MULTIPLE CORRELATION BETWEEN DIFFERENT METEOROLOGICAL PARAMETERS IN PRE-MONSOON AND MONSOON RAINFALL OVER BANGLADESH

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A Thesis on

Multiple Correlation between different Meteorological Parameters in Pre-Monsoon and Monsoon Rainfall over Bangladesh

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LOVELY YESMIN

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DEDICATED TO
MY LATE PARENTS FOR
MAKING IT POSSIBLE FOR ME TO BECOME
THE PERSON I AM

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Abstract

In this research work we have tried to find out the multiple correlation between five meteorological parameters dry bulb temperature, wet bulb temperature, minimum temperature, maximum temperature and rainfall of pre-monsoon season with the rainfall of monsoon season over Bangladesh. Initially correlation coefficients (CC) between different parameters of pre-monsoon season and rainfall of the monsoon have been studied. The correlation coefficients between these parameters with the monthly and seasonal rainfall have been studied.

In this research work we have used the data of thirty meteorological stations during 1951 to 2000 all over Bangladesh. We have collected these raw data from Bangladesh Meteorological Department (BMD). We processed these raw data and obtained the monthly and seasonal average. Using these processed data we have analyzed:

1) The average dry bulb temperature (DBT), wet bulb temperature (WBT), minimum temperature (MinT), maximum temperature (MaxT) and rainfall for the month of March, April and May and pre-monsoon season itself.
2) The average rainfall for the month of June, July, August and September and the monsoon season itself.
3) The correlation coefficients between the monthly/seasonal rainfall of monsoon season with the monthly/seasonal DBT, WBT, MinT, MaxT and rainfall of pre-monsoon season. The multiple correlations between the monthly/seasonal rainfall of monsoon season with the monthly/seasonal DBT, WBT, MinT, MaxT and rainfall of pre-monsoon season.

The average DBT gradually increases from the northeastern to the southwestern part of the country. The southern part of the country has the maximum WBT whereas the northern part has the minimum. Starting from the central part of the country the minimum temperature increases towards south and decreases towards north during this season. The highest maximum average temperature exits at Rajshahi-Ishwardi-Jessore-Khulna-Satkhira belt and the lowest at Sylhet. Jessore and some northern part of the country have the minimum rainfall during pre-monsoon season. During monsoon season the maximum rainfall has been recorded at Teknaf, Cox's Bazar and Sylhet region and the minimum rainfall at Jessore, Chandpur and other west and north western belt.

From the analysis it has been observed that the correlation coefficient between the pre-monsoon maximum temperature and monsoon rainfall is positive at most of the places of the central (especially Chandpur and Madaripur), southwestern and a few places of the northern part of the country. It has been found that the correlation co-efficient between the pre-monsoon WBT and monsoon rainfall is positive mostly at the southern, southwestern and the extreme northern part of the country. From this study it has been also found that the multiple correlation co-efficient between the DBT, WBT, MinT, MaxT and rainfall of pre-monsoon and the rainfall of monsoon has a positive value all over the country.

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CHAPTER I

Introduction

Weather is the state of the atmosphere, as determined by the simultaneous occurrence of several meteorological phenomena at a geographical locality or over broad areas of the Earth. More popularly, weather refers to a certain state of the atmosphere as it affects human's activities on the Earth's surface. It involves day-to-day changes in such atmospheric phenomena as temperature, humidity, precipitation, air pressure, wind and cloud cover etc. Condition of the atmosphere at a particular location over a long period of time (from one month to many millions of years, but generally 30 years). Climate is the sum of atmospheric elements (and their variations): solar radiation, temperature, humidity, clouds and precipitation, atmospheric pressure, and wind.

The life of man inhabiting the planet earth is influenced mostly by the climate among all the factors of our physical environment. It is therefore essential to know how climate will change over the coming years. Bangladesh has a tropical monsoon climate with significant variations in rainfall and temperature throughout the country. There are four seasons: the pre-monsoon (March-May) has the highest temperatures and experiences the maximum intensity of cyclonic storms, especially in April; the monsoon (June-September) when the bulk of rainfall occurs; the post-monsoon (October-November) which, like the pre-monsoon season, is marked by tropical cyclones on the coast; and the cool and sunny dry season (December-February). The mean annual temperature is about 25° C, with extremes of 4 and 43°C. Ground frosts can occur in the hills. Humidity ranges between 60 percent in the dry season and 98 percent during the monsoon. Among the four seasons monsoon is the most important one for rainfall in Bangladesh. Most of the annual rainfall occurs in this season.

Significant climate variability exists in monsoon regions of South and East Asia that directly impact regional agricultural practices, health issues, water resource management, and the general welfare of a large percentage of the planet's population.

Bangladesh is located over the vast delta of three great rivers, the Ganges, the Brahmaputra and the Meghna. Its topography is characterized by very flat plains, which dominate most parts of the country and never rise to more than 10 m above sea level. Although a few in numbers, there are mountains higher than 1000 m those are located at Sylhet (Part of the Shillong Plateau) and Chittagong Hill Tracts (located near the northeastern and southeastern borders with India and Myanmar) and that have great effects on the amounts of rainfall in the adjacent areas.

The southwest monsoon makes its arrival at Bangladesh coast through the southeastern part, the mean date of onset is 2nd June, and it takes about 13 days (Ahmed and Karmakar, 1993) to reach the northwestern part of the country. The southwest monsoon begins its withdrawal from 30th September and the withdrawal is completed through the southeastern part of the country 17 days later. The impact of rainfall in Indian sub-continent is tremendous in monsoon season. In this season sometimes large amount of rainfall occurs in Nepal and Northeast of India, which causes flood in northeast India and Bangladesh. It sometimes causes the heavy flood in Bangladesh. The recent floods of 1987, 1988, 1998, 2004 and 2007 are the examples of them. From the recent studies it has been found that DBT (Ara et al., 2005), maximum and minimum temperature and rainfall (Karmakar et al., 2000) have increased over Bangladesh. It has also been found that the sea level height has risen in the Bay of Bengal and the green house gases has increased in the atmosphere.

Most of the severe cyclonic storms form in the pre-monsoon and post-monsoon season. The effect of this type of cyclone is tremendous for the peoples of this subcontinent. The cyclones of 12th November 1970, 29th April 1991 and 15th November 2007 causes unmeasurable losses of lives and properties in Bangladesh. During the last decades the number of depressions/tropical cyclones forming in the Bay of Bengal has decreased remarkably (Alam et al., 2002). Scientists believe that this is happening due to the change in climate in the East, Far East Asia and in Indian subcontinent.

Summer monsoon is the most important and vital season in Indian subcontinent. On an average, more than 80% of Bangladesh's annual rainfall occurs in the monsoon (June-September) season. The quantity of monsoon rainfall has a socio-economic impact on the peoples of Indian subcontinent. However, the studies on the rainfall characteristics over Bangladesh are a few. A study on the water balance of Bangladesh has been made by Khan and Islam (1966) while the variability of annual rainfall by Shamsuddin (1974), spatial and temporal variability by Samad and Islam (1993), monsoon season and aspects of hydrology and agriculture by Shamsuddin and Alam (1990), correlation between winter temperature and monsoon rainfall over Bangladesh by Alam and Hossain (2002) and correlation between winter temperature and post-monsoon rainfall by Alam and Hossain (2004) are among the significant studies towards understanding of rainfall characteristics and distribution in Bangladesh.

The mean rainfall during the monsoon season ranges from 1000 to 3000 mm in the country. The maximum rainfall occurs at Sylhet in the northeastern part and along the coastline in the southern part and with a minimum in the west central part (Matsumoto, 1988; Hussain and Sultana, 1996). The rainfall actually exceeds 5000 mm near the Shillong Plateau (Ohsawa et al., 1998). Because the Shilong Plateau works as a topographic barrier to prevailing southerly monsoon wind, the amount of rainfall is extremely high on the southern slope of the Shillong Plateau. The monsoon rainfall at Cherrapunji located on the southern slope of the Shillong Plateau and about 10-km away from the border of Bangladesh is, on an average, more than 8000 mm (Pant and Kumar, 1997).

Banerjee et al. (1978) showed that the total monsoon rainfall over India is significantly correlated with the latitudinal position of the subtropical ridge of the mean circulation of April at 500 hPa level. Upadhyay et al., (1990) and Kanaujia et al., (1992) determined the rainfall correlation decreases exponentially with distance. Ohsawa et al., (2000) studied the time-log correlation of the 20-day mode of the 850 hPa zonal wind with a reference point at 22.5°N, 90°E for the periodicity of monsoon activity. They find that the significant positive correlation area first appears near the equator in Southeast Asia and then moves in the west-northwest direction toward the Indian subcontinent. Kanamitsu and Krishnamurti (1978) and Verma (1980, 1982) have shown that the future performance of the monsoon is reflected by the upper tropospheric thermal and circulation anomalies over the Indian subcontinent for pre monsoon months. Karmakar et al., (1994) tried to find the correlation between pre monsoon rainfall and monsoon rainfall over different stations of Bangladesh and observed no correlation. Mahbub (2002) tried to find the correlation between winter temperature and monsoon rainfall and found significant correlation in different stations over Bangladesh. The correlation between different meteorological parameters (maximum temperature, minimum temperature, dry bulb temperature, wet bulb temperature, pressure and rainfall) in pre monsoon season and monsoon rainfall has not been analyzed and it has to be analyzed.

The analysis of annual rainfall for the period of 1870-1991 shows no discernible long-term trend in mean annual rainfall over Bangladesh. The climatic change and its impacts on natural disasters have been studied by Karmakar and Nessa (1997). From their study they reported that the decadal mean annual temperature over Bangladesh has an increasing tendency especially after 1961-1970. From the projected values of increasing rainfall during the southwest monsoon season they predicted that the rainfall is likely to increase by 12.74 mm and 23.36 mm by the year 2050 and 2100, respectively. According to Karmakar and Shrestha (2000), during the post-monsoon season the rainfall is likely to increase by 14.05 mm and 25.76 mm by the year 2050 and 2100, respectively.

The monsoon rainfall governs the lifestyle and socio-economic condition of the people of Bangladesh. Since the economy of the country mainly depends on agriculture, which, in turn, relies on rainfall, the study of rainfall pattern is very important for its agricultural planning. In this work, we have tried to investigate the single correlation and the multiple correlations between the monthly rainfall of pre-monsoon and monsoon season and different meteorological parameter e.g. maximum temperature, minimum temperature, dry bulb temperature and wet bulb temperature in the pre monsoon season. We have also tried to find out the correlation between seasonal average rainfall of pre-monsoon and monsoon and the seasonal average of different meteorological parameters in the pre- monsoon season. The main objective of this work is to develop the regression equation of monthly rainfall in different meteorological parameters in the pre monsoon season. If we develop regression equation for the monsoon rainfall on the basis of different meteorological parameters in the pre-monsoon season then we may predict the monsoon rainfall in different stations over Bangladesh few months earlier. This type of early prediction will contribute heavily in agricultural sector as well as in the socioeconomic growth of Bangladesh.

1.1 Pre Monsoon

The hot season from March to May is the traditional period when the winter pattern of pressure and winds gets disturbed prior to the establishment of the summer monsoon and hence, is often referred to as 'Pre - Monsoon' season. The pre-monsoon hot season is characterized by high temperatures and the occurrence of thunderstorms. April is the hottest month when mean temperatures range from 27°C in the east and south to 31°C in the west-central part of the country. In the western part, summer temperature sometimes reaches up to 40°C. After the month of April, the temperature dampens due to increased cloud cover. The pre-monsoon season is the transition period when the northerly or northwesterly winds of the winter season gradually changes to the southerly or southwesterly winds of the summer monsoon or rainy season (June-September). During the early part of this season, the winds are neither strong nor persistent. However, with the progression of this season wind speed increases, and the wind direction becomes more persistent.

During the early part of the pre-monsoon season, a narrow zone of air mass discontinuity lies across the country that extends from the southwestern part to the northeastern part. This narrow zone of discontinuity lies between the hot dry air coming from the upper Gangetic plain and the warm moist air coming from the Bay of Bengal. As this season progresses, this discontinuity weakens and retreats toward northwest and finally disappears by the end of the season, making room for the onset of the summer monsoon. The rainy season, which coincides with the summer monsoon, is characterized by southerly or southwesterly winds, very high humidity, heavy rainfall, and long consecutive days of rainfall which are separated by short spells of dry days. Rainfall in this season is caused by the tropical depressions that enter the country from the Bay of Bengal.

1.2 Monsoon

A monsoon is a seasonal prevailing wind which lasts for several months. The term was first used in English in India, Bangladesh, Pakistan and neighboring countries to refer to the seasonal winds blowing from the Indian Ocean and Arabian Sea in the southwest bringing heavy rainfall to the region. In hydrology, monsoonal rainfall is considered to be that which occurs in any region that receives the majority of its rain during a particular season, and so monsoons are referred to in relation to other regions such as in North America, Sub-Saharan Africa, Brazil and East Asia.

The English name *monsoon*, was derived from the Arabic word *mausim* meaning 'seasons', (Glossary of Meteorology , 1957) referring to seasonal winds experienced by sailors in the Arabian Sea. In terms of total precipitation, total area covered and the total number of people affected, the monsoons affecting the Indian subcontinent. The definition includes major wind systems that change direction seasonally. Most summer monsoons have a dominant westerly component and a strong tendency to ascend and produce copious amounts of rain (because of the condensation of water vapour in the rising air). The intensity and duration, however, are not uniform from year to year.

Strengthening of the Asian monsoon has been linked to the uplift of the Tibetan Plateau after the collision of India and Asia around 50 million years ago. Evidence for when this first happened remains controversial. Many geologists believe the monsoon first became strong around 8 million years ago based on records from the Arabian Sea and the record of wind-blown dust in the Loess Plateau of China. More recently plant fossils in China and new long-duration sediment records from the South China Sea led Peter Clift to propose a much older monsoon starting around 24 million years ago and linked to early Tibetan uplift. Testing of this hypothesis awaits deep ocean sampling by the Integrated Ocean Drilling Program. The monsoon has varied significantly in strength since this time, largely linked to global climate change, especially the cycle of the Pleistocene ice ages.

The land has a small heat capacity compared to ocean. As a result the absorption of solar radiation raises the surface temperature over the land much more rapidly than over the ocean. This surface warming leads to enhanced columns convection, and hence to latent heat releases which produces warm temperatures throughout the troposphere. As a result there is a pressure gradient force at the upper levels directed from the land to ocean. The divergent wind which develops in response to this pressure gradient causes a net mass transport out of the air cumulus above the continent and thereby generates a surface low over the continent. A compensating convergence wind then develops at low levels. This low level flow produces a convergence of moisture which serves to maintain the columns convection which is primarily energy source for the monsoon circulation.

The Bay of Bengal Branch of Southwest Monsoon flows over the Bay of Bengal heading towards North-Eastern India and Bengal, picking up more moisture from the Bay of Bengal. Its hits the Eastern Himalaya and provides a huge amount of rain to the regions of North-East India, Bangladesh and West Bengal. Cherrapunji, situated on the southern slopes of the Eastern Himalaya in Shillong, India is one of the wettest places on Earth.

The agriculture of Bangladesh is heavily dependent on the rains, especially crops. A delay of a few days in the arrival of the monsoon can, and does, badly affect the economy, as evidenced in the numerous droughts in Indian subcontinent. The monsoon is widely welcomed and appreciated by city-dwellers as well, for it provides relief from the climax of summer in June. Bangladesh and some regions of India like in Assam and places of West Bengal experiences heavy flood, which claims huge number of lives and huge loss of property and causes severe damage to economy.

The monsoon area has been defined by Ramage (1971) by the following criteria:

- The prevailing wind direction shifts by at least 120° between January and July
- The average frequency of prevailing wind directions in January and July exceeds 40 percent.
- The mean resultant wind is at least one of the months exceeding 3 m/sec.
- Fewer than one cyclone-anticyclone alternation occurs every two years in either month in a 5° latitude-longitude rectangle.

The area between 35°N, 25°S, 30°W and 170°E satisfies the above definition; India and the surrounding seas fall within this area. In India and its surroundings, monsoon period is divided into three seasons which are a) Pre-monsoon (March to May), b) Monsoon (June to September) and c) Post-monsoon (October to November) (Das, 1995).

The monsoon normally reaches the coastal belt of Bangladesh by the last week of May to the first week of June and progressively engulfs the whole country through June. On an average 20-25 rainy days per month during June to August, decreasing to 12-15 days in September. With the advent of the monsoon, the extreme temperatures of summer fall appreciably throughout the country. Although the mean temperature falls hardly by one degree, the maximum temperature falls by 2-5 °C over most part of the country except the coastal belts where the fall is by 5-6 °C [WMO/UNDP/BGD/79/013, 1986].

1.3 Dry Bulb Temperature (DBT)

The Dry Bulb Temperature (DBT) is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. In construction, it is an important consideration when designing a building for a certain climate. Nall (2004) called it one of "the most important climate variables for human comfort and building energy efficiency". It is usually referred to as air temperature, is the air property that is most common used. When people refer to the temperature of the air, they are normally referring to its dry bulb temperature. The dry bulb temperature refers basically to the ambient air temperature. It is called "Dry Bulb" because the air temperature is indicated by a thermometer not affected by the moisture of the air. DBT can be measured using a normal thermometer freely exposed to the air but shielded from radiation and moisture. The temperature is usually given in degrees Celsius (^oC) or degrees Fahrenheit (^oF). The SI unit is Kelvin (K). Zero Kelvin equals to -273°C.

The dry-bulb temperature is an indicator of heat content and is shown along the bottom axis of the psychrometric chart. Constant dry bulb temperatures appear as vertical lines in the psychrometric chart.

1.4 Wet Bulb Temperature (WBT)

The temperature an air parcel would have if cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the parcel is called the Wet Bulb Temperature (WBT). It is the temperature of adiabatic saturation. This is the temperature indicated by a moistened thermometer bulb exposed to the air flow. Wet Bulb temperature can be measured by using a thermometer with the bulb wrapped in wet muslin. The adiabatic evaporation of water from the thermometer and the cooling effect is indicated by a "wet bulb temperature" lower than the "dry bulb temperature" in the air. The rate of evaporation from the wet bandage on the bulb, and the temperature difference between the dry bulb and wet bulb, depends on the humidity of the air. The evaporation is reduced when the air contains more water vapor. The wet bulb temperature is always lower than the dry bulb temperature but will be identical with 100% relative humidity (the air is at the saturation line). Combining the dry bulb and wet bulb temperature in a psychrometric diagram or Mollier chart, gives the state of the humid air.

Lines of constant wet bulb temperatures run diagonally from the upper left to the lower right in the Psychrometric Chart.

1.4.1 Measurement of wet and dry bulb temperature:

Wet-bulb temperature is measured using a thermometer that has its bulb wrapped in cloth—called a *sock*—that is kept wet with water via wicking action. Such an instrument is called, not surprisingly, a *wet-bulb thermometer.* At relative humidities below 100%, water evaporates from the bulb which cools the bulb below ambient temperature. To determine relative humidity, ambient temperature is measured using an ordinary thermometer, better known in this context as a dry-bulb thermometer. At any given ambient temperature, less relative humidity results in a greater difference between the dry-bulb and wet-bulb temperatures; the wet bulb is colder. When thermal equilibrium is reached at WBT, the loss of heat by the air flowing past the wet bulb must be equal to the sensible heat, which is transformed to latent heat. That is

$$(T-T_w)(C_p+\omega C_{pv})=(\omega'-\omega)L$$

where T is the temperature of the air approaching the wet bulb, T_w is the temperature of the saturated air leaving the wet bulb, C_p is the specific heat at constant pressure of dry air, C_{pv} is the specific heat of water vapor, ω is the mixing ratio of the approaching unsaturated air, ω' is the mixing ratio of the leaving saturated air and L is the latent heat of evaporation.

When the air is humid, only a small amount of moisture will evaporate from the cloth. This means the wet bulb temperature will only be a little lower than the dry bulb temperature. Conversely, if the moisture will evaporate from the cloth quickly. This means that the wet bulb temperature will be much lower than the dry bulb temperature. If it is raining or there is heavy fog, the air is saturated, and the dry bulb temperature will be equal to the wet bulb temperature. The precise relative humidity is determined by finding one's wet-bulb and dry-bulb temperatures on a psychrometric chart (or via complex calculation).

1.5 Rainfall

Rain is a type of precipitation, a product of the condensation of atmospheric water vapour that is deposited on the Earth's surface. It forms when separate drops of water fall to the Earth from clouds. Not all rain reaches the surface; some evaporates while falling through dry air. When none of it reaches the ground, it is called virga, a phenomenon often seen in hot, dry desert regions.

Rain plays a role in the hydrologic cycle in which moisture from the oceans evaporates, condenses into drops, precipitates (falls) from the sky, and eventually returns to the ocean via rivers and streams to repeat the cycle again. The water vapour from plant respiration also contributes to the moisture in the atmosphere. A major scientific explanation of how rain forms and falls is called the Bergeron process. More recent research points to the influence of Cloud condensation nuclei released as the result of biological processes.

Rainfall is typically measured using a rain gauge. It is expressed as the depth of water that collects on a flat surface, and is routinely measured with an accuracy up to 0.1 mm or 0.01 in. Rain gauges are usually placed at a uniform height above the ground, which may vary depending on the country.

Precipitation, especially rain, has a dramatic effect on agriculture. All plants need at least some water to survive, therefore rain (being the most effective means of watering) is important to agriculture. While a regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, even devastating to crops. Plants need varying amounts of rainfall to survive. Agriculture of all nations at least to some extent is dependent on rain. Bangladeshi's agriculture, for example is heavily dependent on the rains, especially crops like rice, oilseeds and coarse grains. A delay of a few days in the arrival of the monsoon can, and does, badly affect the economy, as evidenced in the numerous droughts in Bangladesh and India.

When classified according to amount of precipitation, rain can be divided into (http://my.athenet.net):

- very light rain — when the precipitation rate is < 0.25 mm/hour
- light rain — when the precipitation rate is between 0.25 mm/hour - 1.0 mm/hour
- moderate rain — when the precipitation rate is between 1.0 mm/hour - 4.0 mm/hour
- heavy rain — when the precipitation rate is between 4.0 mm/hour - 16.0 mm/hour
- very heavy rain — when the precipitation rate is between 16.0 mm/hour - 50 mm/hour
- extreme rain — when the precipitation rate is > 50.0 mm/hour

Islam et al., (2005*a*) studied the spatial and temporal variations of precipitation in and around Bangladesh. Radar data from the Bangladesh Meteorological Department were employed as a preliminary analysis. It was the first research work to investigate the spatial and temporal distribution of rainfall over the country for 135 consecutive days, from 16 April to 30 August 2000. Radar data were averaged in 10 km grid boxes to obtain daily rainfall over the country. Rain gauge data at 33 locations were utilized to check the radar results. The distributions of rainfall obtained by both the radar and the rain gauges were similar in pattern, but the time of the maximum rainfall determined by the radar was a few hours earlier than that determined by the rain gauges. The distribution of rainfall over the whole radar domain suggests that 21.00 to 09.00 h local standard time (LST) is the most likely time for rainfall to occur in Bangladesh, while 06.00 h LST is the most likely time for maximum rainfall to occur over the entire country. The occurrence of 21.00 to 09.00 h LST rainfall is possibly linked to the local effects such as complex terrain and sea and land breeze circulations. The morning maximum rainfall at 06.00 h LST in Bangladesh was different from that of the Indian subcontinent or of the mountain area where, generally, maximum rainfall occurs in the afternoon. The northern border of Bangladesh, close to the Shillong hill of India, was the region with the highest rainfall, while the second highest volume of rainfall occurred on the eastern border. In order to observe the characteristics of large-scale cloud activity, analyses of the Japanese GMS-5 hourly infrared data, within a larger domain of 80°-100°E and 10-30°N were conducted. The cloud activities in and around Bangladesh were obtained in 10 by 10 grid boxes. The northwestern part of Bangladesh was largely affected by pre-monsoon clouds, while the whole country was affected by the peak monsoon activities.

Terao et al., (2006) studied the nocturnal jet and its effects on early morning rainfall peak over northeastern Bangladesh during the summer monsoon season. Diurnal variations of rainfall and upper wind over Bangladesh during the summer monsoon season were investigated through the data analysis of rain gauge, 4-times-daily rawinsonde and pilot balloon observations. Over the northeastern part where the total monsoon rainfall is heavy a rainfall peak appears at 3 to 6h local time in the early morning. In the lower troposphere, the southeasterly accelerates in the evening, and the wind direction exhibits a clockwise change at night. This feature corresponds with the nocturnal jet, which can be a cause of the midnight-early morning rainfall peak in the northeastern part of Bangladesh through the increased wind blowing against the southern edge of the Meghalaya Mountains.

Islam et al., (2005*b*) studied the characteristics of precipitation systems analyzed from radar data over Bangladesh. To obtain precise rainfall distributions and to clarify the characteristics of precipitation systems, radar data from the Bangladesh Meteorological Department (BMD) were used in the first investigation in Bangladesh. The distribution of precipitation over Bangladesh obtained from radar data shows heavy precipitation in the northeast and southeast of the country, which is consistent with the rain-gauge rainfall data. Using the radar data characteristics of 185 analyzed convective systems, the development location, lifetime, shape, size, propagation speed, and direction were identified. They divided the BMD radar data into 3-regions: Northern, Central, and Southern, each being 600km east to west and 200km north to south. In general, precipitation systems develop in the Northern region and tend to move eastward. Precipitation system development in the central and Southern regions is significant during the peak-monsoon months (June-August). Their analysis shows that the average time of maximum precipitation in the Northern region is 00-06 LST, in the Central region 06 LST and 15-18 LST, and in the Southern region 06-09 LST. The average lifetime of these systems is 5.7 hours.

Kripalani et al., (1996) studied the rainfall variability over Bangladesh and Nepal. In this 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 annual spatial rainfall patterns, and the spatial patterns of variability were presented. Dominant structures of seasonal rainfall are determined through the empirical orthogonal functions. A homogeneous series for all

Bangladesh Monsoon Rainfall is prepared and its temporal characteristics were studied. It is observed that the standardized rainfall for this series shows random fluctuations up to 1963, thereafter the standardized values are much above the normal values. Further the rainfall variations over Bangladesh are not related to 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.

Ahmed and Kim (2003) studied the results of the 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 to 1998. According to them the summer monsoon in Bangladesh prevails from early June to mid-October, with an average duration of 110 days in the west to 134 days in the southeast, and an average number of rainy days of 60 days in the west to 100 days in the northeast and southeast. 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. For three stations they found that during the wettest monsoon season the consecutive rain day's ranges from 8-10 days and 30-40 days for the west and northeast, respectively. During the driest monsoon season the rain days varies from 3-6 days in the west to 20-30 days in the northeast. Frequency of consecutive rain 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 monsoon season in terms of the intraseasonal 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 than 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. It is also found that the monsoon rainfall over Bangladesh in 1995 varies with a periodicity of 20 days, and this rainfall variation is closely associated with synoptic-scale monsoon activities spreading over South and Southeast Asia. The active/break cycle of the rainfall variation during the 1995 summer monsoon season can be mostly explained by the northward propagation of what is called the 10-20 day variation of monsoon activities.

Oshawa et al. (1998) studied the characteristics of rainfall over Bangladesh during the monsoon season of 1995 using surface meteorological data, aero logical data, rain gauge data, GMS-4/5 infrared data and 700 hPa isobaric charts. They found that the monsoon rainfall in 1995 was normal over Bangladesh. The monsoon season over Bangladesh can be divided into BAM (Bangladeshi Active Monsoon) phase, BBM (Bangladesh Break Monsoon) phase and transient phase. Four periods of BAM phase and three periods of BBM phase were selected. By comparing the features of BAM and BBM phase, it was found that the positions of the monsoon trough and the vertical wind profiles were obviously different, but the vertical thermodynamic structures were not different between both phases. They also found that the temporal variation such as BAM and BBM phase could be interpreted, to some extent, in terms of the spatial structure of monsoon circulation relative to the monsoon trough. They concluded that the variation of rainfall over Bangladesh was depended on the movement of the deep convective area located to the south of the monsoon trough with strong southwesterly wind in its lower layer.

Islam et al., (2002) studied the application of a method to estimate rainfall in Bangladesh Using GMS-5 Data. They used the Japanese Geostationary satellite 5 (GMS-5) data to estimate rainfall in Bangladesh over a period of 61 days from June 1, 1996. The 3-hourly digital data over 33 ground-truth stations throughout Bangladesh obtained from GMS-5 were analyzed. Satellite rainfall was estimated by the Convective Stratiform Technique (CST) algorithm. The amount of rainfall calculated by the CST was compared with that calculated from the ground-truth data. That calculated by the CST was 1.1 times larger than that from the ground-truth rainfall. The average daily rainfalls were 15 mm as calculated from satellite and 14.3 mm from the ground-truth data. The correlation between the satellite and the ground-truth rainfall was significant at coastal stations but not inland ones. Satellite and ground truth data were used to derive a linear regression equation for estimating the amount of surface rain from satellite data. Data from stations throughout the country that showed good correlations gave a slope term of 0.84 and intercept constant of -0.1 in the regression equation.

Heavy rainfall takes place in Bangladesh during summer monsoon. Some parts of the country have the climatic rainfall over 6000 mm during this season. Usually the northeastern Bangladesh has much rainfall, where the late night-early morning maximum rainfall was observed by rain gauges and the radar in Dhaka (Oshawa et al., 2000, 2001; Terao et al., 2002; Islam et al., 2005). From their study they suggested that the late night-early morning maximum is associated with the Shillong Plateau, east-west elongated mountainous range whose highest peak is about 2000 m located right in the north of the late night-early morning maximum rainfall region.

It has been found that the hills and mountain ranges cause striking variations in rainfall distribution. On the southern slope of the Khasi-Jaintia hills the annual rainfall is over 8000 mm while to the north, in the Brahmaputra valley, it drops to about 1200 mm. The annual rainfall at Cherrapunji is 11420 mm (at elevation of 1313 m) which is obviously due to orographic lifting. It has also been found that from the West Coast, rainfall increases along the slopes of the Western Ghats, and rapidly decreases on the eastern lee side. In the higher reaches of the Western Ghats, there are places with seasonal rainfall of 5000 mm. Within 80 km on the lee side, rainfall is only 400 mm (Rao, 1976). In the northwestern parts of the subcontinent rainfall progressively decreases westwards, from 400 mm in Rajasthan to 50 mm in Baluchistan. Southwest Srilanka and the hills get good rains at this time but not the other parts of the island. Rainfall in the Andaman and Nicobar Islands during the southwest monsoon season is about 1400 mm to 1900 mm, while in Laccadives and Maldives in the Arabian Sea, it is only about 1000 mm though both the groups are in the same latitude belt.

D'Amato and Lebel (1998) suggested a possible explanation for the improvement of forecast by the study of which demonsatrated that interannual variability of Sahel rainfall is linked to the number rather than the magnitude of the rainfall events. The square root transformation can also be beneficial for forecasts over either smaller regions or shorter periods, such as statistical predictions of regional rainfall (Feddersen et al., 1999). The square root transformation can also be beneficial for forecasts over either smaller regions or shorter periods, such as statistical predictions of regional rainfall (Feddersen et al., 1999). The square root transformation gives less weight to anomalies in large rainfall amounts and can be considered as equivalent to using a non-Euclidean positively curved measure of forecast skill (Stephenson 1997).

