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Variability and Trend of Monthly Climatic Variables in Dinajpur District

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Abstract

An attempt was made to investigate the monthly variability and trend for 20 climatic variables of Dinajpur district for 1948-2004. The variety of exploratory data analyses (EDA) tools and different robust and nonrobust measures were used for the analyses. The positive rates of total rainfall were fairly high in February, April, May, October and December where the residuals follow nonnormal and stationary but significant positive rate is documented only in September (+ 4.22*). The rate of growth of average cloud was documented less negative for August (- 0.0006) but significant positive for rest of the months. The rates of total frequency of insignificant rainfall were recognized approximately significant negative for April (- 0.035) and significant negative for May (- 0.069*) and September (- 0.079*), and the fairly high negative rates were accounted in February and December with nonnormal residual. Historical climatic data needs exploratory analysis and warrants tougher justification in classical analyses for outlier and residual's nonnormality and nonstationarity.

Key words: Climate, Temperature, Variability

Introduction

Dinajpur is the highest wheat producing area of Bangladesh and the wheat crop is much sensitive to climatic changes. The local climate of a crop varies systematically with the crop density, the stage of growth, foliage distribution and intensity, wetness of the soil and the cultural practices. Again, in a particular place, climatic variables may vary for both the within and between years. The knowledge of the variability and trend for monthly climatic variables may help for the proper planning and management practices in the agricultural sector of Dinajpur. Talukder *et al*. (1988), Ahmed and Karmakar (1993), Ali *et al*. (1994) tried to detect and measure rainfall variability within years but overlooked the possibility of the between-years variability. Rahman and Alam (1996) and Karmakar (2001) made some efforts in this area, but their studies lack modern statistical techniques. There is a scope to examine whether the trends under study are deterministic or stochastic by checking in the model adequacy. Karmakar (2001) also estimated trend regression coefficient of 5-year moving average for total (country averaged) annual and seasonal rainfall of Bangladesh for the period 1948-90. Rahman and Alam (1996) examined the trend pattern of annual and seasonal rainfall over the last 16 years of all of the high Barind districts in Bangladesh by using simple regression techniques. Not even the normality and stationarity of residuals were checked in their studies. Karmakar (2001) analyzed the decadal trend and variability of total annual (country averaged) rainfall of Bangladesh from 1948 to 1990. In this paper, an attempt was made to explore the the variability and trend of 20 climatic variables using the exploratory data analytic tools on monthly aspects.

Methodology

Sources of Data

The daily and monthly data for 1948-1972 and 1981-2004 on climatic factors of Dinajpur were collected from Bangladesh Meteorological Department, 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 were collected. In this study, the daily and the monthly missing data for 1973-1976 were filled in by the medians of the observed data from 1948-1972 and the missing data for 1977-1980 were filled in by the medians of the observed data from 1981-2004. Daily missing values are placed by the median of the corresponding daily data of the months/years.

Methodology

The within-year and between-year seasonal and monthly patterns were 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 was 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 were used to investigate the within-year variability pattern of data. Boxplots were considered primarily and to determine between-year seasonal and monthly variation and effects of climatic variables, year-season and year month two-way classification table are constructed and median polish were employed on it. The trend of the number of weeks containing 0–5 millimeter (ml) rainfall were investigated as it was 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 were 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 were examined from these fits by normal probability plot and the rescaled moments (RM) test for normality (Imon, 2003).

1. Exploratory Data Analyses (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 primarily used 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) and 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 they are treated as outliers. The stem-and-leaf plot is used to examine the shape and spread of 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.

Results and Discussion

The monthly climatic data of Dinajpur are analyzed over the years. The boxplots for monthly data (1-January,…,…,……,12-December) are shown in Fig.1 and the bar diagrams of the coefficient of variations of these variables are shown in Fig. 2. The month by month boxplots clearly indicate annual cycle but the opposite pictures are found in terms of CV as shown in Fig. 1 and 2. Several outliers are detected in boxplots and the stem-and-leaf plots help to get better idea about the outliers and their time occurrences but these are shown in Appendix.

