0.05; ** p<0.01; *** p<0.001

It is found that coefficients estimated for various stations as dummy are not statistically significant at all and which infers that stations considered are homogeneous in nature. A Hausman test was conducted to choose appropriate model to fit for this panel time series data and its result is shown in Table 7.

Table-7: Strata output of Hausman test

```
---------------------------------------------------------------------------------
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random        Difference          S.E.
-------------+----------------------------------------------------------------
         hum |    .0512824     .0512475         .000035         .0003355
       cloud |    .5354535     .5355185       -.0000649         .0016293
         tem |   -.1057942    -.1058224        .0000282         .0009847
    sunshine |    .0935778     .0935461        .0000317         .0010485
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg


Test:  Ho:  difference in coefficients not systematic
                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.01
                Prob>chi2 =      1.0000
---------------------------------------------------------------------------------
```

Insignificant Hausman test statistic suggests that a random effect panel regression model to be fitted. Hence finally we have fitted a random effect panel model for the considered time series data. The detailed outputs are presented in Table 8.

Table-8: Strata out for the random effect panel regression model.

```
---------------------------------------------------------------------------------
Random-effects GLS regression                   Number of obs      =      1296
Group variable: Station1                        Number of groups   =         3

R-sq:  within  = 0.3349                         Obs per group: min =       432
       between = 0.6832                                        avg =     432.0
       overall = 0.3349                                        max =       432

Random effects u_i ~ Gaussian                   Wald chi2(4)       =    650.04
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
        rain |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         hum |   .0512475   .0081071     6.32   0.000     .0353579    .0671371
       cloud |   .5355185   .0419128    12.78   0.000     .4533709    .6176661
         tem |  -.1058224    .025443    -4.16   0.000    -.1556897   -.0559551
    sunshine |   .0935461    .026557     3.52   0.000     .0414954    .1455968
       _cons |  -.0099588   .0249211    -0.40   0.689    -.0588031    .0388856
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .89555128
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Coefficient of non-determination is 0.66, implies that about 34% variation of rainfall can be explained by these explanatory variables. Cloud cover, Humidity and Sunshine have significant positive effects on rainfall whereas Temperatures has significant negative effect on rainfall for the study period (1981-2017).

5. Conclusion:

The prime objectives of the research work are to find the seasonal variations of rainfall and its related some others climatic variables in the northern part of Bangladesh. A suitable panel regression model of rainfall on these climatic variables is fitted. Among the three cities, in the study, the overall average monthly rainfall is found the highest in Rangpur with high variability and the lowest is in Rajshahi with low variability. For all these three cities seasonal effect of rainfall is the highest for the month of July, seasonal effect of sunshine is the highest for the month of March, and that of cloud cover is the highest for the month of July. But for humidity variable, the seasonal effects of Bogura and Rajshahi stations are the highest for the month of July but for that of Rangpur station is in September. Since all of these time series data have seasonal variations and non-stationary so to run panel data regression model it is needed to make transformation for getting stationary time series data. For rainfall data it is needed two times transformation to get stationary form. Firstly, using fourth root power transformation and the secondly make a twelve periods lag difference transformation to obtain stationary form. But for all other climatic variables only twelve periods lag difference transformation is sufficient for getting stationary form. Insignificant Cook-Weisberg test statistic suggest the homoskedasticity and lowest variance inflating factor conferred the absent of multicollinearity among independent variables. A panel regression model is employed to check the effect of cloud cover, bright sunshine, temperature and humidity on rainfall which is conferred by Lagrange multipliers test statistic. Since hausman test statistic is insignificant hence a random effect panel regression model is fitted for the data. Coefficient of non-determination is 0.66, implies that about 34% variation of rainfall can be explained by these explanatory variables. Cloud cover, humidity and sunshine have significant positive effects on rainfall whereas temperature has significant negative effect on rainfall. The fitted model might help to predict the amount of rainfall for coming year on the basis of different climatic variables for taking better decision regarding agriculture as well as other sectors which are directly or indirectly depend on the amount of rainfall. One can try to fit a dynamic panel regression model such as GMM with Arellano Bond correction or two step analysis of panel data models for further study.

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