J. Agrofor. Environ. 5 (2): 27-32, 2011 ISSN 1995-6983

Variability and trend of decadal and annual climatic variables in Dinajpur district

Jahanara Afrose Syeda
Department of Statistics, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

Abstract: An attempt is made to investigate the decadal and annual trend and variability for 20 climatic variables of Dinajpur district for 1948-2004. The variety of exploratory data analyses (EDA) tools and different robust and nonrobust measures are used for the analyses. The significant positive rates are found for annual average relative humidity in the evening (0.175%/yr) and soil temperature (0.073^{0}C/yr) at the depth of 5cm but significant negative for average range temperature (0.029^{0}C/yr), maximum temperature (0.020^{0}C/yr), difference of relative humidity at morning and evening (-0.044%/yr) and total frequency of insignificant rainfall (0.261days/yr). The fairly high positive rates are observed for annual total rainfall, maximum rainfall, average relative humidity, relative humidity in the morning, cloud, minimum temperature, wet bulb temperature and maximum wind-speed but negative for total frequency of zero rainfall, average evaporation, difference of dry and wet bulb temperature and sunshine-hour with the nonnormal and/or nonstationary residual. The very low positive rate is found for ASLP (+0.0007mb/yr) with normal and stationary residual but negative for ADBT (-0.0004^{0}C/yr) with nonstationary residual. The historical climatic data needs exploratory analysis and warrants tougher justification in classical analyses for outlier and residual's nonnormality and nonstationarity. The findings support that the climate of Dinajpur is changing in different terms which may affect its agricultural production
Key words: Variability, decadal, annual, climatic variables, Dinajpur.

Introduction

Dinajpur is the highest wheat producing area of Bangladesh and this cereal is much sensitive to climatic changes. So, to challenge flood, drought, crop failure or any disaster caused by climatic changes, it is really important to study whether the characteristics of Dinajpur climate are changing. In this paper, an attempt is taken to study the variability and trend for climatic variables in Dinajpur mainly using the exploratory data analytic tools and the analysis is carried out on almost 20 variables based on the decadal and annual aspects. In a particular place, climatic variables may vary for both the within and between years. Since the green house effect is believed to be responsible for the apparent trend in climatic variables, it is imperative for climatilogists to analyze time series of the climatic data to calculate its variability over the years.

A brief discussion on the necessity of the study of variability and trend of climatic variables in a place is given in the introductory section. In the section 2, some commonly used EDA techniques like stem-and-leaf plot and boxplot together with some robust measures of location and dispersion are used. Section 3 upholds sources and nature of the data and the methodologies used. Finally, the findings of the study are presented in the section 4.

Materials and Methods

Sources of Data: The daily and monthly data for 1948-1972 and 1981-2004 on climatic factors of Dinajpur are collected from Bangladesh Meteorological Deptt., Agargaon, Dhaka, Bangladesh. The collected data are the total rainfall in mm (TR) and maximum rainfall (MXR) in mm, total frequency of insignificant rainfall in days (TFIR), average dry bulb temperature in ^{0}C (ADBT), average maximum temperature in ^{0}C (AMXT), average minimum temperature in ^{0}C (AMNT), average range temperature in ^{0}C (ARNT), average wet bulb temperature in ^{0}C (AWBT), average difference of dry bulb and wet bulb temperature in ^{0}C {AT(D-W)}, average relative humidity in percentage (ARH), average difference of relative humidity between morning and evening in percentage (ARH(0-12)), average wind speed in knots (AWS), average maximum wind speed in knots (AMWS), average sea level pressure in mb (ASLP), average cloud in octas (AC). Besides, the data of daily and monthly evaporation in percentage (AE) for 1987-2000, average soil temperature (AST) in ^{0}C at the depths of 5, 10, 20 and 50cm, respectively for 1987–2000 and the average sunshine-hour (ASH) for 1989-2004 are collected. In this study, the daily and the monthly missing data for 1973-1976 are filled in by the medians of the observed data for 1948- 1972 and the missing data for 1977-1980 are filled in by the medians of the observed data for 1981-2004. Daily missing values are placed by the median of the corresponding daily data of the months/years.

Analytical methods

The within-year and between-year decadal and annual patterns are investigated for the data for 1948-2004 with the exploratory data analyses techniques like boxplot, stem-and-leaf plot, and median polish table. The statistical package Minitab 11.12 is used for the analysis. The nonrobust measures like mean, coefficient of variation and robust measures like median, 5% trimmed mean and the percentage ratio of quartile deviation to median are used to investigate the within-year variability pattern of data. The trend of the number of weeks containing 0–5 millimeter (ml) rainfall are investigated as it is considered insignificant from agricultural view and this analysis can focus about the drought. To test whether the trend is deterministic or stochastic, the stationarity of residuals are checked after trend fitting using the sample autocorrelation function (ACF) and from the partial autocorrelation function (PACF) and Box-Peirce test statistic. The normality of the residuals are examined from these fits by normal probability plot and the rescaled moments (RM) test for normality (Imon, 2003).

