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Regional Differentials of Annual Average Humidity over Bangladesh

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Abstract

The annual average humidity of 30 meteorological stations of Bangladesh has been studied over the period (1981-2008). Trends, periodicities and frequency distribution of the annual average humidity are found by the standard statistical techniques. The test of normality of the frequency distribution of the annual average humidity is done by the method suggested by Geary (1935, 1936). It is seen that the frequency distribution of most of the stations of Bangladesh follow normal distribution. Positive trends are shown for the data of Dinajpur, Rajshahi, Mymensingh, Ishurdi, Jessore, Madaripur, Satkhira, Hatiya, Sitakunda, Teknaf & Patuakhali, while Dhaka the capital of Bangladesh has negative trend. The periodigram analyses of the annual average humidity of most of the stations show a significant cycle of range 8 to 12 years.

Introduction

Bangladesh has a tropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures and high humidity. Three seasons are generally distinctly recognized in Bangladesh, a hot, muggy summer season from March to June, a hot, humid and rainy monsoon season from June to November, and a warm hot, dry winter season from December to February. The country of Bangladesh is mainly agricultural. The agricultural activities of our country largely depend on climate. But due to unnatural behavior of atmosphere, the cultivation is often hampered. Humidity (atmospheric moisture) is an important component of environment. Atmospheric moisture level has significant influence on plant growth and development. Both very low and high relative humidity may cause some physical discomfort mainly indoor diseases as the relative humidity of the air directly affects temperature. Therefore, considering the humidity as one of the important components of plant growth and physiology, the present study is a modest attempt to thoroughly analyze the humidity data of Bangladesh during the periods (1981-2008).

In this paper the main focus of this study is to analyze the annual average humidity of Bangladesh. For this purpose the annual average humidity of 30 meteorological stations of Bangladesh has been studied on the basis of available data of 28 years (1981-2008). Then the frequency distribution, trends and periodicities of the annual average humidity are investigated. The data of Humidity in percentage of 30 meteorological stations for 28 years (1981-2008) were taken from Climatology Division of Bangladesh Meteorological Department (BMD).

Some Characteristics of the Humidity

The mean annual average humidity of each station on the basis of the available data shows that the area of Bangladesh like Barisal, Bhola, Maijdi Court, Hatiya, Sandwip, Patuakhali, Khepupara and Comilla are recorded the highest average humidity of Bangladesh ranging from

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80.14 (%) to 82.82 (%) where as the lowest annual humidity ranging from 74.11 (%) to 76.75 (%) is observed to the north and north east part of the country. The highest standard deviation of annual average humidity is amounting to 4.273 recorded in Dinajpur and the lowest standard deviation of annual average humidity is amounting to 1.036 recorded in Feni. The co-efficient of variation of humidity of the stations ranges from 1.303 percent to 5.657 percent. It is highest in Dinajpur followed by Mymensingh, Satkhira and Madaripur and lowest in Feni followed by Chandpur and Khulna. The minimum annual average humidity is recorded in Dinajpur followed by Mymensingh and the maximum humidity is recorded in Khepupara followed by Patuakhali and Bhola. The relative variation of humidity (CV) in Table 1 indicates that the variations of humidity across the country are wide.

Table 1: Descriptive statistics of yearly average humidity (%) of different stations