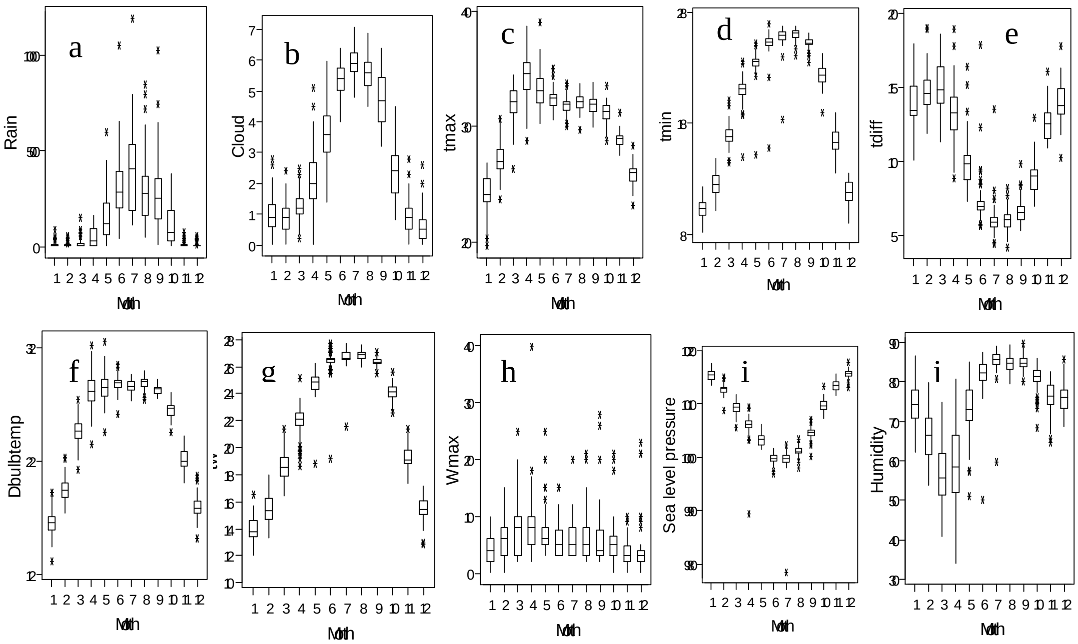

Fig.1 Boxplot of monthly (a) TR (b) AC (c) AMXT (d) AMNT(e) ARNT (f) ADBT (g) AWBT (h) AMWS (i) ASLP and (j) ARH

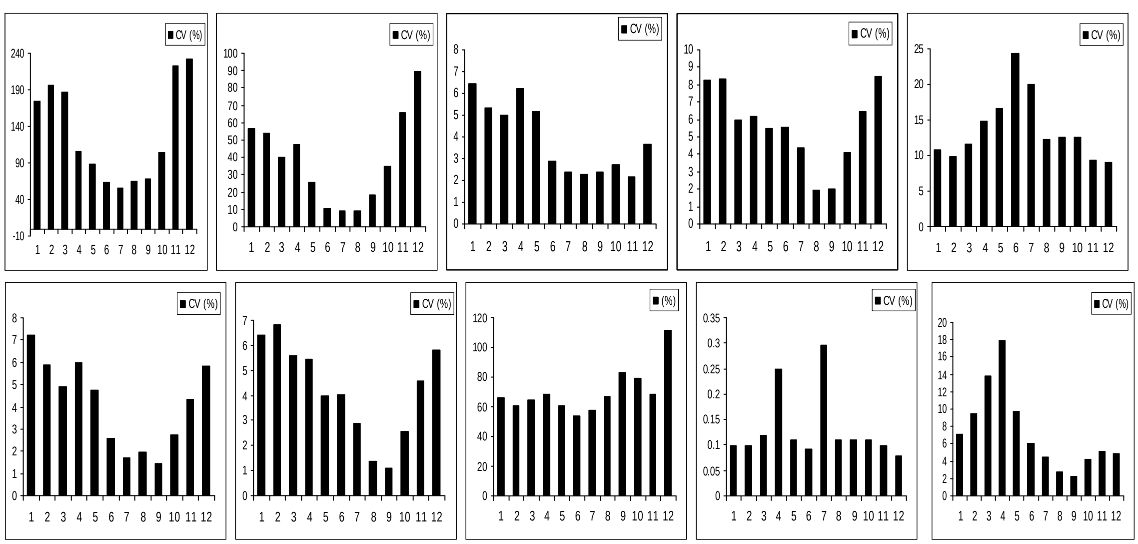

Fig. 2 Bar diagram of monthly (a) TR (b) AC (c) AMXT (d) AMNT(e) ARNT (f) ADBT (g) AWBT (h) AMWS (i) ASLP and (j) ARH

The within-year variabilities for monthly climatic variables of Dinajpur are examined. The nonrobust measurements like monthly means and CVs are presented in Table 1 and Table 2, respectively but the robust measurements are not presented in this paper. The months containing the highest and lowest means and CVs are presented in Table 3.

Table 1. Variability for monthly mean

Month	TR	AC	AE	ASH	ASLP	AMXT	AMNT	ARNT	ADBT	AWBT	AT (D-W)	AST (5cm)	AWS	AMWS	ARH	ARH (12)	ARH (0)	ARH (0-12)
Jan	9.09	1.0	17.6	5.7	1015.4	24.2	10.3	13.9	16.6	14.0	2.6	16.6	0.8	4.0	74.9	65.4	92.3	26.9
Feb	6.00	0.9	28.7	7.6	1012.7	27.2	12.5	14.7	19.5	15.5	4.0	19.3	1.0	5.5	66.1	51.7	88.4	36.7
Mar	14.42	1.3	47.3	8.2	1009.4	31.9	16.9	14.9	24.6	18.6	6.0	24.1	1.5	8.0	56.7	41.6	81.1	39.5
Apr	50.61	2.1	55.7	7.5	1005.9	34.2	21.0	13.3	28.2	21.9	6.2	28.9	1.9	8.8	59.2	47.0	80.5	33.5
May	149.2	3.6	48.0	6.9	1003.4	33.3	23.4	9.9	28.7	24.8	3.9	30.1	1.7	6.9	72.9	65.2	88.4	23.2
Jun	306.5	5.4	43.8	4.9	999.68	32.4	25.1	7.3	28.8	26.3	2.4	30.7	1.6	5.8	81.7	76.6	92.0	15.4
Jul	391.6	6.0	34.9	4.2	999.37	31.8	25.8	6.1	28.6	26.7	1.9	30.6	1.5	5.9	85.1	80.1	93.4	13.3
Aug	302.3	5.6	35.9	5.3	1001.1	32.1	26.0	6.1	28.8	26.9	2.0	30.7	1.4	5.8	84.6	79.9	93.6	13.7
Sep	280.9	4.7	32.9	5.1	1004.6	31.9	25.3	6.6	28.3	26.3	2.0	29.8	1.1	6.2	84.9	81.1	94.3	13.2
Oct	113.6	2.4	30.9	7.2	1009.7	31.2	22.3	8.9	26.5	24.1	2.4	28.0	0.7	5.4	80.9	77.0	94.1	17.2
Nov	6.95	0.9	25.3	8.0	1013.5	28.9	16.3	12.6	22.1	19.3	2.8	23.2	0.5	3.4	76.2	72.0	93.1	21.1
Dec	5.79	0.6	18.8	7.1	1015.6	25.8	11.8	14.0	18.0	15.4	2.5	18.7	0.6	4.2	76.2	70.3	93.2	23