Exploratory Data Analysis (EDA) and Robust Techniques

Exploratory data analysis methods are used primarily to explore data before using more traditional methods, or to examine residuals from a model. These methods are particularly useful for identifying extraordinary observations and noting violations of traditional assumptions, such as nonlinearity or nonconstant variance. Tukey (1977) demonstrated ample weakness of classical parametric statistics to handle real world data due to its strong dependence on extraneous assumptions and advocated using the EDA methods. EDA is a set of techniques which are used primarily to explore data before using more traditional methods, or to examine residuals from a model. It employs a variety of techniques to maximize insight into a data set, uncovers underlying structure, extracts important variables, detects outliers and anomalies, tests underlying assumptions, develops parsimonious models and determines optimal factor setting. Most EDA techniques are graphical with a few quantitative techniques. The reason for the heavy reliance on graphics is that graphics is the best means through which data can speak itself without assumptions, models, hypotheses and even concept of probability. Boxplots are used to assess and compare sample distributions. This plot consists of the so called *five number summary* (median, first and third quartiles, and upper and lower inter-quartile ranges). Here it is tried to plot the data in a box whose midpoint is the sample median, the top of the box is the third quartile (Q3) and the bottom of the box is the first quartile (Q1). The upper whisker extends to this adjacent value- the highest data value within the upper limit = Q3 + 1.5 (Q3 - Q1). Similarly, the lower whisker extends to this adjacent value- the lowest value within the lower limit = Q1- 1.5 (Q3 - Q1). An observation is considered to be unusually large or small when it is plotted beyond the whiskers and those are treated as outliers. The stem-and-leaf plot is used to examine the shape and spread of the sample data. The plot is similar to a histogram on its side, nonetheless, instead of bars, digits from the actual data values indicate the frequency of each bin (row) and thus it becomes more informative than the histogram. Median Polish fits an additive model to a two-way design and identifies data patterns not explained by row and column effects. This procedure is similar to analysis of variance except medians are used instead of means, thus adding robustness against the effect of outliers. The term robustness signifies insensitivity to small deviations from the assumption. That means a robust procedure is nearly as efficient as the classical procedure when classical assumptions hold strictly but is considerably more efficient over all when there is a small departure from those. The main application of robust techniques is to try to devise estimators, which are not strongly affected by outliers in a sense that the robust techniques can cope with outliers by keeping small the effects of their presence. The EDA techniques considered in this paper are very robust, but are mainly designed for graphical display. In a quantitative analysis, robust estimates of location and dispersion are often required. As an estimator of location parameter, median are used instead of mean. But it is now evident (Alam *et al*., 2003) that when contamination is not high, trimmed mean (TRM) performs better than the median. As an estimator of scale parameter, the median absolute deviation (MAD) is used instead of the standard deviation. The robust version of the relative measure of dispersion like the coefficient of variation (CV) is found where mean and standard deviations are replaced by median (or trimmed mean). Again the percentage ratio of quartile deviation (QD) to median is used instead of MAD.

Analyses and Results

Decadal Analyses: The within and between-decade variability analyses for annual data of climatic variables (TR, AC, ARH, AMWS, AWS, ASLP, AMXT, AMNT, ARNT, ADBT and AWBT) are conducted in respect of both robust and nonrobust measurements. Table 1 shows the results of within-decade variability analyses. The first highest variation is experienced in the decadal AWS, the second highest variation is observed in the decadal AMWS and the third highest variation is obtained in the decadal TR in terms of CV, CV(Med), QD/Med and QD/TRM while the lowest variation is found in decadal ASLP and then in decadal ADBT. The results of the between-decade variability analyses for annual data of climatic variables are shown in the Table 2 where the nonrobust decadal averages and variations of climatic variables in terms of mean and CVs are presented and robust measurements are not presented.