Stations	Min (^{0}F)	Max (^{0}F)	Mean (%)	Mean Deviation (MD)	Std. Deviation (SD)	Skewness ($\sqrt{\beta_1}$)	Kurtosis (β_2)	CV (%)	$a=\frac{MD}{SD}$
DINAJPUR	67	81	75.54	3.597	4.273	-0.605	-0.964	5.657	0.842
RANGPUR	72	84	79.54	1.564	2.301	-1.346	3.671	2.893	0.679
RAJSHAHI	73	80	76.75	1.429	1.777	0.024	-0.476	2.315	0.804
BOGRA	74	82	77.39	1.492	1.912	0.074	0.177	2.471	0.780
MYMENSINGH	68	83	78.32	2.827	3.878	-1.485	1.563	4.951	0.729
SYLHET	75	80	78.11	1.250	1.499	-0.551	-0.573	1.919	0.834
SRIMONGAL	72	83	79.21	2.153	2.859	-1.072	0.742	3.609	0.753
ISHURDI	71	79	76.04	2.033	2.516	-0.764	-0.266	3.309	0.808
DHAKA	71	77	74.11	1.281	1.663	-0.078	-0.596	2.244	0.770
COMILLA	78	84	80.68	1.439	1.786	-0.021	-0.874	2.214	0.806
CHANDPUR	78	82	79.07	0.811	1.052	0.878	0.637	1.330	0.771
JESSORE	74	81	77.96	1.689	1.953	-0.428	-1.129	2.505	0.865
FARIDPUR	76	81	77.96	0.974	1.290	0.294	-0.180	1.655	0.755
MADARIPUR	71	81	76.89	3.028	3.457	-0.187	-1.455	4.508	0.875
KHULNA	78	83	79.79	0.934	1.258	0.315	0.363	1.577	0.742
SATKHIRA	69	81	75.89	3.153	3.725	-0.853	-0.815	4.908	0.846
BARISAL	79	85	82.82	1.242	1.679	-1.113	0.922	2.027	0.739
BHOLA	79	86	82.68	1.170	1.565	-0.107	0.359	1.893	0.748
FENI	78	81	79.50	0.893	1.036	-0.107	-1.089	1.303	0.862
M. COURT	73	83	80.14	1.337	2.031	-2.035	5.129	2.534	0.658
HATIYA	78	83	80.61	1.492	1.750	-0.014	-1.285	2.171	0.852
SITAKUNDA	72	83	78.46	2.689	3.191	-0.649	-0.723	4.067	0.843
SANDWIP	76	85	82.64	1.388	1.967	-1.976	4.483	2.380	0.706
COX'SBAZAR	76	81	79.04	1.043	1.374	-0.438	-0.473	1.738	0.759
TEKNAF	71	84	77.82	2.457	3.031	-0.538	-0.153	3.895	0.822
RANGAMATI	75	81	77.93	1.378	1.783	-0.096	-0.530	2.288	0.773
PATUAKHALI	73	86	81.64	2.128	2.909	-1.417	2.094	3.563	0.732
KHEPUPARA	75	88	80.39	1.793	2.657	0.320	2.099	3.305	0.675
CHUADANGA	71	77	74.46	1.316	1.598	-0.135	-0.569	2.146	0.823
CHITTAGONG	73	80	78.04	1.181	1.575	-1.227	2.410	2.018	0.749

Probability Distribution of the Yearly Average Humidity

Yearly average humidity of the different stations over the Bangladesh for the period 1981-2008 have been used to test whether the frequency distribution of the yearly average humidity follows normal or not.
We know departure of

$$\sqrt{\beta_1} = \frac{(\ 3rdcentralmoment\ )^2}{(2ndcentralmoment)^3} = \frac{\mu_3{}^2}{\mu_2{}^3}$$

From the normal value of zero is an indication of skewness in the frequency function of the sampled population, while departure is,

$$\beta_2 = \frac{(4thcentralmoment)}{(2ndcentralmoment)^2} = \frac{\mu_4}{\mu_2{}^2}$$

from the normal value of 3 is an indication of kurtosis, for a large samples rough tests of normality may be obtained by comparing $\sqrt{\beta_1}$ and (β_2-3) with the approximate value of their standard error, viz, $\sqrt{\sigma/n}$ and $\sqrt{24/n}$ respectively. But β_2 cannot be safely used if the sample size is less than 200.
R. C. Geary (1935, 1936) has suggested an alternative statistic which may be used for detecting change in kurtosis. Particularly when samples contain less than 50 observations, the statistic is,

$$a = \frac{\text{Mean Deviation}}{\text{Standard Deviation}}$$

$$= \frac{\frac{1}{n}\sum_{i=1}^{n}\left|x_i - \bar{x}\right|}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}}$$

For the normal population itself, this ratio has the value, $a = \sqrt{2/\pi} = 0.7979$, the ratio will be higher for platykurtic and lower for leptokurtic distributions. We have data of annual average humidity for 28 years of 30 stations. To test the normality of the frequency distribution for the annual average humidity, we calculate $\sqrt{\beta_1}$ and a. Table 1 gives the values of these two statistics $\sqrt{\beta_1}$ and a for yearly average humidity. For sample size n=30, using table 34 B of Biometrika tables critical values at 5% level of significance for the measures of skewness is 0.662. So departures of $\sqrt{\beta 1}$ from the normal value of zero for humidity are insignificant in most of the stations except the station Chandpur. Similarly, using table 34A of Biomatrika tables for the sample size 30, the upper critical value at 5% level is 0.8625 and lower critical value at 5% level is 0.7404.Our calculated value of ‘a’ lies between the two critical values in most of the stations except the stations Jessore and Madaripur. Hence the frequency distribution of different stations over the Bangladesh more on less follows the normal distribution other than the Chandpur, Jessore and Madaripur.

