Relationship between Monsoon Rainfall and Winter Minimum Temperature over Bangladesh

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mathematics

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Declaration

This is to certify that the thesis work entitled "Relationship between Monsoon Rainfall and Winter Minimum Temperature over Bangladesh" has been carried out by Md. Mahmudul Hasan in the Department of Mathematics, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Approval

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Dedication

To

My beloved parents

Md. Abdul Gafur Gazi & Mahfuza Khatun

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Abstract

In this thesis it has been tried to find the correlation between the rainfall of the monsoon months and the minimum temperature of the winter months and rainfall of the monsoon season and minimum temperature of the winter season all over Bangladesh. The thermal capacity of the soil changes with the available moisture present in the soil. So it is assumed/expected that winter minimum temperature has some relationship/dependency on the monsoon rainfall. Hence regression equation is developed to estimate winter minimum temperature on the basis of the monsoon rainfall. In this research work the data of 34 stations all over Bangladesh has been used. These raw data have been collected from Bangladesh Meteorological Department (BMD). The collected raw data have been processed by developing and using Fortran code to obtain the monthly and seasonal average. The data have been broken decade wise because of the data volume and data distribution is not suitable enough for a single calculation by taking the whole period. For the analysis purpose a package software has been used to get the regression equation and the coefficient of determination (r^2) from which the coefficient of correlation(r) is determined. The primary investigation showed that the relationship is not systematic and guided not to accommodate all the results. So only 9 stations has been chosen region wise: two stations from southern, two from eastern, two from northern, two from western and one from central region. The following cases has been investigated

i) Monsoon rainfall vs Winter minimum temperature
ii) July rainfall vs January minimum temperature
iii) August rainfall vs January minimum temperature

It has been found that some correlation coefficients are positive and some are negative. On the basis of magnitude out of 108 possible cases only 39 have been found with values greater than or equal to 0.4. It is also observed that except the stations of the northern region all other stations experienced negative correlation between August rainfall and January minimum temperature during the decade 1994-2003. It is also found that the negative correlation coefficients less than or equal to 0.4 is not found in the southern and central regions.

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Some Fundamentals

1. Seasons:

People say Bangladesh is a land of six seasons; summer, rainy, autmn, late autmn, winter and spring. But in meteorology only four seasons are considered: pre-monsoon, monsoon, post-monsoon and winter. From March to May is pre-monsoon, monsoon comprises of June to September, post-monsoon comprises of October and November and winter comprises of December to February, which means that though sum of months of the four seasons is twelve but they do not belong to the same calendar year. In our discussion the winter season of a year will comprise of January, February of that year and December of previous year.

2. Temperature Distribution

The sun is the principle source of energy for most of the processes which occur in our planet. Other sources such as the stars and the earth's interior are negligibly small. Solar energy is generated by nuclear fusion processes which occur when hydrogen is converted into helium deep in the interior of the sun. The energy generated in the interior of the sun travels to its surface whence it is radiated into space. The luminous region of the sun is called the photosphere. It comprises hot gases under pressure and in various states of ionization. Approximately 99 percent of the electromagnetic radiation emitted by the sun lies in the wavelength range between 0.15 and 4.0(μ). The spectral distribution of this energy is 9 percent in the ultraviolet, 45 percent in the visible and 46 percent in the infrared. We shall refer to this energy as solar radiation. Disposition of solar radiation occurs in two conditions.

1. Disposition of solar radiation under cloudless conditions.
2. Disposition of solar radiation with cloudy skies.

Disposition of solar radiation under cloudless conditions:

In the absence of clouds the incoming solar radiation may be depleted in the following ways:

(a) Absorption of ultraviolet radiation in the upper atmosphere-principally by ozone and oxygen.
(b) Absorption of infrared radiation –mainly by water vapour and to a lesser extent by carbon dioxide and oxygen.
(c) Scattering by molecules which comprise dry air and water vapour.
(d) Absorption, scattering and diffuse reflection by aerosols.

Some of the scattered and diffusely reflected solar radiation is, however, directed downwards. It has been estimated that on a cloudless day as much as fifty percent of this radiation reaches the earth's surface. The global radiation received by a horizontal surface at the earth therefore compromises both depleted downward direct solar radiation and sky radiation.The average undepleted radiant flux intercepted by the earth is $S\pi a^2$, Where S is the solar constant and a is the earth's radius. Now the sunlit hemisphere has a curved surfacearea of $2\pi a^2$, and so the average undepleted insolation on the sunlight hemisphere is

$$\frac{S\ a^2}{2\pi a^2}=\frac{S}{2}$$

If the total flux were distributed over the entire earth in the form of an average-valuecontinuous insolation, the mean value would be reduced to S/4. This would be approximately equal to 350 w m^{-2}.

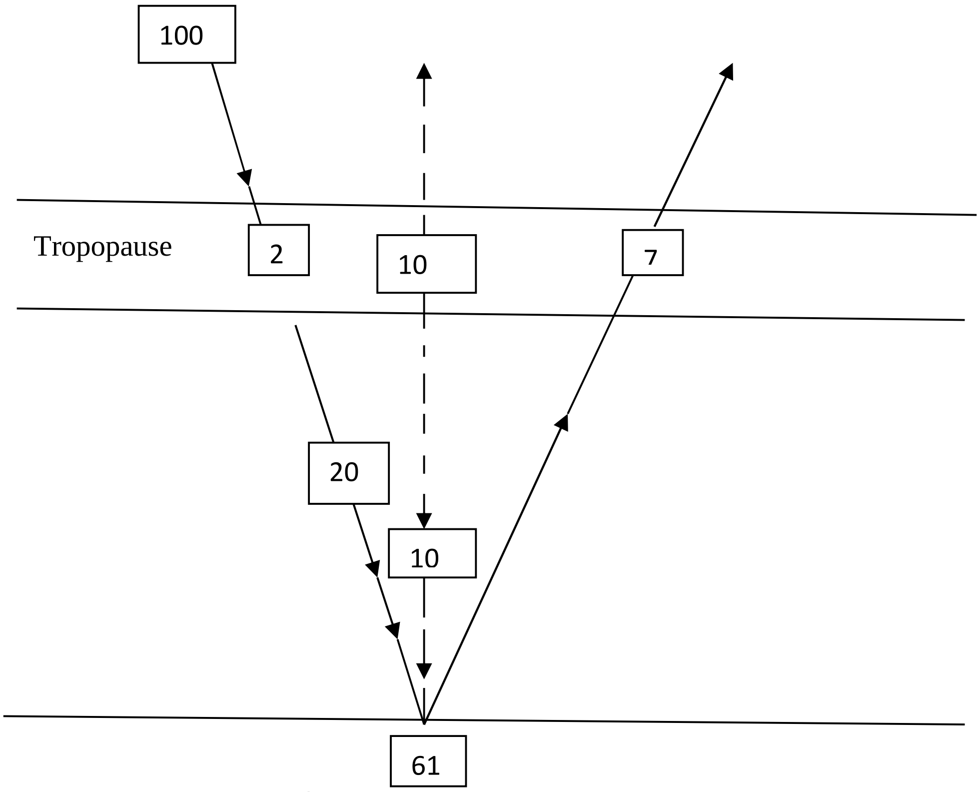

Figure-0.1: Disposition of solar radiation under cloudless conditions

Figure-0.1 indicates schematically the approximate disposition of the solar radiation. Most of the ultraviolet radiation is absorbed by ozone and oxygen in the upper atmosphere, and it is assumed that only about 98 percent of the total incoming solar radiation reaches the troposphere. About 20 percent of the undepleted radiation is absorbed by water vapour, carbon dioxide, aerosols etc. A further 20 percent is scattered or diffusely reflected, and it is assumed that half of this radiation eventually reaches the earth’s surface. Thus about 68 units of the original solar radiation reach the earth’s surface. If it is assumed that 7 units are reflected back to space, this leaves about 61 percent of the incoming solar radiation to be absorbed by the earth’s surface. The ratio of the radiation reflected by a surface to that incident on it is known as albedo of the surface. It is often expressed as a percentage. The average albedo of the earth-atmosphere system under cloudless conditions is therefore 7+10=17 percent.

Disposition of solar radiation with cloudy skies :

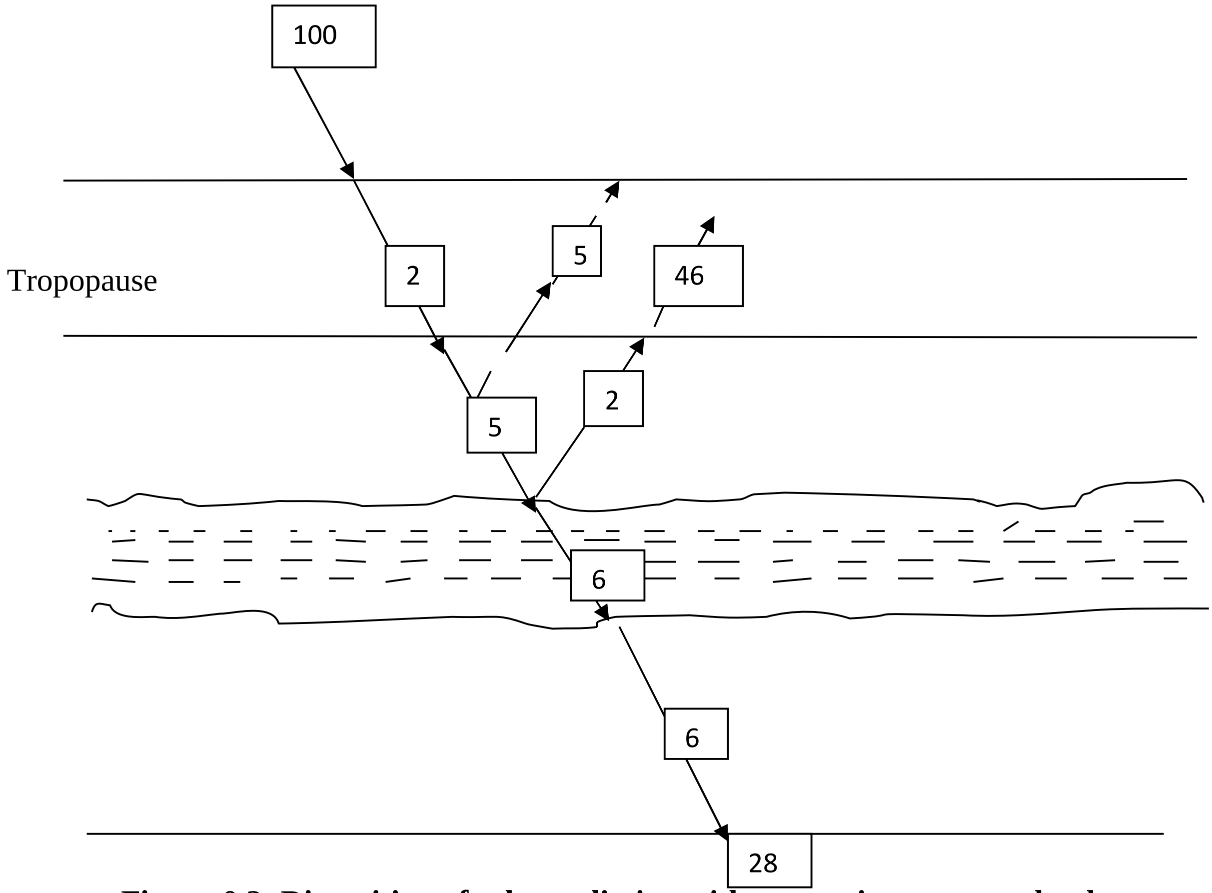

Figure-0.2: Disposition of solar radiation with composite overcast cloud

Figure-0.2 indicates the mean disposition of solar radiation for a composite overcast layer. It is assumed that in the tropopause 2 units are absorbed and between the tropopause and the top of the cloud, 5 units are absorbed and a similar amount is scattered by the air. Thus only 88 percent of the original solar radiation reaches the cloud top. For an average cloud albedo of 0.55, the radiation diffusely reflected upwards from the cloud would be 48 units (i.e. 0.55×88). We shall assume that 2 units are absorbed by water vapour and the remaining 46 units continue outwards into space as diffuse reflection. Assuming a cloud absorptivity of 7 percent, the amount absorbed in the cloud is approximately 6 units (i.e. 0.07× 88). Since 48 units are reflected from the cloud top and another 6 units are absorbed within it, only 34 of the 88 units incident on the top of the cloud are transmitted. These leave the bottom of the cloud in the form of diffuse radiation. If another 6 units are absorbed by the atmosphere below the cloud, then 28 percent of the original solar radiation would reach the earth's surface. Reflection from the earth's surface and atmospheric scattering would, of course, occur beneath the cloud However, most of this upward-directed radiation would be dispersed downwards again by the cloud. Some upward transmission through the cloud would occur, but these minor effects are neglected generally in view of the approximations made to the other items. As a result, it is assumed that 28 units are absorbed at the earth under overcast conditions.