Table 1. Within-Decade Variability for Annual Data

Issues	Mean	Median	Tr Mean	StDev	Min	Max	Q1	Q3	QD	CV	CV (Med)	(QD/ Med)	CV (TRM)	QD/ TRM	Range
TR	1579	1727	1579	684	401	2117	1033	2052	509.5	43.319	39.606	29.5	43.319	32.267	1716
AMXT	30.44	30.51	30.442	0.51	29.76	31.1	30	30.895	0.47	1.665	1.662	1.54	1.665	1.544	1.31
AMNT	19.71	19.77	19.714	0.24	19.37	20	19.5	19.931	0.231	1.238	1.234	1.168	1.238	1.172	0.583
ARNT	10.73	10.55	10.726	0.51	10.24	11.5	10.3	11.225	0.455	4.736	4.814	4.312	4.736	4.242	1.26
ADBT	24.909	24.902	24.909	0.268	24.634	25.34	24.69	25.129	0.218	1.0759	1.07622	0.875	1.07592	0.8752	0.708
AMWS	5.92	5.12	5.92	2.33	3.3	9.21	3.99	8.26	2.135	39.36	45.508	41.7	39.358	36.064	5.91
ARH	74.49	73.7	74.49	2.73	71.91	78.9	72.4	77	2.315	3.665	3.704	3.141	3.665	3.108	6.99
AC	2.817	2.754	2.817	0.33	2.461	3.21	2.51	3.161	0.328	11.82	12.092	11.91	11.821	11.644	0.749
AWBT	21.604	21.648	21.604	0.254	21.352	21.98	21.37	21.817	0.2235	1.1757	1.17332	1.03	1.17571	1.03	0.631
AWS	1.196	1.101	1.196	0.6	0.493	2.09	0.7	1.742	0.522	50.08	54.405	47.41	50.084	43.645	1.601
ASLP	1007.6	1007.6	1007.6	0.2	1007.3	1008	1007	1007.7	0.15	0.0199	0.01985	0.0149	0.01985	0.0149	0.5

Tr Mean=trimmed mean StDev=standard deviation Min=minimum Max=maximum

Table 3 presents the At a glance picture for decadal position in respect of the highest and lowest means and CVs for the annual data. The variable of TR has the highest average in the 4th decade and lowest average in the 3rd decade while the variation is highest in the 3rd decade and lowest in the 1st decade. The variable of AC has the highest average in the 4th decade and lowest in the 1st decade while the variation appears to be the highest in the 3rd decade and lowest in the 2nd decade. The highest average for ARH is observed in the 5th decade and lowest average is found in 4th decade while the highest variation for ARH is in the 4th decade and lowest in the 2nd decade. The decadal average for AMWS is highest in the 4th decade and lowest in the 1st decade while the decadal variation is highest in the 2nd decade and lowest in the 4th decade. The decadal average for the variable of ASLP is highest in the 1st decade and lowest in the 2nd decade while the decadal variation for the variable of ASLP is highest in the 1st decade and lowest in the 3rd decade. The variable of AMXT posses the highest average in the 1st decade and lowest in the 4th decade but the highest variation occurs in the 3rd decade and lowest occurs in the 5th decade. The variable of AMNT has the highest average in the 2nd decade and lowest in the 4th decade. On the other hand, the highest variation of AMNT is found in the 4th decade and lowest in the 3rd decade. For the variable of ARNT, the highest average is in the 1st decade and lowest in the 5th decade while the variation is highest in the 1st decade and lowest in the 5th decade. For the variable of ADBT, the highest average is seen in the 4th decade and lowest in the 5th decade while the highest variation is experienced in the 4th decade and lowest in the 3rd decade. For the variable of AWBT, the highest average is observed in the 5th decade and lowest in the 1st decade while the variation is highest in the 4th decade and lowest in the 2nd decade.

Table 2. Between-Decade Variability for Annual Data

Variable	Decade	1951-60	1961-70	1971-80	1981-90	1991-00
TR	Mean	1664	1727	401.4	2117	1987
	CV(%)	18.44	26.4	70.63	21.26	23.7
AC	Mean	2.55	2.46	2.75	3.21	3.11
	CV(%)	8.24	5.92	12.8	6.98	8.24
ARH	Mean	73.7	72.84	75.09	71.91	78.9
	CV(%)	2.86	1.64	2.53	4.55	2.13
AMWS	Mean	3.3	4.68	5.12	9.21	7.3
	CV(%)	23.09	47.66	40.12	21.47	25.38
ASLP	Mean	1007.8	1007.3	1007.7	1007.5	1007.6
	CV(%)	0.099	0.029	0.009	0.05955	0.05954
AMXT	Mean	31.07	30.51	30.72	29.76	30.2
	CV(%)	1.571	1.39	1.758	1.223	1.19
AMNT	Mean	19.6	20	19.8	19.4	19.9
	CV(%)	3.466	1.844	0.298	5.507	2.2
ARNT	Mean	11.5	10.6	10.9	10.4	10.2
	CV(%)	8.24	6.16	5.44	7.42	5.21
ADBT	Mean	24.803	24.92	24.9	25.34	24.6
	CV(%)	1.451	0.919	0.606	2.96	1.09
AWBT	Mean	21.35	21.39	21.65	21.65	21.98
	CV(%)	1.218	1.131	1.497	3.13	1.64