Monsoon normally reaches the coastal districts of Bangladesh by the last week of May to first week of June and progressively engulfs the whole country through June. Generally heavy to very heavy rain with overcast skies characterizes the monsoon season. On the average there are about 20-25 rainy days per month during June to August, decreasing to 12-15 days in September. More than 75% of the total annual rainfall occurs in this season. The rainfall is greater over the northeastern, the southern and the southeastern districts than over the central, western and northwestern districts. During the first two months of the season the rainfall is between 450-600 mm per month over the northern and southern districts and it is 700-850 mm per month over the districts of Sylhet and the southeastern districts of Chittagong and Chittagong Hill Tracts. Over the central districts, the rainfall is 250-380 mm per month in the two months. The rainfall over the country decreases gradually as the season advances. In September the rainfall is 200-250 mm over the country except in the district of Sylhet and the Coastal districts of Barisal, Noakhali, Chittagong and Chittagong Hill Tracts, where the rainfall is 300-450 mm (WMO/UNDP/BGD/79/013, 1986).

Anderson and Ahmed (1979) studied the pre-monsoon rainfall and its variability in Bangladesh. In their study they made an attempt at an inventory pre-monsoon rainfall, both monthly and seasonally, and its variability over time and space. The technique employed was that of trend surface mapping. They found that the coefficient of correlation between the observed data and the computed trend surface was very highly significant. The residual maps of the respective surfaces explain the effect of the hills and the discontinuity surface of air masses on the rainfall of this season. They have been hoped that the maps of the spatial distribution of pre-monsoon rainfall and its variability would be useful to the agricultural planners and hydrologists of Bangladesh in the estimation, planning and conservation of the water resources of the country.

In this research work we have studied the multiple correlation between four meteorological parameters dry bulb temperature, wet bulb temperature, minimum temperature and maximum temperature with the rainfall of monsoon season over Bangladesh. Initially correlation coefficients between different parameters of pre-monsoon season and rainfall of the monsoon have been studied. The correlation coefficients between these parameters with the monthly and seasonal rainfall have been studied.

CHAPTER II

Methodology

In this research work we have used the DBT, WBT, Minimum Temperature, Maximum Temperature and Rainfall of pre monsoon season and the rainfall of monsoon season for thirty meteorological stations all over Bangladesh. The raw data has been collected from Bangladesh Meteorological Department (MBD). We first processed the available data to obtain the monthly and seasonal average of them. Then we computed the single and multiple correlation coefficients of different parameters.

The mathematical formulations which have been used in this analysis are discussed in the following sub-sections.

2.1 Average

Most of the time when we refer to the "average" of something, we are talking about the arithmetic mean. The arithmetic mean also referred to as the arithmetic average or simply as the mean. It is the central value of the items in a series. The average or mean is obtained by summing up the values of all observation and then dividing the sum by the number of observations.

Let the individual values of observations are denoted by $x_1, x_2, x_3, \ldots\ldots x_n$. Their sum is written as

$$\sum x = x_1 + x_2 + x_3 + \ldots\ldots\ldots\ldots + x_n \qquad (2.1)$$

then $$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$$

where, x_i = individual observation

n = number of observation

$\bar{x}$ = mean or average of observation

In this research work we have calculated the mean of DBT, WBT, MinT, MaxT and rainfall of pre-monsoon and monsoon seasons for all of the stations under consideration.

2.2 Regression

The term regress means to return and, therefore, regression means something like returning or passing back. In statistics regression analysis is a technique which examines the relation of a dependent variable to specified independent variables. Regression analysis can be used as a descriptive method of data analysis without relying on any assumptions about underlying processes generating the data (Cook D.R and Weisberg 1982).

When paired with assumptions in the form of a statistical model, regression can be used for prediction (including forecasting of time-series data), inference, hypothesis testing, and modeling of causal relationships. These uses of regression rely heavily on the model assumptions being satisfied.

2.2.1 Regression Equations

The key relationship in a regression is the regression equation. A regression equation contains regression parameters whose values are estimated using data. The estimated parameters measure the relationship between the dependent variable and each of the independent variables. When a regression model is used, the dependent variable is modeled as a random variable because of either uncertainty as to its value or inherent variability. The data are assumed to be sample from a probability distribution, which is usually assumed to be a normal distribution.

A regression equation is mathematical formulation which is used to estimate a dependent variable from the independent variable. Let X1 is a dependent variable and X_2, X_3, X_4 are the independent variables. Then for the case of these four variables, the simplest regression equation of X_1 on X_2, X_3 and X_4 is given as

$$X_1 = b_{1.234} + b_{12.34}X_2 + b_{13.24}X_3 + b_{14.23}X_4 \qquad (2.2.1)$$

where $b_{1.234}$, $b_{12.34}$, $b_{13.24}$ and $b_{14.23}$ are constants. If we consider X_4 as a constant in the above equation (2.2.1), the graph of X_1 versus X_2 and X_3 is a plane with direction ratios $b_{12.34}$ and $b_{13.24}$. If we keep X_3 constant, the graph of X_1 versus X_2 and X_4 is a plane with direction ratios $b_{12.34}$ and $b_{14.23}$. If we keep X_2 constant, the graph of X_1 versus X_3 and X_4

is a straight line with slope $b_{13.24}$ and $b_{14.23}$. It is clear that the subscript after the dot indicate the variables held constant in each case.

When X_4 is taken as constant, due to the fact that X_1 varies partially because of variation in X_2 and partially because of variation in X_3 we call $b_{12.34}$ as partial regression coefficients of X_1 on X_2 keeping X_3 and X_4 constant.

Just as there exist least-squares regression lines approximating a set of N data points (X,Y) in a two dimensional scatter diagram, so also there exist least-square regression hyper planes fitting a set of N data points (X_1 , X_2 , X_3 , X_4) in a four dimensional scatter diagram.

The least square regression hyper plane of X_1 on X_2, X_3 and X_4 has the equation (2.3.1) where $b_{1.234}$, $b_{12.34}$, $b_{13.24}$ and $b_{14.23}$ are determined by solving simultaneously the normal equations

$$\begin{aligned}
\sum X_1 &= b_{1.234}N + b_{1.2.34}\sum X_2 + b_{13.24}\sum X_3 + b_{14.23}\sum X_4 \\
\sum X_1X_2 &= b_{1.234}\sum X_2 + b_{1.2.34}\sum X_2^2 + b_{13.24}\sum X_2X_3 + b_{14.23}\sum X_2X_4 \\
\sum X_1X_3 &= b_{1.234}\sum X_3 + b_{1.2.34}\sum X_2X_3 + b_{13.24}\sum X_3^2 + b_{14.23}\sum X_3X_4 \\
\sum X_1X_4 &= b_{1.234}\sum X_4 + b_{1.2.34}\sum X_2X_4 + b_{13.24}\sum X_3X_4 + b_{14.23}\sum X_4^2
\end{aligned} \qquad (2.2.2)$$

These can be obtained formally by multiplying both sides of equation (2.2.2) by 1, X_2, X_3 and X_4 successively and summing on both sides.

If $x_1 = X_1 - \overline{X_1}, x_2 = X_2 - \overline{X_2}, x_3 = X_3 - \overline{X_3}$ and $x_4 = X_4 - \overline{X_4}$, the regression equation of X_1 on X_2 , X_3 and X_4 can be written more simply as

$$x_1 = b_{12.34}x_2 + b_{13.24}x_3 + b_{14.23}x_4 \qquad (2.2.3)$$

where $b_{12.34}$, $b_{13.24}$ and $b_{14.23}$ can be obtained from the normal equation

$$\begin{aligned}
\sum x_1x_2 &= b_{12.34}\sum x_2^2 + b_{13.24}\sum x_2x_3 + b_{14.23}\sum x_2x_4 \\
\sum x_1x_3 &= b_{12.34}\sum x_2x_3 + b_{13.24}\sum x_3^2 + b_{14.23}\sum x_3x_4 \\
\sum x_1x_4 &= b_{12.34}\sum x_2x_4 + b_{13.24}\sum x_3x_4 + b_{14.23}\sum x_4^2
\end{aligned}$$

These equations which are equivalent to the normal equations (2.2.2) can be obtained formally by multiplying both sides of equation (2.2.3) by x_2, x_3 and x_4 successively and summing on both sides.

2.3 Simple correlation

Correlation is a measure of the relation between two or more variables. The measurement scales used should be at least interval scales, but other correlation coefficients are available to handle other types of data. Correlation coefficients can range from -1.00 to +1.00. The value of -1.00 represents a perfect *negative* correlation while a value of +1.00 represents a perfect *positive* correlation. A value of 0.00 represents a lack of correlation.

The elementary principles of two-variable linear correlation

$$Y_c = a + bX \qquad (2.3.1)$$

This permitted us to make estimation of the value of the dependent variable from values of the independent variable. Next it was demonstrated that the total variation of the dependent variable was the sum of (1) the explained variation and (2) the variation which we had failed to explain by our hypothesis; that is

$$\sum y^2 = \sum y_c^2 + \sum y_s^2 \qquad (2.3.2)$$

It should be remembered that we computed Σy^2 by the formula

$$\sum y^2 = \sum Y^2 + \overline{Y}\sum Y \qquad (2.3.3)$$

And that Σy_c^2 was computed from the expression

$$\sum y_c^2 = \sum Y_c^2 + \overline{Y}\sum Y$$

In which

$$\sum Y_c^2 = a\sum Y + b\sum XY$$

Or, more simply

$$\sum y_c^2 = b\sum xy$$

that Σy_S^2 was obtained by subtracting the explained variation from the total variation; that is

$$\sum y_S^2 = \sum y - \sum y_c^2$$

Finally the ratio

$$r^2 = \frac{\sum y_c^2}{\sum y^2} \qquad (2.3.4)$$

was know as the coefficient of determination, and its square root was called the coefficient of correlation.

2.4 Multiple correlation

Exactly the same principles are involved in multiple correlation as in simple correlation, but the procedure is more laborious, since there is more than one independent variable. Also, it is necessary to use slightly different symbols. The illustration in this chapter will deal with the relationship between the rainfall of monsoon and dry bulb temperature, wet bulb temperature, minimum temperature and maximum temperature of pre-monsoon season. Rainfall of monsoon season is the dependent variable, and the other three are independent variables.

It simplifies the notations somewhat if, instead of using different letters, each of the variables is designated by the letter X, differentiating between the variables by means of subscripts. This is particularly true if the number of variables is large. We shall therefore designate our variables in this manner:

Dependent variable:

Rainfall of monsoon season X_1

Independent variables:

Dry-bulb temperature (DBT) of pre-monsoon X_2

Wet-bulb temperature (WBT) of pre-monsoon X_3

Maximum temperature of pre-monsoon X_4

Minimum temperature of pre-monsoon X_5

We use an estimating equation of the type

$$X_{c1.234} = a_{1.234} + b_{12.23}X_2 + b_{13.23}X_3 + b_{14.23}X_4$$

The coefficient of multiple determinations and the coefficient of multiple correlations are

$$R^2_{1.234} = \frac{\sum X^2_{c1.234}}{\sum x_1^2}$$

This expression is put into a general form for four variables by writing multiple correlations between X_1 and X_2, X_3, X_4 can be written as:

$$R^2_{1.234} = 1 - [(1 - r^2_{12})(1 - r^2_{132})(1 - r^2_{1423})]$$

2.4.1 Multiple correlation of 5 variables

Multiple correlation deals with the combined or total influence of a group of independent variables. Multiple correlation between rainfall of monsoon season (1) and DBT(2), WBT(3), MaxT(4) and MinT(5) of pre-monsoon season can be written as

$$R^2_{1.2345} = 1 - [(1 - r^2_{12})(1 - r^2_{132})(1 - r^2_{1423})(1 - r^2_{15234})] \quad (2.4.1)$$

Suffix 1 indicates the average rainfall of June, July, August, September and monsoon, suffix 2 indicates the average DBT of March, April, May and pre-monsoon season, suffix 3 indicates the average WBT of March, April, May and pre-monsoon season, suffix 4 indicates the average MaxT of March, April, May and pre-monsoon season and suffix 5 indicates the average MinT of March, April, May and pre-monsoon season.

In this way we can calculate rainfall of monsoon season and DBT of pre-monsoon season (r_{12}), rainfall of monsoon season and WBT of pre-monsoon season (r_{13}), rainfall of monsoon season and MaxT of pre-monsoon season (r_{14}), rainfall of monsoon season and MinT of pre-monsoon season (r_{15}), DBT and WBT of pre-monsoon (r_{23}), DBT and MaxT of pre-monsoon season (r_{24}), DBT and MinT of pre-monsoon season (r_{25}), respectively.

$$r_{12} = \frac{\sum (x_{1i} - \overline{x_1})(x_{2i} - \overline{x_2})}{\sqrt{(x_{1i} - \overline{x_1})(x_{2i} - \overline{x_2})^2}}$$

$$r_{13} = \frac{\sum (x_{1i} - \overline{x_1})(x_{3i} - \overline{x_3})}{\sqrt{(x_{1i} - \overline{x_1})^2 (x_{3i} - \overline{x_3})^2}}$$

$$r_{14} = \frac{\sum (x_{1i} - \overline{x_1})(x_{4i} - \overline{x_4})}{\sqrt{(x_{1i} - \overline{x_1})^2 (x_{4i} - \overline{x_4})^2}}$$

$$r_{15} = \frac{\sum (x_{1i} - \overline{x_1})(x_{5i} - \overline{x_5})}{\sqrt{(x_{1i} - \overline{x_1})^2 (x_{5i} - \overline{x_5})^2}}$$

$$r_{23} = \frac{\sum (x_{2i} - \overline{x_2})(x_{3i} - \overline{x_3})}{\sqrt{(x_{2i} - \overline{x_2})^2 (x_{3i} - \overline{x_3})^2}}$$

$$r_{24} = \frac{\sum (x_{2i} - \overline{x_2})(x_{4i} - \overline{x_4})}{\sqrt{(x_{2i} - \overline{x_2})^2 (x_{4i} - \overline{x_4})^2}}$$

$$r_{25} = \frac{\sum (x_{2i} - \overline{x_2})(x_{5i} - \overline{x_5})}{\sqrt{(x_{2i} - \overline{x_2})^2 (x_{5i} - \overline{x_5})^2}}$$

From these equations $r_{13.2}$, $r_{14.23}$ and $r_{1523.4}$ can be calculated. Substituting these values in Equation 2.4.1 we can calculate the required coefficient of determination. In this study we used a software named Instat+v3.33 to measure the correlation co-efficient.

The following table (Table 2.1) represents the list of the stations considered along with the starting year and the years when data was not available. In Table 2.2 the value of the correlation coefficients, in different significance level along with the number of years in which data was available, for different stations are tabulated.

First of all the raw data, collected from BMD, has been processed to obtain monthly and seasonal average of them. Using the processed data the correlation coefficients have been computed.

We have considered 30 stations all over Bangladesh. The computations are made station wise. These data have been plotted over the Bangladesh map, indicating the stations also, and interpolations have been done. The longitude from 88° to 92.75° and the latitude from 20.5° to 26.63° are used along X and Y axis respectively.

Table 2.1 Starting year and unavailability of data of different meteorological parameters used for different stations:

Stations Name	Starting Year	Data Unavailable Year	Stations Name	Starting Year	Data Unavailable Year
Dhaka	1953	1974	Ishwardy	1961	1967, 1968, 1969, 1980
Mymensing	1950	1991	Bogra	1948	1967, 1967, 1968
Kutubdia	1977	1978, 1981, 1982, 1983, 1984, 1984	Rangpur	1957	1968, 1974, 1999
Faridpur	1948		Dinajpur	1948	1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980
Madaripur	1977	1979	Khulna	1948	1956, 1967, 1968, 1975
Chittagong	1949		Satkhira	1948	1955
Sandip	1966	1975	Jessore	1949	1965, 1966, 1967, 1968, 1978
Sitakundu	1977		Barisal	1949	1952, 1955
Rangamati	1957	1967,1968	Patuakhali	1973	1974, 1980
Comilla	1948	1963, 1967, 1968, 1978	Khepupara	1974	
Chandpur	1966	1971, 1972, 1978, 1980, 1997, 1998	Bhola	1966	
Maizdy Court	1951	1976, 1977	Rajshahi	1964	1969, 1970
Feni	1974		Teknaf	1977	
Hatiya	1966	1972, 1981, 1995, 1996, 1967, 1998	Sylhet	1957	1973
Cox's Bazar	1948		Srimongal	1948	1960, 1961, 1981

Table 2.2: Value of correlation coefficient in different significance level for different stations:

Name of Stations	No. of Years	95% Level	99% Level
Dhaka	47	$\geq$ 0.24	$\geq$0.34
Mymensing	50	$\geq$ 0.24	$\geq$0.33
Bogra	50	$\geq$ 0.24	$\geq$0.33
Srimongal	50	$\geq$ 0.24	$\geq$0.33
Kutubdia	14	$\geq$ 0.46	$\geq$0.61
Faridpur	53	$\geq$ 0.23	$\geq$0.32
Cox'e Bazar	53	$\geq$ 0.23	$\geq$0.32
Madaripur	23	$\geq$ 0.35	$\geq$0.48
Chittagong	52	$\geq$ 0.23	$\geq$0.32
Sandip	34	$\geq$ 0.29	$\geq$0.39
Bhola	34	$\geq$ 0.29	$\geq$0.39
Sitakundu	24	$\geq$ 0.35	$\geq$0.48
Teknaf	24	$\geq$ 0.35	$\geq$0.48
Rangamati	42	$\geq$ 0.26	$\geq$0.36
Comilla	48	$\geq$ 0.24	$\geq$0.33
Maizdy Court	48	$\geq$ 0.24	$\geq$0.33
Khulna	48	$\geq$ 0.24	$\geq$0.33
Chandpur	35	$\geq$ 0.29	$\geq$0.39
Rajshahi	35	$\geq$ 0.29	$\geq$0.39
Feni	27	$\geq$ 0.32	$\geq$0.44
Hatiya	29	$\geq$ 0.31	$\geq$0.43
Sylhet	43	$\geq$ 0.26	$\geq$0.36
Ishwardy	40	$\geq$ 0.25	$\geq$0.37
Rangpur	41	$\geq$ 0.25	$\geq$0.37
Dinajpur	45	$\geq$ 0.26	$\geq$0.36
Satkhira	51	$\geq$ 0.24	$\geq$0.34
Jessore	47	$\geq$ 0.24	$\geq$0.34
Barisal	49	$\geq$ 0.24	$\geq$0.34
Patuakhali	25	$\geq$ 0.34	$\geq$0.46
Khepupara	26	$\geq$ 0.33	$\geq$0.45

CHAPTER III

Results and Discussion

3.1 Distribution of average DBT, WBT, MinT and MaxT of different months of Pre-Monsoon Season all over Bangladesh

In this section the distribution of average DBT, WBT, MinT and MaxT of March, April and May have been discussed.

3.1.1 Distribution of average DBT of March, April and May

In this sub-section the average DBT of March-May for all over Bangladesh has been described. The average is made over the available data during 1951-2000 as many years as obtained which are described in Table 2(a).

Figs 3.1.1(a-c) show the average DBT distribution of March, April and May for all over Bangladesh. The average DBT gradually increases from north-eastern to south-western part of the country as shown in Fig. 3.1.1(a). The highest value of the average DBT has been recorded as 26.7°C at Satkhira and Madaripur and the lowest value is recorded to be 20.6°C at Teknaf. The average DBT of March at Sylhet is found to be 24°C.

The Fig 3.1.1(b) shows that the average DBT distribution of April has a very good similarity with that of the average DBT distribution of March. Like March the average DBT of April also gradually increases from north-eastern to south-western part of the country. The highest value of the average DBT has been recorded 29.5°C at Satkhira and the lowest value is recorded to be 23.8°C at Teknaf.

It has been found from figure 3.1.1(c) that the average DBT distribution of May has a very good similarity with that of the average DBT distribution of March and April. Like March and April the average DBT of May also gradually increases from north-eastern to south-western part of the country. With a similarity of the DBT distribution of March and April the highest value of the average DBT in May also has been recorded 30.2° C at Satkhira and the lowest value is recorded to be 25.2°C at Teknaf.

From this study of the average DBT analysis it has clearly been found that the average DBT of March-May increases gradually from north-eastern to south-western part of the country. The highest and lowest values of the average DBT have been found at Satkhira and Teknaf, respectively.

3.1.2 Distribution of average WBT of March, April and May

In this sub-section the average WBT of March-May for all over Bangladesh is described.

The average WBT distribution of March, April and May for all over Bangladesh has been shown in Figs. 3.1.2(a-c). The figure 3.1.2(a) shows that the average WBT is lowest at the northern districts Rangpur and Dinajpur which is less than 19° C. Then the average WBT gradually increases from the northern to the southern part of the country. The highest average WBT has been measured at Khepupara and Sandwip which is more than 23° C.

The figure 3.1.2(b) shows that the average WBT distribution for April has a very good similarity with that of the March. Like March the lowest average WBT has been recorded at the northern districts Rangpur and Dinajpur which is about 22° C. Then the average WBT gradually increases from the northern to the southern part of the country and the highest value has been measured at Khepupara and Sandwip which is about 26° C.

It also can be seen from figure 3.1.1(c) that the average WBT pattern for May has also a similarity with that of March and April. In this case also the northern districts have the lower average WBT and the southern districts have higher WBT. But the lowest value of average WBT has been recorded at Sylhet of about 24° C and the highest one is at Khulna, Khepupara and Sandwip which is about 27° C.

From this analysis it can be concluded that during the period of March-May the minimum WBT exists at the northern part of the country and it gradually increases towards the south. The southern part of the country has the higher WBT during these months.

3.1.3 Distribution of average Minimum Temperature for the months of March-May

In this section the average minimum temperature for the month of March to May has been described for all over Bangladesh.

Figs.3.1.3 (a-c) represents the average minimum temperature for the months of March, April and May for all over the country. It seems that about 19° C average temperature has been recorded at the central part of the country in March as in Fig 1.1.3(a). From central part the average minimum temperature decreases toward the north and increases toward the south. More than 21° C average temperature has been recorded at Sandwip-Hatia-Kutubdia-Khepupara belt. About 18° C average temperature is observed at

Sylhet, Mymensing, Bogra and Rajshahi area. The lowest average temperature is recorded at Rangpur, Dinajpur and Ishwardi which is less than 17° C.

The average minimum temperature pattern for the month of April has a good similarity with that of March as in Fig. 3.1.3(b). The figure shows that about 23°C average temperature has been recorded at the central part of the country. Then the minimum average temperature decreases toward the northern and increases toward the southern part of the country. Over 24°C average minimum temperature has been recorded at Chittagong, Hatia, Sandwip, Khepupara, Khulna and Satkhira region. The lowest average temperature is recorded at Rangpur, Dinajpur, Sylhet and Srimongal which is less than 21° C.

The average minimum temperature pattern for the month of May has a good similarity with that of March and April as in Fig. 3.1.3(c). Around 24° C average temperature has been recorded at the central part of the country. Then like March and April the minimum average temperature decreases toward the northern and increases toward the southern part of the country. The minimum average temperature exceeds 25° C level at Teknaf, Cox's Bazar, Kutubdia, Sandwip, Khepupara, Khulna, Satkhira, Patuakhali and Barisal area. On the other hand Sylhet and Srimongal records about 23°C of minimum average temperature.

From the analysis of the data for the minimum average temperature it can be concluded that from the central part the temperature increases towards the southern part and decreases towards the northern part of the country.

3.1.4 Distribution of the average Maximum Temperature for the months of March-May

The maximum average temperature of March, April and May for all over the country are shown in Figs.3.1.4 (a-c). Almost a uniform average temperature distribution has been found throughout the country in the month of March as in Fig. 1.1.4(a). A temperature of 31°-32°C has been recorded at most of the places of the country. A temperature of 33°C exceeds at Ishwardi-Jessore-Khulna-Satkhira belt which is the highest average maximum temperature during March.

It can be found from Fig. 3.1.4(b) that in April the lowest maximum average temperature is recorded at Sylhet which is 31°C. Then from Sylhet the temperature increases towards the west and south western part of the country. The highest maximum average temperature of 35.5°C has been recorded at Ishwardi. Less than 32°C has been recorded at Teknaf-Cox's Bazar-Chittagong-Sitakundu-Sandwip-Hatia belt.

From Fig. 3.1.4(c) it can be found that the maximum average temperature distribution has a very good similarity between April and May. Like April the lowest maximum average temperature is recorded at Sylhet which is 31°C. Then the temperature increases towards the west and south western part of the country. The highest maximum average temperature is recorded at Ishwardi-Jessore belt which is greater than 34.6°C.

From this analysis it can be concluded that the highest maximum average temperature during the pre-monsoon period exists at Rajshahi-Ishwardi-Jessore-Khulna-Satkhira belt. Sylhet has the lowest maximum average temperature during this period.

3.1.5 Distribution of average Rainfall for the months of March-May

In this section we have discussed the distribution of average rainfall all over Bangladesh during 1951-2000 for the different months of pre monsoon.

Fig 3.1.5(a) shows the distribution of average rainfall for the month of March all over Bangladesh. In this month the average rainfall is maximum at Sylhet which is more than 120 mm. From Sylhet the average rainfall decrease towards the west and north-west. It also decreases towards the southern part of the country and at Teknaf it is less than 20 mm. From Sylhet it decreases gradually towards the northern part of the country and in Rajshahi, Rangpur and Dinajpur the average rainfall is about 20 mm. Satkhira-Khulna-Patuakhali-Khepupara region have the average rainfall in March from 30-50 mm.

Fig 3.1.5(b) represents the distribution of average rainfall for the month of April all over Bangladesh. The distribution pattern of the rainfall of this month has a very good similarity with the rainfall of March (Fig 3.1.5(b)). Like March the average rainfall is maximum at Sylhet. Starting from the north-eastern part of the country it gradually decreases towards west, north and south-western part. The average rainfall is maximum at Sylhet which is about 330 mm. At Dinajpur-Rangpur-Bogra-Rajshahi region the average rainfall recorded was about 60 mm. The average rainfall at Khulna-Satkhira region is about 80 mm whereas in Jessore it is about 20 mm.

The distribution of average rainfall for the month of May is shown in Fig 3.1.5(c). The maximum rainfall has been recorded at Sylhet which is more than 550 mm. From Sylhet the rainfall pattern decreases toward all directions of the country. The recorded rainfall at Dinajpur-Rangpur-Bogra region is about 180 mm whereas for Rajshahi it is about 130 mm. Among the south-western stations the minimum rainfall has been recorded at Jessore which is about 20 mm. The average rainfall of Chittagong-

Cox's Bazar-Teknaf region is more than 250 mm where as the central part of the country it lies between 250-350 mm.

From this analysis it has been found that during March, April and May the maximum rainfall was recorded at Sylhet. The rainfall gradually decreases from east to western, northern and southern part of the country. In Jessore and also north-western part of the country has the minimum rainfall during this period.

3.1.6 Distribution of the Average Rainfall for the months of June-September

Fig 3.1.6(a) shows the distribution of average rainfall for the month of June all over Bangladesh. The maximum rainfall recorded toward the northeast and extreme southern part of the country. The Fig shows that the Srimongal-Sylhet and Cox's Bazar-Teknaf region has the maximum rainfall in this month. The average rainfall recorded at Sylhet and Teknaf are 800 mm and more than 950 mm, respectively. From Sylhet and Teknaf region the average rainfall decreases toward the northern and western part of the country. In the middle part of the country the average rainfall of about 350-400 mm and in Jessore area only about 100 mm rainfall is recorded which is minimum during the month of June. From 275-375 mm rainfall has been recorded at Rajshahi-Bogra-Dinajpur-Rangpur region.

Fig 3.1.6(b) represents the distribution of average rainfall for the month of July all over Bangladesh. The distribution pattern of the rainfall in this month has a very good similarity with the rainfall of June (Fig 3.1.6(a)). Like June the maximum rainfall recorded toward the northeast and southern part of the country. From the central part of the country the rainfall increases toward the north-eastern, southern and extreme southern part and decreases toward the western part of the country. The maximum rainfall has been recorded at Cox's Bazar-Teknaf region which is about 1000 mm. The recorded rainfall for Chittagong-Sandwip-Sitakundu-Hatia belt was about 650 to 800 mm. Less than 100 mm average rainfall was measured at Jessore which is the minimum in July. About 300-450 mm average rainfall was recorded in the central part of the country.

Fig 3.1.6(c) shows the distribution of average rainfall for the month of August all over Bangladesh. The average rainfall is again higher in the northeast, southern and extreme southern part of the country. Teknaf has the highest rainfall of around 900 mm where as Chandpur has the lowest one which is less than 100 mm in this month. The amount of average rainfall at Sylhet is more than 600 mm. Then it decreases toward the western part of the country. The recorded average rainfall for Jessore is more around 120 mm. It can also be found from this figure that the average rainfall at Mymensing-Rangpur-Dinajpur-Bogra region is 300-350 mm.

The average rainfall distribution for the month of September all over the country is shown in Fig 3.1.6(d). The average rainfall pattern of this month has a very good similarity with the average rainfall for August. The maximum and minimum average rainfall has been recorded at Sylhet and Chandpur, respectively. More than 500 and 400 mm rainfall is recorded at Sylhet and at Teknaf respectively. Most of the southern part of the country has an average rainfall of 300-400 mm in this month. Khulna-Satkhira-Jessore has a rainfall of about 175-250 mm. The middle part of the country records 200-250 mm rainfall during this month. On the other hand the northern parts records 250-300 mm of average rainfall.

From this analysis it has been found that the maximum amount of average rainfall is observed at Teknaf, Cox's Bazar and Sylhet region during the monsoon period. The minimum rainfall has been observed at Jessore, Chandpur and other west and west northern belts. It has also been found that the maximum rainfall during monsoon period is recorded in July at Teknaf. The recorded rainfall pattern for the central part of the country has a good similarity during this period.