Table 2. Variability for monthly CV

Month	TR	AC	AE	AS	ASLP	AMXT	AMNT	ARNT	ADBT	AWBT	AT (D-W)	AST (5cm)	AWS	AMWS	ARH	ARH (12)	ARH (0)	ARH (0-12)
Jan	173.7	56.5	11.3	17.0	0.1	6.5	8.3	10.8	7.2	6.4	25.6	4.0	118.6	66.1	7.1	10.8	4.2	17.1
Feb	196.2	53.8	14.8	12.1	0.1	5.3	8.3	9.8	5.9	6.8	21.7	4.7	89.5	60.7	9.4	15.7	5.3	14.9
Mar	187.3	40.2	10.9	6.8	0.1	5.0	6.0	11.7	4.9	5.6	22.6	3.9	73.1	64.3	13.8	23.8	7.8	15.0
Apr	105.6	47.2	19.7	13.6	0.2	6.2	6.2	14.9	6.0	5.4	32.9	4.6	50.1	68.4	17.9	26.6	9.6	20.5
May	88.6	25.8	20.3	15.3	0.1	5.2	5.5	16.6	4.7	4.0	34.5	4.2	36.4	60.4	9.7	11.3	4.6	20.2
Jun	62.7	10.7	17.6	24.9	0.1	2.9	5.6	24.4	2.6	4.0	30.8	1.8	44.8	53.8	6.1	6.4	2.4	23.4
Jul	55.9	9.1	20.0	29.3	0.3	2.4	4.4	20.0	1.7	2.9	29.8	2.1	59.5	57.7	4.5	5.2	1.8	23.9
Aug	64.9	9.1	20.3	19.3	0.1	2.3	2.0	12.2	2.0	1.4	17.7	2.2	49.6	67.2	2.8	3.6	1.4	21.2
Sep	68.1	18.2	15.7	21.6	0.1	2.4	2.0	12.6	1.5	1.1	14.8	1.5	54.3	83.2	2.2	3.5	1.5	16.7
Oct	104.1	34.7	8.8	15.5	0.1	2.7	4.1	12.5	2.7	2.6	20.0	1.9	73.7	79.0	4.2	5.7	2.0	20.4
Nov	223.2	65.5	10.3	7.0	0.1	2.2	6.5	9.4	4.3	4.6	19.3	4.1	96.7	68.2	5.2	7.6	2.8	17.9
Dec	232.1	89.6	11.1	9.8	0.1	3.7	8.5	9.1	5.8	5.8	17.9	5.2	85.5	111.8	4.8	9.2	3.2	19.5

Table 3. The months containing highest and lowest means and CVs

Issues	TR	AC	AE	ASH	ASLP	AMXT	AMNT	ARNT	ADBT	AWBT	AT(D-W)	AST (5cm)	AWS	AMWS	ARH	ARH (12)	ARH (0)	ARH (0-12)
HM	Jul	Jul	Apr	Mar	Dec	Apr	Aug	Mar	Aug	Aug	Apr	Jun	Apr	Apr	Jul	Sep	Sep	Mar
LM	Dec	Dec	Jan	Jul	Jul	Jan	Jan	Jul	Jan	Jan	Jul	Jan	Nov	Nov	Mar	Mar	Apr	Sep
HCV	Dec	Dec	May	Jul	Apr	Jan	Dec	Jun	Jan	Feb	May	Dec	Jan	Dec	Apr	Apr	Apr	Jul
LCV	Jul	Aug	Oct	Mar	Dec	Nov	Aug	Dec	Sep	Sep	Sep	Sep	May	Jun	Sep	Sep	Aug	Feb

HM= Highest Mean LM=Lowest Mean HCV= Highest CV LCV= Lowest CV

The monthly effect obtained from median polish table is presented in Table 4. Some are shown graphically in Fig. 4. For the variables TR, AMNT, AWBT and AC, the positive effects are found during May-October but the negative effects are observed during November-April. For the ADBT, the positive effect is determined during April-September while the negative effect is experienced during October-March but the opposite of ADBT happened in ASLP. The negative effect is found in AMXT during October- February including July, in ARNT during May-October, in ARH during December- May, in AMWS during October-January and in AWS during September-February.