Table 3. Decades of Highest and Lowest Means and CVS for Annual Data

Issues	TR	AC	ARH	AMWS	ASLP	AMXT	AMNT	ARNT	ADBT	AWBT
Highest Mean	4th	4th	5th	4th	1st	1st	2nd	1st	4th	5th
Lowest Mean	3rd	1st	4th	1st	2nd	4th	4th	5th	5th	1st
Highest CV	3rd	3rd	4th	2nd	1st	3rd	4th	1st	4th	4th
Lowest CV	1st	1st	2nd	4th	3rd	5th	3rd	5th	3rd	2nd

Annual Analyses: Table 4 presents the within-year variability for the annual data in terms of both robust and nonrobust measurements. The first highest variation is experienced for the variable AWS, the 2nd highest variation is found for AMWS and the third highest variation is observed for TR in terms of both the robust and nonrobust measurement while the lowest variation is seen for ASLP.

Table 4. Within-Year Variability for Annual Data

Issues	TR	AC	ARH	ARH (0)	ARH (0-12)	ARH (12)	AMXT	AMNT	ARNT
Mean	1636.9	2.9	74.9	90.4	23.0	67.3	30.4	19.7	10.7
Med	1798	2.8	73.9	89.7	23.2	66.9	30.4	19.8	10.5
TRM	1650	2.9	74.9	90.4	23.0	67.3	30.4	19.8	10.6
Min	211	2.1	67.9	85.4	20.0	60.4	28.9	16.6	9.2
Max	3185	3.6	81.9	95.2	26.8	74.8	31.9	20.7	13.7
Q1	1289.5	2.5	72.9	88.2	22.0	64.2	30.0	19.5	10.1
Q3	2141	3.2	77.3	92.8	24.2	70.2	30.8	20.0	11.2
CV	43.69	13.8	4.5	3.0	6.8	5.5	2.0	3.2	7.8
QD(Med)	23.7	12.1	3.0	2.6	4.7	4.5	1.4	1.2	5.5
QD(TRM)	25.80	11.8	2.9	2.6	4.7	4.4	1.3	1.2	5.5
Range	2974	1.5	14.0	9.8	6.8	14.4	2.9	4.1	4.5

Continued

Issues	ADBT	AWBT	AST(5)	AT(D-W)	AMWS	AWS	ASLP	AE	ASH
Mean	24.9	21.6	25.9	3.2	5.8	1.2	1007.5	35.0	6.5
Med	24.8	21.6	25.9	3.4	5.4	1.1	1007.6	35.0	6.4
TRM	24.9	21.7	25.9	3.2	5.7	1.1	1007.6	35.2	6.5
Min	23.8	20.0	25.3	2.1	1.8	0.3	1005.4	27.8	5.9
Max	26.0	22.6	26.6	4.1	13.1	3.8	1008.8	40.2	7.2
Q1	24.5	21.3	25.5	2.9	3.6	0.7	1007.2	33.1	6.2
Q3	25.1	22.0	26.2	3.6	7.6	1.5	1007.8	37.9	6.7
CV	1.9	2.2	1.6	16.4	45.2	54.3	0.0596	10.2	4.8
QD(Med)	1.1	1.5	1.5	9.3	36.9	37.6	0.0298	6.8	3.7
QD(TRM)	1.1	1.5	1.5	9.6	35.2	37.2	0.0298	6.8	3.7
Range	2.2	2.6	1.3	2.0	11.3	3.6	3.4	12.4	1.3