Test of Randomness and Analysis of Trends

Before examining the trends of a time series meteorological data it is essential to test the randomness of the series. The test statistic for randomness is given by

$$\tau_t = \frac{4p}{n(n-1)} - 1$$

Where p is the number of pairs in which $u_j > u_i$, for j>i where u_j and u_i are the jth and ith observations of the series and n is the total number of observations in the series. This test was suggested by Mann (1945). The value of τ will be tested for significance by the statistics τ_t which is defined by the formula $\tau_t = t_g \sqrt{\frac{4n+10}{9n(n-1)}}$

Where t_g is the value at α% point normal distribution approximately for two tailed test.
Table: 2 shows that the value of τ statistic for all 30 stations. It is seen from the table that only the value of τ for Rajshahi, Ishurdi and Hatiya are significant at 5% level of significance whereas the value of τ for Dinajpur, Mymensingh, Dhaka, Jessore, Madaripur, Satkhira, Sitakunda, Teknaf and Patuakhali are significant at 1% level of significance. Thus we can conclude that the data of those twelve stations have significant trends.

In this study, the humidity data of all the stations are divided into two equal parts on the basis of available data for each station. Student t- test is performed to the mean differences of two periods for each station and the results are presented in Table: 2. As the frequency distribution of average humidity of Chandpur, Jessore and Madaripur are not normal; Mann-Whitney U- test is performed instead of t- test. From Table: 2 it is observed that the significant trends are noticed for the data of stations Dinajpur, Rajshahi, Mymensingh, Ishurdi, Dhaka, Jessore, Madaripur, Satkhira, Hatiya, Sitakunda, Teknaf and Patuakhali. Trends values of those twelve stations are computed and presented in Figure: 1(1) to Figure: 1(12).

Table 2: Mann-Kendall, Student's t, Mann-Whitney U test results of yearly average humidity (%) of different stations:

Station	Mann-Kendall Statistic (S)	Variance(S)	Kendall's tau	Student's t value	Mann-Whitney U Value
Dinajpur	207	2525.667	0.568**	-4.853**	22.50**
Rangpur	15	2428.333	0.043	-0.733	86
Rajshahi	116	2467.333	0.33*	-2.721*	43*
Bogra	75	2471.000	0.213	-0.886	73.5
Mymensingh	220	2486.667	0.617**	-3.556**	30**
Sylhet	-25	2414.333	-0.073	-0.623	98
Srimangal	-2	2444.000	-0.006	-1.06	84
Ishurdi	128	2486.000	0.361*	-2.99**	44.50*
Dhaka	-172	2435.333	-0.496**	-2.967**	98**
Comilla	6	2444.667	0.017	-0.104	98

Cont. Table

Station	Mann-Kendall Statistic (S)	Variance(S)	Kendall's tau	Student's t value	Mann-Whitney U Value
Chandpur	-50	2300.667	-0.155	-0.354	98
Jessore	146	2419.333	0.427**	-3.272**	38.50**
Faridpur	29	2403.667	0.085	-0.433	82
Madaripur	190	2481.333	0.536**	-9.136**	2.5**
Khulna	-56	2252.667	-0.173	-1.212	98
Satkhira	137	2419.000	0.395**	-3.978**	41**
Barisal	-30	2407.333	-0.088	-0.556	98
Bhola	11	2367.000	0.033	-0.597	98
Feni	9	2347.667	0.027	-0.359	92
M.Court	46	2301.333	0.139	-1.122	81.5
Hatiya	99	2467.667	0.283*	-0.106	95.5
Sitakunda	211	2503.000	0.588**	-6.491**	6**
Sandwip	79	2380.333	0.233	-0.408	68.5
Cox's Bazar	-6	2404.667	-0.018	-0.135	93.5
Teknaf	175	2472.333	0.496**	-3.706**	27**
Rangamati	46	2451.333	0.132	-1.519	66.5
Patuakhali	143	2465.667	0.406**	-2.57*	50*
Khepupara	69	2419.000	0.200	-0.491	72
Chuadanga	-84	2424.667	-0.244	-1.579	98
Chittagong	94	2412.667	0.275	-0.855	65.5