Table 4. Monthly effects of monthly climatic data from median polish tables

Month	TR	AMNT	AWBT	AC	ADBT	ASLP	AMXT	ARNT	ARH	AMWS	AWS
Jan	-53.38	-11.4	-9	-1.238	-10.7	7.62	-7.756	2.686	-1.38	-1	-0.48
Feb	-57.13	-9.39	-7.7	-1.363	-7.82	4.99	-4.761	3.539	-9.94	0	-0.23
Mar	-55.63	-4.8	-4.5	-1.038	-2.69	1.54	0.214	3.809	-20.8	1.5	0.175
Apr	-12.38	-0.658	-1.03	-0.138	0.683	-1.54	2.551	2.086	-18.4	2	0.675
May	42.88	1.775	1.925	1.438	1.408	-4.49	1.151	-1.51	-2.58	1	0.4
Jun	211.9	3.558	3.425	3.163	1.465	-8.13	0.466	-4.08	5.893	0	0.375
Jul	321.88	4.1625	3.725	3.713	1.29	-8.09	-0.016	-5.26	9.438	0	0.125
Aug	199.9	4.41	3.825	3.438	1.523	-6.68	0.239	-5.03	8.645	0	0.15
Sep	177.38	3.49	3.225	2.463	0.945	-3.04	0.016	-4.63	8.185	0	-0.13
Oct	12.375	0.6575	1.025	0.138	-0.68	1.87	-0.639	-2.5	4.873	-0.5	-0.43
Nov	-57.13	-5.425	-3.73	-1.313	-5.21	5.82	-3.024	1.509	0.008	-1.875	-0.63
Dec	-57.13	-9.91	-7.6	-1.688	-9.37	7.86	-6.079	2.759	-0.01	-2	-0.65

The rates of linear trend for the year-effects obtained from median polish tables are examined and the rates for TR, AC, ARH, AMNT, ADBT, AMWS and AWS are documented positive but the rates for AMXT and ARNT are established negative but no trend is found apparently for the ASLP. The rates of trend for the variables are also examined for all the twelve months and shown in Table 5. The less positive rates for TR are established for January, June, July, August and November but less negative for March. The positive rates are fairly high in February, April, May, October and December where the residuals follow nonnormal and stationary. Significant positive rate is documented only in September (+ 4.22*).

The approximately significant negative TFIR rates are recognized in April (<u>- 0.035</u>) and significant negative rates are acknowledged for May (- 0.069*) and September (- 0.079*). The fairly high negative rates are accounted in February and December with nonnormal residual and in June with normal and stationary residual. The less negative rates are pointed in January, March and October with nonnormal and stationary residual. The very slight positive rates are found in July, August and November.

The rate of growth of MXR is found negative for January (- 0.0013), March (-0.109) and June (-0.114) but it is noted positive for February (+ 0.169), April (+ 0.242), May (+ 0.290), July (0.223), August (0.161), September (+ 1.71), October (+ 0.845), November (+ 0.056) and December (+ 0.189).Residuals are nonnormal for all cases.

The rate of growth of AC is documented less negative for August (- 0.0006) but significant positive for rest of the months of January (+0.015*), February (+0.0125*), March (+ 0.0097*), April (+0.035*), May (+0.024*), July (0.009*), September (0.025*), October (+ 0.020*), November (+ 0.013*) and December (+ 0.013*) except June (+ <u>0.0067</u>) where the rate is approximately significant.

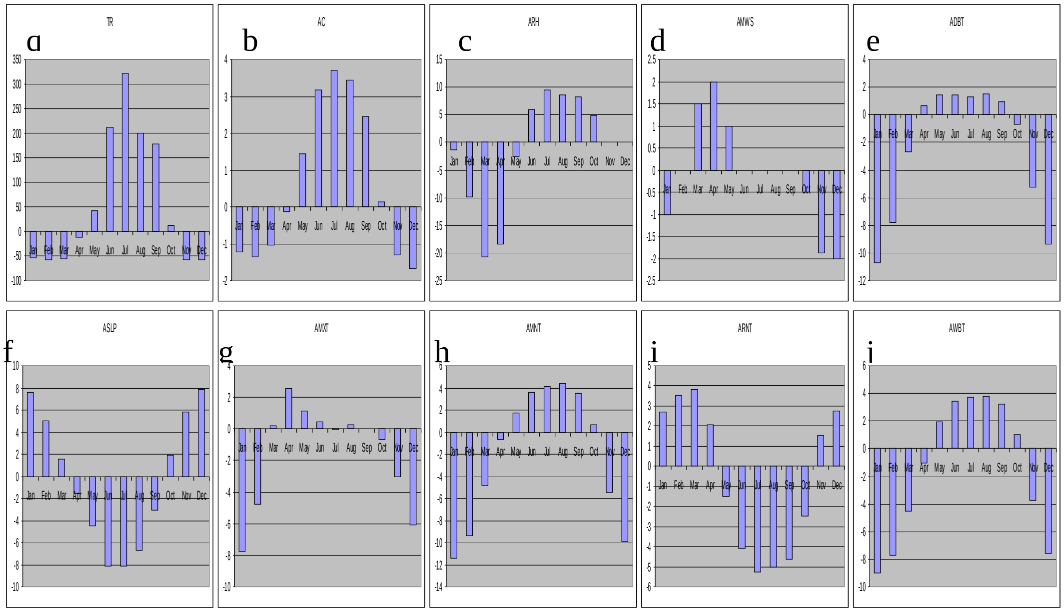

Fig. 4. Monthly effect for (a) TR (b) AC (c) ARH (d) AMWS (e) ADBT (f) ASLP (g) AMXT (h) (AMNT) (i) ARNT (j) AWBT