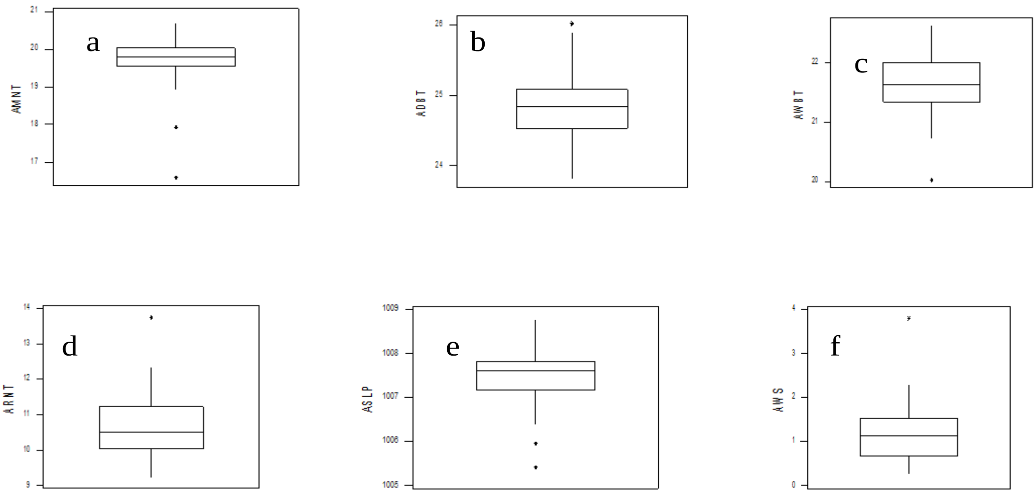

Fig. 1. Boxplots of annual (a) AMNT (b) ADBT (c) AWBT (d) ARNT(e) ASLP (f) AWS

The boxplots shown in Fig. 1 present the medians and variations for some annual climatic variables where some lower and higher outliers are detected. The lower and higher (HI) outliers are also obtained from stem-and-leaf displays which are presented in Table 5 with the occurrences years for extreme outliers. The higher outlier of AMNT is observed 20.69^0C in 1999 and the lower outlier is 16.59^0C in 1981. The higher outlier of ARNT is found 13.7^0C in 1957 and the higher outlier of ADBT is seen 26.0^0C in 1985. The lower outlier of AWBT is obtained 20.0^0C in 1981 and the lower outlier of ASLP is experienced 1005.4mb in 1959. The higher outlier of AMWS is noted 13.0knots in 1990 and the higher outlier of AWS is found 3.8 knots in 1981.

Table 5. Detected Outliers and the Respective Year for Extreme Outliers for Annual Data

Issues	AMNT	ARNT	ADBT	AWBT	ASLP	AMWS	AWS
Detected outliers	(LO: 1659, 1792 and HI: 2069) Leaf Unit = 0.010	(HI: 137) Leaf Unit = 0.10	(HI: 258, 260, 260)Leaf Unit = 0.10	(LO: 200) Leaf Unit = 0.10	(LO: 10054, 10059) Leaf Unit = 0.10	(HI: 130) Leaf Unit = 0.10	(HI: 38) Leaf Unit = 0.10
extreme outlier	LO: 1659 -1981 HI: 2069 -1999	HI: 137- 1957	HI: 260-1985	LO: 200- 1981	LO: 10054- 1959	HI: 130- 1990	HI: 38- 1981

LO-lower HI-higher

Table 6. Rates of LT for Annual Mean and Residual's Stationarity and Normality

Variable	Rate of LT	Variable	Rate of LT
ARH(12)	+0.175* (t=9.33, N, S)	ASLP	+0.0007 (t=0.15, N, S)
AST(5)	+0.073* (t=3.99, N, S)	ARNT	-0.029* (t=-5.36, Ap. N, S)
ARH(0)	+0.131 (t=10.29, Ap. N, NS)	AMXT	-0.020* (t=-4.96, Ap. N, S)
AC	+ 0.015 (t=6.36, Ap.N, NS)	ARH(0-12)	-0.044* (t=-3.93, N, S)
AWBT	+0.165 (t=5.18, NN, S)	TFIR	-0.261* (t=-2.81, N, S)
ARH	+0.108 (t=4.60, NN, NS)	FZR	-0.057 (t=-5.64, Ap.N, NS)
AMWS	+ 0.075 (t=3.99, Ap.N, NS)	AT(D-W)	-0.016 (t=-4.61, NN, NS)
MXR	+3.67 (t=2.03, NN, NS)	AE	-0.484 (t=-2.40, NN, S)
TR	+10.5 (t=1.86, NN, NS)	ASSH	-0.014 (t=-0.86, Ap. N, S)
AMNT	+0.008 (t=1.79, N, NS)	ADBT	-0.0004 (t= -0.11, Ap. N, NS)

*Significant at 5% level S = Stationarity NS = Not stationarity NN = Not normal Ap.N = Approximately normal, Ap. S = Approximately stationary

Table 6 presents the rates obtained from linear trend for annual data of climatic variables with the respective 't' values and the residual's stationarity and normality. The significant positive rates are found for ARH(12) (+0.175*) and AST(5) (+0.073*) but negative for ARNT (-0.029*), AMXT (-0.020*), ARH(0-12) (-0.044*) and TFIR (-0.261*); fairly high positive rates are observed for TR, MXR, ARH (+0.108), ARH(0) (+0.131), AC (+0.015), AMNT (+0.0087), AWBT (+0.165), and AMWS (+0.075) but negative for FZR (-0.057), AE (-0.484), AT(D-W) (-0.0169) and ASSH (-0.014) with nonnormal and/or nonstationary residual. The very low positive rate is found for ASLP (+0.0007) with normal and stationary residual but negative for ADBT (-0.0004) with nonstationary residual.