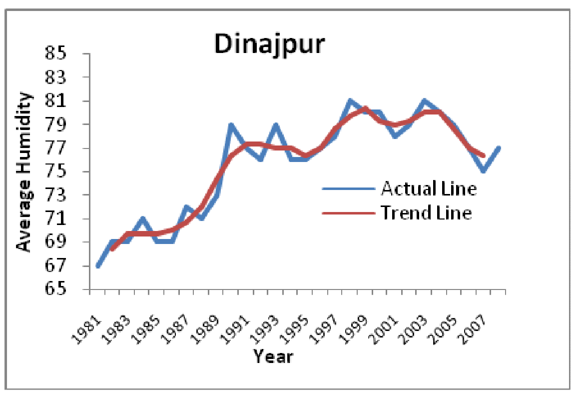
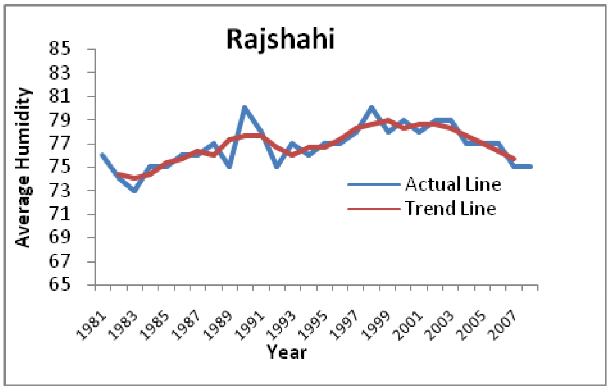


Figure: 1(1)



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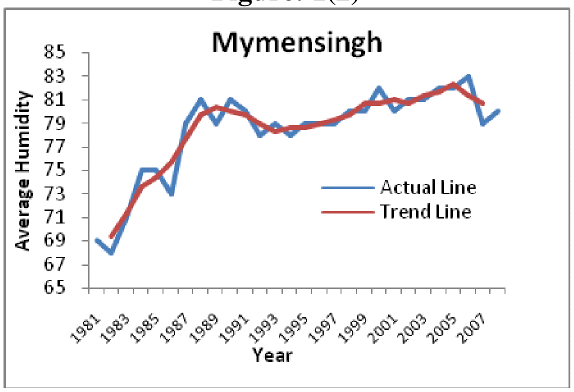

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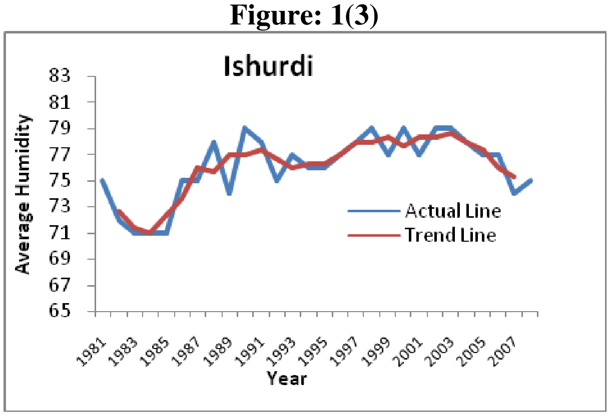

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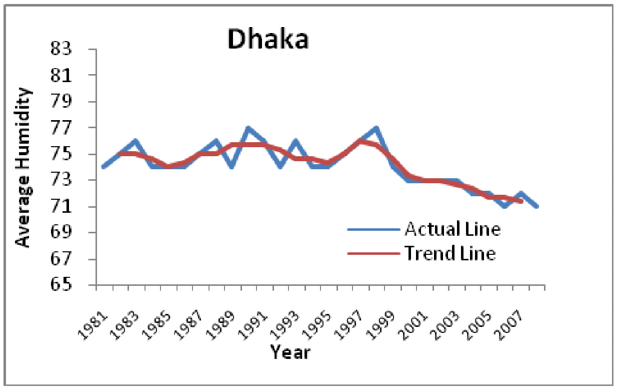