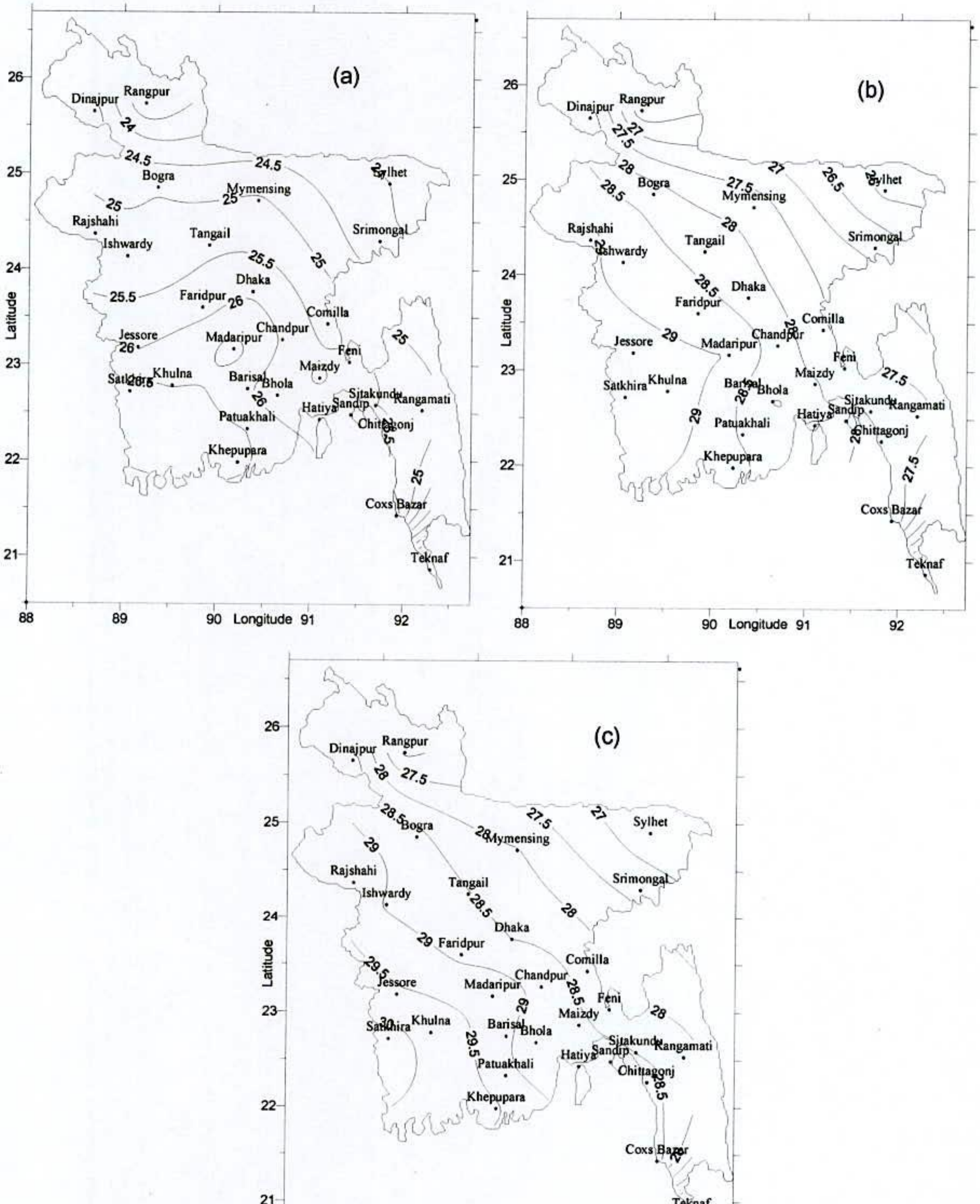

Fig 3.1.1: Distribution of average DBT for the month of (a) March, (b) April and (c) May all over Bangladesh

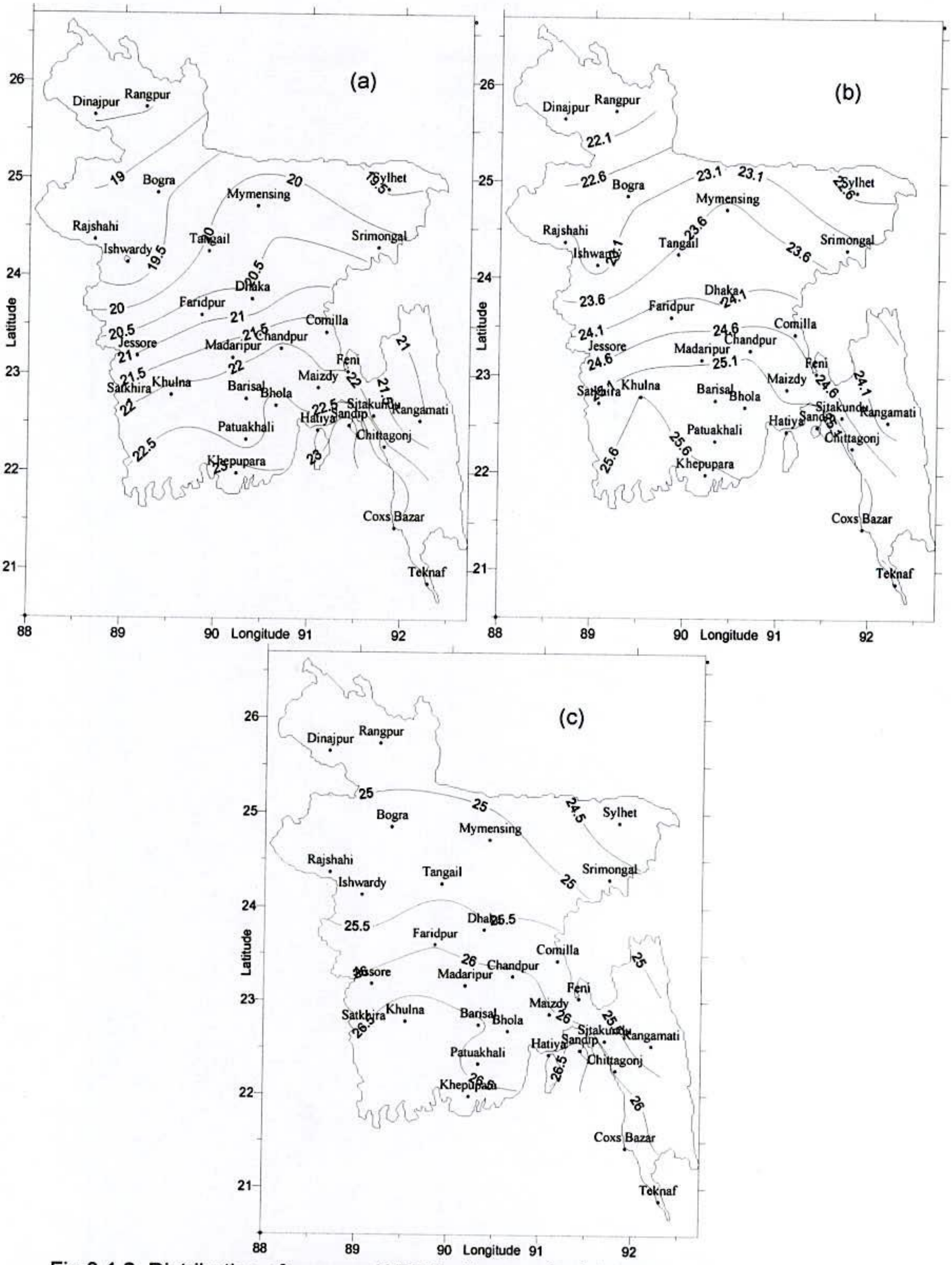

Fig 3.1.2: Distribution of average WBT for the month of (a) March, (b) April and (c) May all over Bangladesh

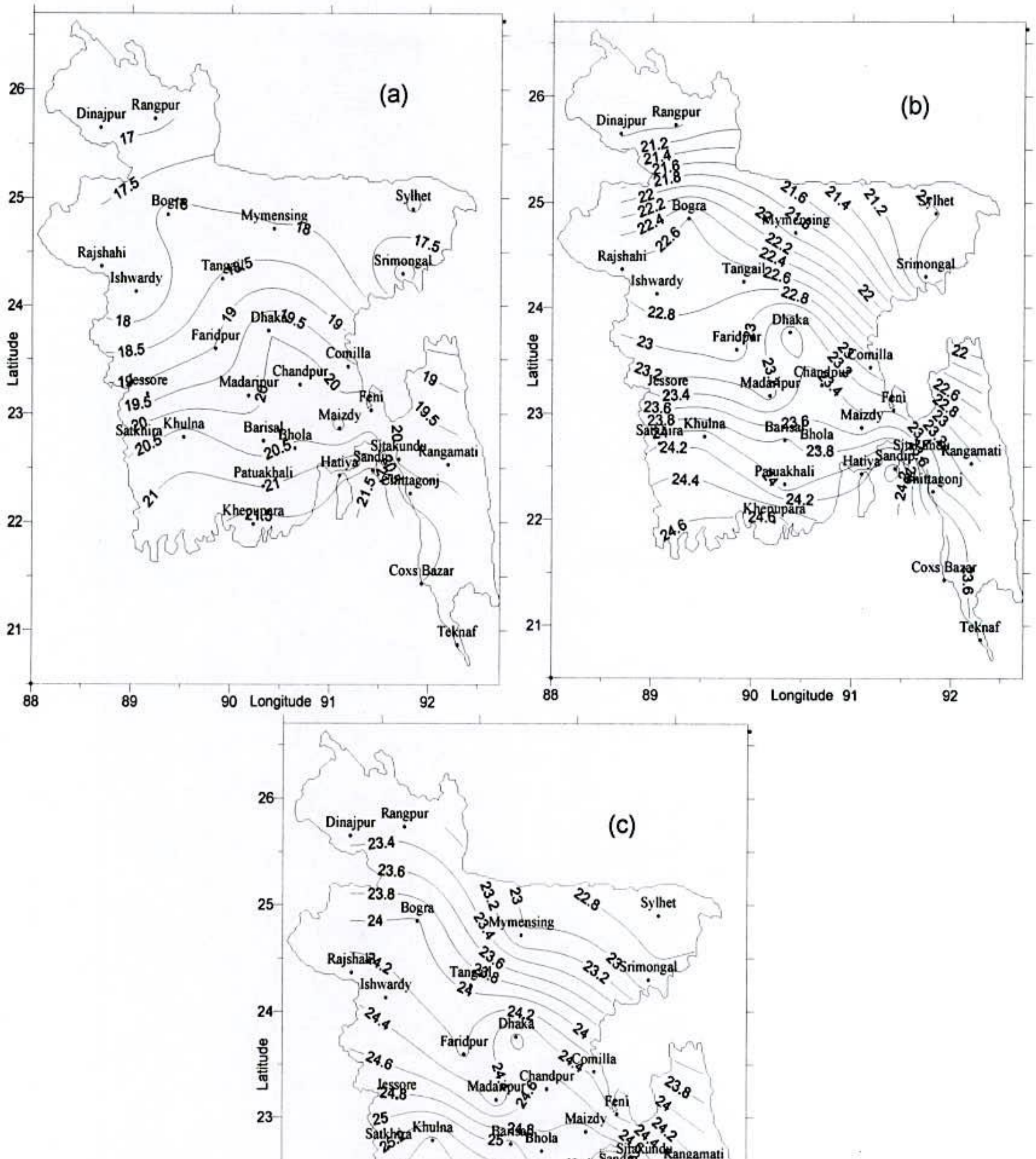

Fig 3.1.3: Distribution of average Minimum Temperature for the month of (a) March, (b) April and (c) May all over Bangladesh

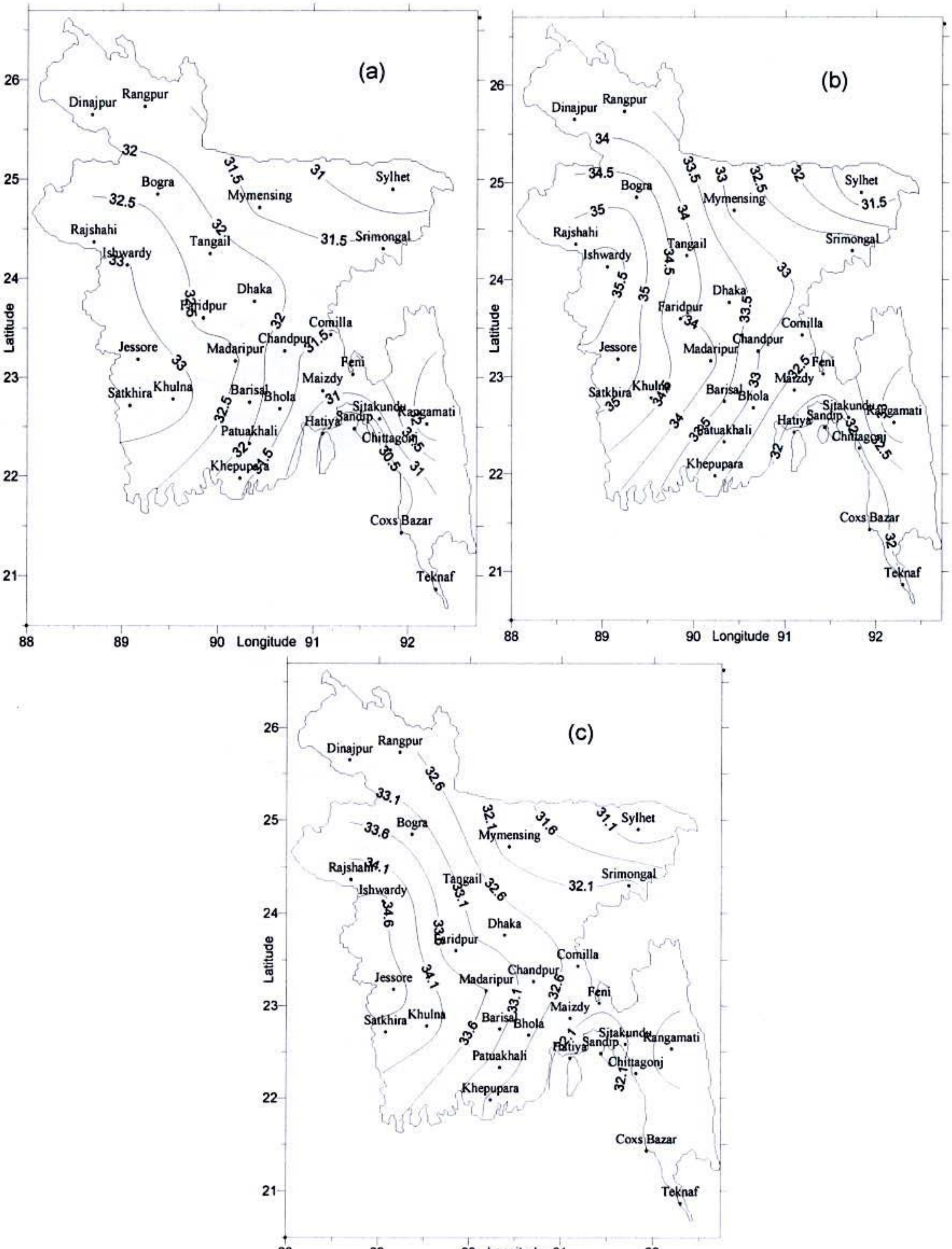

Fig 3.1.4: Distribution of average Maximum Temperature for the month of (a) March, (b) April and (c) May all over Bangladesh

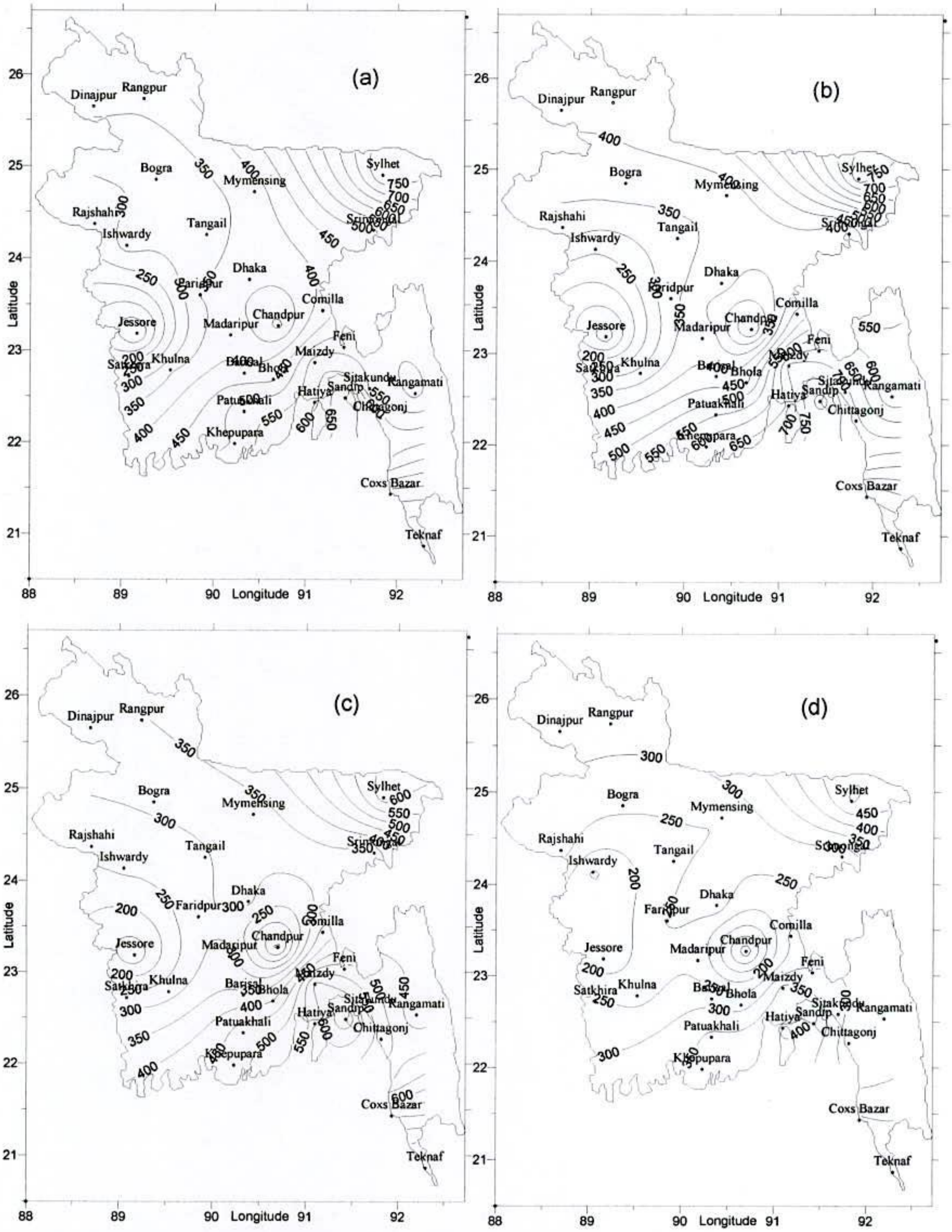

Fig 3.1.6: Distribution of average Rainfall for the month of (a) June, (b) July (c) August and (d) September all over Bangladesh during 1951-2000

3.2 Correlation coefficients (CC) between DBT of March, April and May and Rainfall of March, April and May

3.2.1 Distribution of the CC between DBT of March and rainfall of March, April and May

The distribution of CC between the DBT of March and the rainfall of March is shown in Fig 3.2.1(a). From the distribution pattern we see that the CC is negative all over the country with a few exceptions. The CC between the average DBT of March and the rainfall of March is maximum at Madaripur and its value is 0.19. The minimum CC is observed to be -0.62 at Rajshahi which is significant at 99% level.

The distribution of CC between the DBT of March and the rainfall of April is shown in Fig 3.2.1(b). The figure show that the distributions of CC are positive from the south-western to the middle and then to the north-western parts of the country while it is negative in many of the other remaining places. The CC is maximum at Barisal and its value is 0.19. The minimum CC is observed to be -0.42 at which is significant at 95% level.

The distribution of CC between the DBT of March and the rainfall of May is shown in Fig 3.2.1(c). The figure shows that the distribution of CC is positive at the central part, most of the southern part and few of the northern part of the country. Also at the extreme south of the country such as Kutubdia-Cox's Bazar-Teknaf zone the CC is negative. It is positive for most of the other parts of the country. The maximum value of the CC is found 0.36 at Hatiya with 95% level significance. The minimum CC is observed at Sitakundu which is -0.28.

3.2.2 Distribution of the CC between DBT of April and rainfall of March, April and May

The distribution of CC between the DBT of April and the rainfall of March is shown in Fig 3.2.2(a). The figure shows that the distribution of CC is negative for all over the country except Bogra, Jessore, Madaripur, Satkhira, Barisal and Patuakhali station. The maximum value of CC is observed at Madaripur which is 0.23. The minimum CC of -0.42 is observed at Sitakundu.

The distribution of CC between the DBT of April and the rainfall of April is shown in Fig 3.2.2(b). The figure shows that the distribution of CC between the DBT of April and the rainfall of April has a very good similarity with Fig 2.1.2(a). Here also the CC is negative for all over the country except Rangpur, Jessore, Satkhira, Barisal and Patuakhali station. The maximum value of CC is observed at Patuakhali which is 0.17. The minimum CC of -0.68 is observed at Feni, which is significant at 99% level.

The distribution of CC between the DBT of April and the rainfall of May is shown in Fig 3.2.2(c). The figure shows that the distribution of CC is positive at the most of the southern part, the central part and the north-eastern part of the country. Most of the other part of the country has a negative CC. The CC at Bhola is found to be 0.30 with 95% significance level. The minimum CC is observed at Faridpur -0.39, which is significant at 99% level.

3.2.3 Distribution of the CC between DBT of May and rainfall of March, April and May

The distribution of CC between the DBT of May and the rainfall of March is shown in Fig 3.2.3(a). From the distribution pattern we see that the CC is negative all over the country except the extreme southern part and with a few exception like Barisal-Madaripur zone which has a positive CC. The maximum CC is found with a significance of 95% at Madaripur which is 0.40. The minimum CC is observed to be -0.30 at Chandpur.

The distribution of CC between the DBT of May and the rainfall of April is shown in Fig 3.2.3(b). The figure shows that the distribution of CC is negative for all over the country except Jessore, Satkhira, Barisal, Maizdy Court, Sitakundu, Khepupara stations. The maximum CC at Khepupara is found to be 0.39 with a significance of 95%. The minimum CC is observed at Khulna is -0.35.

The distribution of CC between the DBT of May and the rainfall of May is shown in Fig 3.2.3(c). This figure shows that the distribution of CC for all over the country has a negative value with a few exceptions which has a similarity with Fig 3.2.3(a) and Fig 3.2.3(b). It has a positive value at Rangpur, Jessore, Chandpur, Satkhira and Barisal. The maximum value of the CC is 0.28 which is found at Chandpur. The minimum CC is observed at Cox's Bazar -0.70, Rajshahi -0.60 and Srimongal -0.60, which are significant at 99% level.

3.2.4 Distribution of the CC between average Pre-monsoon DBT and average rainfall of March, April and May

The distribution of CC between the average pre-monsoon DBT and the average rainfall of March is shown in Fig 3.2.4(a). The figure shows that the distribution of CC is negative for all over the country except Bogra, Madaripur, Satkhira, Barisal and Patuakhali station. The maximum value of CC is observed at Madaripur which is 0.30. The minimum CC of -0.55 is observed at Khepupara with a significance of 99%.

The distribution of CC between the average pre-monsoon DBT and the average rainfall of April is shown in Fig 3.2.4(b). From the distribution pattern we see that the CC is negative all over the country except Satkhira, Barisal and Patuakhali. The maximum CC is found at Satkhira which is 0.20. The minimum CC is observed to be -0.60 at Feni, which is significant at 99% level.

The distribution of CC between the pre-monsoon DBT and the rainfall of May is shown in Fig 3.2.4(c). The figure shows that the distribution of CC is positive at Rangpur, Chandpur, Satkhira, Hatiya, Sandip and Khepupara. All of the other part of the country has a negative CC. The maximum CC is found at Chandpur which is 0.36 with 95% significance level. The minimum CC is observed at Dinajpur -0.52, which is significant at 99% level.

3.2.5 Distribution of the CC between Pre-monsoon rainfall and DBT of March, April and May and the CC between Pre-monsoon DBT and Pre-monsoon rainfall

The distribution of CC between the DBT of March and the average pre-monsoon rainfall is shown in Fig 3.2.5(a). From the distribution pattern we see that the CC is both negative and positive all over the country and there is no specific zone which is positive or negative. The CC at Rangpur is positive where as it is negative at other northern districts like Dinajpur, Bogra, Rajshahi etc. The similar characteristic of the CC distribution is found for the other parts of the country. The maximum CC of 0.22 is observed at Madaripur. The minimum CC is observed to be -0.56 at Feni, which is significant at 99% level.

The distribution of CC between the DBT of April and the pre-monsoon rainfall is shown in Fig 3.2.5(b). From the distribution pattern we see that the CC distribution is negative for all over the country except a few places e.g. Rangpur, Satkhira and Barisal.

The CC is maximum at Satkhira which is 0.16. The observed minimum CC is -0.59 at Feni, which is significant at 99% level.

The distribution of CC between the DBT of May and the pre-monsoon rainfall is shown in Fig 3.2.5(c). The CC distribution between the DBT of May and the pre-monsoon rainfall is similar with that of the CC distribution between the DBT of April and the pre-monsoon rainfall as shown in Fig 3.2.5(b). Like April the CC distribution is negative in May also for all over the country except a few places e.g. Rangpur, Satkhira and Barisal. The CC is maximum at Satkhira which is 0.20. The observed minimum CC is -0.68 at Cox's Bazar, which is significant at 99% level.

The distribution of CC between the average Pre-monsoon DBT and the average pre-monsoon rainfall is shown in Fig 3.2.5(d). The CC distribution is negative for all over the country except Rangpur, Satkhira and Barisal. The maximum CC is observed at Satkhira which is 0.24 with a significance of 95%. The observed minimum CC is -0.77 at Feni, with a level of significance at 99%.

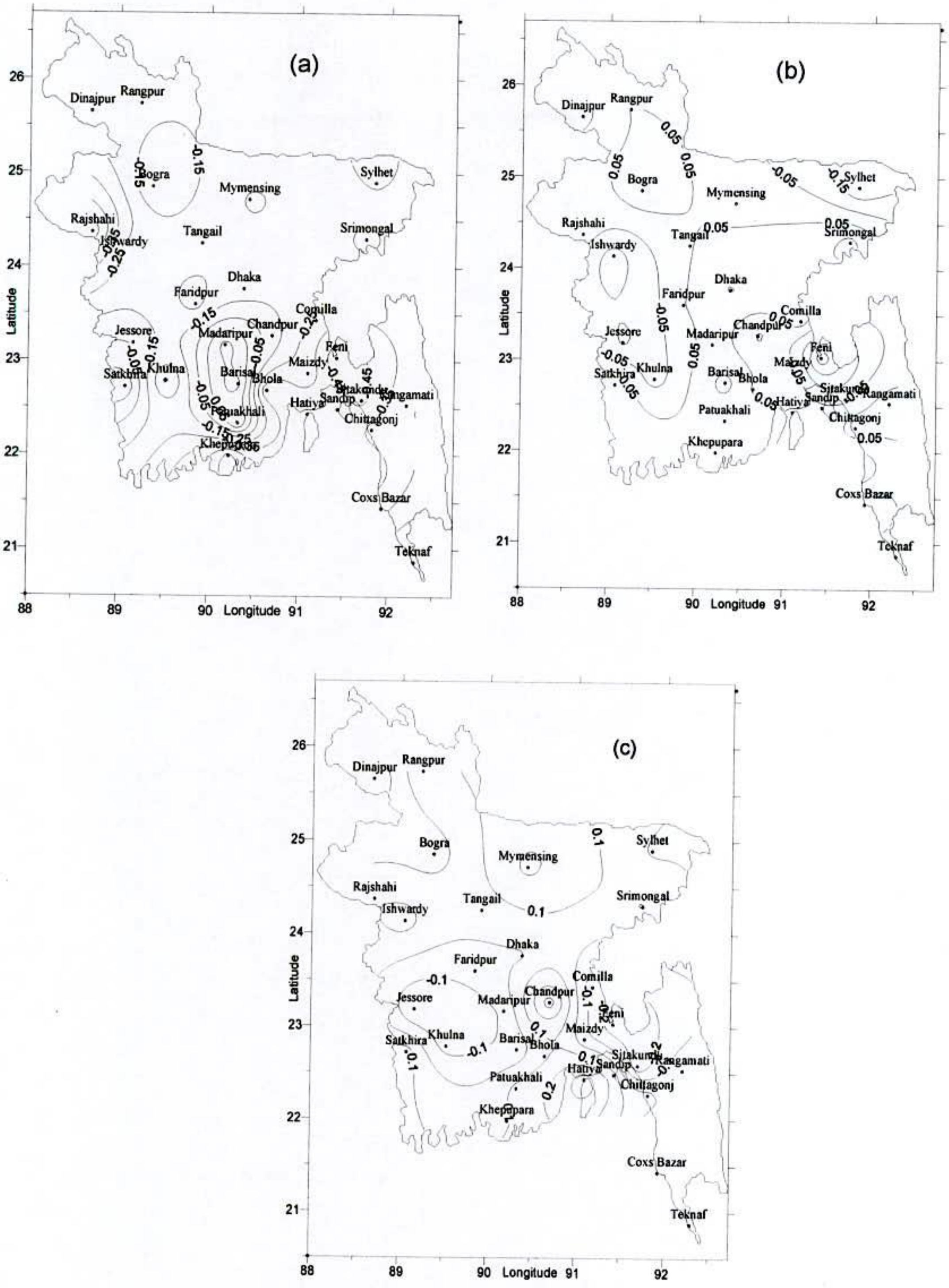

Fig 3.2.1:Correlation coefficient between DBT of March and rainfall of (a) March, (b) April and (c) May rsepectively

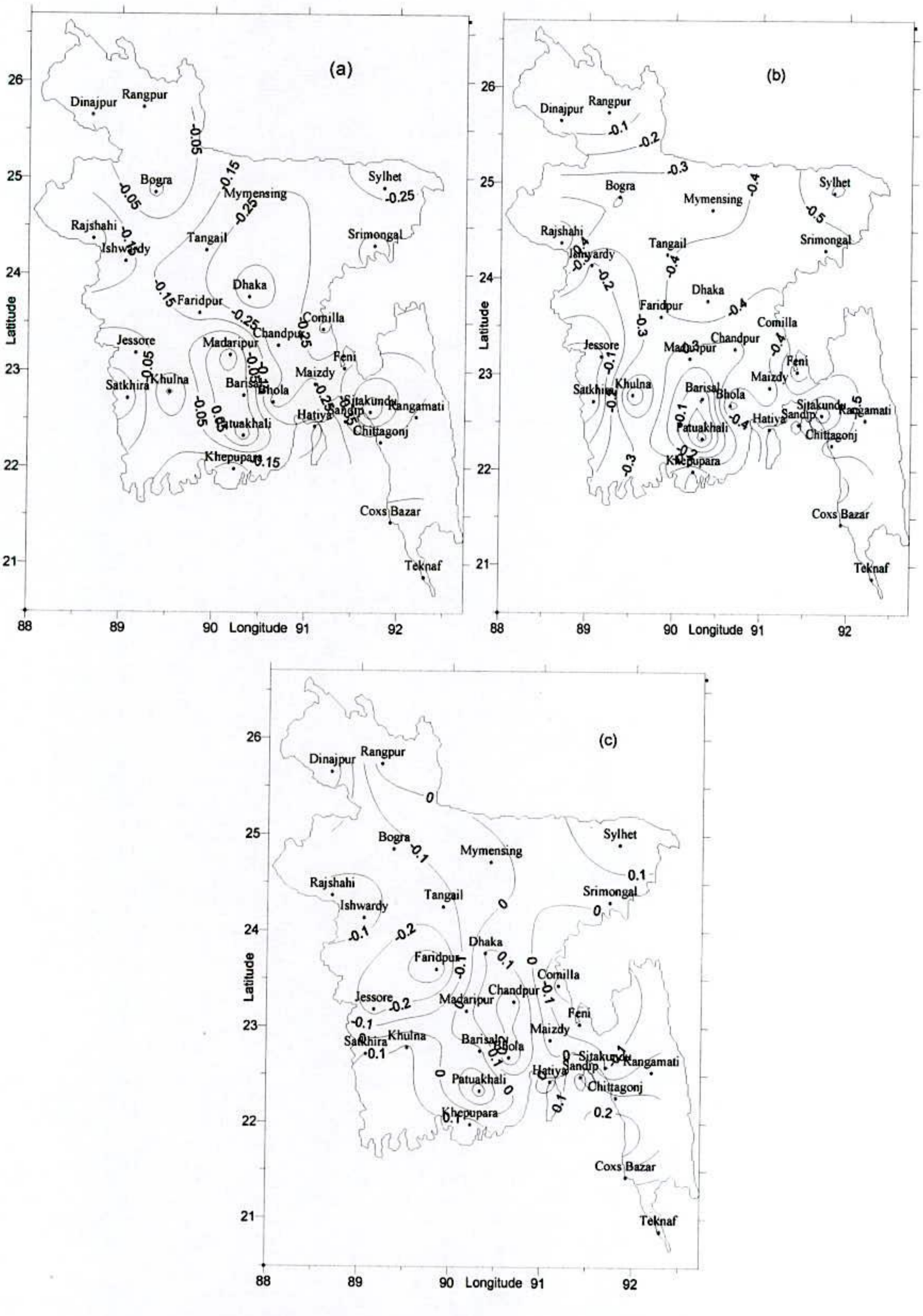

Fig 3.2.2: Correlation coefficient between DBT of April and rainfall of (a) March, (b) April and (c) May respectively