Table 7 presents the rates obtained from LT for the CV of the annual climatic data and the respective't' values, residual's stationarity and normality. The significant positive rate is found for AMXT (+0.030*) but negative rates for AT(D-W) (-0.423*), ARH(12) (-0.207*), ARH (-0.160*), ARH(0) (-0.087*), ARNT (-0.143*), AWBT (-0.048*) and AMNT (-0.041*); fairly high positive rate for FZR (+0.215) but negative for ASLP (-0.001) TR (-0.305), ADBT (-0.019) and AST(5) (-0.020) with abnormal and nonstationary residual; less positive for ASSH (+0.062) but negative for AE (-0.211) with normal and stationary residual. The approximately significant negative rate is established for ARH(0-12) (-0.081).

Table 8 presents the rates of LT for maximum values and Residual's Stationarity and Normality. The significant positive growth rates are established for annual maximum ARH(12) (+ 0.040*), AST (+ 0.074*) and AWBT (+ 0.010*) but significant negative for ARNT (-0.061*), AT(D-W) (–0.068*), AMXT(- 0.038*) ARH(0-12) (– 0.084*); approximately significant positive for AMNT (+ 0.007) but negative for ASLP (- 0.0089) and AE (-0.949); relatively high positive rate for AC (+ 0.003) and less positive rate for ARH (+ 0.002) with normal and stationary residual and fairly high positive rates for ARH(0) (+ 0.077), AWS (+ 0.015), AMWS (+ 0.122), MXR (+ 1.53) and TR (+ 1.51) with nonstationary and/or abnormal residual but negative for ADBT (- 0.007) and ASSH (- 0.023) with normal and stationary residual.

Table 7. Rates of LT for Annual CVs and Residual's Stationarity and Normality

Variable	Rate of LT for CV	Variable	Rate of LT for CV
AMXT	+0.030* (t=2.93, N, S)	ARNT	-0.143* (t=-5.35, N, S)
ASSH	+0.062 (t=0.20, N, S)	AWBT	-0.048* (t=-4.28, N, S)
FZR	+0.215 (t=3.54, NN, NS)	AMNT	-0.041* (t=-3.31, N, S)
-	-	ARH(0-12)	-0.081 (t=-1.62, N, S)
-	-	AE	-0.211 (t=-0.58, Ap.N, S)
AT(D-W)	-0.423* (t=-6.25, N, S)	ASLP	-0.001 (t=-1.98, NN, S)
ARH(12)	-0.207* (t=-6.22, N, S)	TR	-0.305 (t=-1.45, NN, NS)
ARH	-0.160* (t=-6.10, N, S)	ADBT	-0.019 (t=-1.38, N, NS))
ARH(0)	-0.087* (t=-5.73, Ap. N, S)	AST(5)	-0.020 (t=-0.22, NN, S)

Table 8. Rates of LT for Maximum Values and Their Residual's Stationarity and Normality

Variable	Rate of LT for Maximum Values	Variable	Rate of LT for Maximum Values
ARH12	+ 0.040* (t=2.47, Ap. N, S)	ARH	+ 0.002 (t=0.20, N, S)
AST	+ 0.074* (t=2.49, Ap. N,S)	ARNT	-0.061* (t=-6.87, N, S)
AWBT	+ 0.010*(t=5.13, Ap. N, S)	AT(D-W)	– 0.068* (t=-6.46, Ap. N, S)
AMNT	+ 0.007 (t=1.96, Ap. N, S)	AMXT	- 0.038* (t=-3.28, N,S)
ARH0	+ 0.077 (t=9.56, Ap. N, NS)	ARH(0-12)	– 0.084* (t=-2.79, N, S)
AWS	+ 0.015(t=2.14, NN, NS)	ASLP	- 0.0089 (t=-1.51, Ap. N, S)
AMWS	+ 0.122 (t=2.17, NN,S)	AE	-0.949 (t=-1.50, N, S)
MXR	+ 1.53(t=2.05, NN, S)	ADBT	- 0.0073(t=-1.05, Ap. N, S)
TR	+ 1.51 (t=0.81, NN, NS)	ASSH	- 0.0235(t=-0.83, Ap. N, S)
AC	+ 0.0035 (t=1.18, N,S)	DR	-

* Significant at 5% level of significance, The underlineed values are approx significant, N- normal S-Stationary NN-nonnormal NS-Nonstationary Ap. N- Approx normal