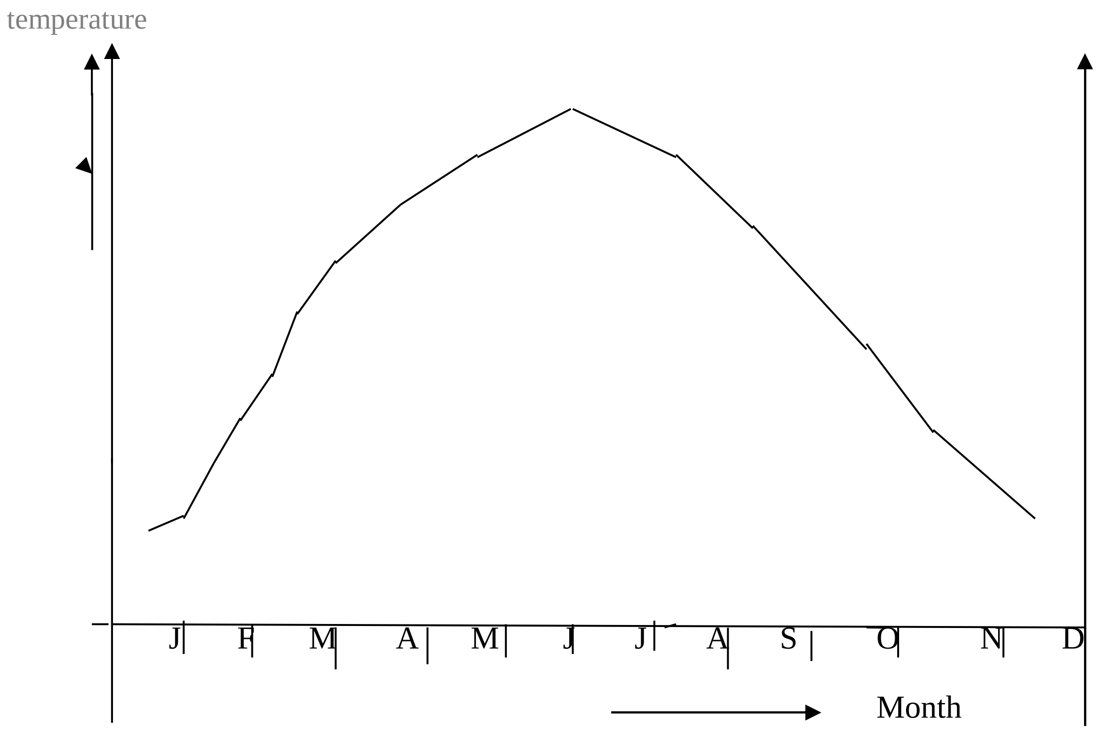

Figure-0.3: Average annual temperature distribution pattern of Northern Hemisphere.

Figure-0.3 represents average annual temperature distribution pattern of Northern Hemisphere. From the figure it is clear that at the beginning of the year (January) the average temperature is lowest. The average temperature of February and December is little bit more than the average temperature of January. These three months are under Winter. The average temperature of March, April, August, September and October is moderate. The average temperature is highest in May, June and July. The highest maximum temperature is occurred at any days of these three months. So there exist a peak (highest maximum temperature) which is generally happened in June.

3.Winter Minimum Temperatures:

There are two terminologies in measuring of temperature; one is maximum temperature and another one is minimum temperature. Maximum and minimum temperature occurs once in a day. We get the reading through Maximum Minimum Thermometer. Liquid-in-glass Thermometers are accurate and inexpensive for this purpose. A liquid, usually red –colored alcohol or mercury, is free to move within a thin opening inside the glass enclosure of the thermometer. The opening is so narrow that even small temperature changes cause a relatively large change in the length of the liquid. The glass also expands and contracts as temperature changes, but its expansion and contraction is negligible compared to that of the liquid. Modified liquid-in-glass thermometers have been designed specifically for measuring daily maximum and minimum temperatures. In these special thermometers, the length of the liquid thread at either its maximum expansion or maximum contraction is preserved until the thermometer is reset. The maximum expansion is maximum temperature and the maximum contraction is minimum temperature. Generally we aware of the minimum temperature in Winter and maximum temperature in Summer. In Winter, generally the minimum temperature occurs at 2am-6am. But we are not interested on time when minimum temperature is recorded rather on the recorded minimum temperature itself.

4. Correlation:

All sciences, natural, social or biological are largely concerned with the study of interrelations among variables. Many physical and chemical laws can be expressed in the form of mathematical equations; each law expressing a relationship among a number of variables. Thus, Newton's laws of motion express relationship among variables such as force, mass and acceleration. Relation which can be formulated mathematically involve certain unknown constants called parameters. The numerical determination of these parameters is of utmost importance both from the theoretical and practical points of view. If the relationships are exact and the mathematical forms of these relationships are known, it would be possible, at least in principle, to determine the relevant parameters by solving appropriate equations. But sometimes errors of observation or measurement obscure the underlying relationship. More often, we can not postulate a unique relationship between variables. That is, a particular value of one variable does not always correspond to the same set of the other variables involved. Thus, there is no unique relationship between the height and weight of an individual; for any given height there is a wide range of weights, and vice versa. Occasionally, theory only indicates the nature of the relationships (linear, parabolic, exponential etc.), but does not specify their exact mathematical forms. Frequently little is known about the nature or form of the relationship or the relationship is very complicated in form. We are then interested to find an approximate relation which is useful for practical purposes. Correlation means association-more precisely it is a measure of the extent to which two variables are related. The relationship between more than one variable is considered as correlation. The number which quantifies the strength of the relationship is called the coefficient of correlation. Correlation is a widely used statistical technique. Correlation coefficients are the index of the measurement of the relationship among the set of variables.

Classification of correlation:

Correlation is described or classified in several different ways. Three of the most important are:

(i) Positive, negative, and zero correlation
(ii) Simple, Partial and multiple correlation
(iii) Linear and non-linear correlation

Positive, negative, and zero correlation: If an increase in one variable is forced due to an increase in the other then this is known as a positive correlation. If an increase in one variable tends to be associated with a decrease in the other then this is known as a negative correlation. When there is no relationship between two variables this is known as a zero correlation. Thus if any change in one variable has no impact on the other then we will say that the variables are not correlated or they have no correlation.

Simple, Partial and multiple correlation: According to the number of variables there are three types of correlation coefficients. They are (i) Simple correlation (ii) Multiple correlation and (iii) Partial correlation. The distinction between simple, partial and multiple correlations are based upon the number of variables in consideration. Simple correlation is defined as a variation related amongst any two variables. The multiple correlation and partial correlation are categorized as related variation among three or more variables. In multiple correlation three or more variables are studied simultaneously. For example, when we study the relationship between the yield of rice per acre and both the amount of available rainfall and the amount of fertilizers used, it is a problem of multiple correlations. In partial correlation we recognize more than two variables. But consider only two variables to be influencing each other, the effect of other influencing variable being kept constant. For example, in the rice problem taken above if we limit our correlation analysis of yield and rainfall with the assumption that a certain amount of fertilizer is used, it becomes a problem of partial correlation.

Linear and non-linear correlation: The distinction between linear and non-linear correlation is based upon the constancy of the ratio of change between the variables. If the amount of change in one variable tends to bear a constant ratio to the amount of change in the other variable then the correlation is said to be linear. Correlation would be called non-linear or curvilinear if the amount of change in one variable does not bear a constant ratio to the amount of change in the other variable. For example, if we double the amount of rainfall, the production of rice, would not necessarily be doubled, which means their relationship is not linear.

Classification of methods:

There are several methods available to calculate the correlation coefficient. Among them Product-moment (Pearson product-moment) method to calculate simple correlation between two variables is widely used. Let us consider two variables x and y, and the data take the form of n pairs (e.g. [x_1, y_1], [x_2, y_2], [x_3, y_3],………,[x_n, y_n]). The mathematical formula of linear correlation coefficient of Pearson product moment (Blanched formula) method:

$$r = \frac{n\sum x \; -(\sum x)(\sum y)}{\sqrt{[n\sum x^2-(\sum x)^2][n\sum y^2-(\sum y)^2]}}$$

Which can be written as

$$r = \frac{s_x}{\sqrt{(s_x)(s_y)}}$$

Where x and y are n paired observations,

$$s_x = \sum(x_i - \bar{x})(y_i - \bar{y})$$

$$s_x = \sum(x_i - \bar{x})^2$$

$$s_y = \sum(y_i - \bar{y})^2$$

Here $\bar{x}$ is the mean of the x values, and $\bar{y}$ is the mean of the y values.

Requirements for Pearson's correlation coefficient:

- Scale of measurement should be interval or ratio.
- Variables should be approximately normally distributed.
- The association should be linear.
- There should be no outliers in the data.

Interpretation of coefficient of correlation: Coefficient of correlation denoted by r is the degree of correlation between two variables. The value of r always lies between -1 and +1.

- When r is 1, we say there is a perfect positive correlation. A value of the coefficient close to +1 indicates a strong positive linear relationship.
- When r is a value between 0 and 1, we say there is a positive correlation.
- When r is 0, we say there is no correlation. A correlation of zero means there is no relationship between the two variables. A value close to 0 indicates no linear relationship.
- When r is a value between -1 and 0, we say that there is a negative correlation.
- When r is -1, we say there is perfect negative correlation. A value close to -1 indicates a strong negative linear relationship.

5. Regression:

In correlation analysis our target remains to find the strength of relationship among the variables. Generally we do not classify the variables as dependent or independent. Our prime target remains to asses the effect on one variable when other variable is changed. The relationship, if there is any, may be linear or non-linear. If there are only two variables then we use the terminology 'simple', if more than two we use 'multiple' and in case of multiple considering others as constant we calculate 'partial' correlations. Sometimes we are interested to estimate a variable which has relationship with other variable(s). In such case we consider dependent variable and independent variable(s) and it requires certain mathematical relationship among the variables. If certain mathematical form of relationship is established then the discrete data form gives us a continuous type of locus (generally). Assuming that the relationship holds for all possible domain of the independent variables we are able to estimate the dependent variable whenever we desire. If our asking is within the domain of the given data set then we say 'interpolation' is to be done, but if that is outside of the given domain then the terminology 'extrapolation' is used. Regression is practically an extrapolation, which means we should have a mathematical relationship among the variables. But practical data do not give exact mathematical relation. The exact relation can be obtained if we can eliminate some error from the data. As the basis of the regression has the root in correlation so there must be same type classification. For simplicity (and as using transformations non-linear can be transformed to linear) we are going to discuss about simple linear Regression that means we will consider only two variables one dependent and one independent, also the assumed relationship is linear. The general form of Simple Linear Regression is:

$$y = a + b \quad + \varepsilon$$

Where:

y = the variable that we are trying to predict.

x= the variable that we are using to predict y.

a = the intercept.

b= the slope denote regression coefficient.

ε = the regression residual.

The regression line (known as the least squares line) is a plot of the expected value of the dependent variable for all values of the independent variable. Technically, it is the line that "minimizes the squared residuals". The regression line is the one that best fits the data on scatter plot. Using the regression equation, the dependent variable may be predicted from the independent variable. Since the regression model is usually not a perfect predictor, there is also an error term in the equation. In the regression equation, y is always the dependent variable and x is always the independent variable. For n pair of observation ((x_i, y_i): i=1, 2, ………, n), the parameter a and b can be estimated by using Least Square method. As we have seen, the least-squares regression line of y on x is

$$y = a + b$$

where a and b are obtained from the normal equations

$$\sum y = a \quad + b \sum x$$

$$\sum x \quad = a \sum x + b \sum x2$$

Which yield

$b = \frac{(n \sum x \quad) - (\sum x)(\sum y)}{n \sum x^2 - (\sum x)^2}$

and $a = \bar{y}$-$b\bar{x}$

It is important to note that if the slope is zero, it has no prediction ability because for every value of the independent variable, the prediction for the dependent variable would be the same. Knowing the value of the independent variable would not improve our ability to predict the dependent variable. Thus, if the slope is not significantly different than zero, the linear regression model cannot be used to predict the dependent variable.

CHAPTER-1.

INTRODUCTION

1.Background:

Climate is the most important phenomenon for life on the earth. It is not a constant process but changing continuously. Rainfall and Temperature are two major components of the climate/meteorology. Rain has always been valued by mankind, because good crops and abundant water supplies are possible only by timely and plentiful rainfall. The impact of Indian sub-continental rainfall is tremendous in monsoon season. Studies on rainfall characteristics of Bangladesh are a few. A preliminary investigation of the water balance of the country was done by Khan and Islam (1966) while the variability of annual rainfall by Shamsuddin (1974), spatial and temporal variability by Samad and Islam (1993) and monsoon season and aspects of hydrology and agriculture by Shamsuddin and Alam (1990) are among the significant contributions towards understanding of rainfall characteristics and distribution in Bangladesh.