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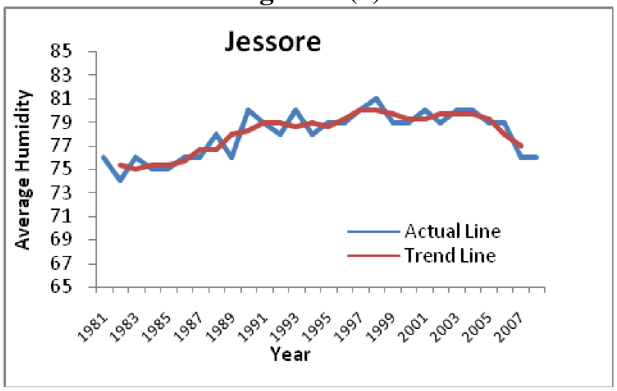

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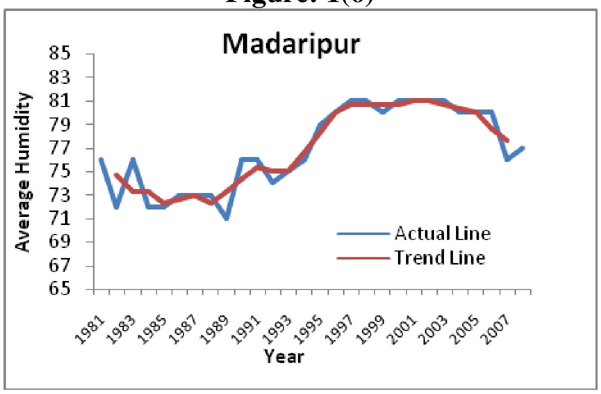

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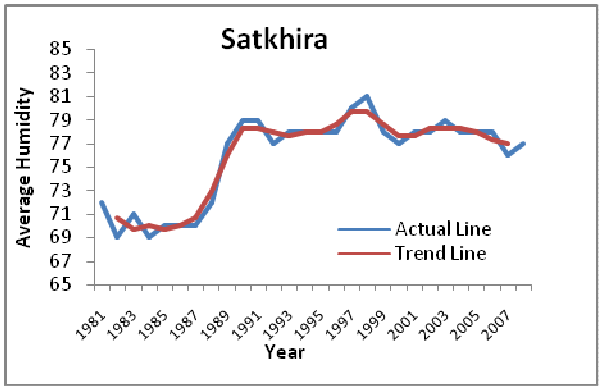

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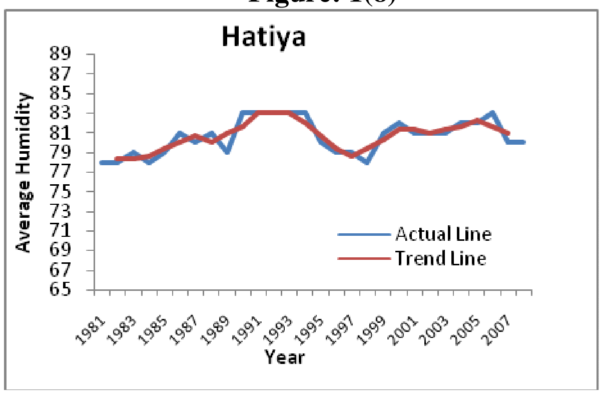

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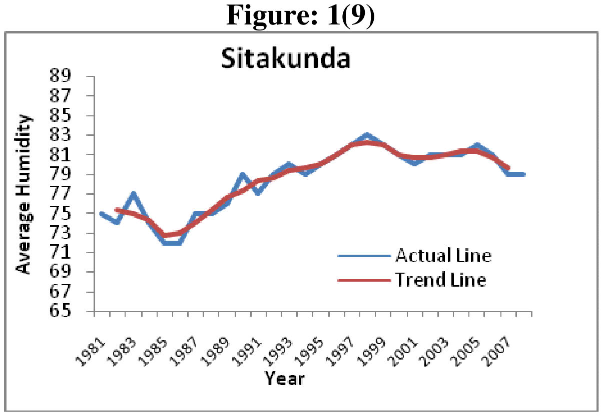

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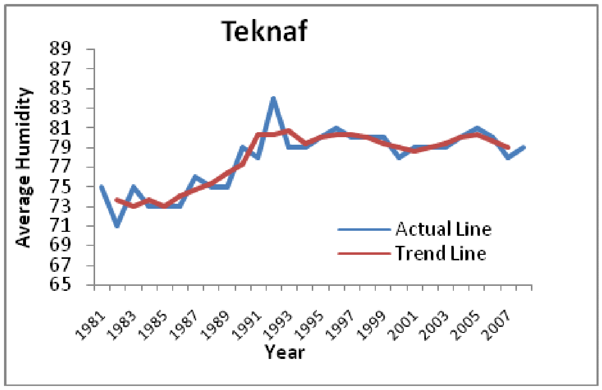