Table 9 presents the rates of LT for minimum values and Residual's Stationarity and Normality. The significant positive growth rates are recognized for minimum ARH(12) (+ 0.354*), ARH (+ 0.338*), ARH(0) (+ 0.286*) and AC (+ 0.0102*) but negative for AMXT (- 0.0578*); approximately significant positive rates for AWBT (+ 0.0116) but negative for AE (- 0.207) and AT(D-W) (- 0.0027); fairly high positive rate for ARH(0-12) (+ 0.0232) and less positive rates for AST (+ 0.032), AMNT (+ 0.003), ARNT (+ 0.00068) and ASSH (+ 0.0007) but less negative for DR (- 0.0049) and ADBT (- 0.00397) with normal and stationary residual. The fairly high positive rates are also experienced for AMWS (+0.0673), AWS (+ 0.0163) and ASLP (+ 0.0378) with abnormal and/or non-stationary residual.

Table 9. Rates of LT for Minimum Values and Residual's Stationarity and Normality

Variable	Rates of LT for Minimum Values	Variable	Rates of LT for Minimum Values
ARH12	+ 0.354* (t=7.09, N, S)	AMWS	+ 0.0673(t=7.01, NN, NS)
ARH	+ 0.338*(t=6.61, N,S)	AWS	+ 0.0163(t=6.23, NN, NS)
ARH0	+ 0.286* (t=6.43, Ap. N, S)	ASLP	+ 0.0378(t=1.52, NN, S)
AC	+ 0.0102*(t=4.70, N S)	AMXT	- 0.0578* (t=-6.62, N, S)
AWBT	+ 0.0116 (t=1.87, N, S)	AE	- 0.207 (t=-1.85, N, Ap. S)
ARH(0-12)	+ 0.0232(t=1.47 , N, S)	AT(D-W)	- 0.0027 (t=-1.50, N, S)
AST	+ 0.0321 (t=0.72, Ap.N, S)	ADBT	- 0.00397(t=-0.43, N, Ap. S)
AMNT	+ 0.00301 (t=0.47, N,S)	DR	- 0.0049 (t=-0.21, N, S)
ARNT	+ 0.00068 (t=0.13, Ap N, S)	TR	-
ASSH	+ 0.0007 (t=0.02, N, Ap. S)	MXR	-

Table 10 presents the rates of LT for Ist quartiles and residual's stationarity and normality. The significant positive growth rates are approved for the 1st quartile of ARH0 (+ 0.177*), ARH12 (+ 0.258*), AC (+ 0.014*), AWBT (+ 0.026*) and AMNT (+ 0.018*) but negative for AMXT(- 0.021*) AE (-0.315*) and DR (- 0.040*); approximately significant positive for AST(+ 0.072) and ARH(0-12) (+ 0.019), less positive rate for ADBT (+ 0.011) but less negative rates for ASSH (- 0.0143) with normal and stationary residual and for ARNT (- 0.0009) with abnormal and stationary residual, the fairly high positive rates for AWS (+ 0.019), AMWS (+ 0.0672), ARH (+ 0.196), TR (+ 0.117) and MXR (+ 0.0764) but negative for AT(D-W) (- 0.003) with abnormal and/or non-stationary residual. The almost unremarkable positive rate is obtained for ASLP (+ 0.00001).

Table 11 presents the rates of LT for 3rd quartiles and residual's Stationarity and Normality. The significant positive growth rates are accredited for 3^{rd} quartile of ARH(12) (+ 0.053*), AST (+ 0.076*) and AC (+ 0.011*) but significant negative for ARNT (- 0.055*), DR (- 0.012*), ARH(0-12) (- 0.098*) and AMXT (- 0.015*) and approximately significant negative for AE (- 0.608). The fairly high positive rates are obtained for MXR (+ 0.337), ARH(0) (+ 0.080), AWS (+ 0.018), AMWS (+ 0.073), TR (+ 1.77) and AWBT (+ 0.007) but negative for AT(D-W) (- 0.030) with abnormal and/or non-stationary residual. The less positive rates are established for ARH (+ 0.014), and AMNT (+0.002) with abnormal and/or non-stationary residual but less negative for ASLP (- 0.0025), ADBT (- 0.0008) and ASSH (- 0.005) with normal and stationary residual.