Ahmed and Kim (2003) performed statistical analysis of daily rainfall at 19 weather stations of Bangladesh. They used the data from May to October for 35 years period starting from 1964 to1998. Their study shows that the average monsoon rainfall ranges from 1200 mm in the west to 3000 mm in the northeast and southeastern part of the country. Frequency of consecutive rainy days at these stations in the 35 years period shows that episodes with duration 1-3 days are most common. However, episodes of much longer consecutive rain days also occur, ranging from 10-19 days in the west to 18-35 days in the southeast and 20-44 days in the northeast. Oshawa et al. (2000) investigated the rainfall over Bangladesh during the 1995 summer season in terms of the inter seasonal variation of monsoon activities. The rainfall over Bangladesh is basically dominated by the north-south oscillation of the monsoon trough. The rainfall increases when the monsoon trough is located at the foot of the Himalayas, because synoptic-scale convective activity is much more vigorous to the South of the monsoon trough axis to the north of it. In addition, the strong southwesterly wind to the south of the monsoon trough intensifies local convective activity owing to the effects of the orography to the north and east of the country.

Kripalani et al. (1996) studied the rainfall variability over Bangladesh and Nepal. In their study monthly rainfall data for 14 stations over Bangladesh for the period 1901-1977 were used to investigate and understand the inter-annual variability of the summer monsoon rainfall. Monthly, Seasonal and Spatial rainfall patterns and the spatial patterns of variability were presented. Dominant structures of seasonal rainfall are determined through the empirical orthogonal functions. A homogenous series for all Bangladesh monsoon rainfall is prepared and its temporal characteristics were studied. It is observed that the standardized values are much above the normal values. Further the rainfall variations over Bangladesh are not related to the large scale variables such as the Northern Hemisphere surface temperature, Darwin pressure tendency, and the subtropical ridge over the Indian region. However the rainfall variations over Bangladesh are related well with rainfall variations over north-east India. The long term variation of hemispheric or regional surface air temperature are shown by many studies (e.g, Jones and Briffal, 1992; Hansen and Lebedeff, 1987; Jones 1994; Parker et al., 1994) to understand the increase of temperature due to the increasing greenhouse effect, examination of the tropospheric temperature, particularly in the lower part, is important. Chowdhury and Debsharma (1992) observed the increasing tendency of the lowest minimum temperature over Bangladesh. Warric et al., (1994) studied the variations of temperature and rainfall over Bangladesh. While correlation between winter temperature and monsoon rainfall by Alam and Hossain (2002) and correlation between winter temperature and post-monsoon rainfall by Alam and Hossain (2004) throw some light to understand the relationship between monsoon rainfall and temperature of different season. Yasmin (2008), in her thesis, tried to determine multiple correlation between different meteorological parameters in pre-monsoon, of which temperature was present, and monsoon rainfall over Bangladesh.

2.Motivation:

It is generally supposed that plenty of monsoon rainfall has impact on the next winter temperature. As the thermal capacity of moist soil is more than dry soil, so if the rainfall is comparatively higher it is expected that the minimum temperature of the next winter be a bit higher. In this context an investigation is made to find the correlation between monsoon rainfall and minimum temperature of the next winter.

3.Organization of the thesis:

In some fundamentals we have discussed about season, temperature distribution, winter minimum temperature, correlation and regression. chapter 2 contains the methodology. In chapter 3 we have discussed about the results and discussions. In chapter 4 we have presented the conclusion.

CHAPTER II

METHODOLOGY

In this research work we have used the minimum temperature of winter season and the rainfall of monsoon season of 34 meteorological stations all over Bangladesh. The raw data has been collected from Bangladesh Meteorological Department (BMD). Different Fortran programs are written and used to handle the collected raw data from BMD. We got two data files, one containing daily rainfall of all stations all through the years and the other contains the daily minimum temperature of all the stations all through the years, from the commencement to 2014. Obviously the volume of the data for different stations were different as they have not started recording from the same time. Also there were gaps in the file as stations have not recorded that data. Primarily we have calculated the daily average, summing up the available days data and then averaged it dividing the sum by the number of available days. If no data was available we assigned different value so that those can be identified. The seasonal average is done in the similar fashion (counting the number of available months and summing those data and then dividing by the number of available months). In case of winter it was required to taken in account the one year's December and next year's January and February. We have done these jobs using Fortran programs and for these different programs have been written and run. One of such program is listed in the Appendix of this thesis. We have taken rainfall as independent variable and minimum temperature as dependent variable. We have tried to find out the correlation between: monsoon rainfall and winter minimum temperature, July rainfall and January minimum temperature, August rainfall and January minimum temperature.

We want to predict the winter minimum temperature on the basis of monsoon rainfall. As winter minimum temperature is dependent variable so first we have considered the monsoon season and then the winter season. For this reason we have tried to find out the relationship between winter season and its previous year's monsoon. So we have taken the data in such a way that winter minimum temperature data is from 2014 whereas monsoon rainfall data is from 2013. We have tried to find out the correlation between dependent variable and independent variable of the last four decades on the basis of available data. The plots are made decadewise, because the number of data for a particular station is not found suitable to plot. In case of winter and monsoon we have tried to find the relation between: monsoon rainfall data of 1974-1983 and winter minimum temperature data of 1975-1984, monsoon rainfall data of 1984-1993 and winter minimum temperature data of 1985-1994, monsoon rainfall data of 1994-2003 and winter minimum temperature data of 1995-2004 and monsoon rainfall data of 2004-2013 and winter minimum temperature data of 2005-2014. The relation between July rainfall and January minimum temperature and August rainfall and January minimum temperature have been done in the same way (i.e. in case of decades).

A package software is used to find out the correlation between independent variable and dependent variable. Using the package software we have got the scatter diagram with trend line, regression equation and coefficient of determination (r^2).

The regression equation is in the form $y = a + bx$.

where a and b are obtained from the normal equations

$$\sum y = a + b \sum x$$

$$\sum x = a \sum x + b \sum x2$$

Which yield

$b=\frac{(n\sum x\ )-(\sum x)(\sum y)}{n\sum x^2-(\sum x)^2}$

and $a = \bar{y}-b\bar{x}$

The coefficient of correlation r can be obtained by the following formula

$r=\frac{n\sum x\ -(\sum x)(\sum y)}{\sqrt{[n\sum x^2-(\sum x)^2][n\sum y^2-(\sum y)^2]}}$

Which can also be written as

$r=\frac{s_x}{\sqrt{(s_x\ )(s_y\ )}}$

Where x and y are n paired observations,

$$s_x = \sum(x_i - \bar{x})(y_i - \bar{y})$$

$$s_x = \sum(x_i - \bar{x})^2$$

$$s_y = \sum(y_i - \bar{y})^2$$

Here $\bar{x}$ is the mean of the x values, and $\bar{y}$ is the mean of the y values.

CHAPTER III

RESULTS AND DISCUSSION

The thermal capacity of soil has dependency on the available moisture. Thus if the soil is moist enough then it can accumulate more thermal energy and can affect the environmental temperature. Keeping this information in mind we have started to investigate to establish the relationship between the rainfall of monsoon months and the minimum temperature of the winter months and those of the seasons themselves. But our primary investigation was not that much promising as was expected. Thus we have handled all the 34 stations but here we have presented 9 stations: Two stations (Chittagong and Bhola) from southern region, Two stations (Jessore and Ishurdi) from western region, Two stations (Dinajpur and Rangpur) from Northern region, Two stations (Sylhet and Srimangal) from eastern region and another one (Dhaka) is from the central region of Bangladesh. As has been mentioned earlier that the plots are made decade wise so the obtained value of correlation coefficient of the said decades are tabulated in tables 3.1, 3.2 and 3.3. Also as earlier mentioned the relationship between monsoon rainfall and winter minimum temperature, July rainfall and January minimum temperature and August rainfall and January minimum temperature will be discussed so only their results are tabulated.

Table.3.1: Value of correlation coefficients ‘r’ between monsoon rainfall and winter minimum temperature of the stations.

Decade	Chittagong	Bhola	Jessore	Ishurdi	Rangpur	Dinajpur	Srimangal	Sylhet	Dhaka
1974-1983	-0.095	-0.214	+0.268	-0.268	-0.363	+0.606	-0.409	-0.421	+0.182
1984-1993	+0.416	-0.285	+0.315	+0.348	+0.587	+0.670	-0.145	+0.467	+0.167
1994-2003	+0.266	+0.525	-0.268	+0.528	+0.212	-0.000	+0.485	+0.274	+0.195
2004-2013	-0.063	+0.616	+0.421	+0.463	-0.000	+0.438	+0.167	-0.285	+0.494

Table.3.2: Value of correlation coefficients ‘r’ between July rainfall and January minimum temperature of the stations

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Decade	Chittagong	Bhola	Jessore	Ishurdi	Rangpur	Dinajpur	Srimangal	Sylhet	Dhaka
1974-1983	+0.265	+0.000	-0.118	-0.632	-0.660	+0.654	-0.725	+0.105	-0.083
1984-1993	+0.588	+0.084	-0.283	-0.158	+0.564	+0.310	-0.089	+0.706	+0.491
1994-2003	+0.155	+0.000	-0.598	+0.200	+0.126	-0.521	+0.045	+0.192	+0.000
2004-2013	+0.071	+0.531	+0.285	+0.516	+0.045	+0.176	+0.266	+0.202	+0.463

Table.3.3: Value of correlation coefficients 'r' between August rainfall and January minimum temperature of the stations

Decade	Chittagong	Bhola	Jessore	Ishurdi	Rangpur	Dinajpur	Srimangal	Sylhet	Dhaka
1974-1983	+0.404	+0.176	-0.055	-0.486	+0.145	-0.873	+0.806	-0.457	+0.428
1984-1993	-0.000	-0.105	+0.155	+0.276	+0.141	+0.352	-0.679	-0.207	+0.200
1994-2003	-0.155	-0.226	-0.467	-0.032	+0.063	+0.230	-0.339	-0.285	-0.303
2004-2013	+0.643	-0.118	+0.118	+0.444	+0.100	+0.480	+0.032	-0.000	+0.214

It is seen from the tables that some of the correlation coefficients are positive and some though few in number are negative. Out of 9 stations 6 experienced negative correlation between monsoon rainfall and winter minimum temperature during 1974-1983 where as 7 stations experienced negative correlation between August rainfall and January minimum temperature during 1994-2003. In the first case the stations are distributed in the latter case all the stations lie below the extreme northern region.

It is clearly observed from the tables that some of the correlation coefficients are too small, which means that the variable considered are weakly correlated or have no interdependency at all. In the following we will only consider those cases in which the value of r is greater than or equal to 0.40 in magnitude. Out of all the 34 station over Bangladesh, we have selected 9 stations regionwise. To perceive /understand the relationship i.e. the impact of the rainfall on the winter minimum temperature over certain region we will discuss the cases stationwise.

3.1 Chittagong:

In the following the considerable cases at the Chittagong station has been presented From the tables it is seen that out of 12 possible cases four have correlation coefficients greater than or equal to 0.4 in magnitude.

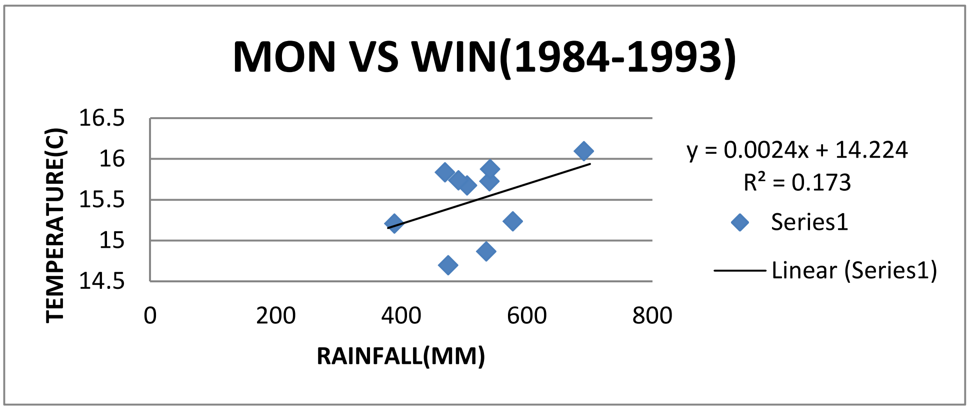

Fig.3.1.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1984 to 1993 at Chittagong.