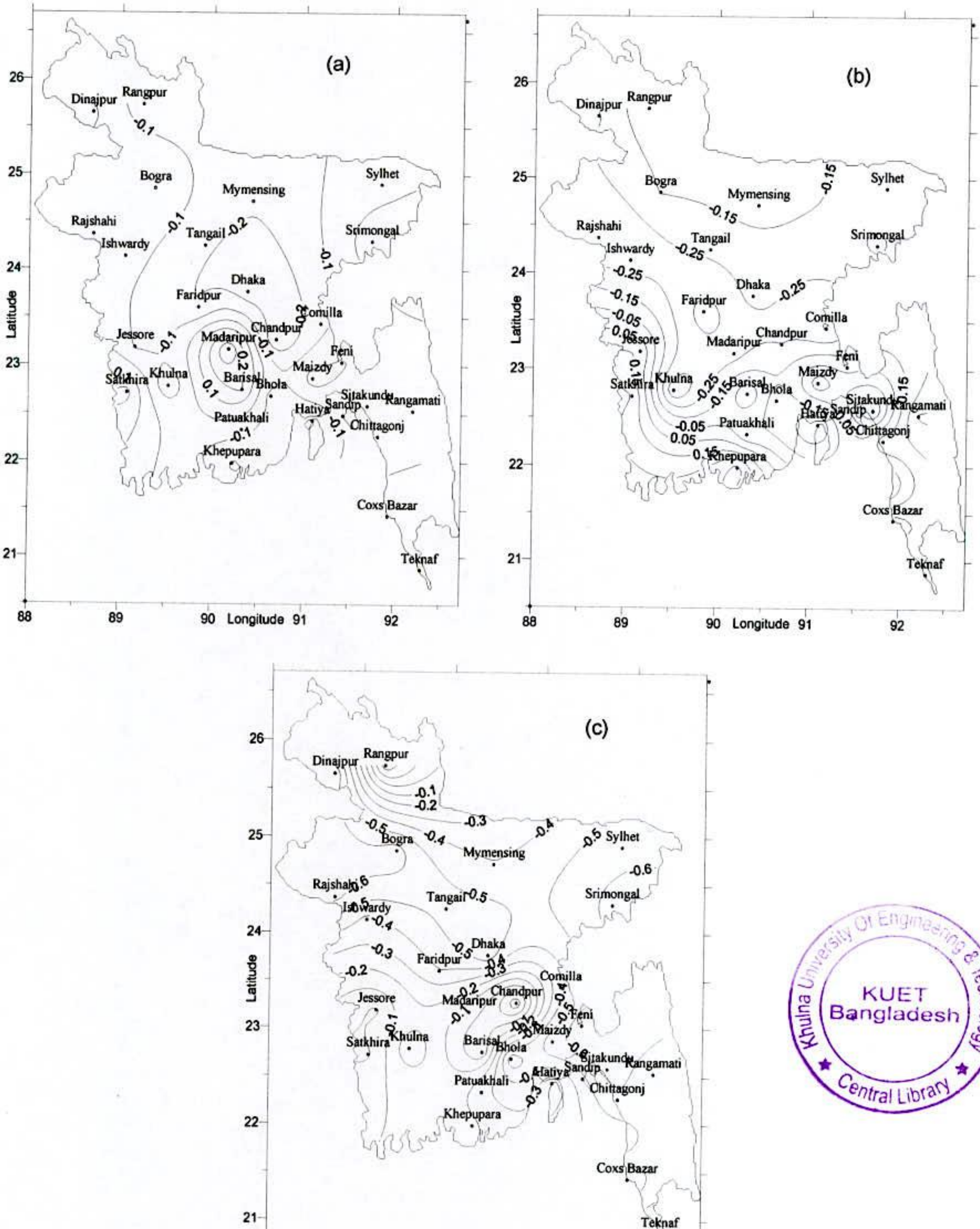

Fig 3.2.3: Correlation coefficient between DBT of May and rainfall of (a) March, (b) April and (c) May rsepectively

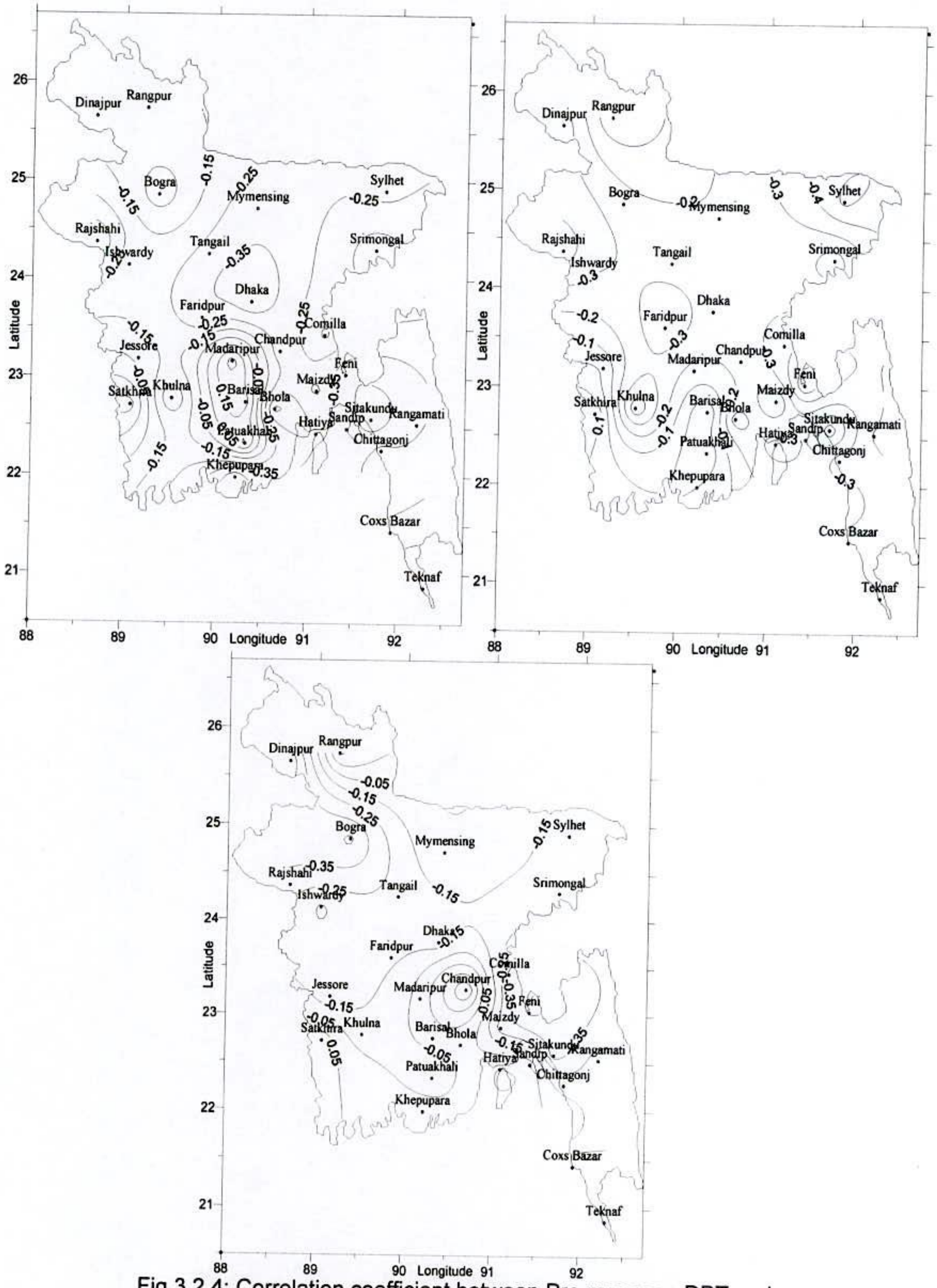

Fig 3.2.4: Correlation coefficient between Pre-monsson DBT and rainfall of (a) March, (b) April and (c) May respectively

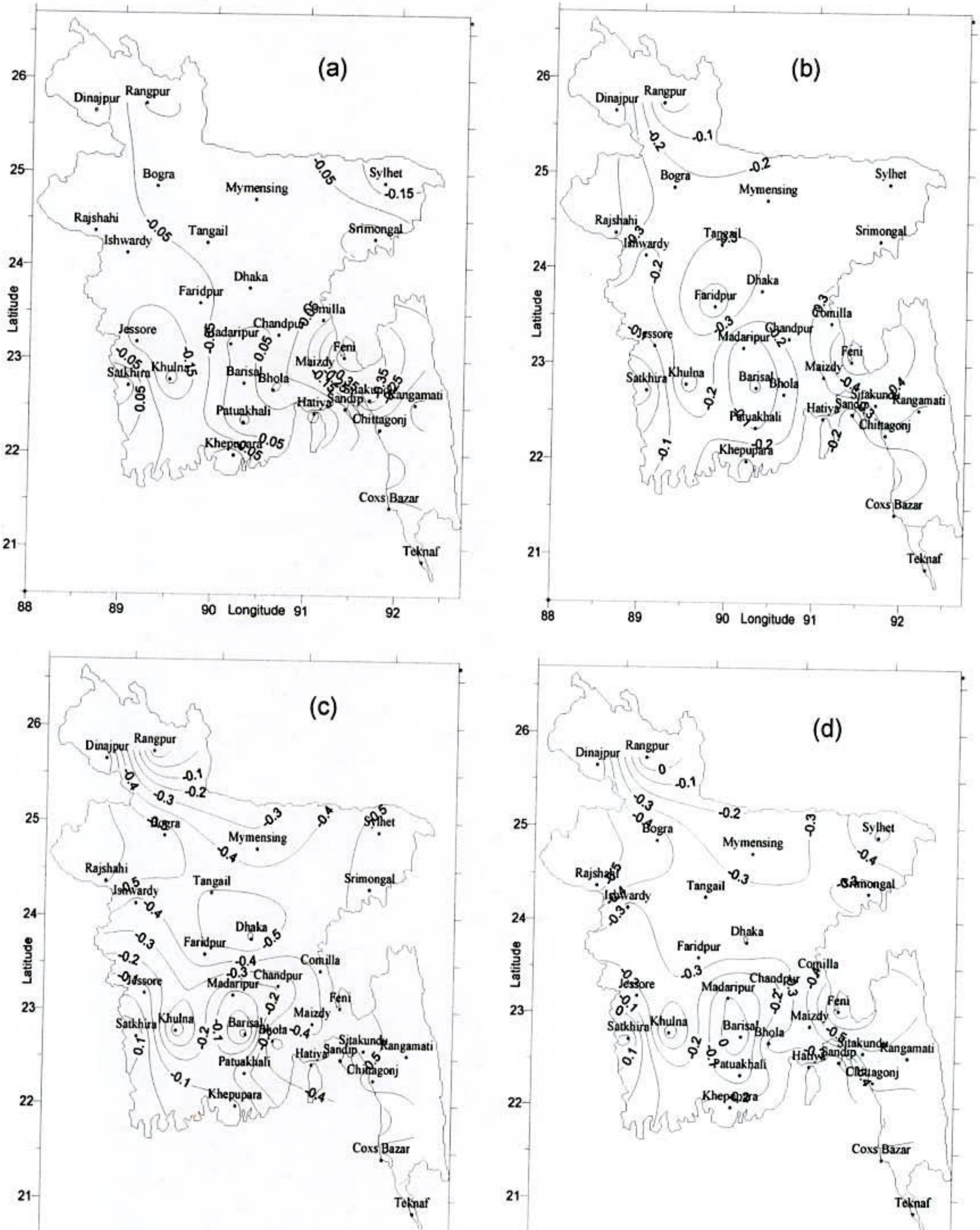

Fig 3.2.5: Correlation coefficient between Pre-monsoon rainfall and DBT of (a) March, (b) April, (c) May and (c) Pre-monsoon season itself.

3.3 Correlation Coefficients between Minimum Temperature of March-May and Rainfall of March-May

3.3.1 Distribution of the CC between Minimum Temperature of March and rainfall of March, April and May

The distribution of CC between the minimum temperature of March and the rainfall of March is shown in Fig 3.3.1(a). The distribution shows that the CC is positive from the middle to the north-eastern part of the country. It is negative at most of the other part with some exception such as the extreme southern part of the country. The CC is maximum at Cox's Bazar which is 0.30. The minimum CC is observed to be -0.32 at Rangamati. The CC is about 95% significant at Cox's Bazar and Rangamati region.

The distribution of CC between the minimum temperature of March and the rainfall of April is shown in Fig 3.3.1(b). The figure shows that the distribution of CC is positive almost everywhere from the middle to the north, north-eastern and south-eastern part of the country. The negative CC is observed in south-western part and Feni-Satkhira region. The CC is maximum at Teknaf and its value is 0.46 which is measured with a significance of more than 95%. The minimum CC is observed at Barisal which is -0.14.

The distribution of CC between the minimum temperature of March and the rainfall of May is shown in Fig 3.3.1(c). The figure shows that the distribution of CC is positive at most of the places from north-western to north-eastern part of the country. The extreme northern part and south-western part has negative CC. Also at the extreme south of the country such as Teknaf has a negative CC. The maximum value of the CC is 0.30 which is found at Ishwardi and Chandpur. The minimum CC is observed at Sitakundu which is -0.31. The CC is about 95% significant at both Ishwardi, Chandpur and Sitakundu region.

3.3.2 Distribution of the CC between Minimum Temperature of April and rainfall of March, April and May

The distribution of CC between the minimum temperature of April and the rainfall of March is shown in Fig 3.3.2(a). From this figure it can be seen that most parts of the country has negative CC. The distribution of CC is positive at Mymensing and extreme southern part of the country like Cox's Bazar and Teknaf. The maximum value of CC is observed at Patuakhali and Cox's Bazar which is 0.18. The minimum CC of -0.65 is observed at Sitakundu which is significant at 99% level.

The distribution of CC between the minimum temperature of April and the rainfall of April is shown in Fig 3.3.2(b). The figure shows that the distribution of CC is negative at all over the country except few stations. The maximum value of CC is observed at Patuakhali which is 0.14 and minimum -0.66 at Madaripur is significant at 99% level.

The distribution of CC between the minimum temperature of April and the rainfall of May is shown in Fig 3.3.2(c). The figure shows that the distribution of CC is positive at the north-eastern, central, south-western and southern part of the country. Many of the other parts have negative CC. The maximum CC has been observed at Sylhet and is 0.33 and significant at 95% level. The minimum CC is observed at Sitakundu which is -0.34.

3.3.3 Distribution of the CC between Minimum Temperature of May and rainfall of March, April and May

The distribution of CC between the minimum temperature of May and the rainfall of March is shown in Fig 3.3.3(a). From the distribution pattern we see that the CC is positive at the northern and southern part of the country. At the central part of the country it is negative. The maximum CC is found with a significance of 99% at Patuakhali which is 0.49. The minimum CC is observed to be -0.46 at Chandpur.

The distribution of CC between the minimum temperature of May and the rainfall of April is shown in Fig 3.3.3(b). The figure shows that the distribution of CC is negative all over the country except southern part of the country and Mymensing region. The maximum CC is found at Patuakhali and is 0.38 with a significance of 95%. The minimum CC is observed at Rajshahi which is -0.52, at 99% significance.

The distribution of CC between the minimum temperature of May and the rainfall of May is shown in Fig 3.3.3(c). This figure shows that the distribution of CC for all over the country has a negative value with a few exceptions which has a similarity with Fig 3.1.3(b). It has a positive value at Jessore, Satkhira, Patuakhali and Khepupara region. The maximum value of the CC is 0.12 which is found at Khepupara. The minimum CC is observed at Sitakundu -0.60 which is significant at 99% level.

3.3.4 Distribution of the CC between Pre-monsoon minimum temperature and rainfall of March, April and May

The distribution of CC between the pre-monsoon average minimum temperature and the rainfall of March is shown in Fig 3.3.4(a). The figure shows that the distribution of CC is negative all most all over the country except the north-eastern and southern part of Bangladesh. The maximum value of CC is observed with a significance level of 99% at Cox's Bazar which is 0.35. The minimum CC of -0.47 is observed at Jessore, which is significant at 99% level.

The distribution of CC between the pre-monsoon average minimum temperature and the rainfall of April is shown in Fig 3.3.4(b). From the distribution pattern we see that the CC is negative all over the country except Mymensing and southern part of Bangladesh. This distribution has a good similarity with that of the distribution of CC for the pre-monsoon average minimum temperature and the rainfall of April as shown in Fig 3.3.4(a). The maximum CC is found at Patuakhali which is 0.24 and minimum -0.53 at Feni.

The distribution of CC between the pre-monsoon average minimum temperature and the rainfall of May is shown in Fig 3.3.4(c). The figure shows that the distribution of CC is positive at the north-eastern and south-western part of the country. Most of the other part of the country has negative CC. The maximum CC is found at Chandpur and is 0.26. The minimum CC is observed at Sitakundu -0.54, which is significant at 99% level.

3.3.5 Distribution of the CC between average Pre-monsoon rainfall and minimum temperature of March, April and May and pre-monsoon season itself

The distribution of CC between the minimum temperature of March and the average pre-monsoon rainfall is shown in Fig 3.3.5(a). From the distribution pattern we see that the CC is positive from the central to the north and north-eastern part of the country. It is also positive at some places of the southern part like Hatiya, Cox's Bazar, Chittagong and Khepupara. It is almost negative for the other part of the country. The maximum CC of 0.31 is observed at Sylhet with a significance level of 95%. The minimum CC is observed to be -0.31 at Sitakundu.

The distribution of CC between the minimum temperature of April and the average pre-monsoon rainfall is shown in Fig 3.3.5(b). From the distribution pattern we see that the CC distribution is negative for all over the country except a few places e.g. Mymensing, Patuakhali, Khepupara and Cox's Bazar. The CC is maximum at Patuakhali which is 0.21 and minimum -0.66 at Madaripur.

The distribution of CC between the minimum temperature of May and the average pre-monsoon rainfall is shown in Fig 3.3.5(c). Except Mymensing, Satkhira, Patuakhali, Khepupara and Cox's Bazar region the CC is negative for all over Bangladesh. The CC 0.50 is observed at Khepupara with a significance level of 99%. The observed minimum CC is -0.57 at Rajshahi.

The distribution of CC between the average Pre-monsoon minimum temperature and the average pre-monsoon rainfall is shown in Fig 3.3.5(d). The figure shows that Sylhet and Srimongal belt has a positive CC. The southern and south-western part of the country also has a positive CC. Most of the other parts have negative CC. The maximum CC is observed at Khepupara which is 0.28 and minimum CC is -0.65 at Sitakundu.

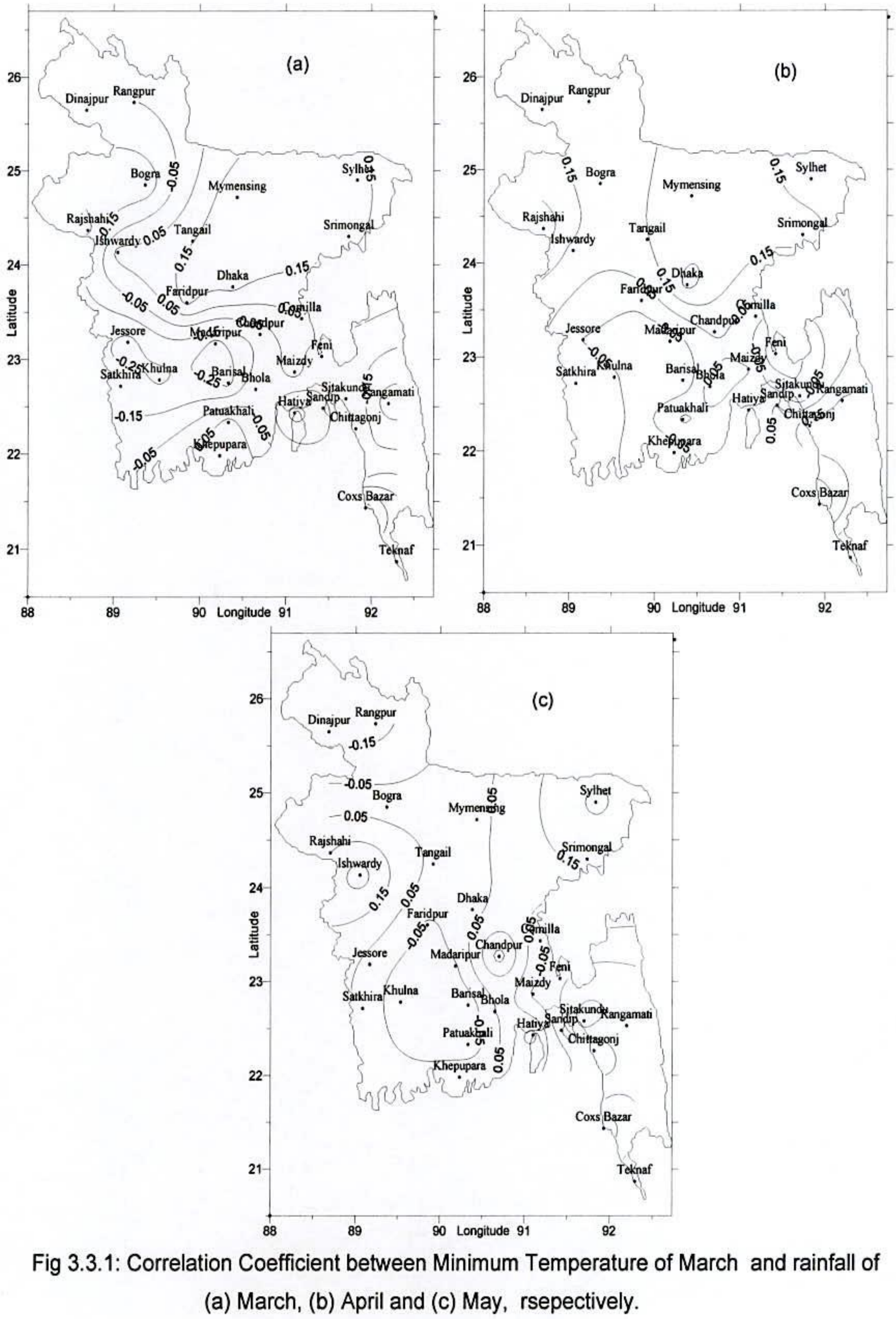

Fig 3.3.1: Correlation Coefficient between Minimum Temperature of March and rainfall of (a) March, (b) April and (c) May, rsepectively.

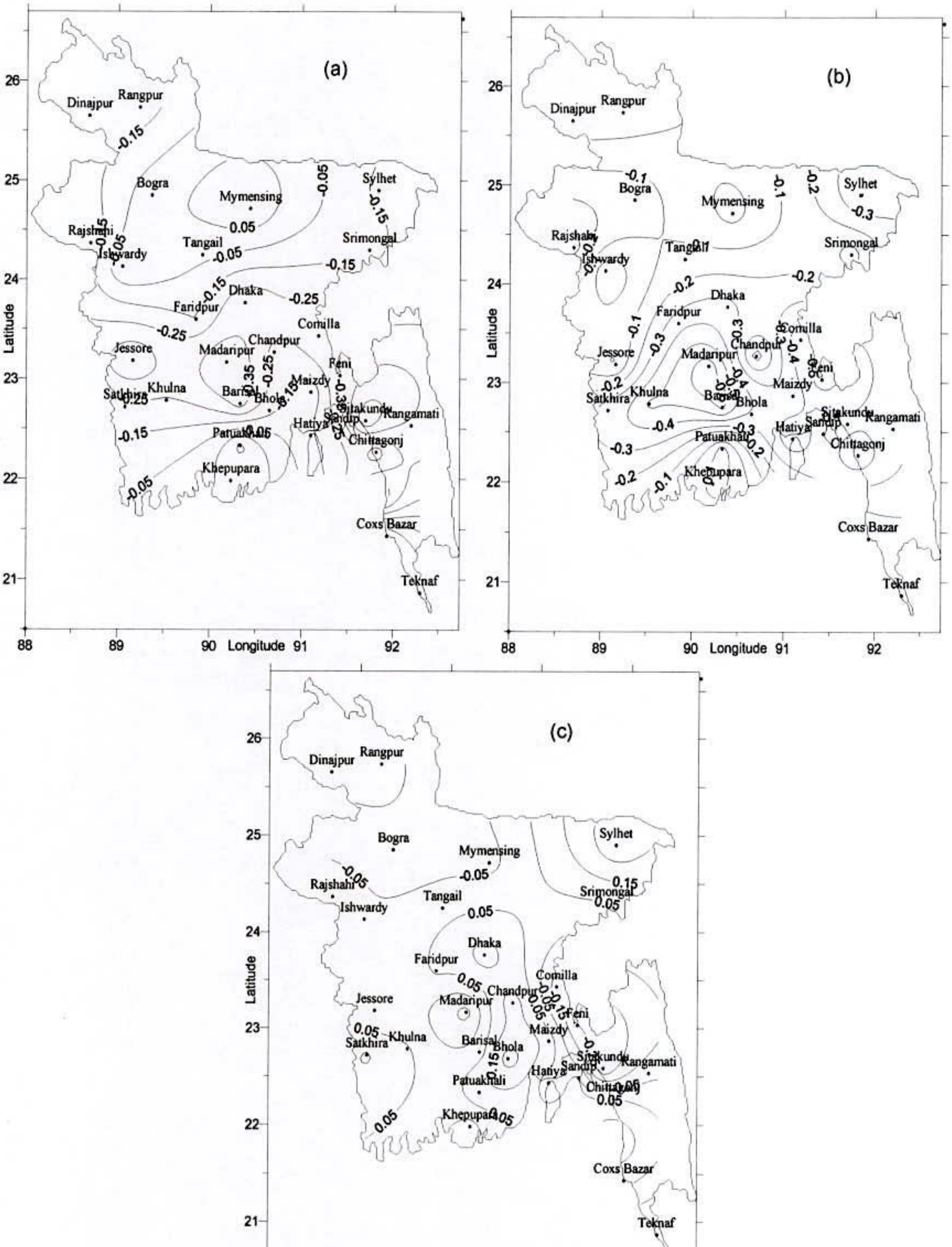

Fig 3.3.2: Correlation Coefficient between Minimum Temperature of April and rainfall of (a) March, (b) April and (c) May rsepectively.

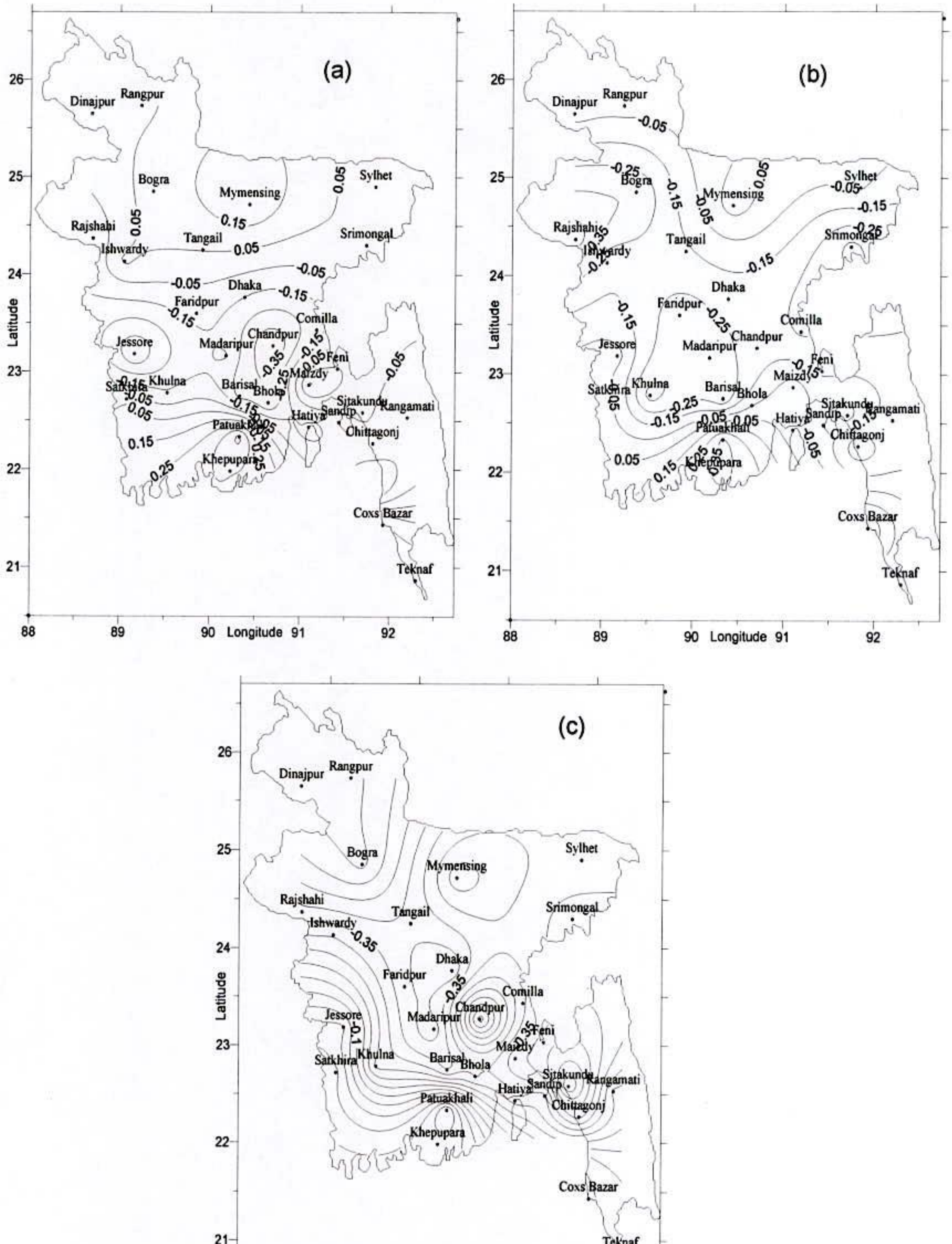

Fig 3.3.3: Correlation Coefficient between Minimum Temperature of May and rainfall of (a) March, (b) April and (c) May rsepectively.

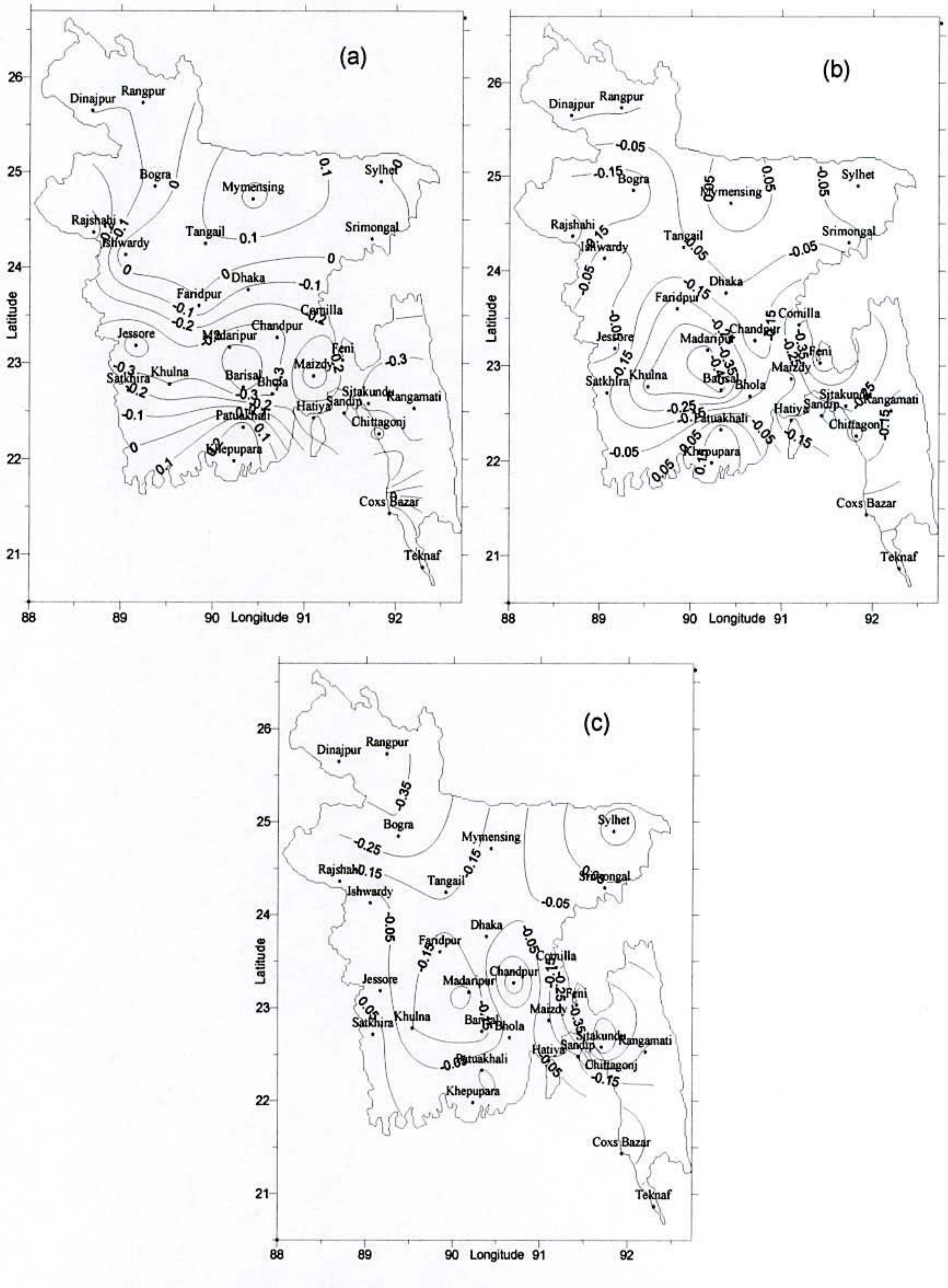

Fig 3.3.4: Correlation Coefficient between Pre-monsoon Minimum Temperature and the rainfall of (a) March, (b) April and (c) May rsepectively.