Table 10. Rates of LT for Ist Quartile and Residual's Stationarity and Normality

Variable	Rate of LT for Ist Quartile	Variable	Rate of LT for Ist Quartile
ARH0	+ 0.177* (t=7.87, N, Ap. S)	AMWS	+ 0.067 (t=5.51, Ap. N, NS)
ARH12	+ 0.258* (t=6.23, N, S)	ARH	+ 0.196 (t=4.80, N, NS)
AC	+ 0.014* (t=5.51 N, S)	TR	+ 0.117(t=2.57 NN, S)
AWBT	+ 0.026* (t=5.42, N, S)	MXR	+ 0.076 (t=2.42, NN, S)
AMNT	+ 0.018* (t=2.96 N,S)	AMXT	- 0.021* (t=-3.19, N, S)
AST	+ 0.072(t=1.58 Ap. N, S)	AE	-0.315*(t=-2.49, N, Ap. S)
ARH(0-12)	+ 0.019 (t=1.50, N, S)	DR	- 0.040* (t=-2.63 N, S)
ADBT	+ 0.011 (t=1.42, N,S)	ASSH	- 0.014 (t=-0.36, N, Ap. S)
ASLP	+ 0.00001 (t=0.00, Ap.N, S)	AT(D-W)	- 0.003(t=-1.82, Ap.N, NS)
AWS	+ 0.019 (t=6.51 NN, NS)	ARNT	- 0.0009 (t=-0.13, NN, S)

Table 11. Rates of LT for 3rd Quartile and Residual's Stationarity and Normality

Variable	Rate of LT for 3rd Quartile	Variable	Rate of LT for 3rd Quartile
ARH12	+ 0.053*(t=3.93, N, S)	AMNT	+ 0.002(t=0.45, NN,S)
AST	+ 0.076*(t=3.70, Ap. N, S)	ARNT	- 0.055*(t=-9.11, N, S)
AC	+ 0.011*(t=3.62, N, S)	DR	- 0.012*(t=-2.48, Ap. N, S)
MXR	+ 0.337 (t=1.26, NN, NS)	ARH(0-12)	- 0.098* (t=-3.69, Ap.N, S)
ARH0	+ 0.080 (t=11.12, Ap.N, NS)	AMXT	- 0.015* (t=-3.31, N, S)
AWS	+ 0.018 (t=3.03, NN, NS)	AE	- 0.608(t=-1.58, N, Ap. S)
AMWS	+ 0.073(t=2.57, AP.N, NS)	ASLP	- 0.0025(t=-0.49, N, S)
TR	+ 1.77 (t=1.99, NN, NS)	ADBT	- 0.0008(t=-0.30, Ap. N, S)
AWBT	+ 0.007 (t=1.78, NN, S)	ASSH	- 0.005(t=-0.22, Ap. N, S)
ARH	+ 0.014(t=0.96, Ap. N, NS)	AT(D-W)	- 0.030 (t=-4.72, Ap. N, NS

Conclusions

Some residuals demonstrate stationarity pattern but several follow non stationarity and a few error support normal distribution but others show abnormality. Sometimes robust and non-robust measures come up with conflicting conclusions. So it is imperative for us to avoid normality assumption based statistical procedures for further analysis of historical climatic data and emphasize the view in favor of EDA and robust techniques in analyzing climatic variables. Significant changes in some variables support that the climate of Dinajpur district is changing, which ultimately may affect its agricultural production.

References

Ahmed, R. and Karmakar, S. 1993. "Arrival and withdrawal dates of the summer monsoon in Bangladesh", International Journal of Climatology, 13, 727–740.

Ali, M. M., Ahmed, M., Talukder, M. S. U. and Hye, M. A. 1994. "Rainfall distribution and agricultural droughts influencing cropping pattern at Mymensingh region", Progressive Agriculture, 5, 197-204.

Gujarati, D. N. 2003. Basic Econometrics, 4th Ed., McGraw-Hill - Irwin, New York

Huber, P. J. 2004. Robust Statistics, Wiley, New York.

Imon, A.H.M.R. 2003. "Regression Residuals, Moments and their use in tests for normality", Communications in Statistics – Theory and methods 32: 1021-1034.

Karmakar, S. 2001. "Global warming and recent climatic changes in Bangladesh", (presented in an workshop on climatology and meteorology, Dhaka.

Mosteller, F. and Tukey, J. W. 1977. Data Analysis and Regression, Addison-Wesley

Rahman, M. S. and Alam, M. S. 1996. "Patterns of rainfall variability and trend in the high Barind region", Rajshahi University Studies Part-B, Journal of Science, 24.

Talukder, M.S.U., Ali, M.A., Huq, M.M. and Hossain, M.A. 1988. " A study on rainfall pattern in Bangladesh", Bangladesh Journal of Agricultural Sciences 15, 217-224.

Tukey, J. 1977. Exploratory Data Analysis, Addison-Wesley, New York.

Velleman, P. F. and Hoaglin, D. C. 1981. "The ABC's of EDA: Applications, Basics, and Computing of Exploratory Data Analysis", Duxbury, MA.