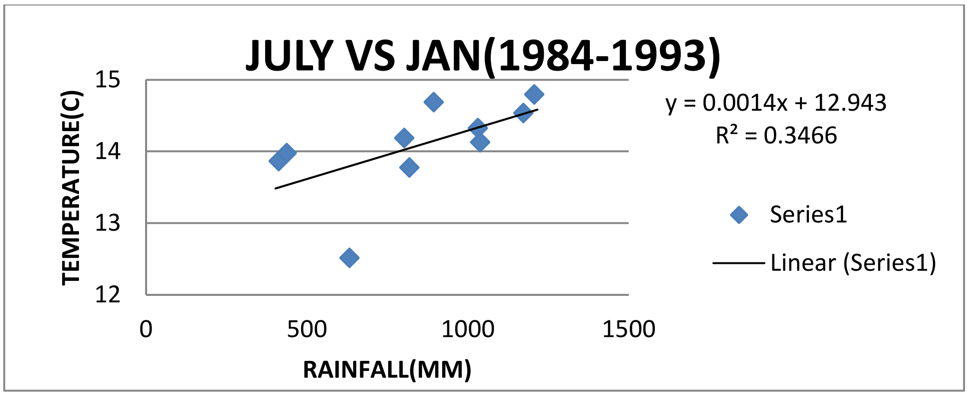

Fig.3.1.2: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1984 to 1993 at Chittagong.

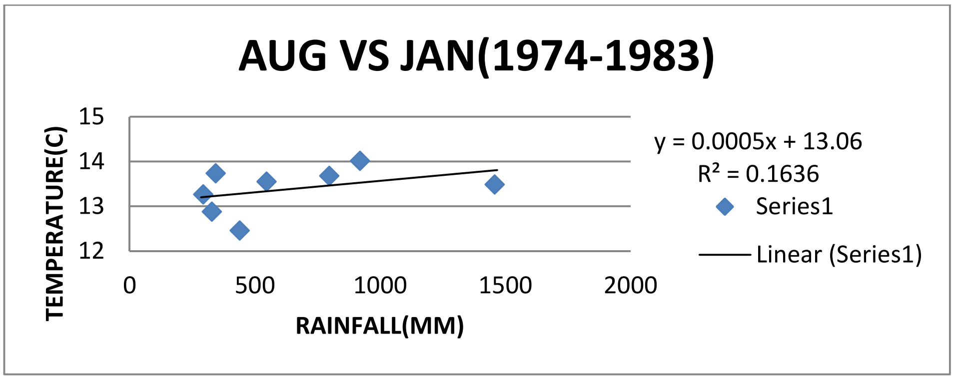

Fig.3.1.3: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1974 to 1983 at Chittagong.

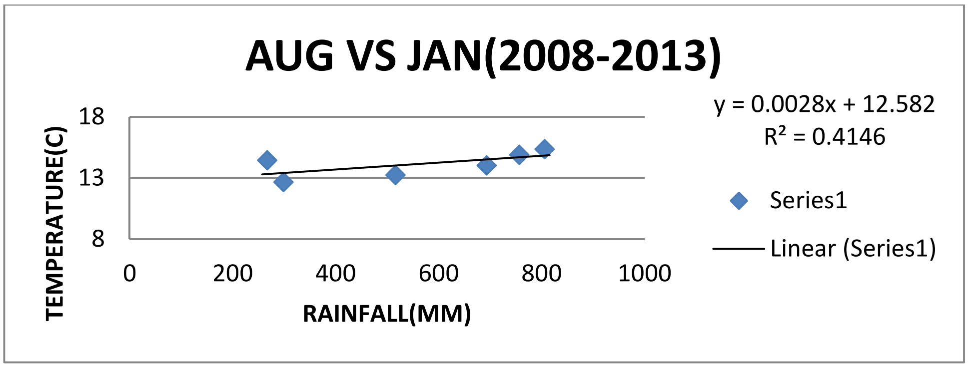

Fig.3.1.4: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 2008 to 2013 at Chittagong.

The figures Fig.3.1.1, Fig.3.1.2, Fig.3.1.3 and Fig.3.1.4 represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1984 to 1993, July rainfall versus January minimum temperature from 1984 to 1993, August rainfall versus January minimum temperature from 1974 to 1983 and August rainfall versus January minimum temperature from 2008 to 2013 at Chittagong respectively. It is clear that scatter diagram has no clear pattern i.e. with change in the amount of rainfall the change in temperature has no pattern. It is also observed that with same amount of rainfall the temperature is not the same. The value of r, the correlation coefficient in the cases are +0.416, +0.588, +0.404 and +0.643 respectively. Here the maximum positive correlation is found between August rainfall and January minimum temperature from 2008 to 2013. The values of r tabulated in the tables indicates that the relationship are not much strong and thus the linear fit is not good except the last case, where the value of coefficient of determination indicative, may be due to less number of data. The value of R^2 indicates that the co-relation between the variables is not well enough. The slope of the line is very low which indicates that temperature has very little dependency on the rainfall.

3.2 Bhola:

From the tables it is found that of the listed twelve cases only three have correlation coefficient greater than or equal to 0.4 in magnitude.

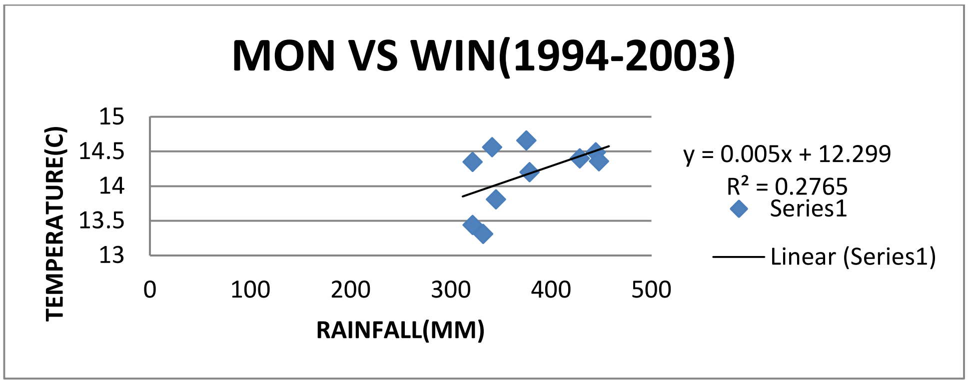

Fig.3.2.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1994 to 2003 at Bhola.

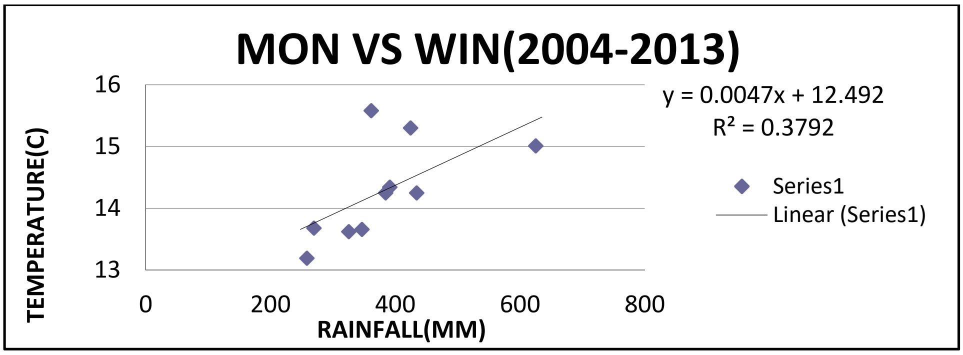

Fig.3.2.2: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2004 to 2013 at Bhola.

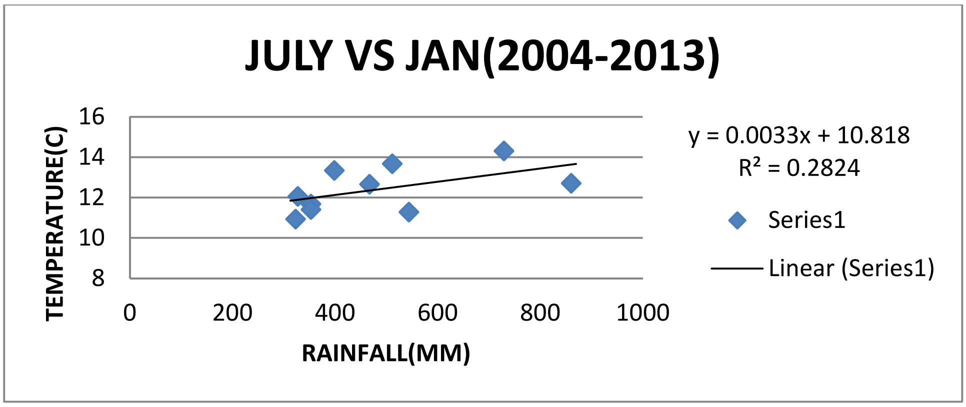

Fig.3.2.3: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 2004 to 2013 at Bhola.

The scatter diagram and linear fits of Monsoon rainfall versus Winter minimum temperature from 1994 to 2003, Monsoon rainfall versus Winter minimum temperature from 2004 to 2013 and July rainfall versus January minimum temperature from 2004 to 2013 at Bhola are presented in the figures Fig.3.2.1, Fig.3.2.2 and Fig.3.2.3 respectively. It is clear that scatter diagram has no clear pattern i.e. with change in the amount of rainfall the change in temperature has no pattern. It is also observed that with the same amount of rainfall the temperature is not the same. The values of r in those cases are +0.525, +0.616 and + 0.531 respectively. Here the maximum positive correlation is observed between Monsoon rainfall and Winter minimum temperature from 2004 to 2013. Out of the possible 12 cases only 3 has been considered, which means that only in 3 cases the value of the correlation coefficient are more than 0.4 in magnitude.

3.3 Jessore:

In the following figures Fig.3.3.1, Fig.3.3.2 and Fig.3.3.3 the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2004 to 2013, July rainfall versus January minimum temperature from 1994 to 2003 and August rainfall versus January minimum temperature from 1994 to 2003 at Jessore has been presented respectively. It is clear that scatter diagram has no clear pattern i.e. changes in the amount of rainfall has not produced regular change in temperature. It is also observed that with same amount of rainfall the temperature is not the same. The values of r in the cases are +0.421, -0.598 and -0.467 respectively. It is interesting to observe here that out of the three cases considerable out of twelve possible according to our decision two have negative values, which has not been seen in the cases of southern region.

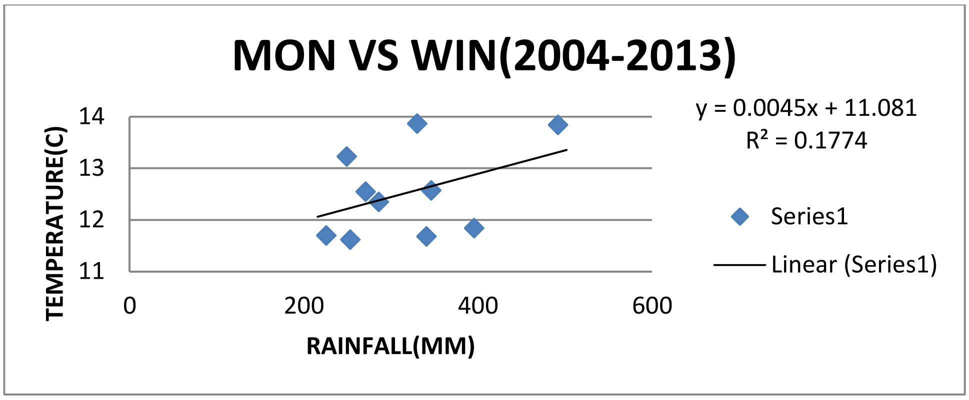

Fig.3.3.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2004 to 2013 at Jessore.

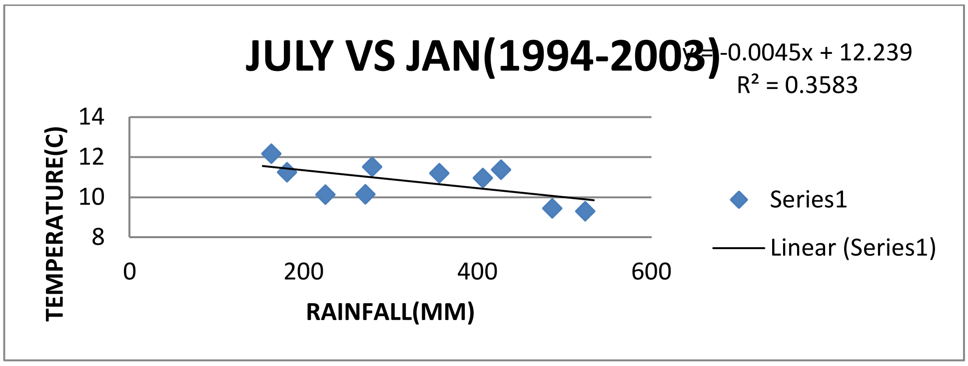

Fig.3.3.2: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1994 to 2003 at Jessore.