Table 5. The rates of LT for the climatic variables of each month

Month	TR	TFIR	MXR	AC
January	+ 0.021 (t=0.16, NN,S)	- 0.0017 (t=-0.28, NN,S)	- 0.0013 (t=-0.01,NN,S)	+ 0.015* (t=3.64, Ap.N, S)
February	+ 0.182 (t=1.98, NN,S)	- 0.012 (t=-1.95, NN,S)	+ 0.169 (t=2.61, NN,S)	+ 0.0125* (t=3.44, Ap.N, S)
March	- 0.067 (t=-0.31, NN,S)	- 0.008 (t=-0.88, NN,S)	- 0.109 (t=-0.98, NN,NS)	+ 0.0097* (t=2.51, N, S)
April	+ 0.853 (t=2.04, NN,S)	- 0.035 (t=-1.83, N,S)	+ 0.242 (t=1.38, NN,S)	+ 0.035* (t=5.54, N, S)
May	+ 1.60 (t=1.52, NN,S)	- 0.069* (t=-2.62, N,S)	+ 0.290 (t=1.08, NN,S)	+ 0.024* (t=3.59, N, S)
June	+ 0.335 (t=0.22, N,S)	- 0.034 (t=-1.25, N,S)	- 0.114 (t=-0.29, NN,S)	+ 0.0067 (t=1.46, N, S)
July	+ 1.128 (t=0.64, N,S)	+ 0.0059 (t=0.19, N,S)	+ 0.223 (t=0.49, NN,S)	+ 0.009* (t=2.37, N, S)
August	+ 0.358 (t=0.22, N,S)	+ 0.005 (t=0.21, N,S)	+ 0.161 (t=0.36 , NN,S)	- 0.0006 (t=-0.17, N, S)
September	+ 4.22* (t=2.92, Ap.N,Ap.S)	- 0.079* (t=-3.74, N,S)	+ 1.71 (t=2.34, NN,S)	+ 0.025* (t=4.27, Ap.N, S)
October	+ 1.47 (t=1.57, NN,S)	- 0.0139 (t=-0.81, N,S)	+ 0.845 (t=1.66, NN,S)	+ 0.020* (t=3.31, N , S)
November	+ 0.059 (t=0.47, NN,S)	+0.00006 (t=0.01, NN,S)	+ 0.056 (t=0.65, NN,S)	+ 0.013* (t=2.84, Ap. N, S)
December	+ 0.284 (t=2.78, NN,S)	- 0.017 (t=-2.87, NN,S)	+ 0.189 (t=2.78, NN,S)	+ 0.013* (t=3.58, Ap. N , S,)

*Significant at 5% level of significance, The underlined values are considered as approximately significant, S = Stationary, NS = Nonstationary N = Normal, NN = Nonnormal

The rates of monthly ADBT are obtained less positive for February (+ 0.006) and October (+ 0.003), and approximately significant positive for June (+ 0.009) and significant positive for July (+ 0.008*), August (+ 0.014*), November (+ 0.027*) and December (+ 0.021*) but the fairly high negative rates are observed for January (– 0.012) and September (– 0.004), approximately significant negative rates for March (– 0.014) and significant negative rates for April (– 0.044*) and May (– 0.023*).

The rates of monthly AMXT is established as significant negative for January (- 0.063*), February (- 0.036*), April (- 0.062*), May (- 0.031*), September (- 0.015*) and December (- 0.019*). The fairly high negative rate is found for March (- 0.048) with nonnormal but stationary residual and for October (- 0.008) with normal and stationary residual. The nearly significant positive rates are originated for June (+ 0.010) and November (+ 0.007) and significant positive for August (+ 0.013*) and less positive for July (+ 0.055).

The growth rates of AMNT are formed less negative for January (– 0.0005) and October (– 0.0004) with normal and stationary residual. The rates are also less negative for May (– 0.002) and September (– 0.001) with nonnormal and stationary residual. But the rates are observed as significant positive for February (+ 0.0205*), March (+ 0.015*), August (0.008*), November (0.025*) and December (0.024*) and less positive for April (+ 0.005) with nearly normal and stationary residual and for June (0.007) and July (0.002) with nonnormal and stationary residual.

The rates of ARNT are found significant negative for January (– 0.063*), February (– 0.057*), March (– 0.063*), April (– 0.068*), May (– 0.029*), September (– 0.014*), November (– 0.018*) and December (– 0.043*) and less negative for October (– 0.008) but positive for June (+ 0.003) and July (+ 0.003) with nonnormal and stationary residual and for August (+ 0.004) with normal and stationary residual.

Table 5. continued

Month	ADBT	AMXT	AMNT	ARNT
Jan	– 0.012 (t=-1.30, N,NS)	- 0.063* (t=-6.82, N,S)	– 0.0005 (t=-0.08,N,S)	– 0.063* (t=-7.29, N, S)
Feb	+ 0.006 (t=0.71, N,S)	- 0.036* (t=-3.46, N,S)	+ 0.0205* (t=2.57,N,S)	– 0.057* (t=-6.49, Ap.N, S)
Mar	– 0.014 (t=-1.46, N,S)	- 0.048 (t=-4.32, NN,S)	+ 0.015* (t=1.95,Ap.N,S)	– 0.063* (t=-5.69, Ap.N, S)
Apr	– 0.044***** (t=-3.57, N,S)	- 0.062* (t=-4.16, N,S)	+ 0.005 (t=0.55,Ap.N,S)	– 0.068* (t=-5.20, N, S)
May	– 0.023***** (t=-2.19, N,S)	- 0.031* (t=-2.39, N,S)	– 0.002 (t=-0.24,NN,S)	– 0.029* (t=-2.29, Ap.N, S)
Jun	+ 0.009 (t=1.60, Ap.N,S)	+ 0.010 (t=1.46, Ap.N,S)	+ 0.007 (t=0.62,NN,S)	+ 0.003 (t=0.26, NN, S)
Jul	+ 0.008* (t=2.25, N,S)	+ 0.055 (t=0.91, N,S)	+ 0.002 (t=0.24,NN,S)	+ 0.003 (t=0.34, NN, S)
Aug	+ 0.014* (t=3.54, N,S)	+ 0.013* (t=2.43, N,S)	+ 0.008* (t=2.26,Ap.N,S)	+ 0.004 (t=0.82, N, S)
Sep	– 0.004 (t=-1.23, N,S)	- 0.015* (t=-2.64, N,S)	– 0.001 (t=-0.32,NN,S)	– 0.014* (t=-2.17, Ap.N ,S)
Oct	+ 0.003 (t=0.67, N,S)	- 0.008 (t=-1.33, N,S)	– 0.0004 (t=-0.05, Ap.N,S)	– 0.008 (t=-0.95, Ap.N, S)
Nov	+ 0.027***** (t=4.06, Ap.N, Ap.S)	+ 0.007 (t=1.45, Ap.N,S)	+ 0.025* (t=3.28, N,S)	– 0.018* (t=-2.01, Ap.N, S)
Dec	+ 0.021* (t=2.69, N,S)	- 0.019* (t=-2.61,N,S)	+ 0.024* (t=3.26, N,S)	– 0.043* (t=-5.08, Ap.N, S)