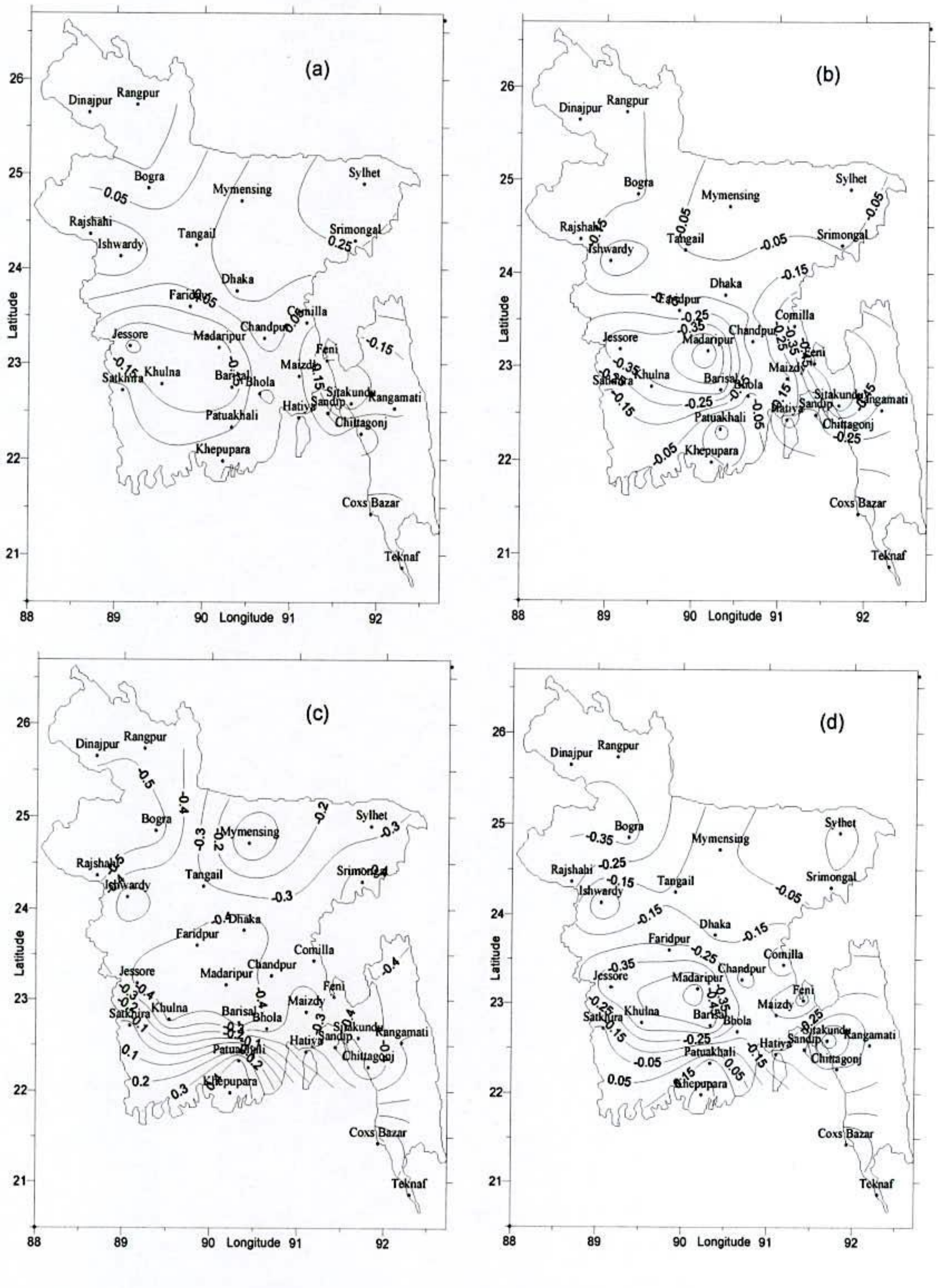

Fig 3.3.5: Correlation coefficient between Pre-monsoon rainfall and Minimum Temperature of (a) March, (b) April, (c) May and (d) Pre-Monsoon season.

3.4 Correlation coefficients between Maximum Temperature (MaxT) of March-May and Rainfall of March-May

3.4.1 Distribution of the CC between MaxT of March and rainfall of March, April and May

The distribution of CC between the MaxT of March and the rainfall of March is shown in Fig 3.4.1(a). From the figure we see that the CC is negative all over the country with a few exceptions. It is positive at the south-western zone of the country. Among all other parts of the country the CC is positive at Bogra, Chandpur and Feni. The maximum CC is observed to be 0.24. The minimum CC of -0.77 is observed at Madaripur and -0.6 at Bhola.

The distribution of CC between the MaxT of March and the rainfall of April is shown in Fig 3.4.1(b). From this figure it can be seen that the south-western zone of the country has a positive CC which has a similarity with the CC between the MaxT of March and the rainfall of March. The CC also has a positive value at the extreme southern part of the country and also Sylhet, Dhaka, Faridpur and Feni. The CC is maximum at Hatiya and its value is 0.22. The minimum CC is observed at Rangpur which is -0.46.

The distribution of CC between the MaxT of March and the rainfall of May is shown in Fig 3.4.1(c). The figure shows that the distribution of CC is negative at the maximum region of the country and positive at most of the southern part and south-western part of the country. It is also positive at the Rajshahi-Ishwardi zone. The maximum value of CC is 0.23 found at Khepupara. The minimum CC is observed at Rangpur which is -0.38.

3.4.2 Distribution of CC between MaxT of April and rainfall of March, April and May

The distribution of CC between the MaxT of April and the rainfall of March is shown in Fig 3.4.2(a). The figure shows that the distribution of CC is negative for all over the country except Khulna-Satkhira-Barisal-Khepupara zone and Feni. The maximum value of CC is observed at Feni which is 0.29. The minimum CC of -0.51 is observed at Patuakhali and -0.4 at Dhaka.

The distribution of CC between the MaxT of April and the rainfall of April is shown in Fig 3.4.2(b). The figure shows that the distribution of CC is negative all over the country except Feni, Satkhira, Barisal and Khepupara region. The maximum value of CC is observed at Khepupara with a significance of 95% which is 0.35. The minimum CC of -0.67 is observed at the extreme southern part of the country i.e. at Teknaf and -0.55 at Rangpur-Dinajpur region which is significant at 99% level.

The distribution of CC between the MaxT of April and the rainfall of May is shown in Fig 3.4.2(c). The figure shows that the distribution of CC is positive at the South-eastern part, extreme southern part and at the Sylhet-Srimongal belt. Most of the other part of the country has a negative CC. The CC at Sandwip is found to be 0.36 with 95% significance level. The minimum CC is observed at Rangpur which is -0.40.

3.4.3 Distribution of the CC between MaxT of May and rainfall of March, April and May

The distribution of CC between the MaxT of May and the rainfall of March is shown in Fig 3.4.3(a). From the distribution pattern we see that the CC is positive at eastern and south-western part of Bangladesh. Most of the other part of the country has a negative CC. The maximum CC is found at Feni which is 0.23. The minimum CC is observed to be -0.32 at Patuakhali.

The distribution of CC between the MaxT of May and the rainfall of April is shown in Fig 3.4.3(b). The figure shows that the distribution of CC is positive at some southern, south-western part of the country. It is also positive at Sylhet. Most of the other part of the country has a negative CC. The maximum CC is found at Sandwip to be 0.23. The minimum CC is observed at Rangamati which is -0.41. At the central region the CC is less than -0.35 which is significant at 99% level.

The distribution of CC between the MaxT of May and the rainfall of May is shown in Fig 3.4.3(c). This figure shows that the distribution of CC at all over the country is negative except Jessore, Chandpur, Feni, Barisal and Khepupara. The maximum value of CC is 0.31 which is found at Feni. The minimum CC is observed at Maizdy Court -0.66 which is significant at 99% level.

3.4.4 Distribution of the CC between Pre-monsoon MaxT and rainfall of March, April and May

The distribution of CC between the average pre-monsoon MaxT and the rainfall of March is shown in Fig 3.4.4(a). The figure shows that the distribution of CC is negative for all over the country except Satkhira, Khulna, Barisal, Feni, Khepupara and Bogra region. The maximum value of CC is observed at Feni which is 0.33 with 95% significance level. The minimum CC of -0.67 is observed at Patuakhali which is significant at 99% level.

The distribution of CC between the average pre-monsoon MaxT and the rainfall of April is shown in Fig 3.4.4(b). From the distribution pattern we see that the CC is negative all over the country except Feni, Satkhira, Barisal and Khepupara. The maximum CC is found at Khepupara which is 0.29. The minimum CC is observed to be -0.60 at Rangamati which is significant at 99% level.

The distribution of CC between the average pre-monsoon MaxT and the rainfall of May is shown in Fig 3.4.4(c). The figure shows that the distribution of CC is negative all over the country except Feni, Khepupara, Sandwip and Chittagong. The maximum CC is found at Khepupara which is 0.26. The minimum CC is observed at Dinajpur -0.62 which is significant at 99% level.

3.4.5 Distribution of the CC between Pre-monsoon rainfall and MaxT of March, April and May and pre-monsoon season itself

The distribution of CC between the MaxT of March and average pre-monsoon rainfall is shown in Fig 3.4.5(a). From the distribution pattern we see that the CC is negative all over the country except Satkhira-Khulna-Barisal-Khepupara belt. The maximum CC of 0.36 is observed at Khepupara with a significance of 95%. The minimum CC is observed to be -0.55 at Rangpur.

The distribution of CC between the MaxT of April and average pre-monsoon rainfall is shown in Fig 3.4.5(b). From the distribution pattern we see that the CC distribution is negative all over the country except Barisal, Khepupara, Sandwip and Feni. The CC is maximum at Khepupara which is 0.39 with a significance level of 95%. The observed minimum CC is -0.58 at Dinajpur which is significant at 99% level.

The distribution of CC between the MaxT of May and the pre-monsoon rainfall is shown in Fig 3.4.5(c). The CC distribution between the MaxT of May and the pre-monsoon rainfall is roughly similar with that of the CC distribution between the MaxT of March and April and the pre-monsoon rainfall as shown in Fig 4.1.5(a) and Fig 4.1.5(b). Like April the CC distribution is negative in May also for all over the country except a few places e.g. Barisal, Khepupara and Feni. The CC is maximum at Feni which is 0.35 with a significance level of 95%. The observed minimum CC is -0.64 at Dinajpur.

The distribution of CC between the Pre-monsoon MaxT and the pre-monsoon rainfall is shown in Fig 3.4.5(d). The CC distribution is negative for all over the country except Barisal, Khepupara and Feni. The maximum CC is observed at Khepupara 0.47 and minimum is -0.78 at Dinajpur which are significant at 99% level.

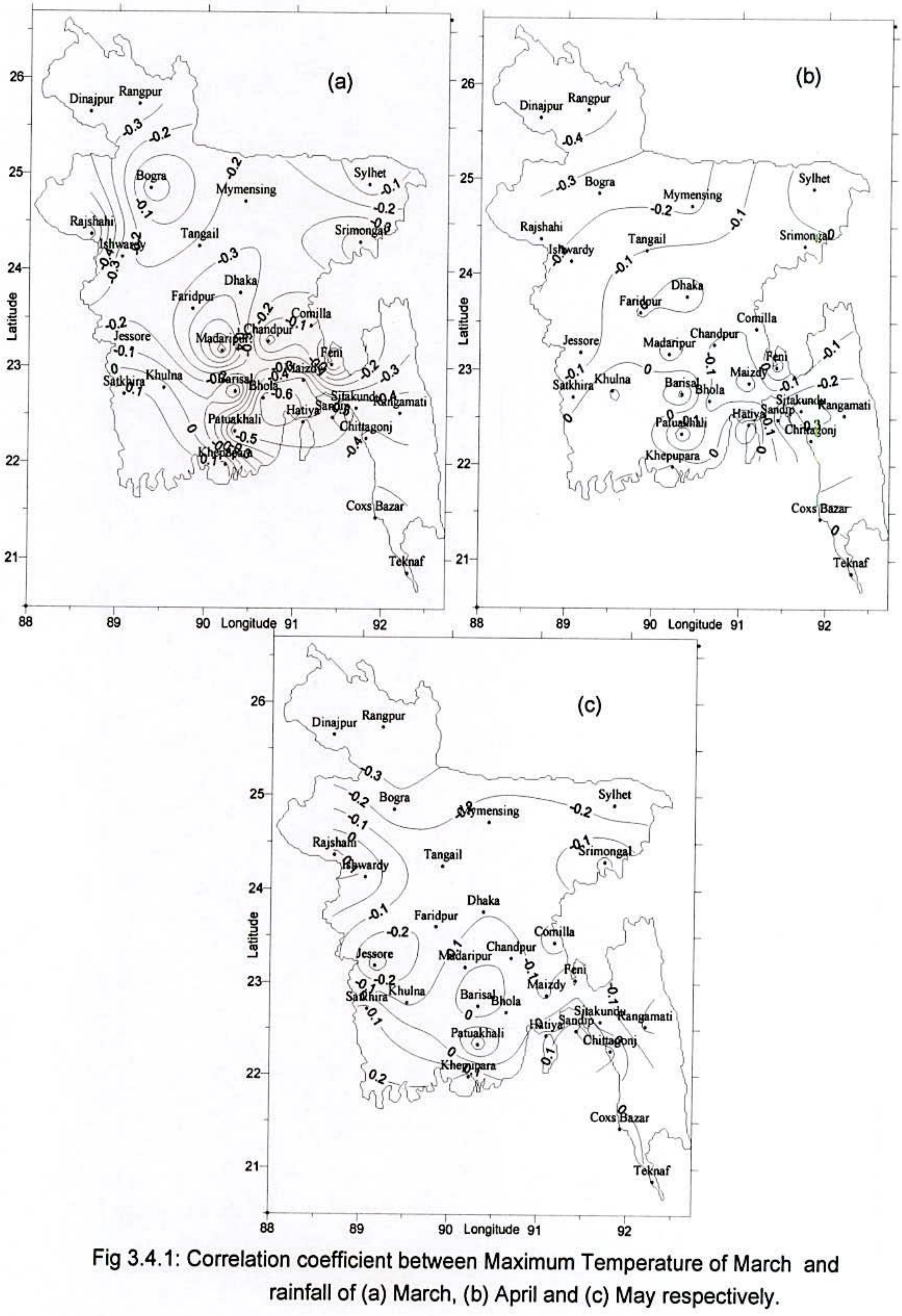

Fig 3.4.1: Correlation coefficient between Maximum Temperature of March and rainfall of (a) March, (b) April and (c) May respectively.

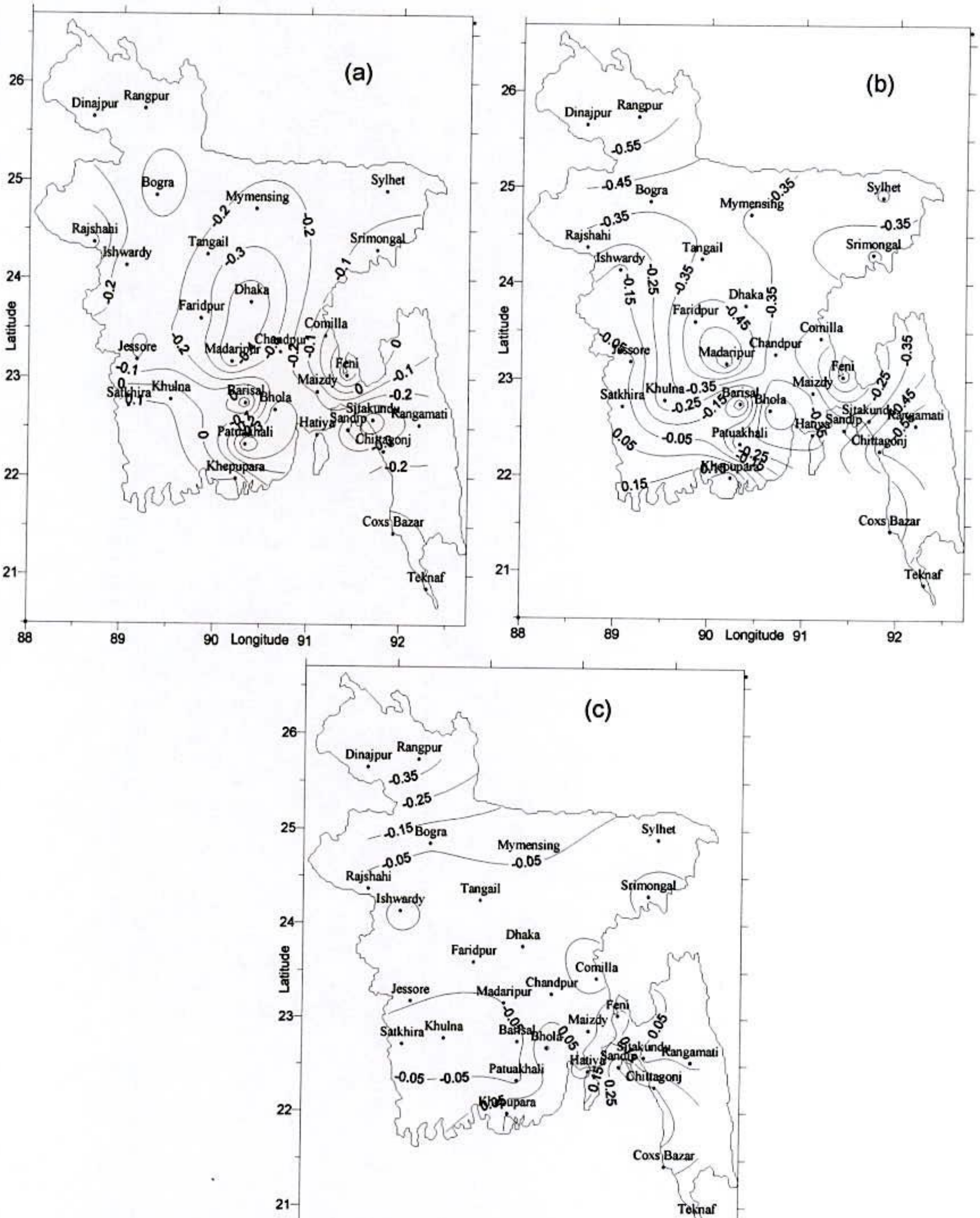

Fig 3.4.2: Correlation coefficient between Maximum Temperature of April and rainfall of (a) March, (b) April and (c) May respectively.

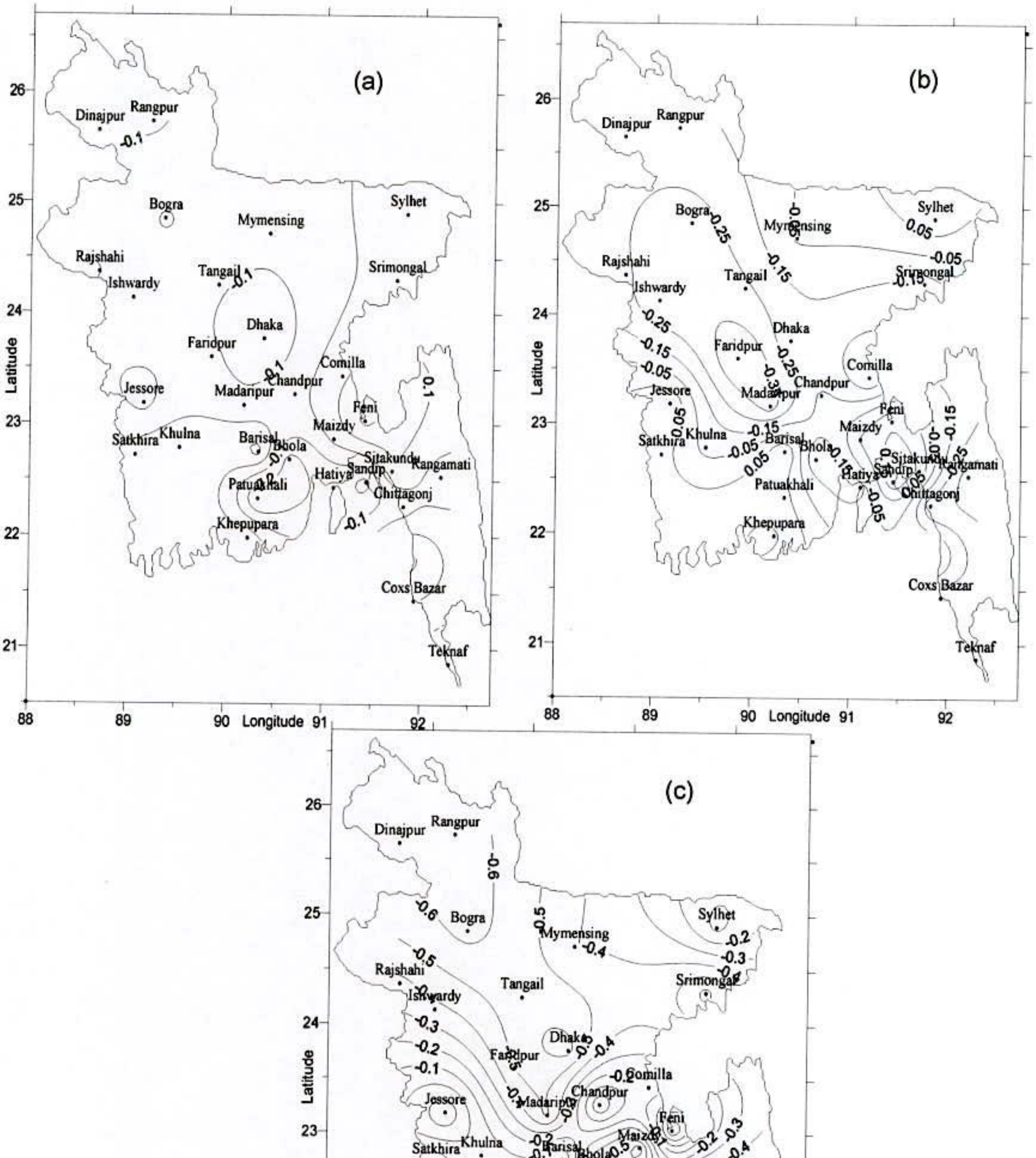

Fig 3.4.3: Correlation coefficient between Maximum Temperature of May and rainfall of (a) March, (b) April and (c) May respectively.

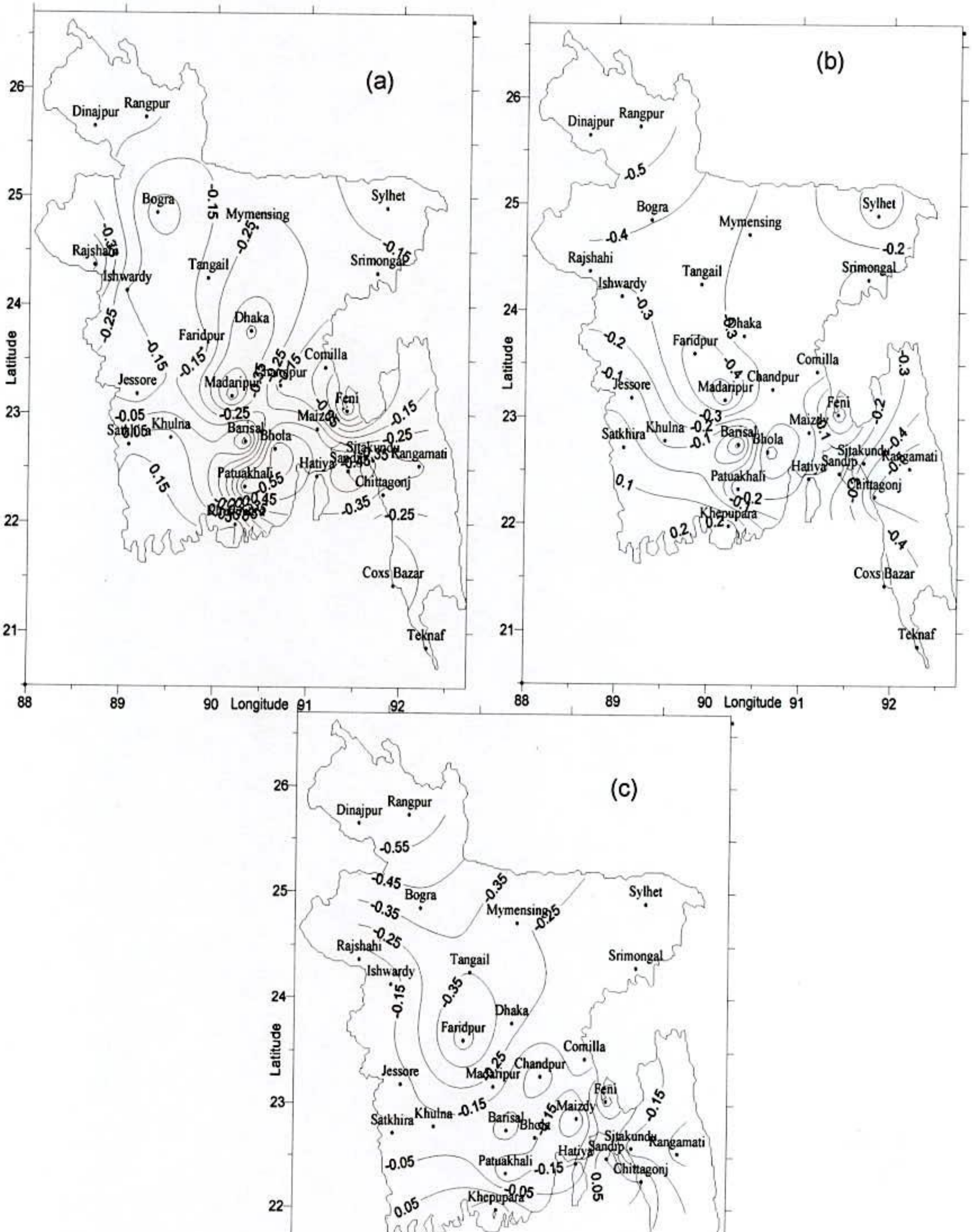

Fig 3.4.4: Correlation coefficient between average Maximum Temperature of Pre-monsoon and rainfall of (a) March, (b) April and (c) May respectively.

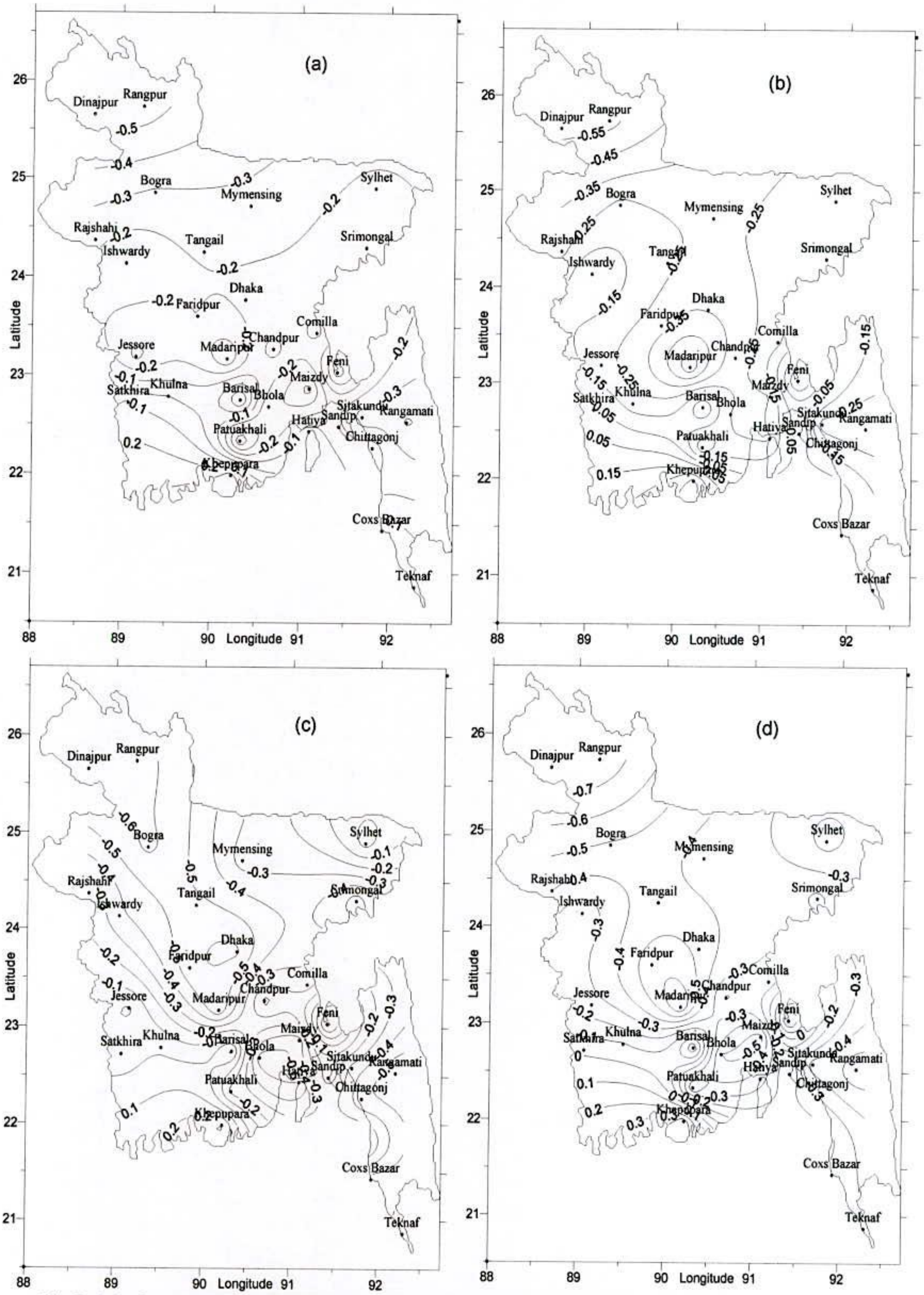

Fig 3.4.5: Correlation coefficient between Pre-monsoon rainfall and Maximum Temperature of (a) March, (b) April, (c) May and (d) Pre-Monsoon season.