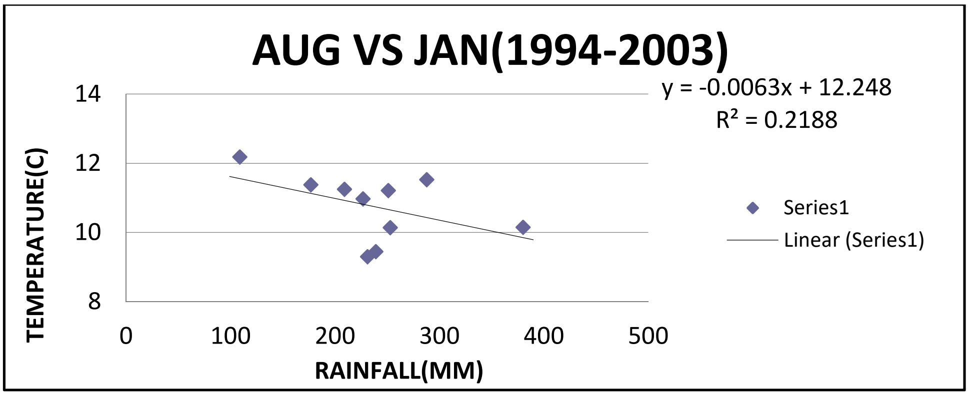

Fig.3.3.3: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1994 to 2003 at Jessore.

3.4 Ishurdi:

For this station it has been seen from the tables that as many as six cases have correlation coefficients greater than 0.4 in magnitude. The scatter diagram and the corresponding linear fit has been plotted below.

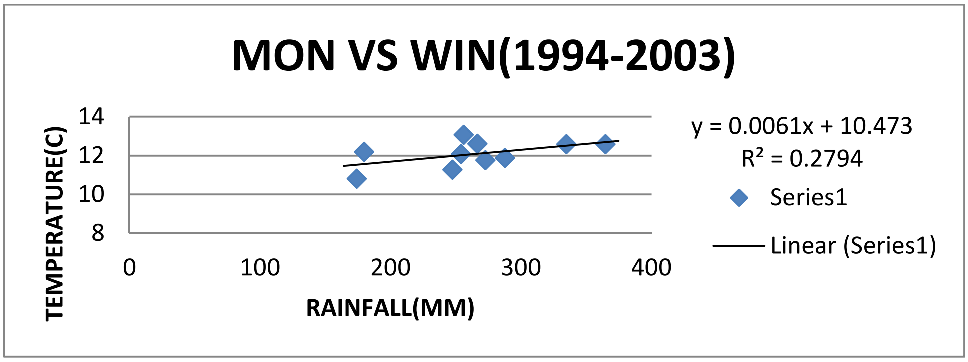

Fig.3.4.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1994 to 2003 at Ishurdi.

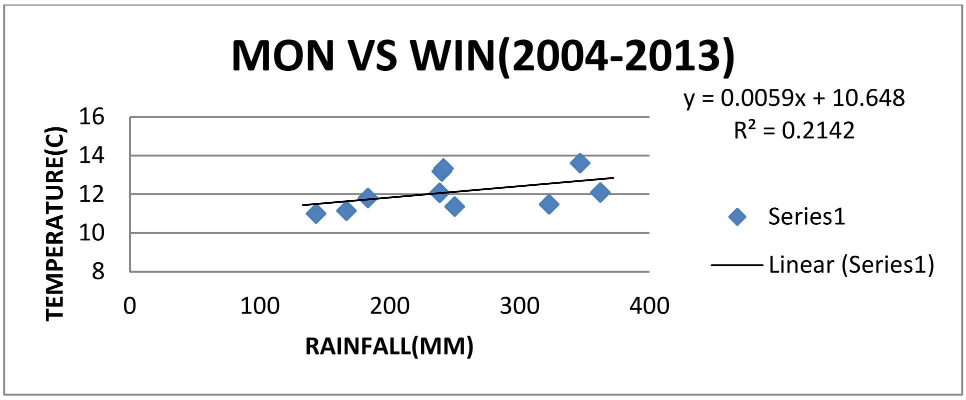

Fig.3.4.2: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2004 to 2013 at Ishurdi.

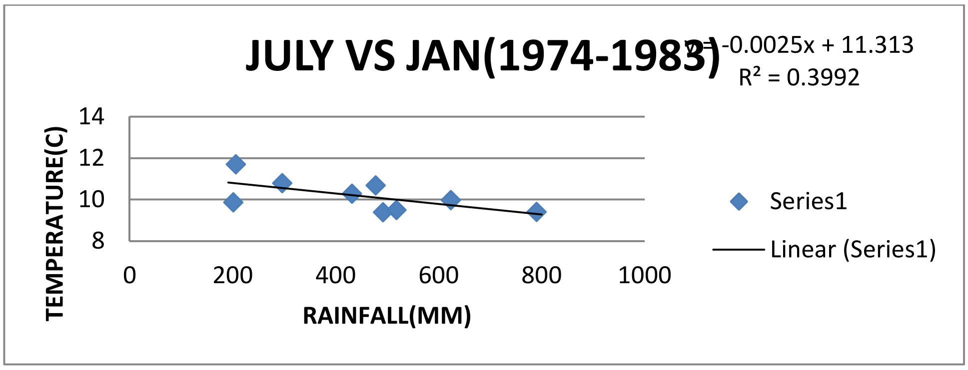

Fig.3.4.3: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1974 to 1983 at Ishurdi.

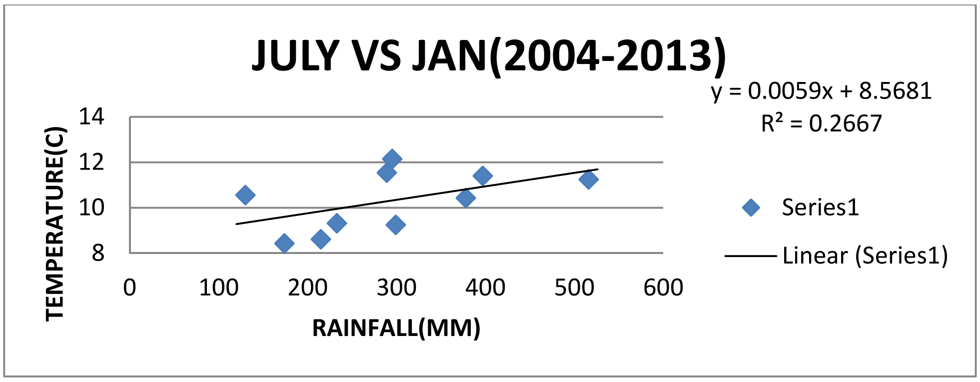

Fig.3.4.4: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 2004 to 2013 at Ishurdi.

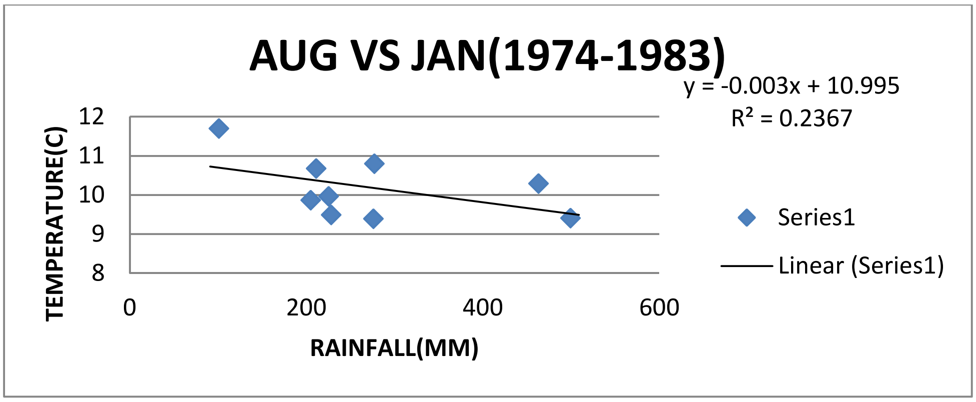

Fig.3.4.5: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1974 to 1983 at Ishurdi.

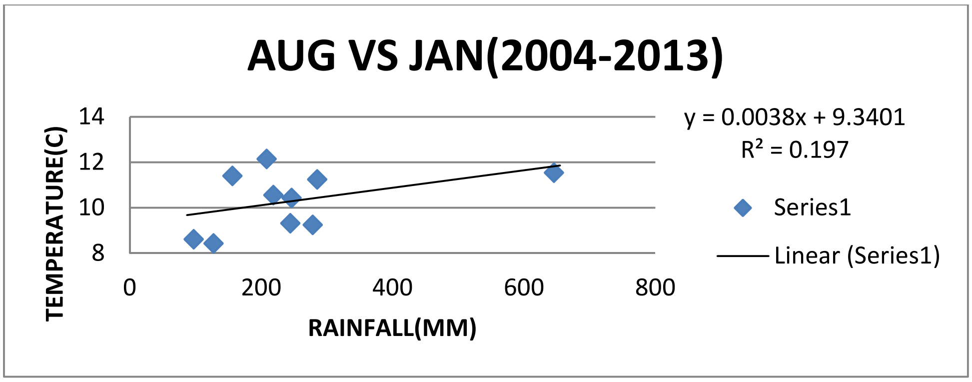

Fig.3.4.6: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 2004 to 2013 at Ishurdi.

The figures Fig.3.4.1, Fig.3.4.2, Fig.3.4.3, Fig.3.4.4, Fig.3.4.5 and Fig.3.4.6 represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1994 to 2003, Monsoon rainfall versus Winter minimum temperature from 2004 to 2013, July rainfall versus January minimum temperature from 1974 to 1983, July rainfall versus January minimum temperature from 2004 to 2013, August rainfall versus January minimum temperature from 1974 to 1983 and August rainfall versus January minimum temperature from 2004 to 2013 at Ishurdi respectively. The values of r in the different cases are +0.528,

+0.463, -0.632, +0.516, -0.486 and +0.444 respectively. At this station also some correlation coefficients are negative and some are positive. Here the maximum positive correlation +0.528 is found between the Monsoon rainfall and Winter minimum temperature from 1994 to 2003 and maximum negative correlation -0.632 is found between July rainfall versus January minimum temperature from 1974 to 1983. Of the cases the linear fit between July rainfall and January minimum temperature during 1974 t0 1983 is quite good, though the relationship is found negative.

3.5 Rangpur:

For this station again only three cases are found in which the value of the correlation coefficients are greater than or equal to 0.4 in magnitude.

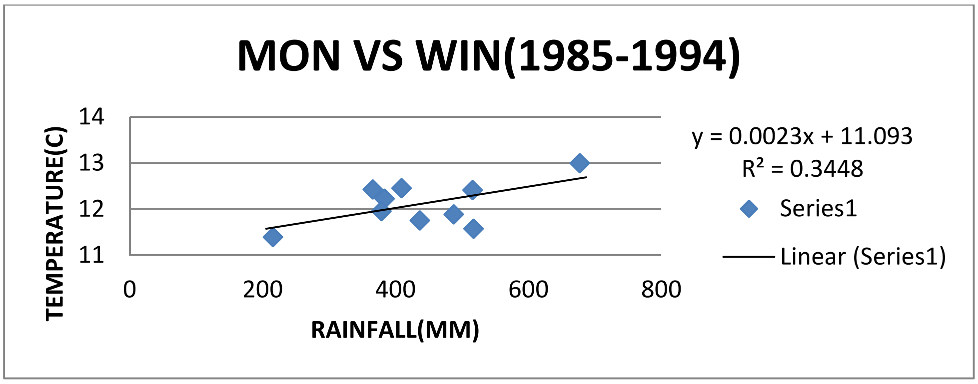

Fig.3.5.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1985 to 1994 at Rangpur.

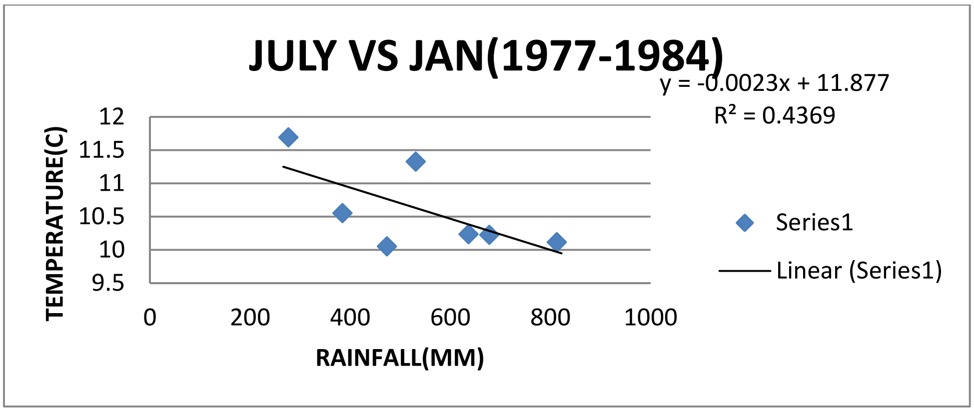

Fig.3.5.2: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1977 to 1984 at Rangpur.