The rates of AWBT are recognized as positive for all the twelve months. The significant positive rates are observed for February (+ 0.03*), March (+ 0.029*), April (+ 0.025*), August (0.011*), November (0.03*) and December (0.029*). The approximately significant positive rates are documented for October (0.007) and the relatively less positive rates are noted for January (+ 0.004), September (0.002) with normal and stationary residual and for May (+ 0.006) with nonnormal and stationary residual. The relatively high rates are established for June (+ 0.011) and July (+ 0.008) with nonnormal and stationary residual.

The rates of AT(D-W) are acknowledged as significant negative for March (– 0.043*), April (– 0.069*), May (– 0.029*) and September (– 0.006*), the fairly high negative rates are observed for January (– 0.017), February (– 0.023) and December (– 0.007) and less negative rates are established for June (– 0.001), October (– 0.003) and November (– 0.002) where all the residuals are nonnormal and/or nonstationary. On the other hand, the rates are found less positive for July (+ 0.0004) with nonnormal residual and the fairly high positive for August (+ 0.003).

AST is approved positive for all the twelve months. The significant rates are experienced for July (0.084*), September (+ 0.06*) and November (+ 0.14*), and the approximately significant rates are obtained for June (+0.057) and August (+ 0.07), and the fairly high rates are originated for March (0.065) and May (0.13) with nonstationary residual and established for October (+ 0.04) and December (+ 0.07) with normal and stationary. The less positive rates are found for January (0.032), February (0.045) and April (0.067) with normal and stationary residual.

The rates of ASLP are established as significant negative for January (- 0.018*) and November (- 0.018*), nearly significant negative for March (- 0.017) and less negative for May (- 0.007) and December (- 0.0017). The less positive rates are acknowledged for June (+0.00 3), August (+ 0.005) and October (+ 0.0015) with normal residual and for July (+0.0179) with nonnormal residual. The fairly high positive rates are found for April (+ 0.023) with nonnormal residual and for September (+0.00 9) with normal residual.

Table 5. continued

Month	AWBT	AT(D-W)	AST(5cm)	ASLP
Jan	+ 0.004 (t=0.67, N,S)	– 0.017 (t=-3.49, N, NS)	+ 0.032, (t=0.72,Ap.N, S)	- 0.018* (t=-2.27, Ap.N,S)
Feb	+ 0.03* (t=4.02, N,S)	– 0.023 (t=-3.79, N, NS)	+ 0.045, (t=0.74,Ap.N, S)	+ 0.011 (t=1.50, N,S)
Mar	+ 0.029* (t=4.02, Ap.N,S)	– 0.043* (t=-4.73, N,S)	+ 0.065, (t=1.05,N,NS)	- 0.017 (t=-1.79, N,S)
Apr	+ 0.025* (t=2.84, N,S)	– 0.069* (t=-5.06, N,S)	+ 0.067 (t=0.75,N, S)	+ 0.023 (t=1.16, NN,S)
May	+ 0.006 (t=0.83, NN,S)	– 0.029* (t=-2.95, N,S)	+ 0.13 (t=1.65, N, NS)	- 0.007 (t=-0.85, N,S)
Jun	+ 0.011 (t=1.32, NN,S)	– 0.001 (t=-0.32, NN,S)	+ 0.057 (t=1.65,N, Ap.S)	+0.00 3 (t=0.42, N,S)
Jul	+ 0.008 (t=1.33, NN,S)	+ 0.0004 (t=0.09, NN,S)	+ 0.084* (t=2.33,Ap.N, S)	+ 0.0179 (t=0.75, NN,S)
Aug	+ 0.011* (t=4.49, N,S)	+ 0.003 (t=1.27, N,S)	+ 0.07 (t=1.66, N,S)	+ 0.005 (t=0.62, N,S,)
Sep	+ 0.002 (t=0.91, N,S)	– 0.006* (t=-2.79, N,S)	+ 0.06* (t=2.39,N,Ap.S)	+0.00 9 (t=1.11, N,S)
Oct	+ 0.007 (t=1.58, N,S)	– 0.003 (t=-0.98, NN, NS)	+ 0.04 (t=1.31,N, S)	+ 0.0015 (t=0.17,N,S)
Nov	+ 0.03* (t=5.12, N,S)	– 0.002 (t=-0.59, N, NS)	+ 0.14* (t=2.99,N, S)	- 0.018* (t=-2.47, Ap.N,S)
Dec	+ 0.029* (t=4.82, N,S)	– 0.007 (t=-2.23,N, NS)	+ 0.07 (t=1.23,N, S)	- 0.0017 (t=-0.27, N,S)

The growth rates of ARH are noted as significant positive for January (+0.155), March (+0.256*), April (+0.350*), May (+0.149*) and September (+0.039*). The fairly high positive rates are observed for February (0.188), October (0.031), November (0.052) and December (0.106), and extremely less positive rates are obtained for June (+0.003) where all the residuals are nonstationary. The less negative rate is found for July (-0.008) with nonnormal residual and the approximately significant negative rate is established for August (- 0.029).