3.5 Correlation coefficients between WBT of March-May and Rainfall of March-May

3.5.1 Distribution of the CC between WBT of March and rainfall of March, April and May

The distribution of CC between the WBT of March and the rainfall of March is shown in Fig 3.5.1(a). From the figure we see that the CC is positive from the middle part of Bangladesh toward north and north-east. The extreme north-western part has a negative CC. Most of the western, south-western, eastern and south-eastern part has also a negative CC. The maximum CC of 0.27 is found at Patuakhali. The minimum CC is observed at Khepupara which is -0.30.

The distribution of CC between the WBT of March and the rainfall of April is shown in Fig 3.5.1(b). From this figure it can be seen that the CC is positive all over Bangladesh with few exception. At Barisal, Comilla and Feni the CC is negative. The maximum positive and negative CC is observed at Dhaka and Feni and is 0.35 and -0.31, respectively.

The distribution of CC between the WBT of March and the rainfall of May is shown in Fig 3.5.1(c). The figure shows that starting from the middle part of the country the distribution of CC is positive at most of the places towards north, north-east and north-western part. Khulna-Barisal-Patuakhali-Khepupara belt has a negative CC. The maximum positive and negative CC is observed at Hatiya and Sitakundu and is 0.33 and -0.33, respectively. The CC is significant about 95% level at Hatiya and Sitakundu.

3.5.2 Distribution of the CC between WBT of April and rainfall of March, April and May

The distribution of CC between the WBT of April and the rainfall of March is shown in Fig 3.5.2(a). The figure shows that the distribution of CC is negative for all over the country except Ishwardi-Bogra-Mymensing and Satkhira, Patuakhali and Hatiya regions. The maximum positive and negative CC is observed at Patuakhali and Sitakundu and is 0.31 and -0.60, respectively.

The distribution of CC between the WBT of April and the rainfall of April is shown in Fig 3.5.2(b). The figure shows that the distribution of CC is negative all over the country except Dinajpur, Rangpur, Bogra, Ishwardi, Faridpur and Jessore. The maximum positive and negative values of CC are observed at Rangpur and Madaripur are 0.46 and -0.66, respectively, which are significant at 99% level

The distribution of CC between the WBT of April and the rainfall of May is shown in Fig 3.5.2(c). The figure shows that from the central part CC is positive at everywhere towards north, north-west and north-eastern part of the country except Ishwardi. Most of the southern and south-western part of the country has also a positive CC. Comilla-Feni-Sitakundu belt has a negative CC. The maximum positive and negative values of CC are observed at Sylhet and Comilla are 0.24 and -0.27, respectively.

3.5.3 Distribution of the CC between WBT of May and rainfall of March, April and May

The distribution of CC between the WBT of May and the rainfall of March is shown in Fig 3.5.3(a). From the distribution pattern we see that the CC is positive at the northern, north-western and north-eastern part of Bangladesh. The CC is mostly negative at the central part and mostly positive at the southern part of the country. The maximum positive and negative values of CC are observed at Patuakhali and Teknaf are 0.31 and -0.30, respectively.

The distribution of CC between the WBT of May and the rainfall of April is shown in Fig 3.5.3(b). The figure shows that the distribution of CC is negative all over the country except Dinajpur, Rangpur, Mymensing, Ishwardi, Jessore, Maizdy Court and Sitakundu region. The maximum positive and negative CC is observed at Sitakundu and Khulna and is 0.21 and -0.49 respectively.

The distribution of CC between the WBT of May and the rainfall of May is shown in Fig 3.5.3(c). This figure shows that the distribution of CC at all over the country is negative except Faridpur, Jessore, Chandpur and Satkhira. The maximum positive and negative CC is observed at Chandpur and Sitakundu and is 0.12 and -0.56, respectively.

3.5.4 Distribution of CC between Pre-monsoon WBT and rainfall of March, April and May

The distribution of CC between the average pre-monsoon WBT and the rainfall of March is shown in Fig 3.5.4(a). The figure shows that the distribution of CC is positive at Ishwardi-Bogra-Mymensing-Sylhet belt. It is negative at almost all the places in the southern, south-eastern and eastern part of the country. The maximum positive and negative CC is observed at Patuakhali and Sitakundu and is 0.38 and -0.38, respectively. The CC is significant about 95% level at Patuakhali and Sitakundu.

The distribution of CC between the average pre-monsoon WBT and the rainfall of April is shown in Fig 3.5.4(b). From the distribution pattern we see that starting from the middle part of the country the CC is positive everywhere towards the north and north-western part of Bangladesh. It is also negative at most of the places towards south, south-east and south-western part of the country. The maximum positive and negative CC is observed at Rangpur and Comilla and is 0.37 and -0.44, respectively. The CC is significant about 99% level at Comilla and Rangpur.

The distribution of CC between the average pre-monsoon WBT and the rainfall of May is shown in Fig 3.5.4(c). The figure shows that the distribution of CC is positive at all of the northern and north-western part of the country except Dinajpur and Rangpur. It is also positive at some places of the south-western and middle part of Bangladesh. The eastern and southern part has a negative CC. The maximum positive and negative CC is observed at Satkhira and Sitakundu and is 0.46 and -0.50, respectively. At Satkhira and Sitakundu the CC is significant of about 99% level.

3.5.5 Distribution of the CC between average Pre-monsoon rainfall and WBT of March, April and May and the Pre-monsoon season itself

The distribution of CC between the WBT of March and the average pre-monsoon rainfall is shown in Fig 3.5.5(a). From the distribution pattern we see that the CC is positive at everywhere towards the north, north-east and north-west from the middle part of Bangladesh. It is also positive at many of the remaining part of the country towards south, south-west and south-east from the central part. The negative CC is observed at Patuakhali and Sitakundu region. The maximum positive and negative CC is observed at

Satkhira and Sitakundu and is 0.34 and -0.30, respectively. The CC is significant about 99% level at Satkhira.

The distribution of CC between the WBT of April and the average pre-monsoon rainfall is shown in Fig 3.5.5(b). From the distribution pattern we see that the CC distribution is positive at all the places from the central to the northern and north-western part of the country. At eastern and southern part of the country the CC is mostly negative. The maximum positive and negative CC is observed at Satkhira and Madaripur and is 0.37 and -0.52, respectively. At both of the places the CC is significant at 99% level.

The distribution of CC between the WBT of May and the pre-monsoon rainfall is shown in Fig 3.5.5(c). The CC distribution is negative all over the country except Ishwardi. This distribution pattern has no similarity with that of the CC distribution pattern of WBT of March and April and the pre-monsoon rainfall. The only positive CC is observed at Ishwardi which is 0.06. The maximum negative CC is observed at Khulna -0.50 which is significant at 99% level.

The distribution of CC between the average Pre-monsoon WBT and average pre-monsoon rainfall is shown in Fig 3.5.5(d). The CC distribution is positive at all over the northern part of the country except the extreme north. All over the south-eastern and southern part has a negative CC. The maximum positive and negative CC is observed at Satkhira and Feni and is 0.39 and -0.58, respectively. The CC is significant about 99% level at Satkhira and Feni.

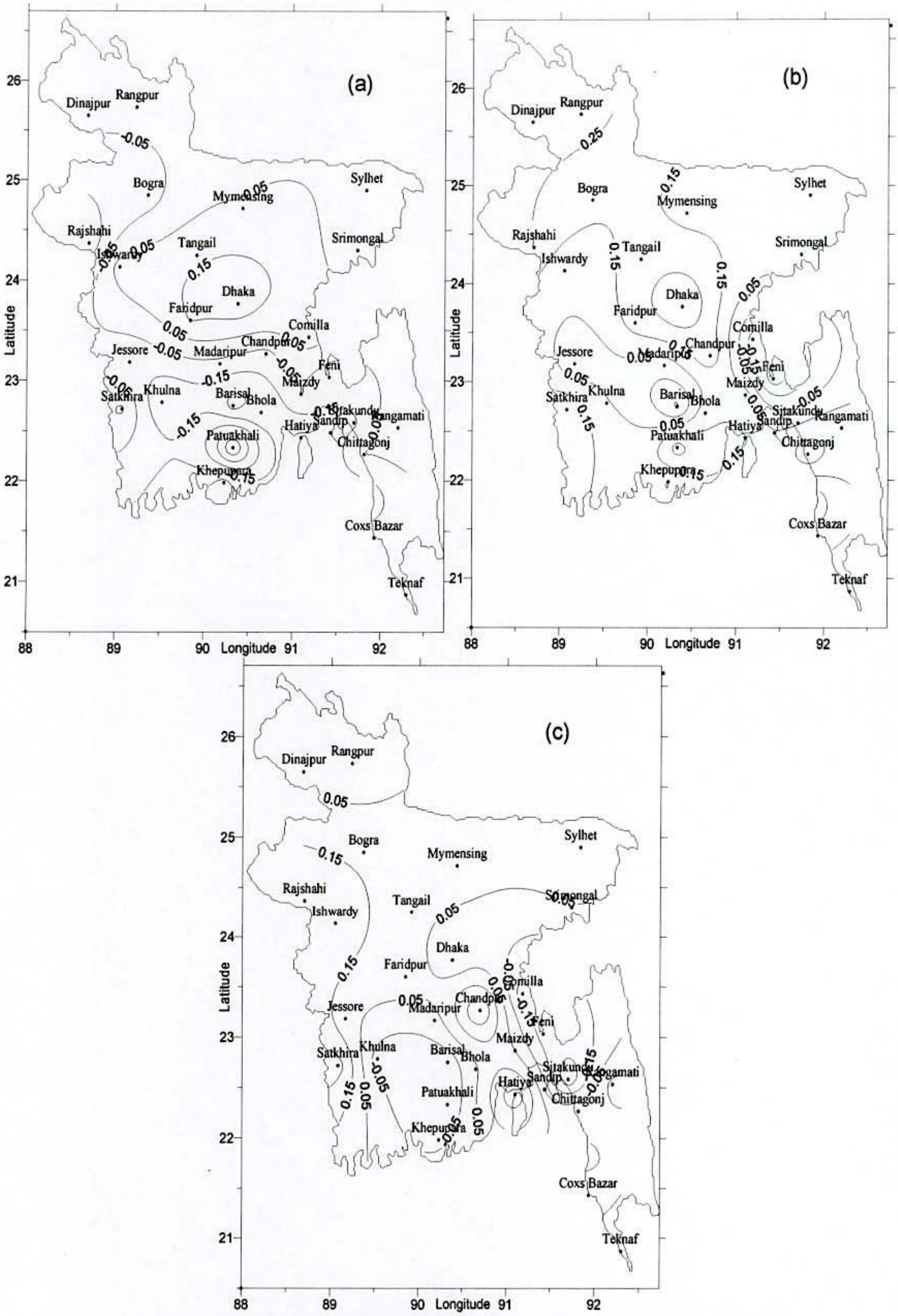

Fig 3.5.1: Correlation coefficient between WBT of March and Rainfall of (a) March, (b) April and (c) May respectively.

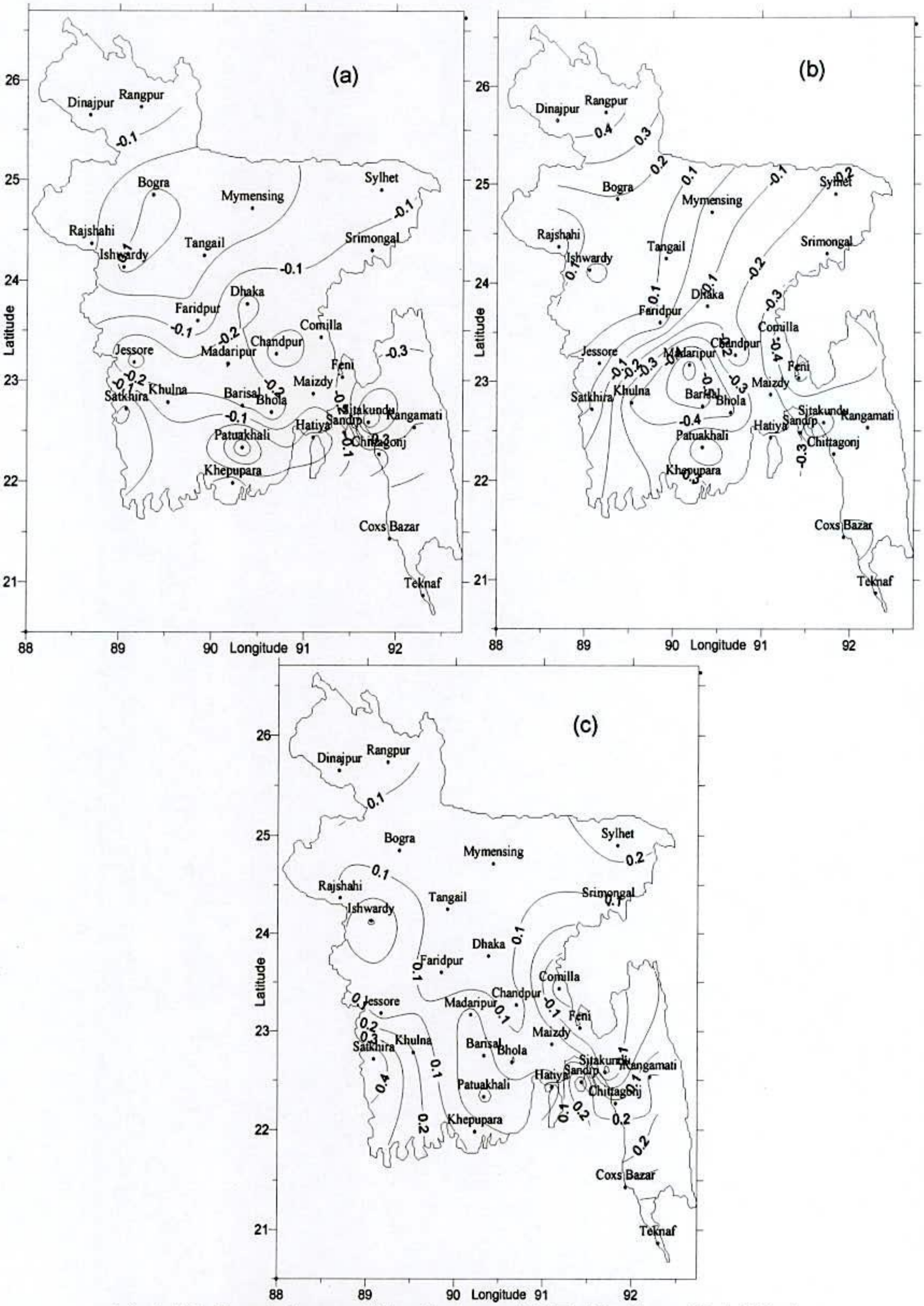

Fig 3.5.2: Correlation coefficient between WBT of April and Rainfall of (a) March, (b) April and (c) May respectively.

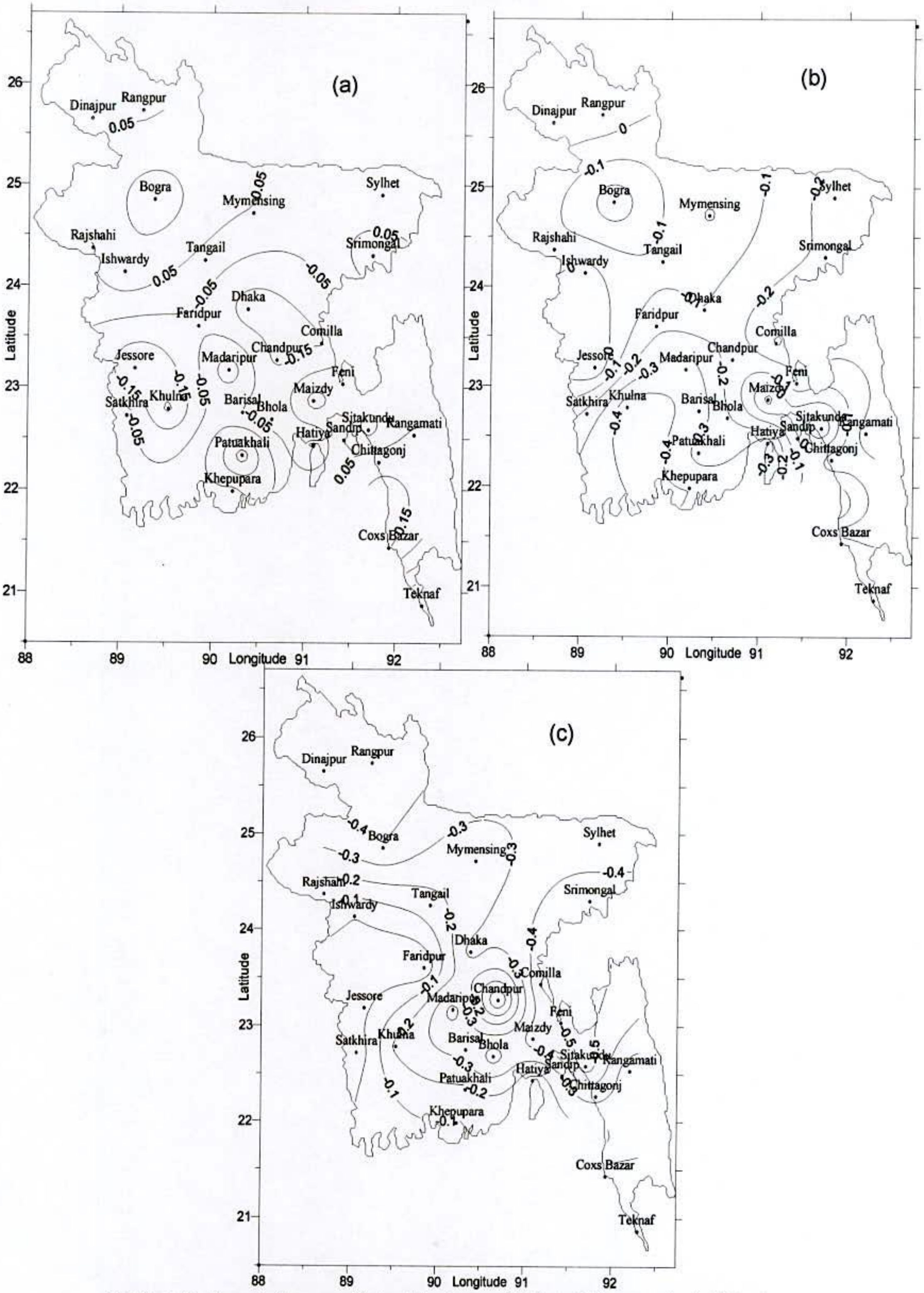

Fig 3.5.3: Correlation coefficient between WBT of May and rainfall of (a) March, (b) April and (c) May rsepectively.

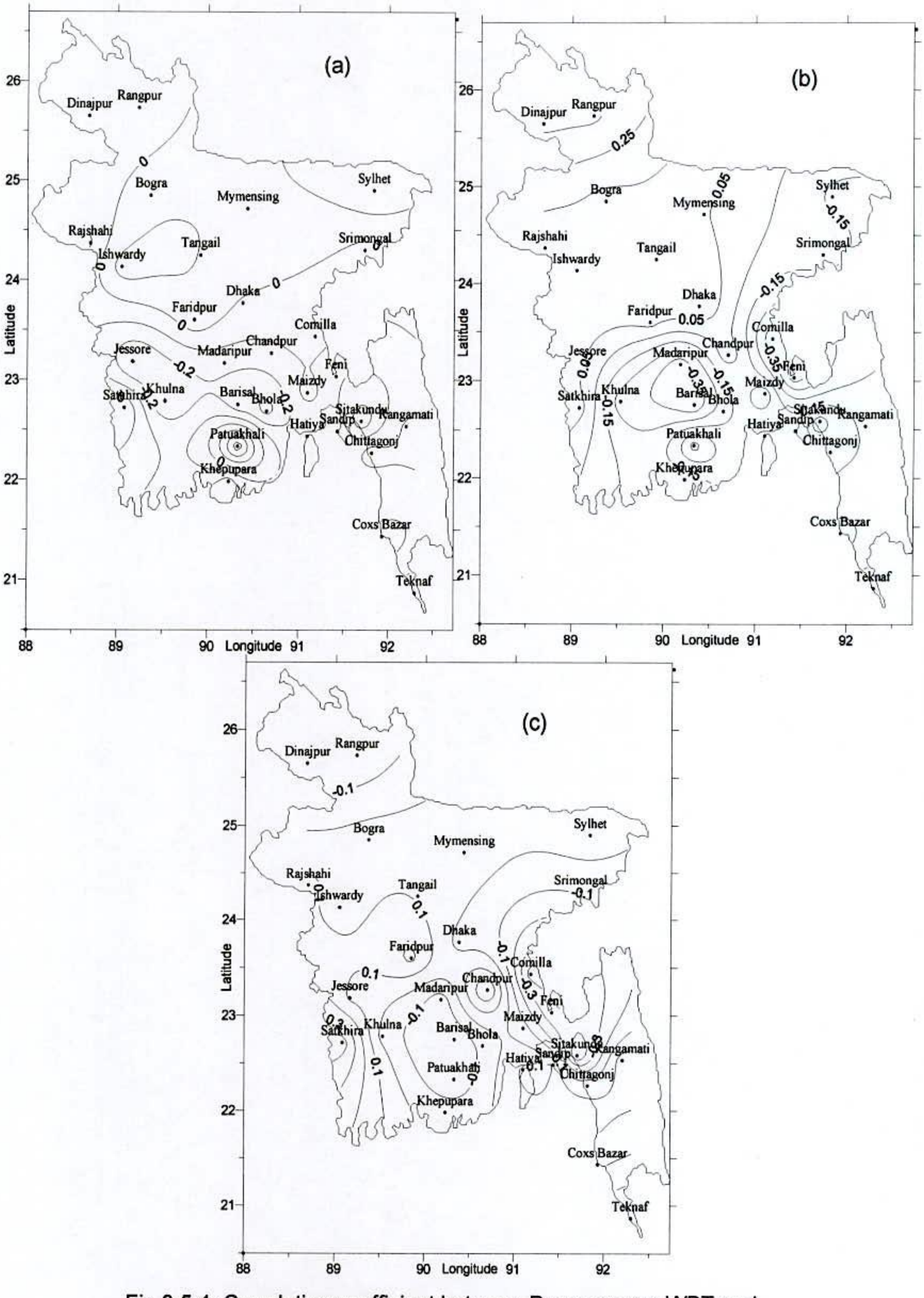

Fig 3.5.4: Correlation coefficient between Pre-monsson WBT and rainfall of (a) March, (b) April and (c) May rsepectively.

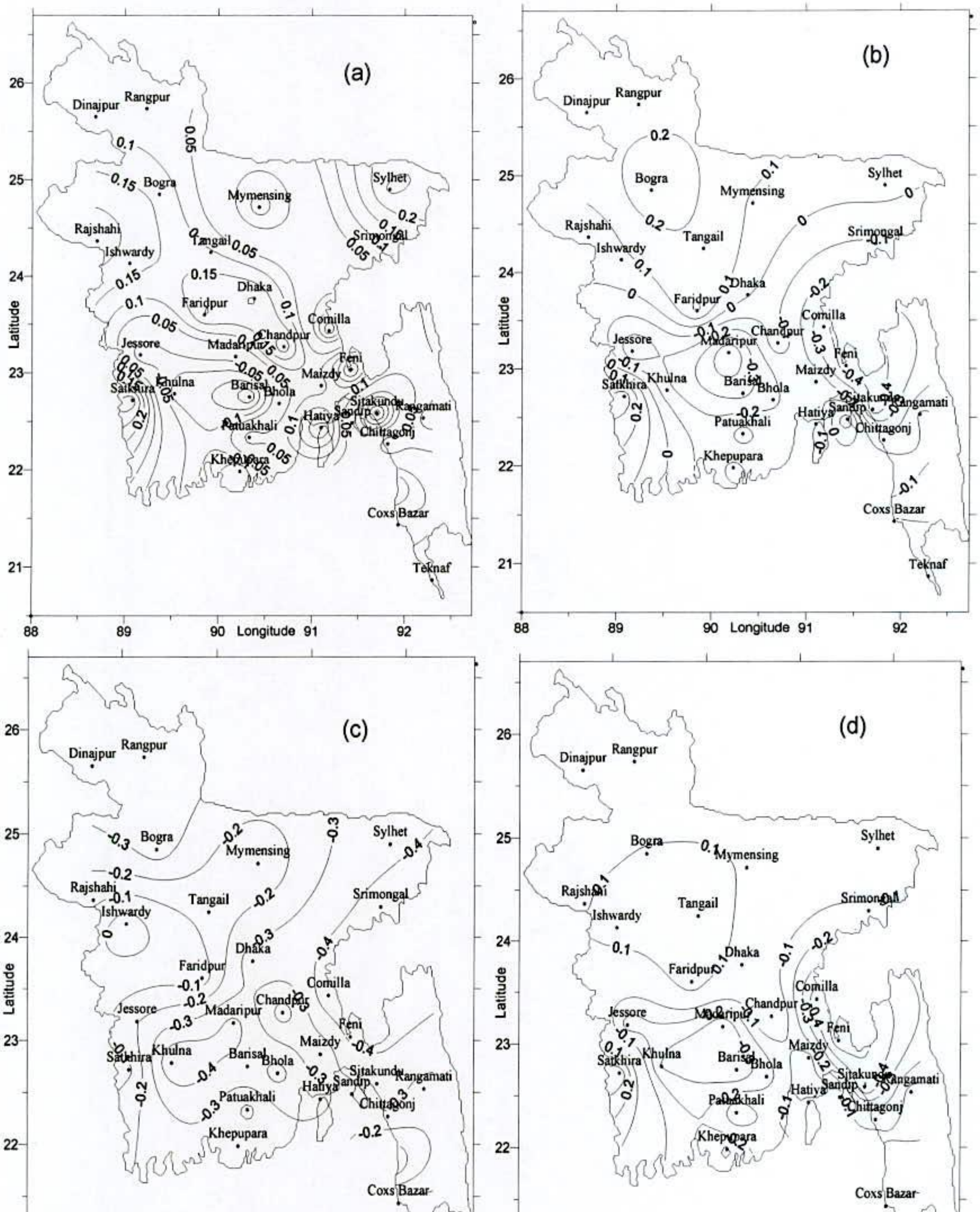

Fig 3.5.5: Correlation coefficient between Pre-monsoon rainfall and WBT of (a) March (b) April, (c) May and (d) Pre-monsoon season.

3.6 Correlation coefficients between DBT of March, April and May and Rainfall of June, July, August and September

3.6.1 Distribution of CC between DBT of March and average rainfall of June, July, August and September

The distribution of CC between the DBT of March and the rainfall of June is shown in Fig 3.6.1(a). From this distribution we see that the CC is positive for the extreme northern part, some places of middle part and the most of the southern part of Bangladesh. The CC is in negative at most of the western, north-eastern and south-eastern part of the country. The CC is maximum at Khepupara and its value is 0.26. The minimum CC of -0.21 is observed at Teknaf.

The distribution of CC between the DBT of March and the rainfall of July is shown in Fig 3.6.1(b). The figure shows that the distribution of CC is positive throughout the Ishwardi- Faridpur-Madaripur-Jessore-Satkhira belt. It is negative at other parts of the country. The CC is maximum at Hatiya and its value is 0.53 with a significance of 99%. The minimum CC is observed at Khulna which is -0.25.

The distribution of CC between the DBT of March and the rainfall of August is shown in Fig 3.6.1(c). The figure shows that the distribution of CC is positive at the many of the west, north-west and some of the southern part of the country. It is negative in the central, northe-eastern, eastern and south-eastern part of the country. The maximum value of CC is 0.33 found at Rangpur with 95% level of significance. The minimum CC is observed at Dhaka which is -0.34.

The distribution of CC between the DBT of March and the rainfall of September is shown in Fig 3.6.1(d). The figure shows that the distribution of CC is positive throughout the central, northern and western part of the country. The CC is negative in the north-eastern, eastern, south-eastern and southern part of the country. The CC is maximum at Madaripur and its value is 0.30. The minimum CC is observed at Sylhet which is -0.33.

3.6.2 Distribution of CC between DBT of April and rainfall of June, July, August and September

The distribution of CC between the DBT of April and the rainfall of June is shown in Fig 3.6.2(a). The figure shows that the distribution of CC is positive at the north western, eastern and southern part of the country. It is negative at the other part of the country. The maximum value of CC is observed at Bogra which is 0.22. The minimum CC is observed at Hatiya which is -0.27.

The distribution of CC between the DBT of April and the rainfall of July is shown in Fig 3.6.2(b). The figure shows that the is negative at most of the places over the country. It is positive at Rangpur and Dinajpur. The maximum value of CC is observed with a significance of 99% at Satkhira which is 0.35. The minimum CC of -0.30 is observed at Feni.

The distribution of CC between the DBT of April and the rainfall of August is shown in Fig 3.6.2(c). The figure shows that the distribution of CC is positive at Srimongal-Mymensing - Tangail - Bogra - Rangpur belt. It is also positive at most of the southern part of the country except few exceptions. The other part of the country has basically a negative CC. The maximum CC at Hatiya is found to be 0.42 with 95% significance level. The minimum CC is observed at Feni which is -0.34.

The distribution of CC between the DBT of April and the rainfall of September is shown in Fig 3.6.2(d). The figure shows that the distribution of CC is positive at Bogra-Ishwardi-Dhaka-Mymensing-Srimongal belt. The CC around this belt is about 0.05. Most of the other parts of the country have a negative CC. The maximum value of CC is observed at Hatiya which is 0.13. The minimum CC is observed at Feni which is -0.32.

3.6.3 Distribution of CC between DBT of May and rainfall of June, July, August and September

The distribution of CC between the DBT of May and the rainfall of June is shown in Fig 3.6.3(a). From the distribution pattern we see that the CC is positive at Dinajpur-Rangpur-Mymensing belt. It is also positive at Chandpur-Feni-Maizdy-Barisal-Bhola-Hatiya belt of the country. The CC is negative for most of the other parts of the country except few exceptions. The maximum CC is found at Khepupara which is 0.22. The minimum CC is observed to be -0.27 at Ishwardi.

The distribution of CC between the DBT of May and the rainfall of July is shown in Fig 3.6.3(b). The figure shows that starting from the northern part of the country the CC is positive all regions up to the middle part of the country except Ishwardi. The southern part of the country has both positive and negative CC. The maximum CC is found to be

0.34 with a significance of 99% at Srimongal. The minimum CC is observed at Sandip which is -0.31.

The distribution of CC between the DBT of May and the rainfall of August is shown in Fig 3.6.3(c). This figure shows that the distribution of CC has a very good similarity with CC between the DBT of May and rainfall of July (Fig 2.2.3(c)). Starting from the northern part of the country the CC is positive all regions up to the middle part of the country except Ishwardi. The other part of the country has both positive and negative CC. The maximum CC is found to be 0.36 with a significance of 95% at Hatiya. The minimum CC is observed at Rangamati which is -0.23.

The distribution of CC between the DBT of May and the rainfall of September is shown in Fig 3.6.3(d). This figure shows that the distribution of CC is positive from the middle part towards the southern part and north eastern part of the country. Most of the northern and western part of the country has a negative CC with few exceptions. The maximum CC is found to be 0.43 with a significance of 99% at Barisal. The minimum CC is observed at Rangamati which is -0.21.

3.6.4 Distribution of CC between average Pre-monsoon DBT and rainfall of June, July, August and September

The distribution of CC between the average pre-monsoon DBT and the rainfall of June is shown in Fig 3.6.4(a). The figure shows that the distribution of CC is zero at many places of the country which means that there is no co-relation for those places. Some of the south western and southern part of the country has a positive CC. The rest of the country has a negative CC. The maximum CC has been observed at Khepupara which is 0.40 with a significance of 95%. The minimum CC of -0.20 is observed at Ishwardi.