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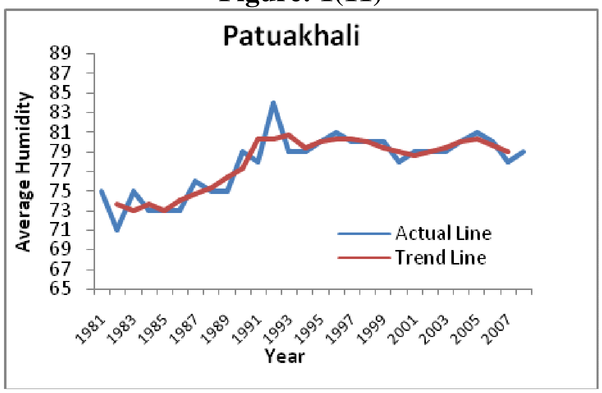


Figure: 1(12)

Periodogram Analysis

Let U_t represent the time series after eliminating the seasonal effects and trend if they exist. Now we want to investigate whether U_t contains a harmonic term with period, μ. To do this we compute the amplitudes according to the formula.

$$A_n = \left(\sum u_t \cos \frac{2\pi t}{\mu}\right)\frac{2}{n}$$

$$B_n = \left(\sum u_t \sin \frac{2\pi t}{\mu}\right)\frac{2}{n}$$

Where n is the number of terms in the series and μ is the trail period, the intensity corresponding to the trail period μ is computed by the formula.

$$S_\mu^2 = A_n^2 + B_n^2$$

Where, S_μ^2 is the amount of intensity.

Let, $U_t = a \sin \frac{2\pi t}{\lambda} + I_t$,

Where, λ is the wave – length of the series or real period.
a is the amplitude and t is time period.

Again, $A = \frac{2}{n}\left(\sum u_t \cos \frac{2\pi t}{\lambda} \right)$

$= \frac{2a}{n}\left(\sum \sin \frac{2\pi t}{\lambda} \cos \frac{2\pi t}{\mu} \right)$

$= \frac{2a}{n}\left(\sum \sin \alpha_t \cos \beta_t \right)$

Where , $\alpha = \frac{2\pi}{\lambda}$ *and* $\beta = \frac{2\pi}{\mu}$

Similarly, $B = \frac{2a}{n} \sum \sin \alpha_t \sin \beta_t$

Now, if $\alpha \longrightarrow \beta$ i, e. $\lambda \longrightarrow \mu$

$A \longrightarrow a \sin \frac{(\alpha+\beta)(n-1)}{2}$ and $B \longrightarrow a \cos \frac{(\alpha+\beta)(n-1)}{2}$

Therefore, $S_\mu^2 = A_n^2 + B_n^2 = a^2$ i, e. S = a
Intensity = amplitude

Thus, S tends to a, if α nearly equal to β and hence the trail period μ is near to the real period λ. If there is no periodic fluctuation, we have $S_m^2 = \frac{4\sigma^2}{n}$, where σ^2 is the variance of the series. In that case the series is supposed to purely random. From Table- 4 it is interesting to note that all the stations have the periodicities of length 11 years.

Now all the calculated periodicities are tested by the Schauster (1898) test. According to Schauter, the probability that, an empirical squared amplitudes is k times of the mean squared amplitude. The test statistic is given by $Ps = P(S^2 > 4vk/n) = e^{-k}$

Or, $k = -\log_e p_s$, where, S_μ^2 is the k times mean squared amplitude.

Where, S_m^2 is the mean squared amplitude, therefore, $k = S_\mu^2 / S_m^2$.

Table-3 gives the different values of k for some selected probabilities P_s.