The growth rates of ARH (0) are pointed as significant positive for January (+0.166*), February (+0.203*), March (+0.234*), April (+0.293*), May (+0.128*), September (+0.062*) October (+0.081*) and December (+0.145*) and the fairly high positive rates for June (+0.057), July (+0.040), August (+0.034), and November (+0.124) with nonnormal and/or nonstationary residual.

The growth rates of ARH (12) are found significant positive for January (+0.317*), February (+0.259*), April (+0.397*), May (+0.135*), September (+0.087*), October (+0.130*) November (0.228*) and December (0.321*) and fairly high rate for March (0.279) with nonnormal residual whereas less negative rates for June (- 0.0110) and July (- 0.011) with nonnormal residual and relatively high rate for August (- 0.030) with normal and stationary residual.

The growth rates of ARH(0-12) are documented as significant negative for January (– 0.151*), November (– 0.103*) and December (– 0.175*) but positive for July (+0.051*) and August (+0.065*) whereas approximately significant negative for April (– 0.104) and October (– 0.048). The relatively high negative rates are originated for February (–0.0 56) and September (– 0.025), and less negative rate for May (– 0.007) with normal and stationary residual but the less negative rate for March (– 0.044) and fairly high positive rate for June (+0.068) are documented with nonnormal residual.

Table 5. continued

Month	ARH	ARH (0)	ARH (12)	ARH(0-12)
Jan	+ 0.155* (t=4.11, Ap.N,Ap.S,)	+ 0.166 *(t=7.55 N, S)	+ 0.317* *(t=8.30, Ap.N, Ap.S)	– 0.151* (t=-4.83, N, Ap.S)
Feb	+ 0.188 (t=4.29, N,NS)	+ 0.203 *(,t=7.80 N, Ap.S)	+ 0.259 *(t=4.63, Ap.N, S)	–0.0 56 (t=-1.29, Ap.N, S)
Mar	+ 0.256* (t=4.80, N,S)	+ 0.234* (,t=5.83 N, S)	+ 0.279 (t=3.93, NN, S)	– 0.044 (t=-0.94, NN, S)
Apr	+ 0.350* (t=4.87, N,S)	+ 0.293* (t=6.02, N, S)	+ 0.397* (t=4.62, N, S)	– 0.104 (t=-1.93, N, S)
May	+ 0.149* (t=2.77, N,S)	+ 0.128* (t=4.57, N, S)	+ 0.135* (t=2.38, N, S)	– 0.007 (t=-0.19, N, S)
Jun	+ 0.003 (t=0.08, NN,S)	+ 0.057 (t=3.45, NN, S)	- 0.0110 (t=-0.28, NN, S)	+ 0.068 (t=2.46, NN, S)
Jul	- 0.008 (t=-0.27, NN,S)	+ 0.040 (t=3.18, NN, S)	- 0.011 (t=-0.34, NN, S)	+ 0.051* (t=2.09, Ap.N, S)
Aug	- 0.029 (t=-1.57, N,S,)	+ 0.034 (t=3.70, NN, S)	- 0.030 (t=-1.33, N, S)	+ 0.065* (t=2.99, Ap.N, S)
Sep	+ 0.039* (t=2.81, N,S)	+ 0.062* (t=7.99, N, S)	+ 0.087* (t=4.44, N, S)	– 0.025 (t=-1.45, N, S)
Oct	+ 0.031 (t=1.15, NN, NS)	+ 0.081* (t=7.71, Ap.N, S)	+ 0.130 *(t=4.18, Ap.N, S)	– 0.048(t=-1.74, Ap.N, S)
Nov	+0.0 52 (t=1.15, NN,NS,)	+ 0.124 (t=9.34, N, NS)	+ 0.228* (t=7.22, N, S)	– 0.103* (t=-3.80, N, S)
Dec	+ 0.106 (t= 4.40, N,NS,)	+ 0.145* (t=10.69, N, S)	+ 0.321* (t=10.76, N, Ap.S)	– 0.175* (t=-6.37, N, Ap.S)

The rate of growth of AE is obtained significant negative for April (-1.40*****) and the approximately significant negative for January (- 0.196), June (- 0.877), August (- 0.877) and October (- 0.308). The fairly high negative rates are found for May (- 0.879), September (- 0.468), November (- 0.220) and December (- 0.169) with normal and stationary residual. The less negative rates are found for February (- 0.198), March (- 0.048) and July (- 0.295) with normal and stationary residuals. The rates of growth of ASSH are found as significant negative for April (- 0.113*) and less negative for January (- 0.051), March (- 0.024), June (- 0.036), October (- 0.037), November (- 0.017) and December (- 0.017) with normal and stationary residual. The less positive rates are observed for February (+ 0.036), May (+ 0.047), July (+ 0.006), August (+0.009) and September (+0.023). The rate of growth of AMWS is experienced positive in all the twelve months (January, + 0.097; February, + 0.097; March, +0.170; April, +0.086; May, +0.089; June, +0.067; July, +0.047; August, +0.038; September, +0.031; October, +0.025; November, +0.080; and December +0.067) but the residuals are nonstationary and/or nonnormal. The rate of growth of AWS is found positive in all the twelve months of (January, +0.029; February, +0.025; March, +0.028; April, (+0.017); May, +0.010; June, +0.016; July, +0.020; August, +0.0181; September, +0.018; October, +0.015; November, +0.016; and December, +0.017) but the residuals are nonstationry and/or nonnormal.