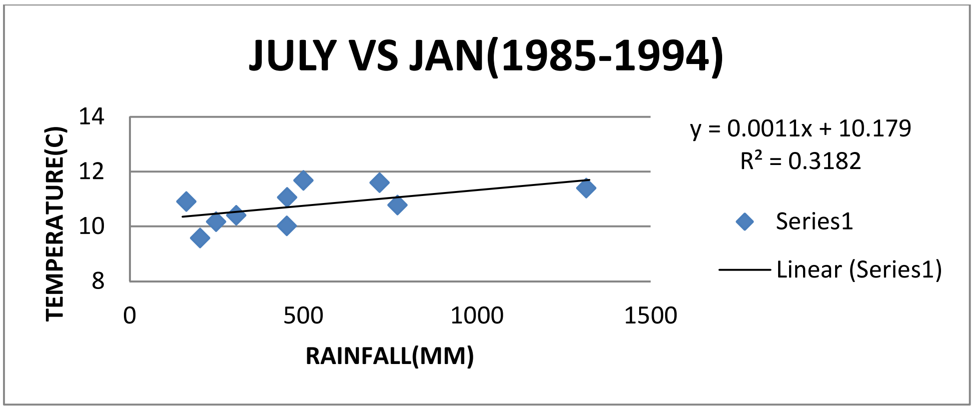

Fig.3.5.3: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1985 to 1994 at Rangpur.

The figure Fig.3.5.1, Fig.3.5.2 and Fig.3.5.3 represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1985 to 1994, July rainfall versus January minimum temperature from 1977 to 1984 and July rainfall versus January minimum temperature from 1985 to 1994 at Rangpur respectively. The values of r in the cases are +0.587, -0.660 and +0.564 respectively. Here the maximum positive correlation +0.587 is found between the Monsoon rainfall and Winter minimum temperature from 1985 to 1994 and maximum negative correlation -0.660 is found between July rainfall versus January minimum temperature from 1977 to 1984. Though the value of coefficient of determination informs us that the linear fit is quite good and the value of coefficient of correlation is high enough but it should be noted that the number of data were 7, not 10.

3.6 Dinajpur:

For this station out of 12 possible a maximum of 7 cases has correlation coefficients greater than 0.4 in magnitude of which 5 is positive and 2 is negative.

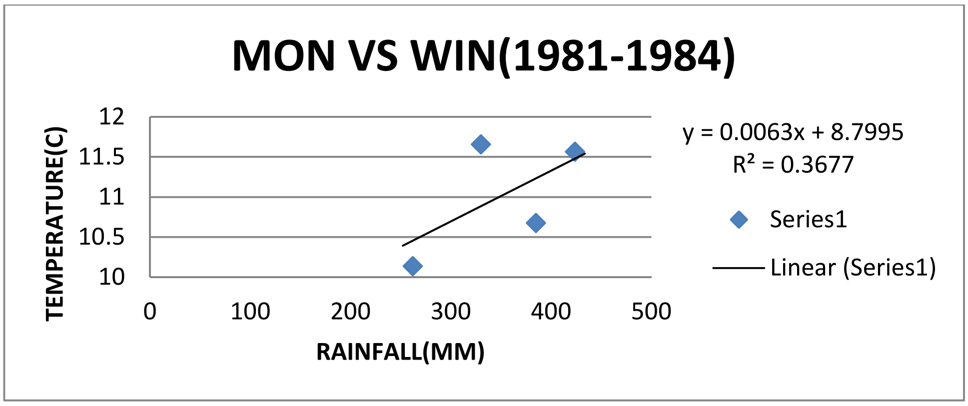

Fig.3.6.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1981 to 1984 at Dinajpur.

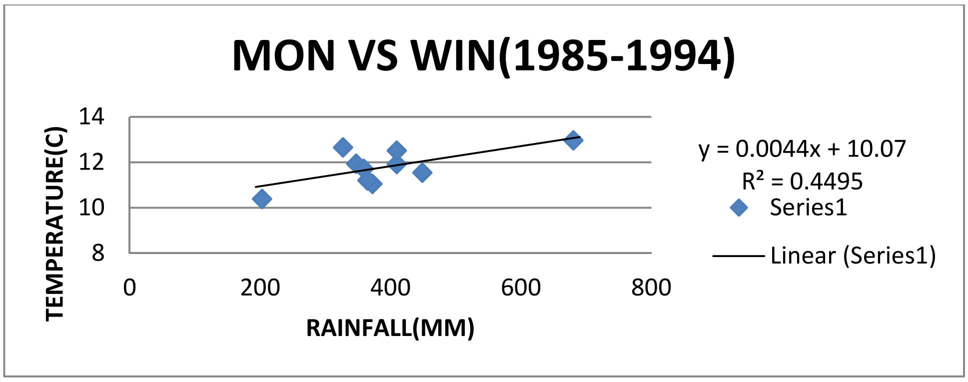

Fig.3.6.2: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1985 to 1994 at Dinajpur.

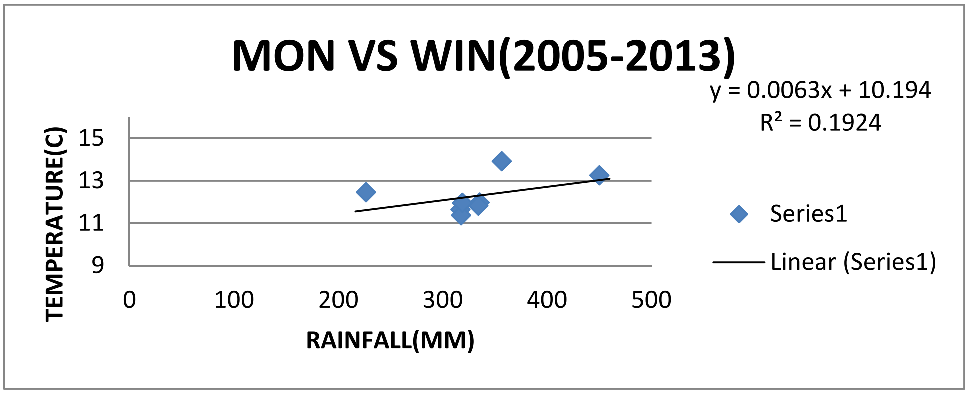

Fig.3.6.3: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2005 to 2013 at Dinajpur.

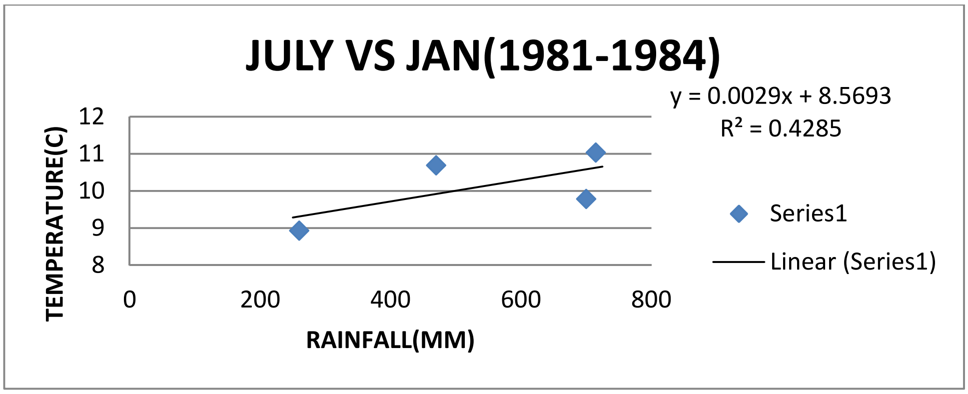

Fig.3.6.4: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1981 to 1984 at Dinajpur.

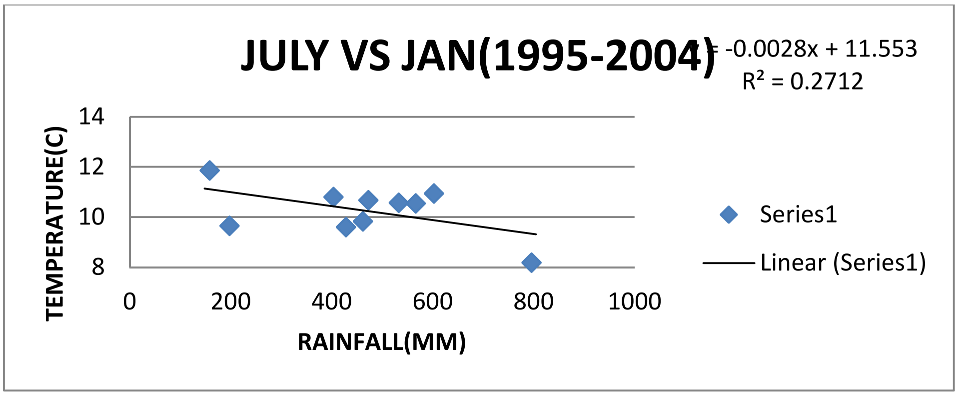

Fig.3.6.5: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1995 to 2004 at Dinajpur.

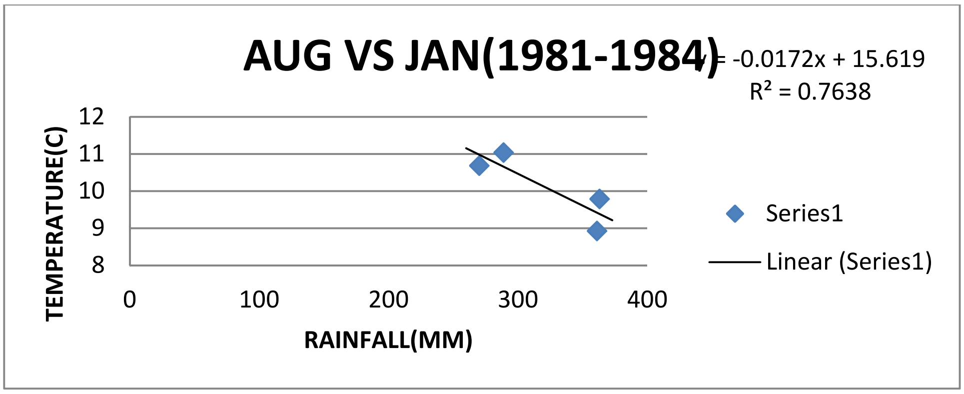

Fig.3.6.6: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1981 to 1984 at Dinajpur.

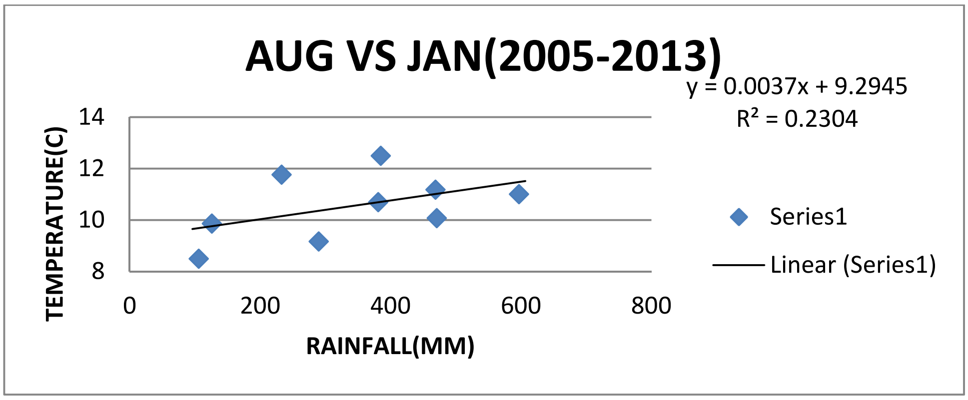

Fig.3.6.7: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 2005 to 2013 at Dinajpur.

The figures Fig.3.6.1, Fig.3.6.2, Fig.3.6.3, Fig.3.6.4, Fig.3.6.5, Fig.3.6.6 and Fig.3.6.7represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1981 to 1984, Monsoon rainfall versus Winter minimum temperature from 1985 to 1994, Monsoon rainfall versus Winter minimum temperature from

2005 to 2013, July rainfall versus January minimum temperature from 1981 to 1984, July rainfall versus January minimum temperature from 1995 to 2004, August rainfall versus January minimum temperature from 1981 to 1984 and August rainfall versus January minimum temperature from 2005 to 2013 at Dinajpur respectively. The values of r are +0.606, +0.670, +0.438, +0.654, -0.521, -0.873 and +0.480 in the cases respectively. Here the maximum positive correlation +0.670 is found between the Monsoon rainfall and Winter minimum temperature from 1985 to 1994 and maximum negative correlation -0.873 is found between August rainfall and January minimum temperature from 1981 to 1984. For the period 1981-1984 as there was only four data so in all the three cases the value of coefficient of determination is found high.

3.7 Srimangal:

For this station 5 cases are found in which the correlation coefficient are greater than or equal to 0.4 in magnitude.