Table-3

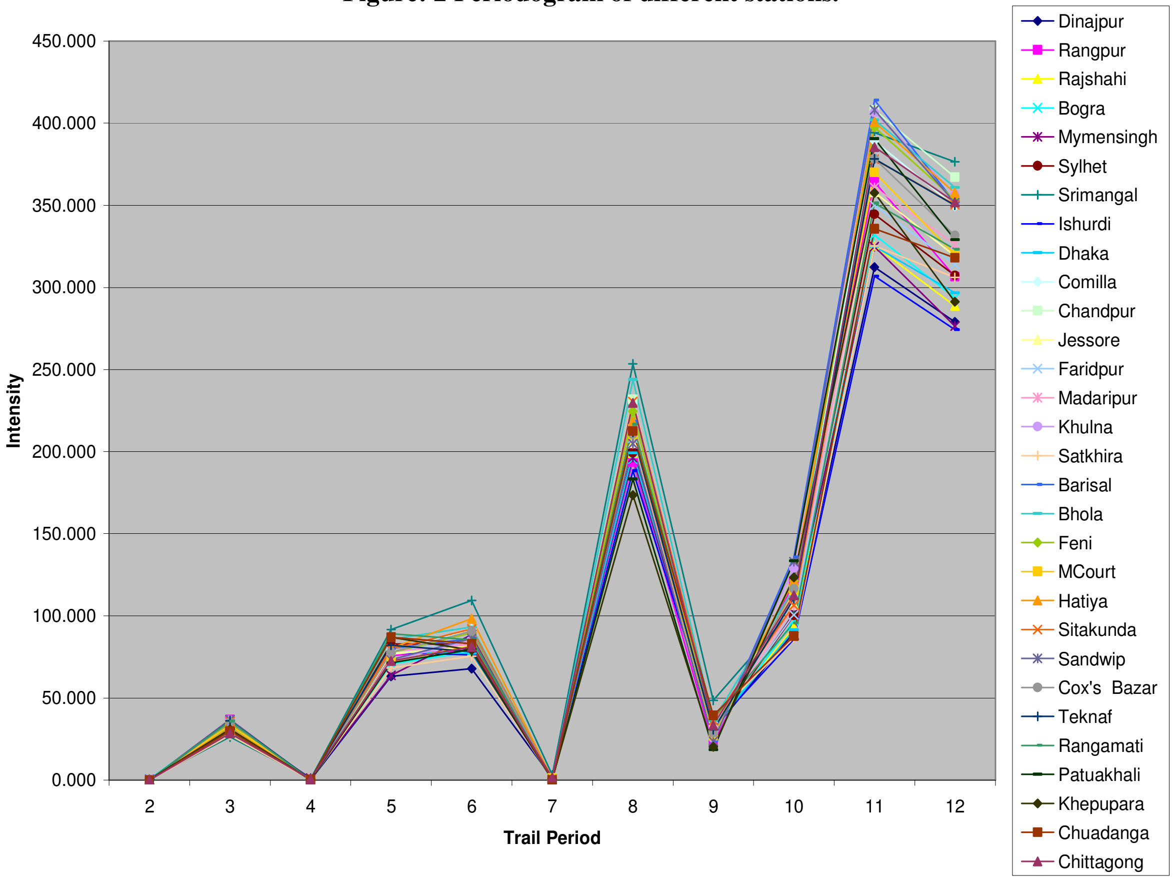
K	P_s
6.9	0.001
5.3	0.005
4.6	0.010
3.0	0.050

Table-4 Intensities and Schuster Test Statistic ‘k’ of different stations.