The distribution of CC between the pre-monsoon DBT and the rainfall of July is shown in Fig 3.6.4(b). It has been found from that starting from the middle the extreme northern part of Bangladesh has a positive CC where as most of the southern part has a negative CC. The maximum CC is 0.41 with a significance of 95%. The minimum CC is observed to be -0.42 at Khepupara.

The distribution of CC between the pre-monsoon DBT and the rainfall of August is shown in Fig 3.6.4(c). The figure shows that most of the places have a positive CC with a few exceptions. The maximum CC is found at Hatiya which is 0.49 with 99% significance level. The minimum CC is observed at Feni which is -0.38 with a significance of 95%.

The distribution of CC between the pre-monsoon DBT and the rainfall of September is shown in Fig 3.6.4(d). It has been found from this distribution pattern that the CC is positive at the eastern and central part of the country. Several places of the country have a zero CC and the rest have a negative CC. The maximum CC is found at Hatiya which is 0.24. The minimum CC is observed to be -0.41 at Khepupara. The maximum and minimum CC for September has a similarity with the CC of July.

3.6.5 Distribution of CC between average monsoon rainfall and DBT of March, April, May and average DBT of Pre-monsoon season

The distribution of CC between the DBT of March and the monsoon rainfall is shown in Fig 3.6.5(a). From the distribution pattern we see that the CC is positive at the extreme northern, south-western, southern and central to eastern part of the country. A CC of 0.44 is observed with a significance of 99% level at Hatiya which is maximum in the country. The minimum CC is observed to be -0.31 at Sylhet.

The distribution of CC between the DBT of April and the average monsoon rainfall is shown in Fig 3.6.5(b). From the distribution pattern we see that the CC distribution is negative at many places of the country. It is positive at Satkhira-Khepupara belt and central to north, north western region of the country. The CC at Satkhira is 0.29 with a significance of 95%. The observed minimum CC is -0.30 at Feni. It can be noted from the observation that Satkhira and Feni also has a maximum and minimum value, respectively.

The distribution of CC between the DBT of May and the average monsoon rainfall is shown in Fig 3.6.5(c). The CC is positive from the central part towards the northern, southern and eastern part of the country. The west and north western part has a negative CC. The CC is maximum at Hatiya which is 0.29. The observed minimum CC is -0.21 at Ishwardi.

The distribution of CC between the Pre-monsoon DBT and the monsoon rainfall is shown in Fig 3.6.5(d). The CC distribution is positive at the extreme northern part, central parts and south-western part of the country. Many of the other parts have a negative CC. The maximum CC is observed at Hatiya which is 0.43 with a significance of 99%. The observed minimum CC is -0.35 at Feni.

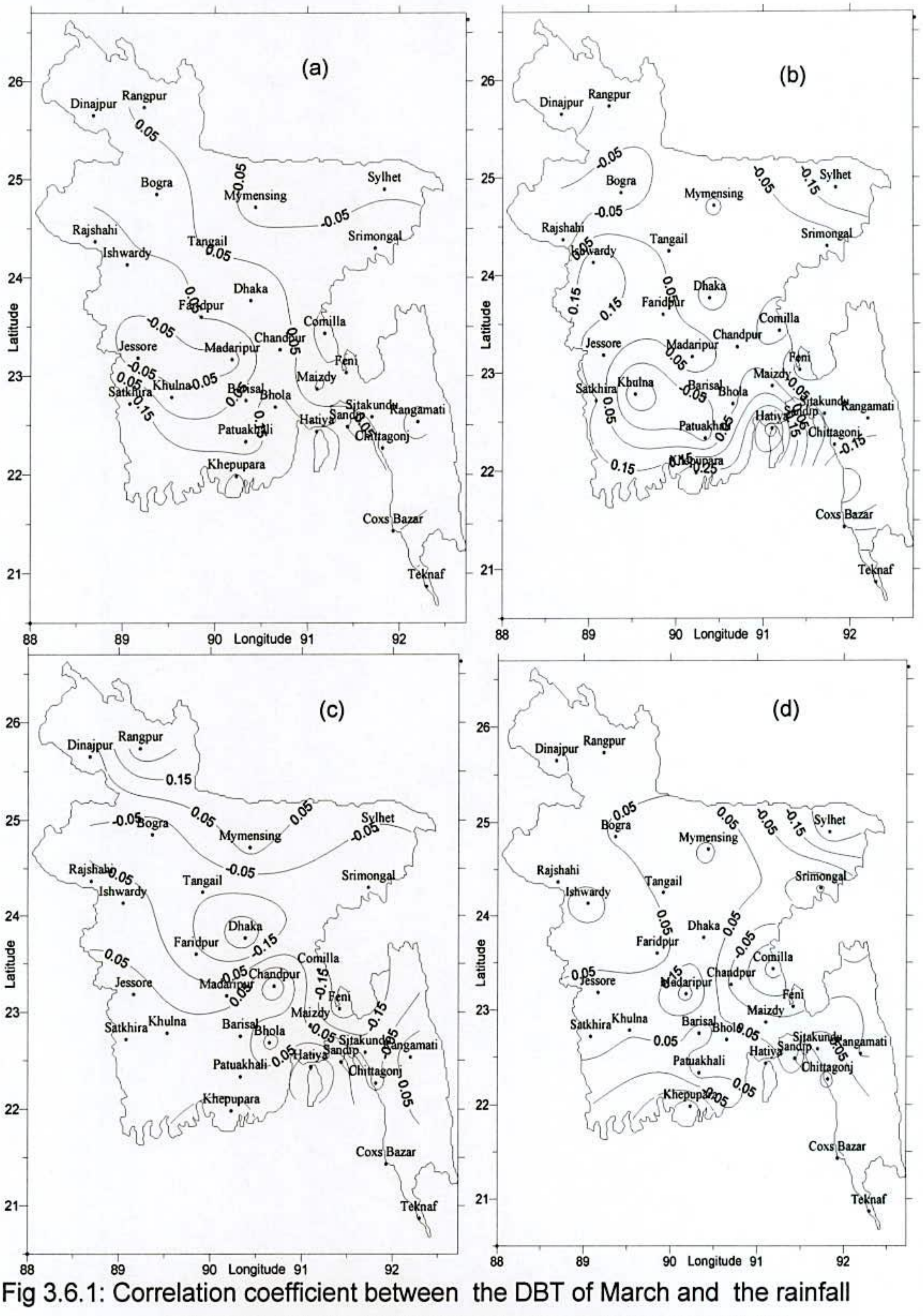

Fig 3.6.1: Correlation coefficient between the DBT of March and the rainfall of (a) June, (b) July, (c) August and (d) September respectively

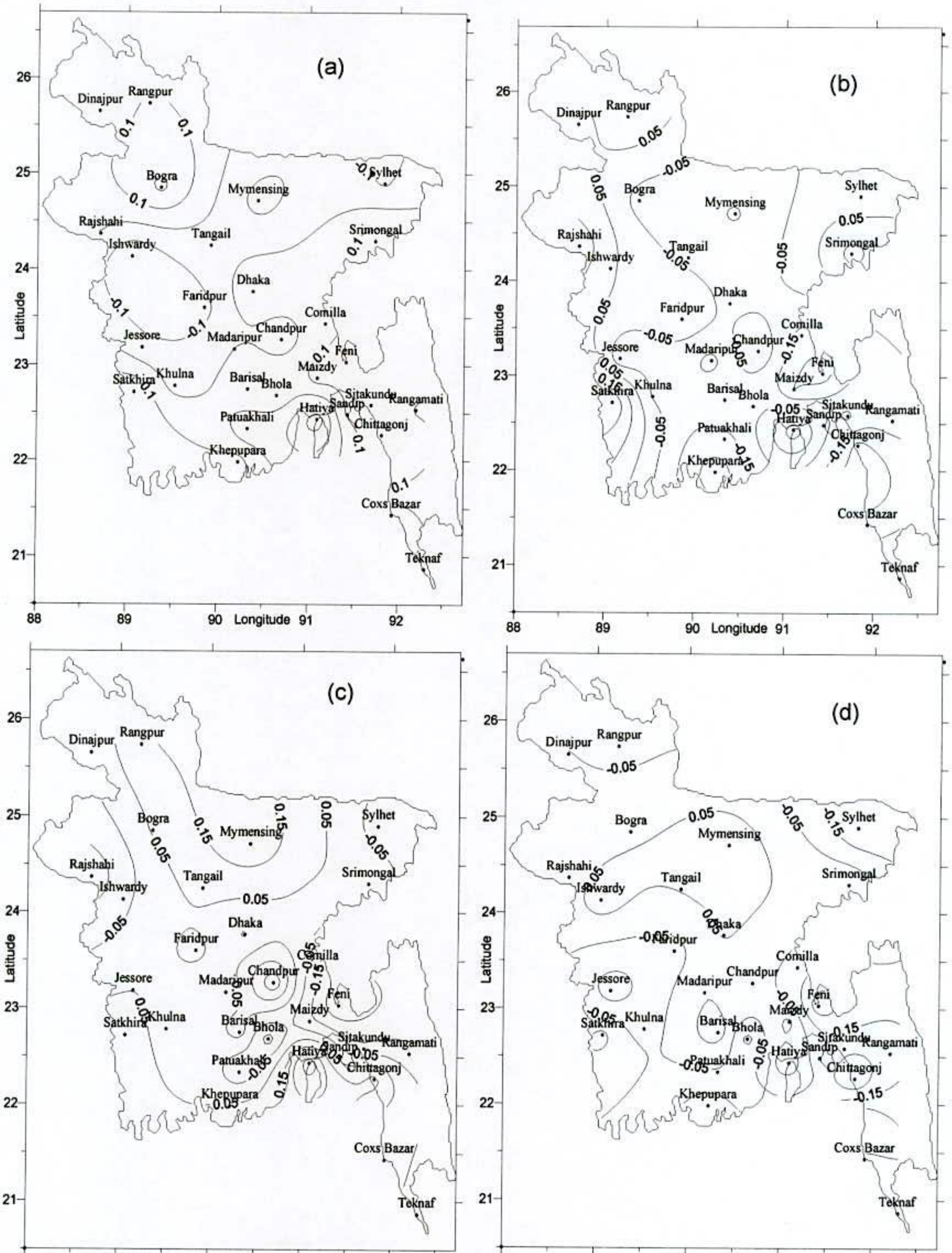

Fig 3.6.2: Correlation coefficient between the DBT of April and the rainfall of (a) June, (b) July, (c) August and (d) September respectively

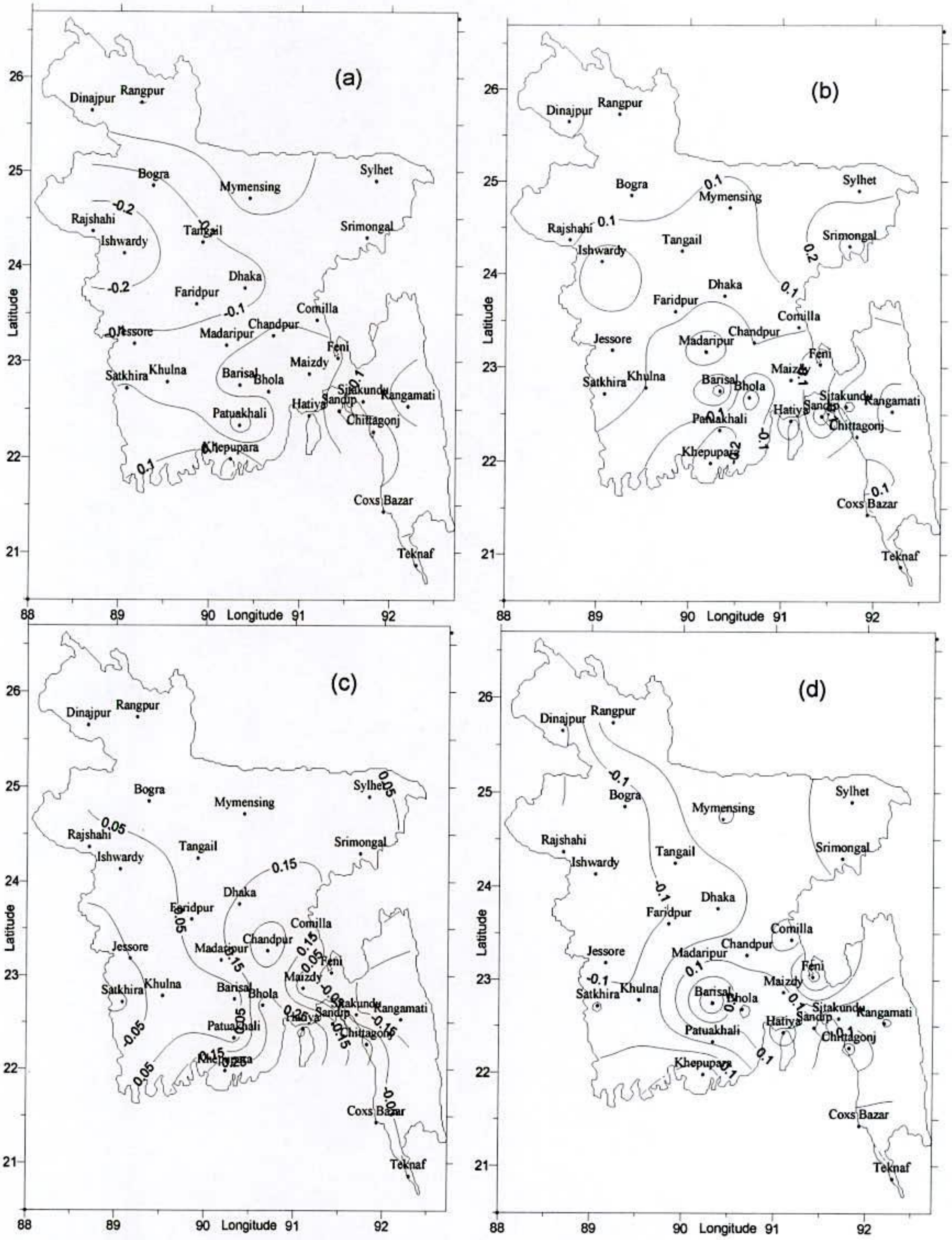

Fig 3.6.3: Correlation coefficient between the DBT of May and the rainfall of (a) June, (b) July, (c) August and (d) September respectively.

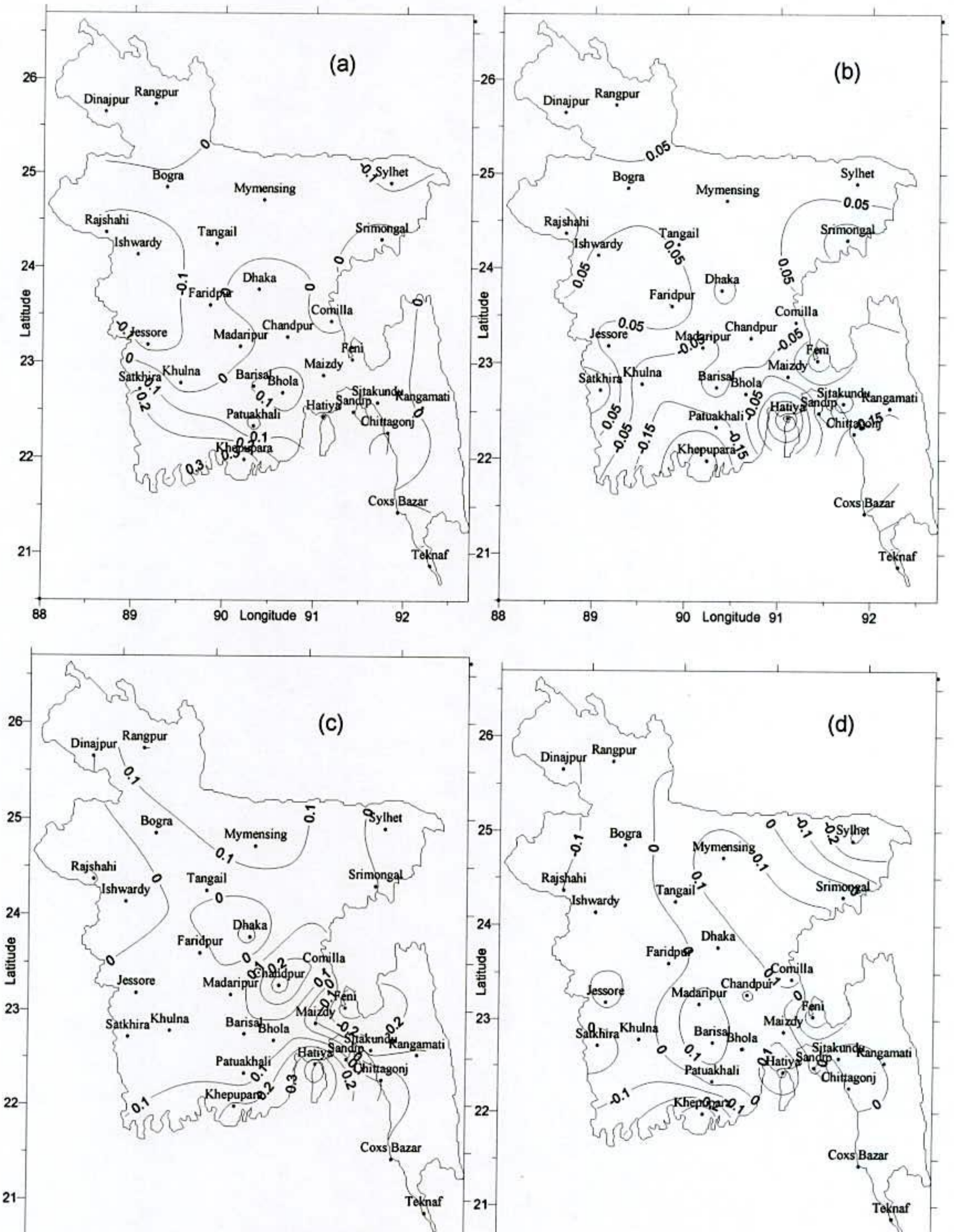

Fig 3.6.4: Correlation coefficient between average Pre-monsoon DBT and Rainfall of (a) June, (b) July, (c) August and (d) September respectively

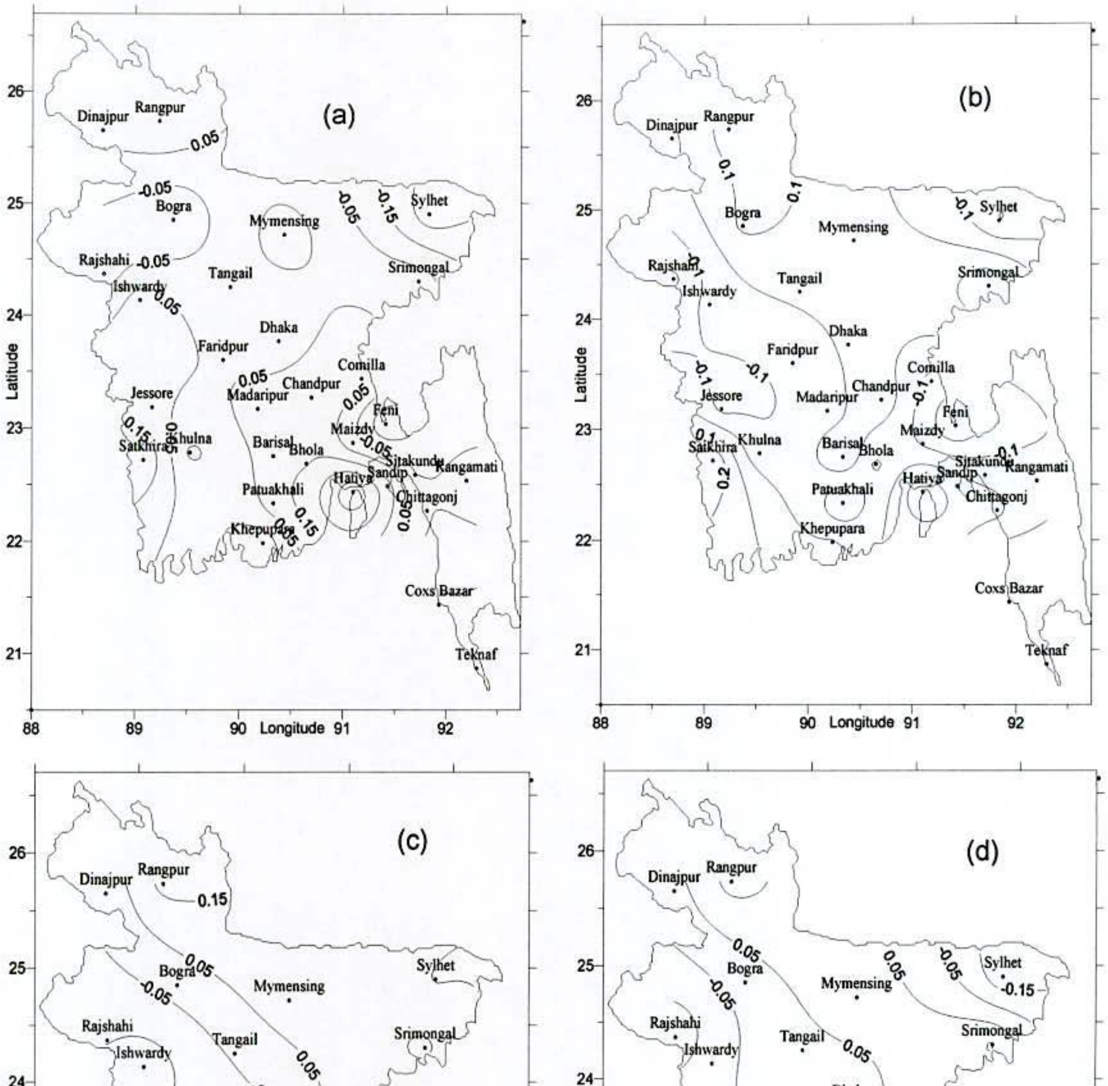

Fig 3.6.5: Correlation coefficient between monsoon rainfall and DBT of (a) March, (b) April, (c) May and (d) Pre-monsoon season.

Table-3.1: Correlation coefficients between BDT (of March, April, May and Pre-monsoon season) and Rainfall (of June, July, August, September and Monsoon Season).

Correlation Coefficients between	Number of stations where CC is positive
DBT(March)-Rain(June)	18
DBT(March)-Rain(July)	17
DBT(March)-Rain(August)	15
DBT(March)-Rain(September)	17
DBT(March)-Rain(Monsoon)	18
DBT(April)-Rain(June)	19
DBT(April)-Rain(July)	9
DBT(April)-Rain(August)	14
DBT(April)-Rain(September)	11
DBT(April)-Rain(Monsoon)	12
DBT(May)-Rain(June)	12
DBT(May)-Rain(July)	18
DBT(May)-Rain(August)	19
DBT(May)-Rain(September)	15
DBT(May)-Rain(Monsoon)	14
DBT(Pre-monsoon)-Rain(June)	15
DBT(Pre-monsoon)-Rain(July)	14
DBT(Pre-Monsoon)-Rain(August)	19
DBT(Pre-Monsoon)-Rain(September)	12
DBT(Pre-Monsoon)-Rain(Monsoon)	15

3.7 Correlation Coefficients between Minimum Temperature (MinT) of March-May and Rainfall of June-September

3.7.1 Distribution of CC between MinT of March and rainfall of June, July, August and September

The distribution of CC between MinT of March and the rainfall of June is shown in Fig 3.7.1(a). From this distribution we see that the CC is positive for all over the country except Srimongal, Maizdy Court, Sitakundu, Chittagong and Teknaf. The CC is maximum at Khepupara and its value is 0.39 with a significance of 95%. The minimum CC of -0.22 is observed at Srimongal.

The distribution of CC between the MinT of March and the rainfall of July is shown in Fig 3.7.1(b). The figure shows that the distribution of CC is positive most of the western, northern and some of the southern part of Bangladesh. It is negative at many of the remaining part of the country. The CC is maximum at Teknaf and its value is 0.44 with a significance of 95%. The minimum CC is observed at Feni which is -0.31.

The distribution of CC between the MinT of March and the rainfall of August is shown in Fig 3.7.1(c). The figure shows that the distribution of CC is positive at many of the west, south-western, southern and some of the northern part of the country. It is negative in the central and eastern part of the country. The maximum value of the CC is 0.28 found at Hatiya and minimum -0.38 at Maizdy Court.

The distribution of CC between the MinT of March and the rainfall of September is shown in Fig 3.7.1(d). The figure shows that the distribution of CC is positive towards most of the northern, north-western and north-eastern part of the country. The CC is maximum at Srimongal and its value is 0.30 with a significance of about 95%. The minimum CC is observed at Ishwardi which is -0.29.

3.7.2 Distribution of the CC between DBT of April and rainfall of June, July, August and September

The distribution of CC between the MinT of April and the rainfall of June is shown in Fig 3.7.2(a). The figure shows that the distribution of CC is positive all over Bangladesh except southern part and Ishwardi. The maximum value of CC is observed to be 0.55 at Teknaf with a significance of 99%. The minimum CC is observed at Cox's Bazar which is -0.14.

The distribution of CC between the MinT of April and the rainfall of July is shown in Fig 3.7.2(b). The figure shows that the distribution of CC is negative at Rangpur-Dinajpur- Rajshahi - Ishwardi region. Starting from the middle part of the country it is also negative at most of the places towards the eastern part. The CC is positive at the extreme southern part and south-western part of the country. The maximum value of CC is observed with a significance of 95% at Teknaf which is 0.43. The minimum CC of -0.30 is observed at Maizdy Court.

The distribution of CC between the MinT of April and the rainfall of August is shown in Fig 3.7.2(c). The figure shows that the distribution of CC is positive at Rangpur-Dinajpur-Bogra-Rajshahi and Jessore-Khulna-Madaripur-Chandpur belt. The figure also shows that CC is negative in the north-eastern and south-western part of the country. The maximum CC at Hatiya is found to be 0.25. The minimum CC is observed at Maizdy Court which is -0.35.

The distribution of CC between the MinT of April and the rainfall of September is shown in Fig 3.7.2(d). The figure shows that the distribution of CC is positive at north-western, south-western and middle part of the country. Most of the other places have negative CC. The maximum value of CC is observed at Maizdy Court which is 0.28 with a significance of 95%. The minimum CC is observed at Sylhet which is -0.32.

3.7.3 Distribution of the CC between MinT of May and rainfall of June, July, August and September

The distribution of CC between the MinT of May and the rainfall of June is shown in Fig 3.7.3(a). From the distribution pattern we see that the CC is positive at northern and extreme south-eastern part of the country. It is also positive at Jessore-Satkhira-Khulna-Barisal-Bhola and Comilla-Feni - Maizdy-Hatiya belt. The CC is negative in other parts of the country. The maximum CC is found with a significance of 95% at Maizdy Court which is 0.28. The minimum CC is observed to be -0.26 at Ishwardi.

The distribution of CC between the MinT of May and the rainfall of July is shown in Fig 3.7.3(b). The figure shows that the CC is positive at central, northern, north-eastern, southern and south-eastern part of the country. The negative CC is observed at north-western, eastern part of the country and at Satkhira region. At Patuakhali the maximum

CC is found to be 0.25. The minimum CC is observed at Bhola which is -0.46 with a significance of 99%.

The distribution of CC between the MinT of May and the rainfall of August is shown in Fig 3.7.3(c). This figure shows that the distribution of CC is positive at northern, north-western, central and southern part of Bangladesh. The negative CC is observed at western, south-western and eastern part of the country. The maximum CC is found to be 0.28 with a significance of 95% at Bogra. The minimum CC is observed at Sitakundu which is -0.22.

The distribution of CC between the MinT of May and the rainfall of September is shown in Fig 3.7.3(d). This figure shows that the distribution is positive at Rangpur-Dinajpur-Rajshahi zone. It is also positive at Maizdy-Hatiya-Chittagong-Rangamati region. Maximum region of the country has negative CC. The maximum CC is found to be 0.19 at Maizdy Court. The minimum CC is observed at Feni which is -0.26.

3.7.4 Distribution of the CC between Pre-monsoon MinT and rainfall of June, July, August and September

The distribution of CC between the pre-monsoon MinT and the rainfall of June is shown in Fig 3.7.4(a). The figure shows that the distribution of CC is positive all over the country except Ishwardi, Srimongal, Hatiya, Sitakundu and Chittagong. The maximum CC has been observed at Madaripur which is 0.30 and minimum of -0.18 at Srimongal.

The distribution of CC between the pre-monsoon MinT and the rainfall of July is shown in Fig 3.7.4(b). It has been found from this distribution pattern that the eastern, north-eastern and the north-western part of Bangladesh have a negative CC. The extreme southern, south-eastern and south-western part of the country has a positive CC. The maximum positive and negative CC have been found at Teknaf and Maizdy Court which are 0.49 and -0.39, respectively and are significant at 99% level.

The distribution of CC between the pre-monsoon MinT and the rainfall of August is shown in Fig 3.7.4(c). The figure shows that the distribution of CC is positive towards the southern, south-western and south-eastern part of the country and Sylhet. The negative CC is observed in the central and eastern part of the country. The maximum positive CC has been observed at Hatiya which is 0.31 and the maximum negative at Maizdy Court which is -0.45. The CC is 95% significant at Hatiya and 99% at Maizdy Court.

The distribution of CC between the pre-monsoon MinT and the rainfall of September is shown in Fig 3.7.4(d). It has been found from this distribution pattern that the CC is positive at the north-western, southern and south-eastern part of the country. It is also positive at Srimongal, Dhaka and Jessore. The maximum positive CC is observed at Teknaf which is 0.27 and maximum negative at Feni and is -0.39.

3.7.5 Distribution of CC between monsoon rainfall and MinT of March, April and May and Pre-monsoon season itself

The distribution of CC between the MinT of March and the average monsoon rainfall is shown in Fig 3.7.5(a). From the distribution pattern we see that the CC is positive at the extreme northern, western and extreme southern part of the country. The CC is negative in the central, north-eastern and eastern part of the country. The maximum negative CC is observed at Maizdy Court and is -0.32 and maximum positive at Khepupara which is 0.36. The observed CC has 95% level of significance at these places.

The distribution of CC between the MinT of April and the average monsoon rainfall is shown in Fig 3.7.5(b). From the distribution pattern we see that the CC distribution is positive at the north-western, western, southern and south-eastern part of the country. The CC is negative in the north-eastern, eastern and most of the central part of the country. The maximum negative CC is observed at Sitakundu and is -0.34 and maximum positive CC at Teknaf and is 0.48. At Teknaf the observed CC has about 99% level of significance.

The distribution of CC between the MinT of May and the average monsoon rainfall is shown in Fig 3.7.5(c). The CC distribution is positive at southern and south-eastern part of the country. The CC is negative in the central, south-western and eastern region of the country. The maximum negative CC has been observed at Sandwip which is -0.36 and positive at Barisal which is 0.27. The CC is 95% significant at Barisal and 99% significant at Sandwip.

The distribution of CC between the average Pre-monsoon MinT and average monsoon rainfall is shown in Fig 3.7.5(d). The CC distribution is positive at Dinajpur-Rangpur-Bogra-Mymensing belt. The CC is also positive at north-western, southern and south-eastern region. The CC is negative in the central, eastern and south-western region. The maximum negative CC has been observed at Sitakundu which is -0.36 and positive CC at Teknaf which is 0.40. The CC is 95% significant at Teknaf and Sitakundu.