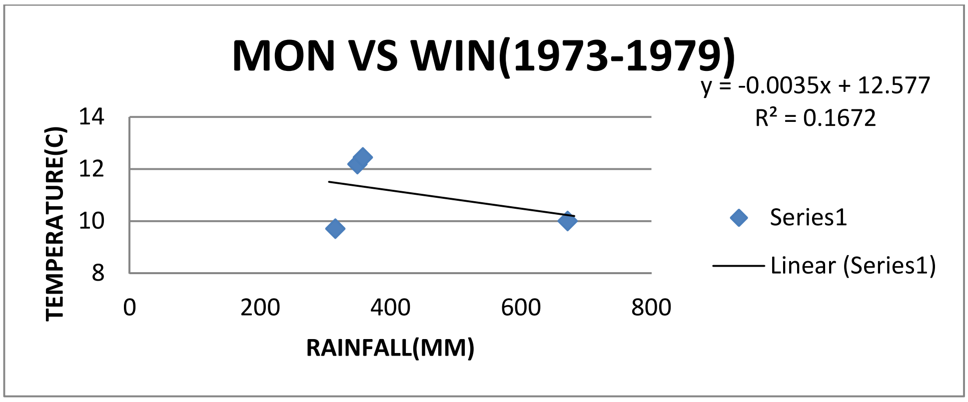

Fig.3.7.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1973 to 1979 at Srimangal.

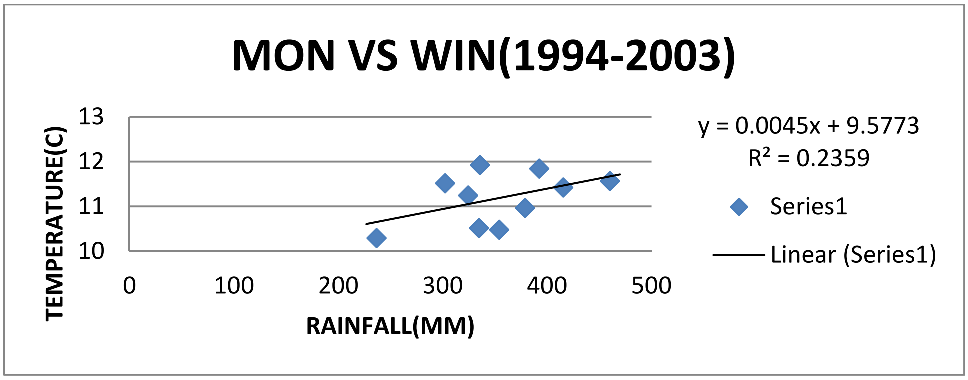

Fig.3.7.2: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1994 to 2003 at Srimangal.

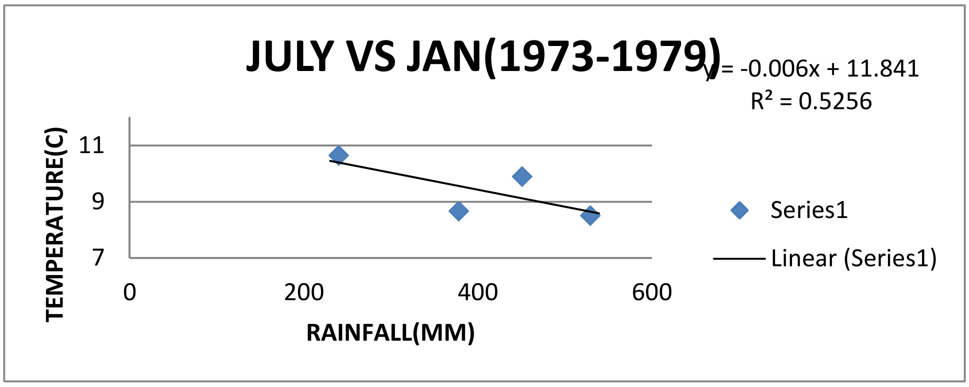

Fig.3.7.3: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1973 to 1979 at Srimangal.

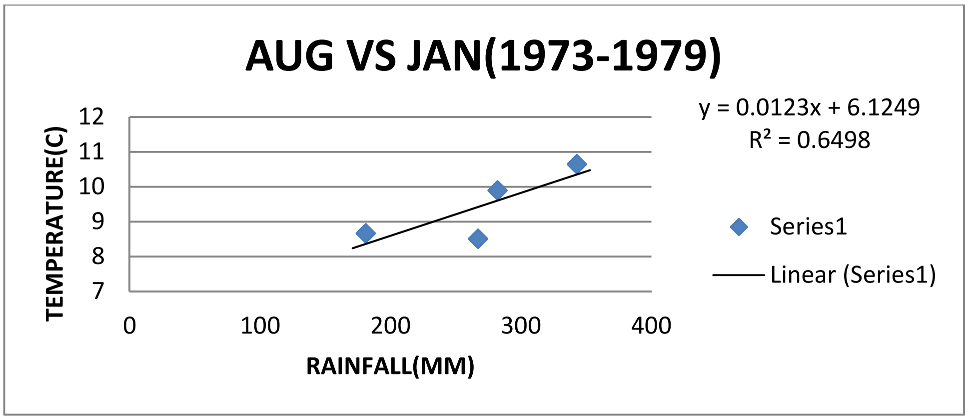

Fig.3.7.4: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1973 to 1979 at Srimangal.

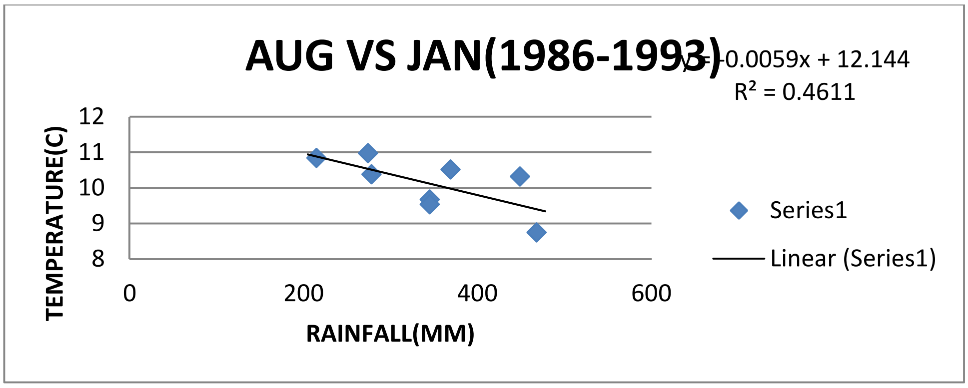

Fig.3.7.5: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1986 to 1993 at Srimangal.

The figures Fig.3.7.1, Fig.3.7.2, Fig.3.7.3, Fig.3.7.4 and Fig.3.7.5 represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1973 to 1979, of Monsoon rainfall versus Winter minimum temperature from 1994 to 2003, July rainfall versus January minimum temperature from 1973 to 1979, August rainfall versus

January minimum temperature from 1973 to 1979 and August rainfall versus January minimum temperature from 1986 to 1993 at Srimangal respectively. The values of r in the cases are -0.409, +0.485, -0.725, +0.806 and -0.679 respectively. Here the maximum positive correlation +0.806 is observed between the August rainfall and January minimum temperature from 1973 to 1979 and maximum negative correlation -0.725 is found between July rainfall and January minimum temperature from 1973 to 1979. In this case also the high value (in magnitude) have occurred in those cases where the number of available data was a few. Yet then the July rainfall versus January minimum temperature showed negative correlation where that August rainfall versus January minimum temperature has showed a negative correlation in the same period.

3.8 Sylhet:

For this station 4 cases are found in the tables in which the value (in magnitude) of the correlation coefficient is greater than or equal to 0.4.

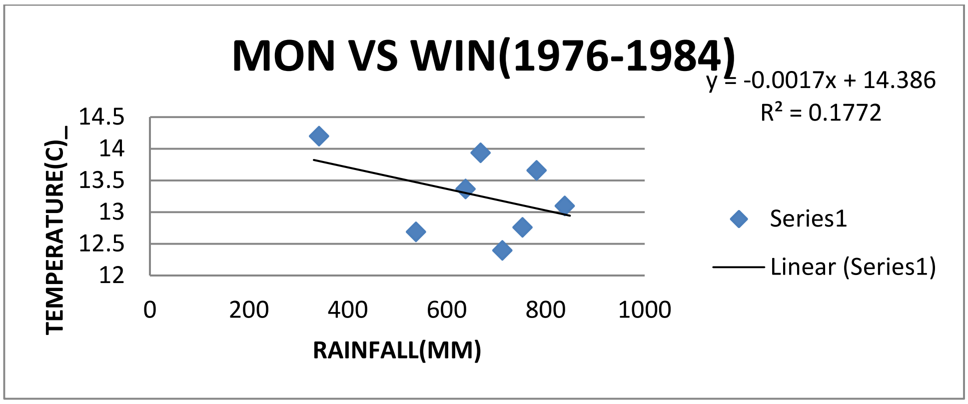

Fig.3.8.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1974 to 1983 at Sylhet.

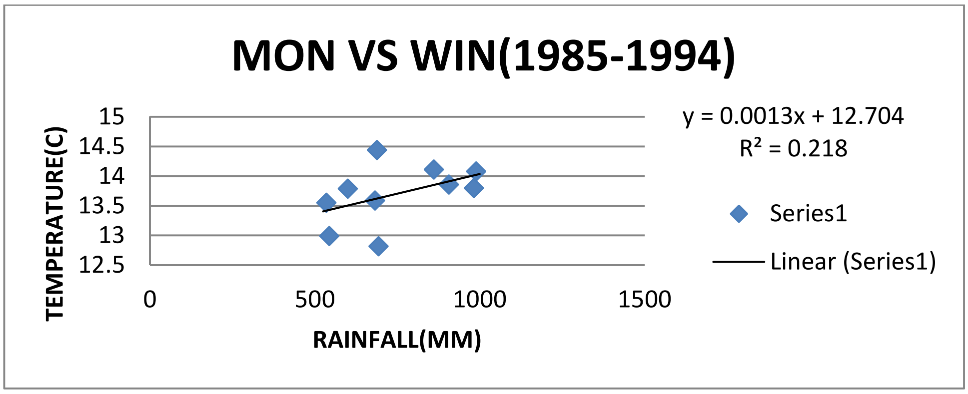

Fig.3.8.2: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1985 to 1994 at Sylhet.

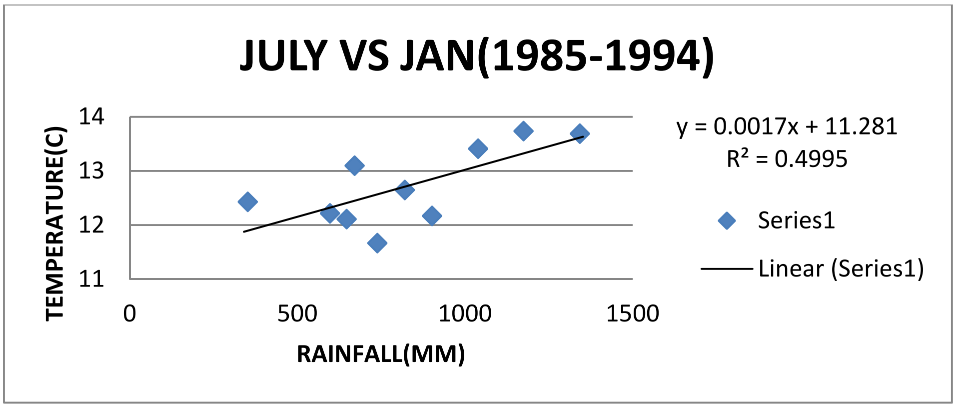

Fig.3.8.3: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1985 to 1994 at Sylhet.

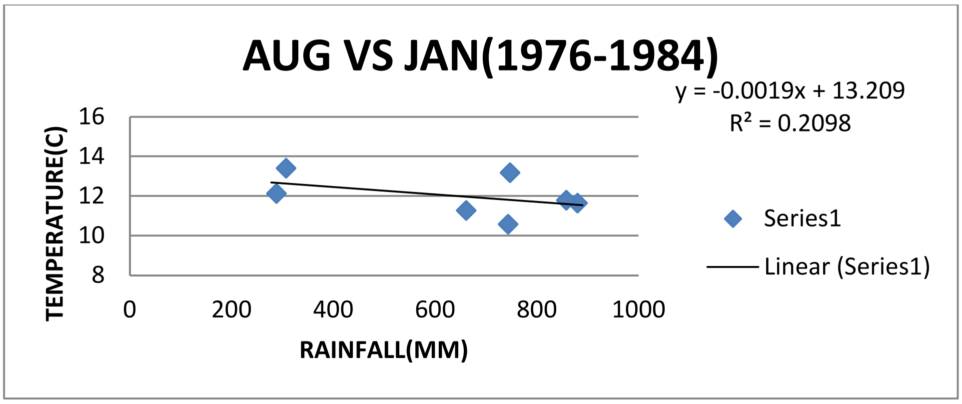

Fig.3.8.4: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1976 to 1984 at Sylhet.