Station	Different values of trail period (μ)											K
	2	3	4	5	6	7	8	9	10	11	12	
Dinajpur	0.413	34.730	0.270	63.167	67.791	1.381	201.100	30.490	89.963	312.354	279.108	51.29
Rangpur	0.005	36.923	0.270	75.847	79.352	0.573	193.683	21.913	120.211	364.283	306.494	205.81
Rajshahi	0.128	33.250	0.250	73.709	78.250	0.064	199.083	31.875	92.936	325.389	288.858	309.89
Bogra	0.617	35.668	0.128	70.699	78.250	0.270	195.505	29.649	96.975	331.991	293.677	272.12
Mymensingh	0.413	33.612	1.046	63.757	88.592	0.846	196.429	30.094	101.556	324.849	276.463	64.84
Sylhet	0.046	32.342	0.066	82.832	82.791	0.119	199.364	30.667	100.242	344.567	307.298	459.44
Srimangal	0.510	26.179	0.694	91.629	109.321	3.028	253.524	48.533	104.697	394.347	376.479	144.98
Ishurdi	0.617	31.750	0.087	77.809	76.230	0.117	188.426	32.447	85.739	306.828	274.248	145.42
Dhaka	0.046	27.954	0.189	78.034	77.158	0.691	199.217	31.831	91.482	324.983	296.706	353.24
Comilla	0.046	29.893	0.026	77.253	91.944	0.133	216.160	29.706	116.792	389.050	349.274	367.02
Chandpur	0.000	31.041	0.051	77.210	84.000	1.034	231.814	31.082	115.434	408.147	367.198	1103.10
Jessore	0.005	30.250	0.026	76.492	81.587	0.261	205.101	28.963	106.639	357.945	319.283	281.85
Faridpur	0.005	32.791	0.128	78.241	83.821	0.188	208.192	32.471	100.501	350.027	313.984	625.05
Madaripur	0.005	31.444	0.148	78.233	82.750	0.247	204.704	29.871	106.094	361.028	326.342	90.71
Khulna	0.000	36.434	0.133	72.778	85.056	0.369	212.117	25.496	129.097	406.756	356.869	767.47
Satkhira	0.046	27.250	0.148	68.267	75.413	0.644	213.912	37.935	86.509	325.360	306.138	76.27
Barisal	0.046	36.015	0.434	80.160	86.281	0.866	218.237	23.848	135.716	414.138	351.848	440.57
Bhola	0.005	32.653	0.026	85.717	93.143	0.644	243.980	36.446	116.746	401.985	360.845	490.23
Feni	0.020	34.760	0.020	77.484	89.607	0.674	224.463	29.573	121.158	397.621	353.396	1104.50
M Court	0.020	33.536	0.133	72.307	81.587	1.130	210.377	27.078	115.739	370.018	319.998	268.13
Hatiya	0.250	31.980	0.066	80.243	98.286	0.871	218.047	29.509	121.541	400.669	357.736	392.81
Sitakunda	0.005	35.668	0.087	79.867	91.934	0.519	230.484	36.300	106.441	378.098	350.395	111.53
Sandwip	0.020	36.862	0.204	73.258	86.117	0.134	204.852	23.524	132.967	408.175	351.509	316.41
Cox's Bazar	0.005	35.148	0.209	77.710	90.770	0.319	210.711	28.607	116.498	378.477	331.656	600.75
Teknaf	0.046	36.036	0.495	82.168	78.260	0.545	211.676	30.547	110.356	378.144	350.037	123.58
Rangamati	0.082	35.760	0.133	89.101	85.413	0.414	216.633	37.726	95.664	351.434	323.213	331.54
Patuakhali	0.184	31.102	0.041	71.291	79.531	0.087	183.292	18.495	133.407	390.549	329.116	244.88
Khepupara	0.005	30.648	0.332	86.841	79.046	0.768	173.489	20.214	123.362	357.555	291.235	152.15
Chuadanga	0.046	29.893	0.189	86.842	82.974	0.044	212.498	39.336	87.666	335.751	317.995	395.00
Chittagong	0.005	28.413	0.454	72.591	81.128	1.512	229.643	33.392	112.408	385.477	352.019	464.45

It is seen from Table 3 and 4 that the periodicities found for the mentioned 30 stations are highly significant. The periodogram of the different stations are shown in Figure: 4.

Figure: 2 Periodogram of different stations.



Conclusion & Suggestions

Bangladesh is predominantly an agricultural country. Since the irrigation system in Bangladesh has not yet been implemented vigorously, the cultivation mainly depends on natural calamities like rainfall, humidity and temperature. But in-depth statistical analysis did not carry out yet on humidity and its relationship with other atmospheric components like temperature and rainfall. Humidity is one of the most valuable components of air, which is very important for tree plantation as the atmospheric moisture levels do significantly influence on plant growth and development. (Theodore W. Tibbitts, 1979).

Moderate to high level of humidity has been shown to reduce the severity of Asthma. Epidemiological studies suggest that relative humidity and humidification equipment can indirectly affect the incidence of Allergies and infection of respiratory disease. It may cause some physical discomforts which are the important reason for losing our working habits day by day. (Environmental Health Perspective, Vol. 65, pp. 351-361, 1986).
To make a valid conclusion about climatological change in Bangladesh along with humidity, the in-depth analysis of climate is required, which are as follows:

1. Rainfall and temperature data during the same period should be studied and establish its relationship with humidity.
2. Since trees are the important factors to increase the amount of water vapor in air which are also positively related to rainfall, therefore, deforestation rates can be included for the further study for temporal comparison of humidity in specific and climate of Bangladesh in general.
3. Inference can be drawn about climate change in Bangladesh if the sea level data can be included for research to be carried out in future.

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