Table 5. continued

Month	AE	ASSH	AMWS	AWS
Jan	- 0.196 (t=-1.57,N, S)	- 0.051 (t=-0.97,Ap.N, Ap.S)	+ 0.097 (N, S)	+ 0.029 (NN, S)
Feb	- 0.198 (t=-0.69,N, S)	+ 0.036 (t=0.72,N, S)	+ 0.097 (N, NS)	+ 0.025 (NN, NS)
Mar	- 0.048 (t=-0.14,N, S)	- 0.024 (t=-0.79,Ap,N, S)	+ 0.170 (NN, S)	+ 0.028 (NN, NS)
Apr	- 1.40 * (t=-2.18,Ap.N, S)	- 0.113* (t=-2.37,N, S)	+ 0.086 (NN, NS)	+ 0.017 (NN, NS)
May	- 0.879 (t=-1.41,N, S)	+ 0.047 (t=0.83,N,S)	+ 0.089 (NN, S)	+ 0.010 (NN, NS)
Jun	- 0.877 (t=-1.88,N, Ap.S)	- 0.036 (t=-0.54,N, S)	+ 0.067 (NN, NS)	+ 0.016 (NN, NS)
Jul	- 0.295 (t=-0.62,N, S)	+ 0.006 (t=0.09,N, S)	+ 0.047 (NN, S)	+ 0.020 (NN, S)
Aug	- 0.745 (t=-1.64,Ap.N, S)	+ 0.009 (t=0.16,N, Ap.S)	+ 0.038 (NN, S)	+ 0.0181 (N, NS)
Sep	- 0.468 (t=-1.42,N,Ap.S)	+ 0.023(t=0.37,Ap.N, Ap.S)	+ 0.031 (NN, S)	+ 0.018 (N, NS)
Oct	- 0.308 (t=-1.87,N,S)	- 0.037 (t=-0.61,N, Ap.S)	+ 0.025 (NN, S)	+ 0.015 (NN, NS)
Nov	- 0.220 (t=-1.30,N, S)	- 0.017 (t=-0.55,Ap.N, S)	+ 0.080 (NN, S)	+ 0.016 (NN, NS)
Dec	- 0.169 (t=-1.25,N, S)	- 0.017 (t=-0.45,N, S)	+ 0.067 (NN, S)	+ 0.017 (NN, NS)

During January, the observed growth rates are negative for AMXT, ARNT, ADBT, AMNT, AT(D-W) and ARH(0-12) but positive for AWBT, AST, ARH(0), ARH(12) and ARH.

During February, the experienced growth rates are negative for AMXT, ARNT, AT(D-W) and ARH(0-12) but positive for AMNT, ADBT, AST , ARH(0) and ARH(12).

During March, the obtained growth rates are negative for AMXT, ARNT, ADBT, AT(D-W) and ARH(0-12) but positive for AMNT, AWBT, AST, ARH(0) and ARH(12).

During April, the agreed growth rates are negative for AMXT, ARNT, ADBT, AT(D-W) and ARH(0-12) but positive for AMNT, AWBT, AST, ARH(0) and ARH(12).

During May, the arranged growth rates are negative for AMXT, AMNT, ARNT, ADBT, AT(D-W) and ARH(0-12) but positive for AWBT, AST, ARH(0) and ARH(12).

During June, the decided growth rates are positive AMXT, AMNT, ARNT, ADBT, AWBT, AST, ARH(0) and ARH(0-12) but negative for AT(D-W) and ARH(12).

During July, the settled growth rates are positive AMXT, AMNT, ARNT, AWBT, AT(D-W), ADBT, AST, ARH(0) and ARH(0-12) but negative for ARH(12).

During August, the established growth rates are positive AMXT, AMNT, ADBT, AWBT, ARNT, AT(D-W), AST, ARH(0) and ARH(0-12) but negative for ARH(12).

During September, the determined growth rates are negative for AMXT, ARNT, ADBT, AT(D-W) and ARH(0-12) but positive for AMNT, AWBT, AST, ARH(0) and ARH(12).

During October, the computed growth rates are negative for AMXT, ARNT, ADBT, AT(D-W) and ARH(0-12) but positive for AMNT, AWBT, AST, ARH(0) and ARH(12).

During November, the documented growth rates are positive for AMXT, AMNT, ADBT, AWBT, AST, ARH(0), ARH(12), AMNT and AWBT but negative for ARNT, AT(D-W) and ARH(0-12).

During December, the permitted growth rates are negative for AMXT, ARNT, AT(D-W) and ARH(0-12) but positive for AMNT, ADBT, AWBT, AST, ARH(0) and ARH(12).

Conclusions

Significant changes in some monthly climatic variables support that the climate of Dinajpur district is changing and these knowledge may help for the proper planning and management practices of growth stage of crop in Dinajpur. Some residuals demonstrate stationary pattern but several follow nonstationarity but a few support normal distribution and others error show nonstationarity. 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.

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