The figures Fig.3.8.1, Fig.3.8.2, Fig.3.8.3 and Fig.3.8.4 represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 1974 to 1983, Monsoon rainfall versus Winter minimum temperature from 1985 to 1994, July rainfall versus January minimum temperature from 1985 to 1994 and August rainfall versus January minimum temperature from 1976 to 1984 at Sylhet respectively. The values of r found in the cases are -0.421, +0.467, +0.706 and -0.457 respectively. Here the maximum positive correlation +0.706) is found between the July rainfall and January minimum temperature from 1985 to 1994 and maximum negative correlation -0.457 is found between August rainfall and January minimum temperature from 1976 to 1984. It is observed that the relationship between the monsoon rainfall and winter minimum temperature during 1985-1994, and those between July and January of the same period are accounted. The strong positive correlation may have influenced the season where the value is not that much strong.

3.9 Dhaka:

In this case again 4 out of possible 12 correlation coefficients are found with magnitude greater than 0.4.

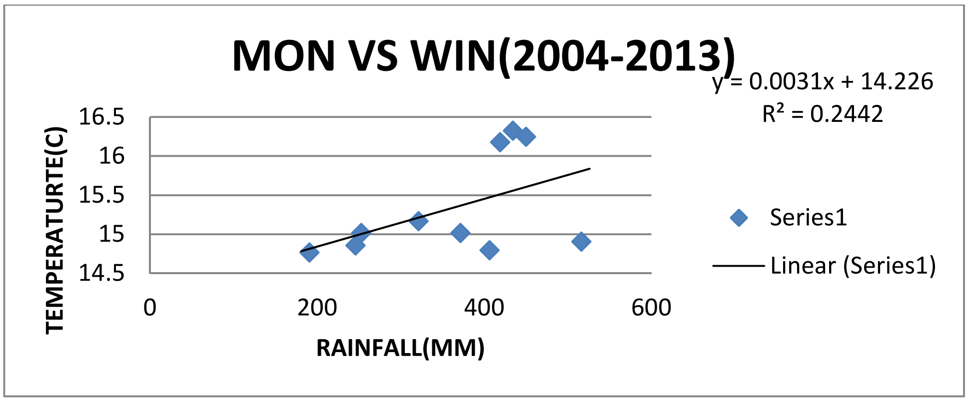

Fig.3.9.1: Scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2004 to 2013 at Dhaka.

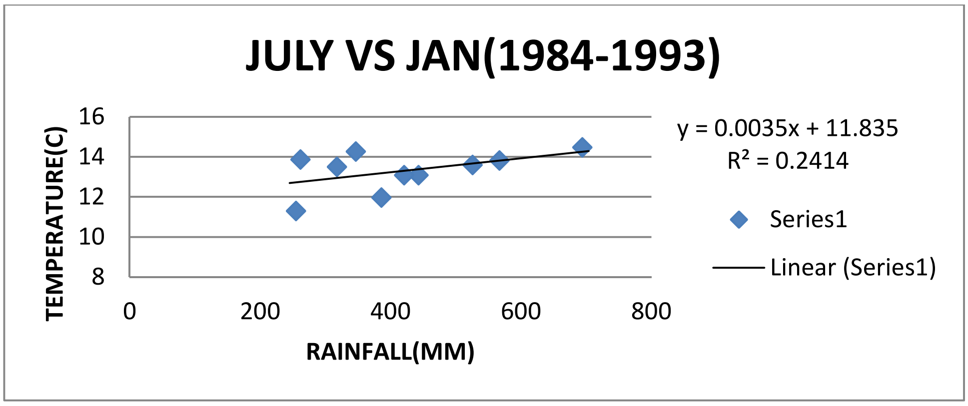

Fig.3.9.2: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 1984 to 1993 at Dhaka.

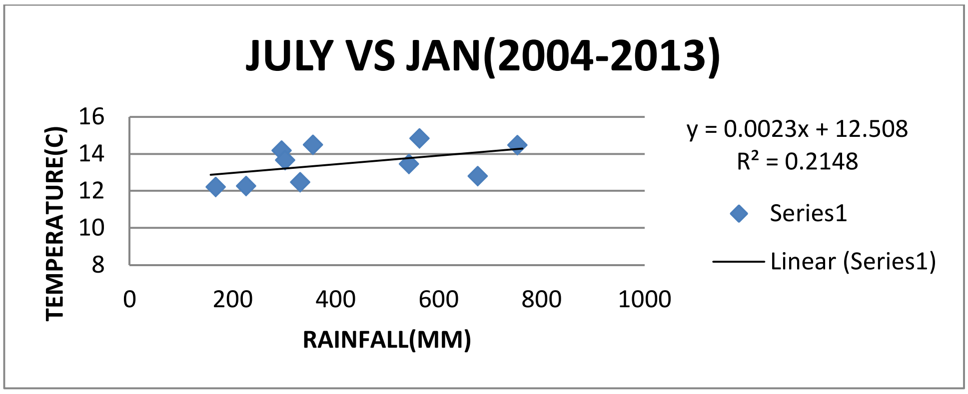

Fig.3.9.3: Scatter diagram and linear fit of July rainfall versus January minimum temperature from 2004 to 2013 at Dhaka.

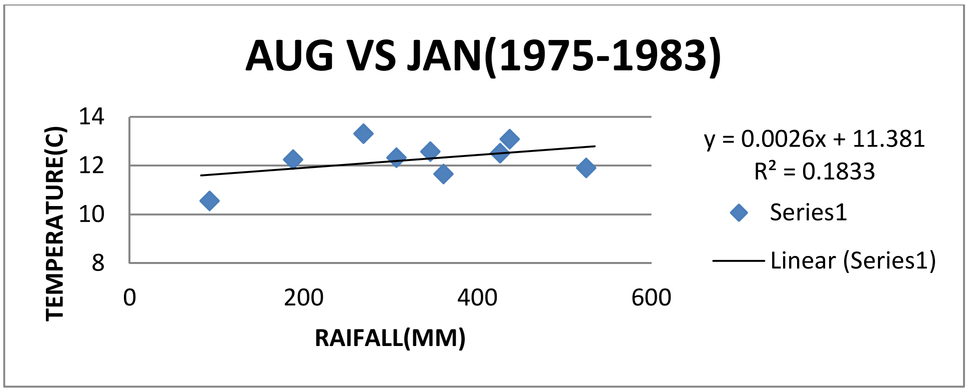

Fig.3.9.4: Scatter diagram and linear fit of August rainfall versus January minimum temperature from 1975 to 1983 at Dhaka.

The figures Fig.3.9.1, Fig.3.9.2, Fig.3.9.3 and Fig.3.9.4 represent the scatter diagram and linear fit of Monsoon rainfall versus Winter minimum temperature from 2004 to 2013, July rainfall versus January minimum temperature from 1984 to 1993, July rainfall versus January minimum temperature from 2004 to 2013 and August rainfall versus January minimum temperature from 1975 to 1983 at Dhaka respectively. The value of r those will be accounted are +0.494, +0.491, +0.463 and +0.428 respectively. Here the maximum positive correlation +0.494 is found between the Monsoon rainfall and Winter minimum temperature from 2004 to 2013. The values of r suggests that the relationships are not that much strong.

CHAPTER IV

CONCLUSION

In this research work though primarily we have worked with all the 34 stations all over Bangladesh and considered all the possible combinations to find the correlation between the rainfall of the monsoon months and the minimum temperature of the winter months and the season themselves but the primary output guided us to present only a few. As a result only 3 combinations are presented and their results are discussed. On the basis of the results presented and discussed in the earlier chapter the following conclusions can be drawn:-

i) Out of 108 correlation coefficients 39 has values greater than or equal to 0.4 in magnitude.

ii) In the decade 1994-2003 except the extreme northern stations all other stations experienced negative relationship between August rainfall and January minimum temperature.

iii) No countable negative correlation coefficient is observed in the southern and the central region but that is found elsewhere.

iv) At Srimangal cases are found in which at the same period the January minimum temperature is negatively correlated with the July rainfall where as positively correlated with the August rainfall.

References

Ahmed R. and Kim I.,2003: Patterns of Daily Rainfall in Bangladesh During the Summer Monsoon Season: Case Studies at Three Stations, Physical Geography, 24(4), 295-318.

Alam, M.M. and Hossain, M.A., 2004: Correlation between winter temperature and post monsoon rainfall over Bangladesh, Presented at the International Conference on Physics for understanding and applications, Dhaka, Bangladesh, 22-24 February.

Alam, M.M. and Hossain, M.A., 2002: Correlation between winter temperature and monsoon rainfall over Bangladesh, Presented at the Biennial Symposium on Physics and modern development, Dhaka,Bangladesh, 30-31 March

Chowdhury, M.H.K. and Debsarma, S.K., 1992, "Climatic change in Bangladesh-A statistical review", Report on IOC-UNEP Workshop on Impacts of sea level rise due to Global Warming, NOAMI, held during 16-19 November 1992 in Bangladesh, pp.15.

Khan, F.K. and Islam, M.A., 1966: Water balance in East Pakistan.

Kripalani, R.H., Inamdar, S. and Sontakke N.A., 1996: Rainfall Variability Over Bangladesh and Nepal: Comparison and connections with Features Over India International Journal of Climatalogy, vol. 16, Issue 6, pp.689-703.

Oshawa, T., Haysashi, T., Mitsuta, Y. and Matsumoto, J., 2000: Intraseasonal variation of monsoon activities associated with the rainfall over Bangladesh during the 1995 summer monsoon season, Journal of geophysical research,105(D24),29445-29459.

Samad, Q.A. and Islam, M.S., 1993: Spatial and Temporal Variability of Rainfall in Bangladseh , Presented in 4th National Conference of the Bangladesh Statistical Association, Dhaka.

Shamsuddin, S.D. and Ahmed,R., 1974: Variability of annual rainfall in Bangladesh, J. of Bangladesh National Geographical Association, 13-20.

Shamsuddin, S.D. and Alam, M.S., 1990: Monsoon seasonally and aspects of hydrological regions with reference of Agriculture in Bangladesh, Malaysian J. of Tropical Geography, 2,25-34.

Warrick, R.A., A.H. and Mirza,M.Q., 1994: "Briefing Doc No. 1", BUP, pp. 17-20.

Yasmin, L., 2008: "Multiple correlation between different meteorological parameters in pre-monsoon and monsoon rainfall over Bangladesh", M.Phil. Thesis(unpublished), KUET, pp-130.

Appendix

```
c     program to calculate seasonal mean for all stations at a time
      dimension rain(12)
      character stn*12
C
c     opening the input data file
C
      open(24,file='monthly_rains_year_all_corr.dat')
C
c     opening the output data files
C
      open(25,file='monsoon_rain_all_corr.dat')
      open(26,file='june_rain_all_corr.dat')
      open(27,file='july_rain_all_corr.dat')
      open(28,file='august_rain_all_corr.dat')
      open(29,file='september_rain_all_corr.dat')
C
c     reading first 12 columns of a line of the data file
C
 1    read(24,57,end=999)stn
  57   format(a12)
C
c     returning to the starting position
C
       backspace(24)
C
c     assigning duty if the first character is not blank
C
```

```
        if(stn(1:1).ne.' ')then
      read(24,50)stn,iyr,(rain(j),j=1,12)
 50   format(a12,2x,i4,12(2x,f7.3))
C
c     writing the monthly rainfall data in different files
C
       rain(6)=30*rain(6)
       rain(7)=31*rain(7)
       rain(8)=31*rain(8)
       rain(9)=30*rain(9)
      write(26,60)stn,iyr,rain(6)
      write(27,60)stn,iyr,rain(7)
      write(28,60)stn,iyr,rain(8)
      write(29,60)stn,iyr,rain(9)
  60  format(a12,2x,i4,2x,f8.3)
C
c     estimating the total rainfall of monsoon
C
       km=4
       amon=0.0
        if(rain(6).eq.-1.0)then
        km=km-1
        else
        amon=amon+rain(6)
        endif
        if(rain(7).eq.-1.0)then
        km=km-1
        else
        amon=amon+rain(7)
```

```
        endif
        if(rain(8).eq.-1.0)then
        km=km-1
        else
        amon=amon+rain(8)
        endif
        if(rain(9).eq.-1.0)then
        km=km-1
        else
        amon=amon+rain(9)
        endif
C
c     averaging the total rainfall of monsoon
C
       if(km.eq.0)then
       amon=-1.0
       else
       amon=amon/km
       endif
C
c     writing the averaged monsoon data
C
       write(25,51)stn,iyr,amon,km
  51  format(a12,2x,i4,2x,f6.2,2x,i2)
C
c      assigning duty if the first character is blank
c      one station is complited
C
       else
```

```
c      transfering the control for the next station
C
       do i=1,4
       read(24,*)
       write(25,*)
       write(26,*)
       write(27,*)
       write(28,*)
       write(29,*)
       enddo
C
c     end of the logical loop
C
       endif
C
c
C
       goto 1
C
C
 999  stop
      end
```