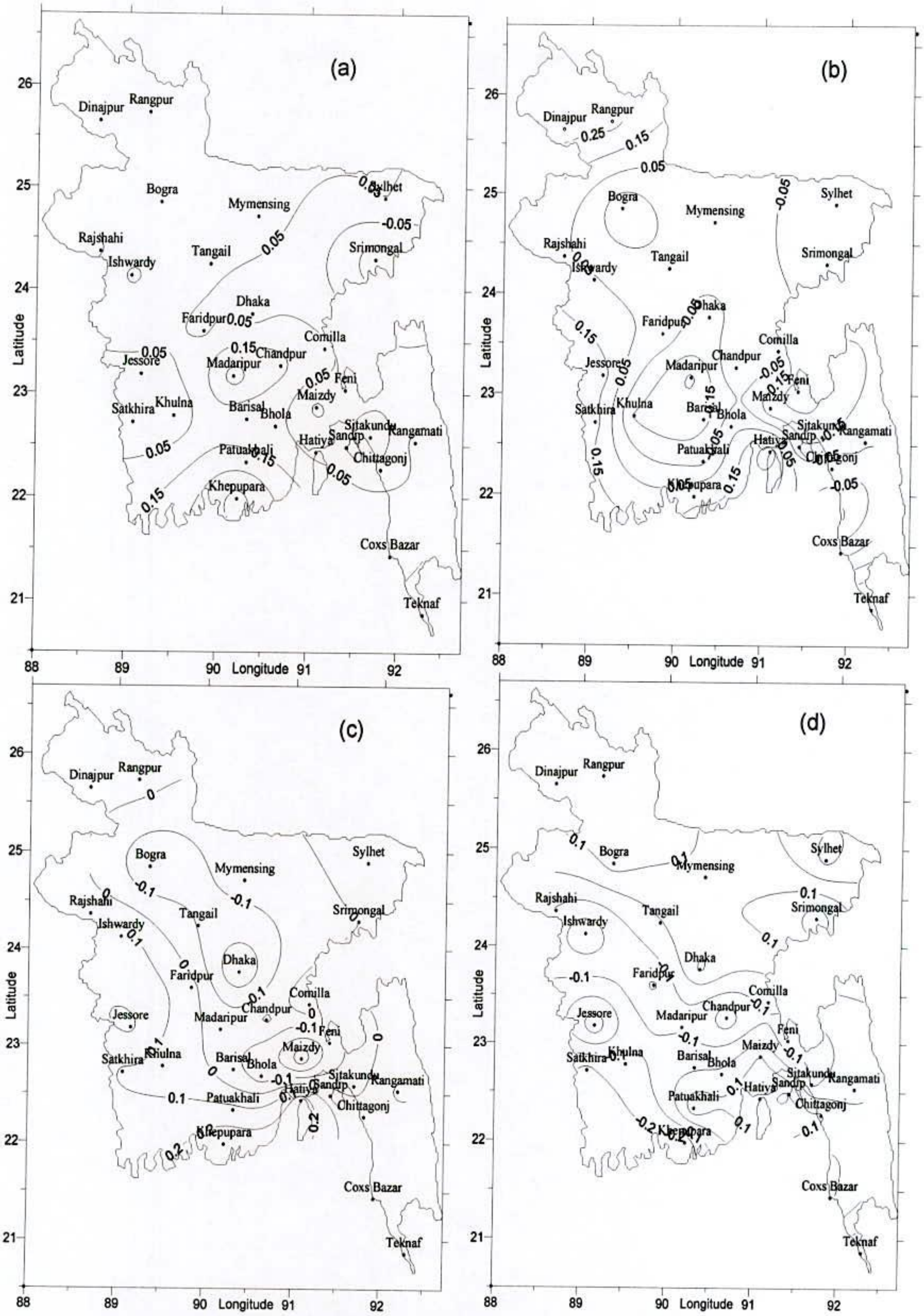

Fig 3.7.1: Correlation Coefficient between the Minimum Temperature of March and the rainfall of (a) June, (b) July, (c) August and (d) September rsepectively.

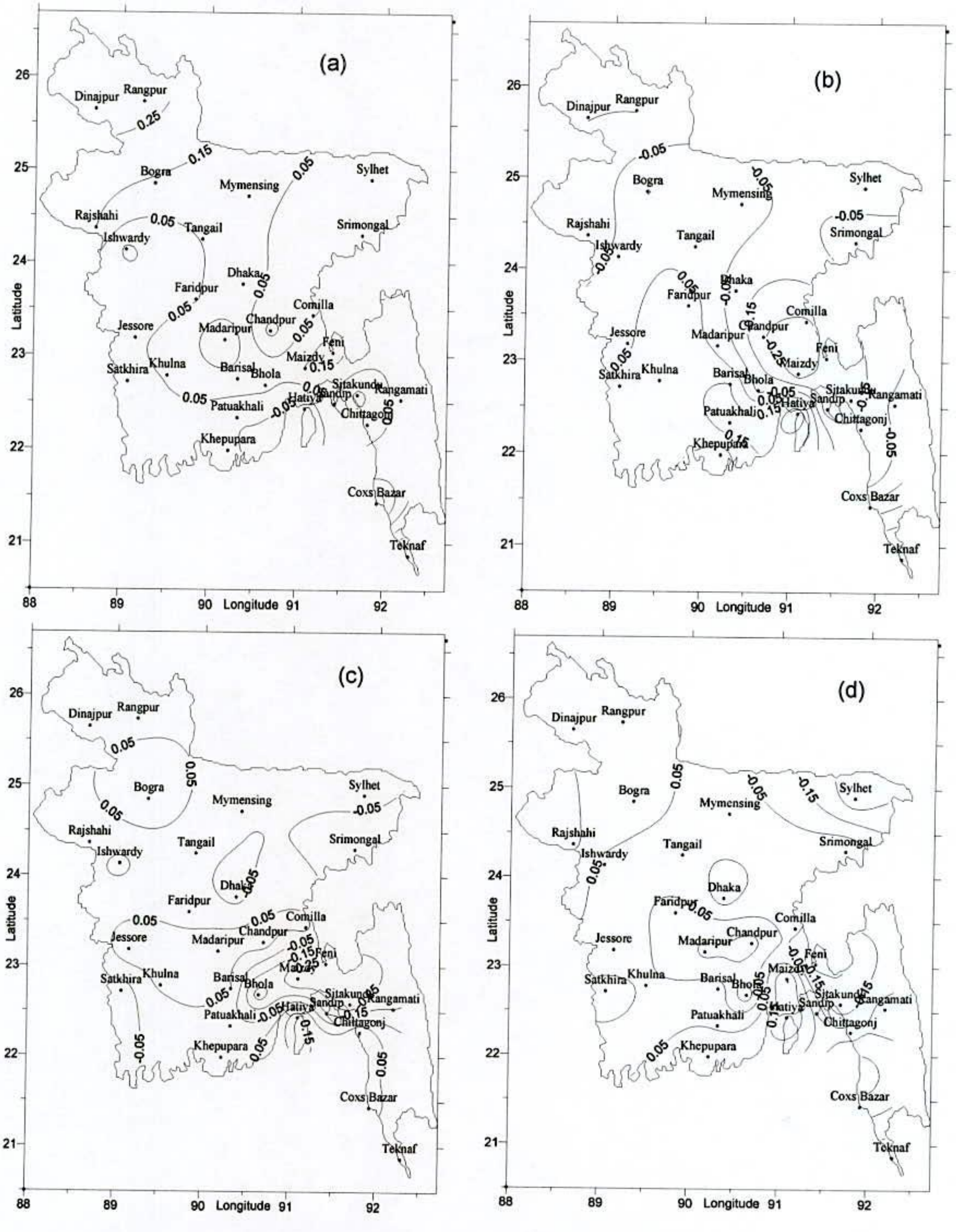

Fig 3.7.2: Correlation coefficient between the Minimum Temperature of April and the rainfall of (a) June, (b) July, (c) August and (d) September respectively.

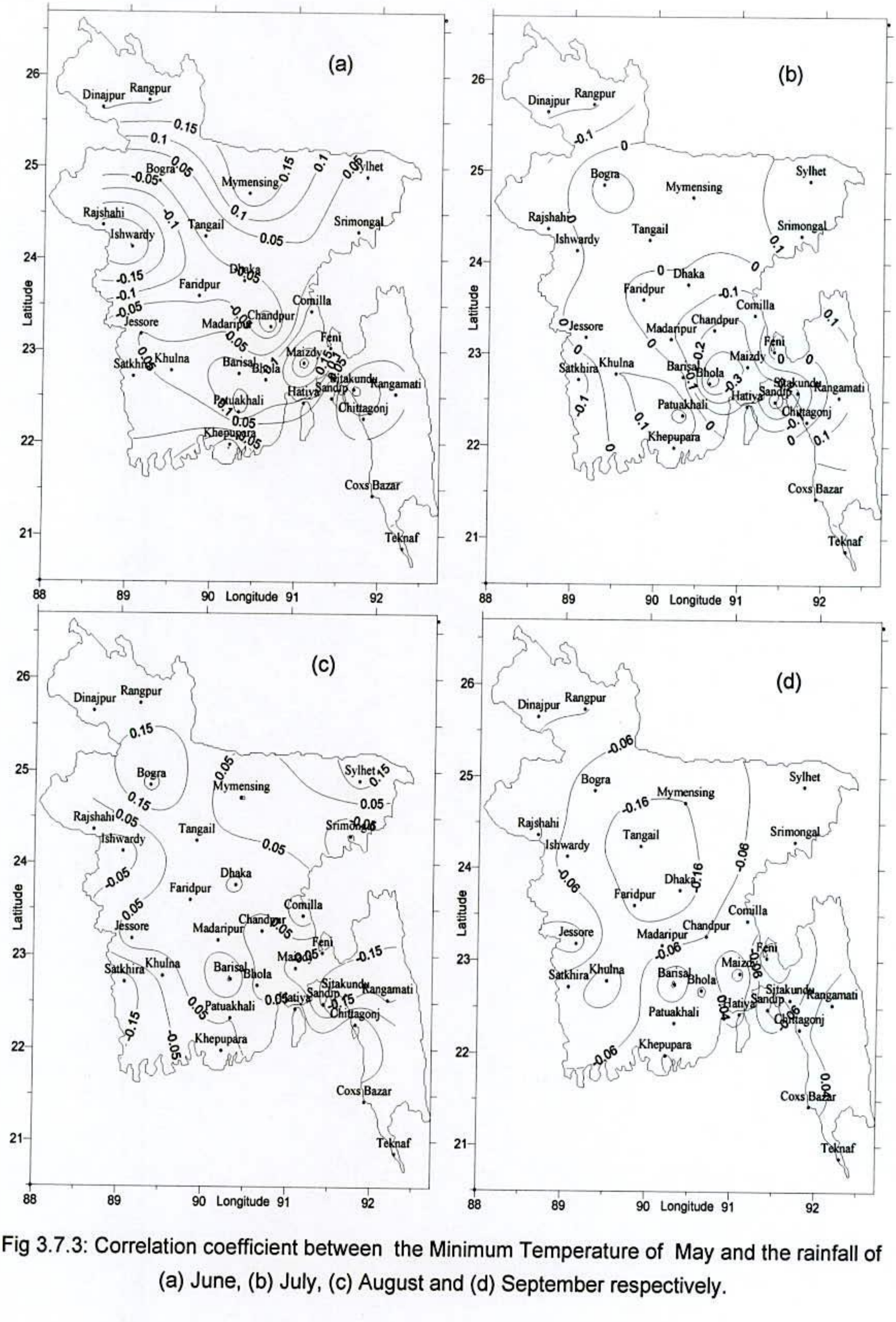

Fig 3.7.3: Correlation coefficient between the Minimum Temperature of May and the rainfall of (a) June, (b) July, (c) August and (d) September respectively.

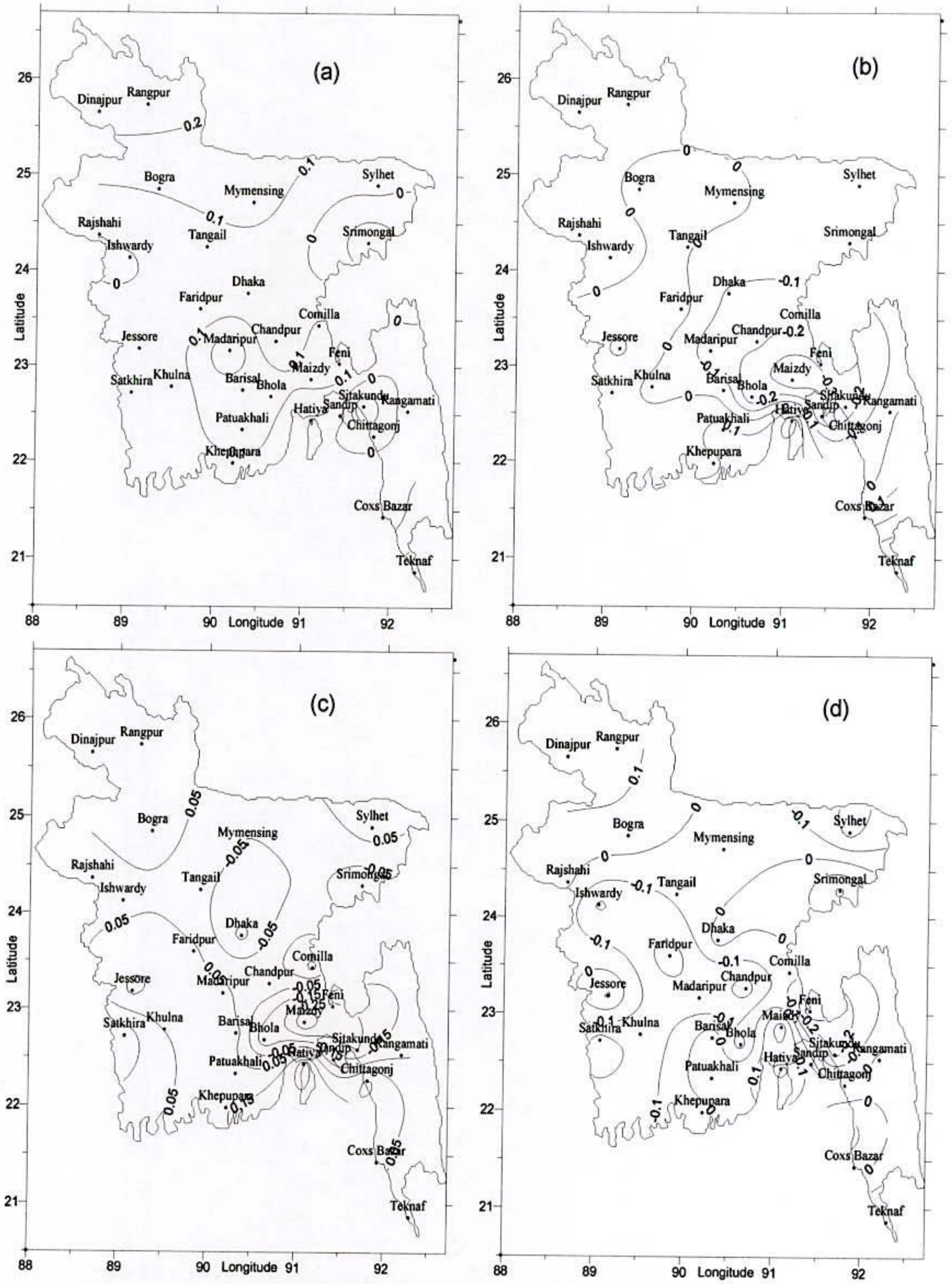

Fig 3.7.4: Correlation coefficient between average Pre-monsoon MinT and Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

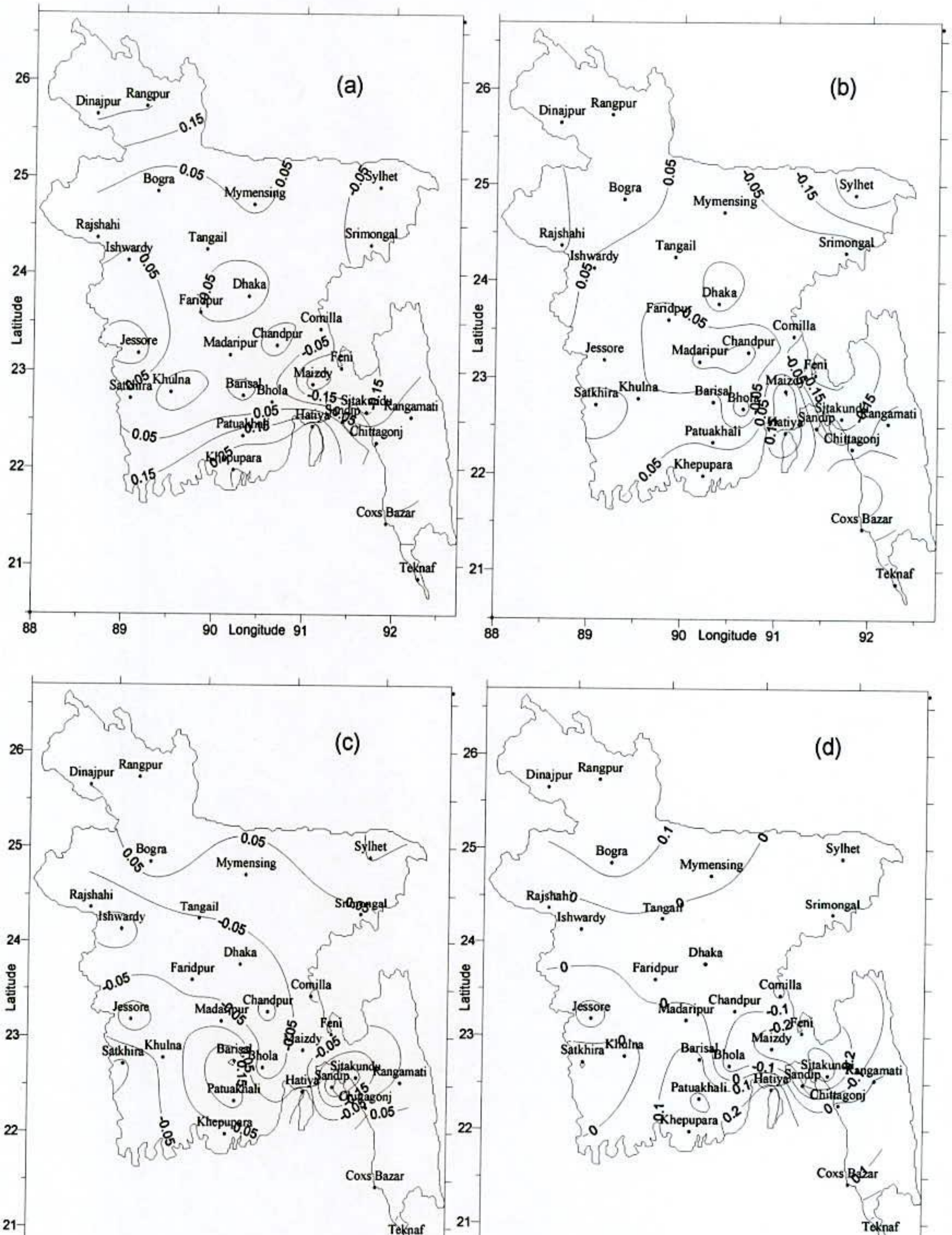

Fig 3.7.5: Correlation coefficient between monsoon rainfall and MinT of (a) March, (b) April, (c) May and (d) Pre-Monsoon season.

Table-3.2: Correlation coefficients between MinT (of March, April, May and Pre-monsoon season) and Rainfall (of June, July, August, September and Monsoon Season).

Correlation Coefficients between	Number of stations where CC is positive
MinT(March)-Rain(June)	23
MinT (March)-Rain(July)	15
MinT(March)-Rain(August)	18
MinT (March)-Rain(September)	14
MinT(March)-Rain(Monsoon)	17
MinT(April)-Rain(June)	20
MinT(April)-Rain(July)	12
MinT(April)-Rain(August)	15
MinT(April)-Rain(September)	17
MinT(April)-Rain(Monsoon)	14
MinT(May)-Rain(June)	17
MinT(May)-Rain(July)	14
MinT(May)-Rain(August)	16
MinT(May)-Rain(September)	13
MinT(May)-Rain(Monsoon)	17
MinT(Pre-monsoon)-Rain(June)	23
MinT(Pre-monsoon)-Rain(July)	10
MinT(Pre-Monsoon)-Rain(August)	19
MinT(Pre-Monsoon)-Rain(September)	16
MinT(Pre-Monsoon)-Rain(Monsoon)	16

3.8 Correlation coefficients between Maximum Temperature of March-May and Rainfall of June-September

3.8.1 Distribution of the CC between MaxT of March and rainfall of June, July, August and September

The distribution of CC between the MaxT of March and the rainfall of June is shown in Fig 3.8.1(a). From this distribution we see that the CC is positive for all the southern part of the country except Patuakhali. It is also positive for most of the northern part, central part and south-western part of the country. The CC is maximum at Madaripur and its value is 0.53 which is significant at 99%. The minimum CC of -0.30 is observed at Feni.

The distribution of CC between the MaxT of March and the rainfall of July is shown in Fig 3.8.1(b). The figure shows that the distribution of CC is positive throughout the western belt and is negative at northern part, south-western region and many places of the central and southern part of the country. The CC is positive at the extreme southern area of the country like Teknaf. The CC is maximum at Hatiya and its value is 0.37 with a significance of 95%. The minimum CC is observed at Khulna which is -0.55.

The distribution of CC between the MaxT of March and the rainfall of August is shown in Fig 3.8.1(c). The figure shows that the distribution of CC is positive at Chandpur-Madaripur-Barisal-Comilla-Feni zone. It is also positive at many of the other parts of the country. The maximum value of the CC is 0.38 which is found at Madaripur with 95% level of significance. The minimum CC is observed at Sitakundu which is -0.30.

The distribution of CC between the MaxT of March and the rainfall of September is shown in Fig 3.8.1(d). The figure shows that the distribution of CC is positive throughout central and west-southwestern belt. The CC has also negative value southern, northern and eastern region of the country. The CC is maximum at Madaripur and its value is 0.20. The minimum CC is observed at Comilla which is -0.33.

3.8.2 Distribution of the CC between MaxT of April and rainfall of June, July, August and September

The distribution of CC between the MaxT of April and the rainfall of June is shown in Fig 3.8.2(a). The figure shows that the distribution of CC is positive in most of the regions of the country. The CC is negative at the north-western and north-eastern part of the country. The maximum value of CC is observed at Madaripur which is 0.29. The minimum CC is observed at Sylhet which is -0.17.

The distribution of CC between the MaxT of April and the rainfall of July is shown in Fig 3.8.2(b). The figure shows that the distribution of CC is positive at Ishwardi-Jessore-Satkhira-Khulna belt. It is negative in the central, northern and north-eastern part of the country. The maximum value of CC is observed at Ishwardi which is 0.14. The minimum CC of -0.40 is observed at Mymensing.

The distribution of CC between the MaxT of April and the rainfall of August is shown in Fig 3.8.2(c). The figure shows that the distribution of CC is positive at Ishwardi-Madaripur-Jessore-Chandpur belt. Srimongal-Sylhet-Mymensing belt has also a positive CC distribution. Most of the remaining part of the country has a negative CC. The maximum CC at Hatiya is found to be 0.44 with 99% significance level. The minimum CC is observed at Chittagong which is -0.20.

The distribution of CC between the MaxT of April and the rainfall of September is shown in Fig 3.8.2(d). The figure shows that the distribution of CC is positive at the northern part of the country except Rajshahi. It is also positive at most of the middle and central part of the country. The remaining parts have negative CC. The maximum value of CC is observed at Maizdy Court which is 0.30 with a significance level of 95%. The minimum CC is observed at Teknaf which is -0.29.

3.8.3 Distribution of the CC between MaxT of May and rainfall of June, July, August and September

The distribution of CC between the MaxT of May and the rainfall of June is shown in Fig 3.8.3(a). From the distribution pattern we see that the CC is negative at all the places of the northern part of Bangladesh except Dinajpur and Rangpur. The CC is positive at Madaripur-Chandpur-Barisal-Khulna-Jessore zone. Most of the south-eastern part of the country has a negative CC. The maximum CC is found at Sandwip which is 0.27. The minimum CC is observed to be -0.27 at Ishwardi.

The distribution of CC between the MaxT of May and the rainfall of July is shown in Fig 3.8.3(b). The figure shows that the CC is positive in the western, eastern and southern part of the country. It is negative in the northern and central region of the country. The maximum CC is found to be 0.25 with a significance of 95% at Jessore. The minimum CC is observed at Bhola which is -0.36.

The distribution of CC between the MaxT of May and the rainfall of August is shown in Fig 3.8.3(c). The distribution shows that the CC is positive all over the country except south-eastern region. The maximum CC is found to be 0.31 with a significance of 95% at Hatiya. The minimum CC is observed with 95% significance level at Rangamati which is -0.26.

The distribution of CC between the MaxT of May and the rainfall of September is shown in Fig 3.8.3(d). This figure shows that the distribution of CC is positive from the middle part towards the southern, south-western and south-eastern part of the country. Most of the northern part, north-western and north-eastern part of the country has a negative CC. It can be mentioned here that the CC has a very good agreement with that of the CC between the DBT of May and rainfall of September. The maximum CC is found to be 0.43 with a significance of 95% at Patuakhali. The minimum CC is observed at Rajshahi which is -0.23.

3.8.4 Distribution of the CC between Pre-monsoon MaxT and rainfall of June, July, August and September

The distribution of CC between the average pre-monsoon MaxT and the rainfall of June is shown in Fig 3.8.4(a). The figure shows that the distribution of CC is positive at the southern and south-western part of the country except Jessore, Patuakhali and Cox's Bazar. It is also positive at most of the central part of Bangladesh. The CC is mostly negative at the northern, western and north eastern part of the country. The maximum CC has been observed at Madaripur which is 0.41 with a significance of 95%. The minimum CC of -0.24 is observed at Feni.

The distribution of CC between the average pre-monsoon MaxT and the rainfall of July is shown in Fig 3.8.4(b). It has been found from this distribution pattern that the extreme northern, central and north-eastern part of Bangladesh has almost negative CC whereas the western and north-western part has almost a positive CC. The other parts of the country have both the negative and positive CC distribution. The maximum CC is found Hatiya which is 0.24. The minimum CC is observed to be -0.40 at Mymensing.

The distribution of CC between the average pre-monsoon MaxT and the rainfall of August is shown in Fig 3.8.4(c). The figure shows that the distribution of CC is positive at all the northern part of Bangladesh except Rajshahi. It is also positive at most of the western, eastern and southern part of the country. The maximum CC is found at Madaripur which is 0.44 with 95% significance level. The minimum CC is observed at Rangamati which is -0.27.

The distribution of CC between the average pre-monsoon MaxT and the rainfall of September is shown in Fig 3.8.4(d). It has been found from this distribution pattern that the CC is zero at most of the places of the country. Madaripur-Chandpur-Barisal-Bhola-Maizdy-Hatiya region has a positive CC. The maximum CC is found at Maizdy Court with a significance of 99% which is 0.36. The minimum CC is observed to be -0.17 at Sandwip.

3.8.5 Distribution of the CC between MaxT of March, April, May and Pre-monsoon season itself

The distribution of CC between the MaxT of March and the average monsoon rainfall is shown in Fig 3.8.5(a). From the distribution pattern we see that the CC is negative at most of the northern part of the country and positive at most of the central and south-western part of the country. Most of the southern and eastern part of Bangladesh has a negative CC. A CC of 0.52 is observed with a significance of 99% level at Madaripur which is maximum in the country. The minimum CC is observed to be -0.17 at Bogra.

The distribution of CC between the MaxT of April and the average monsoon rainfall is shown in Fig 3.8.5(b). From the distribution pattern we see that the CC distribution is negative at the central, northern and eastern parts of the country. It is positive at the southern and south-western part of the country. The CC is maximum at Hatiya which is 0.29. The observed minimum CC is -0.31 which is measured Rajshahi.

The distribution of CC between the MaxT of May and the average monsoon rainfall is shown in Fig 3.8.5(c). The CC distribution is positive at the northern, most of the south-western and southern part of Bangladesh. The extreme southern part has a negative CC. The CC is maximum at Sandwip which is 0.28. The observed minimum CC is -0.17 at Faridpur.

The distribution of CC between the Pre-monsoon MaxT and the average monsoon rainfall is shown in Fig 3.8.5(d). The CC distribution is negative at the northern, western and north-eastern part of Bangladesh. It is positive at most of the south-western part of the country. The maximum CC is observed at Madaripur which is 0.43 with a significance of 95%. The observed minimum CC is -0.24 at Rajshahi.

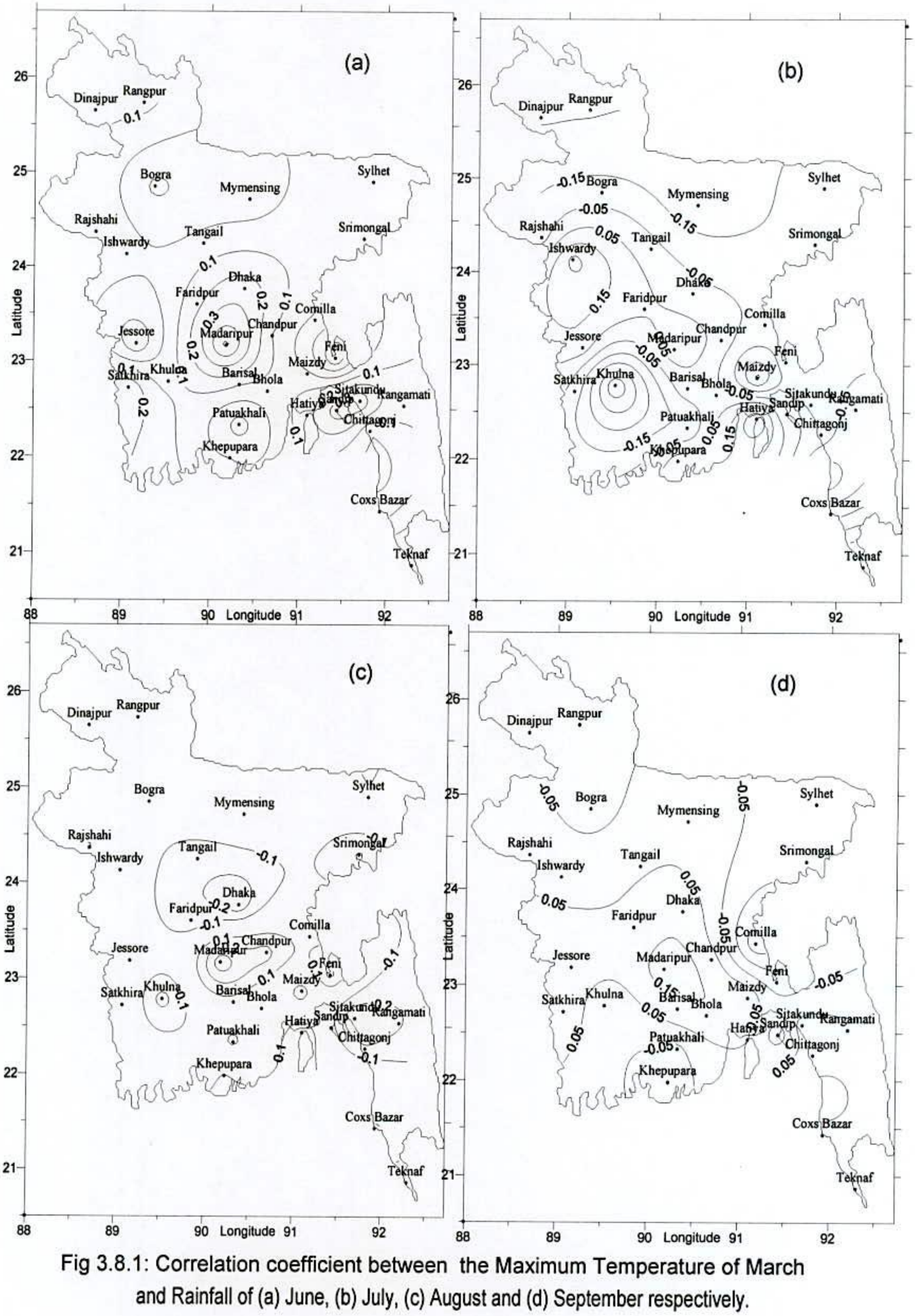

Fig 3.8.1: Correlation coefficient between the Maximum Temperature of March and Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

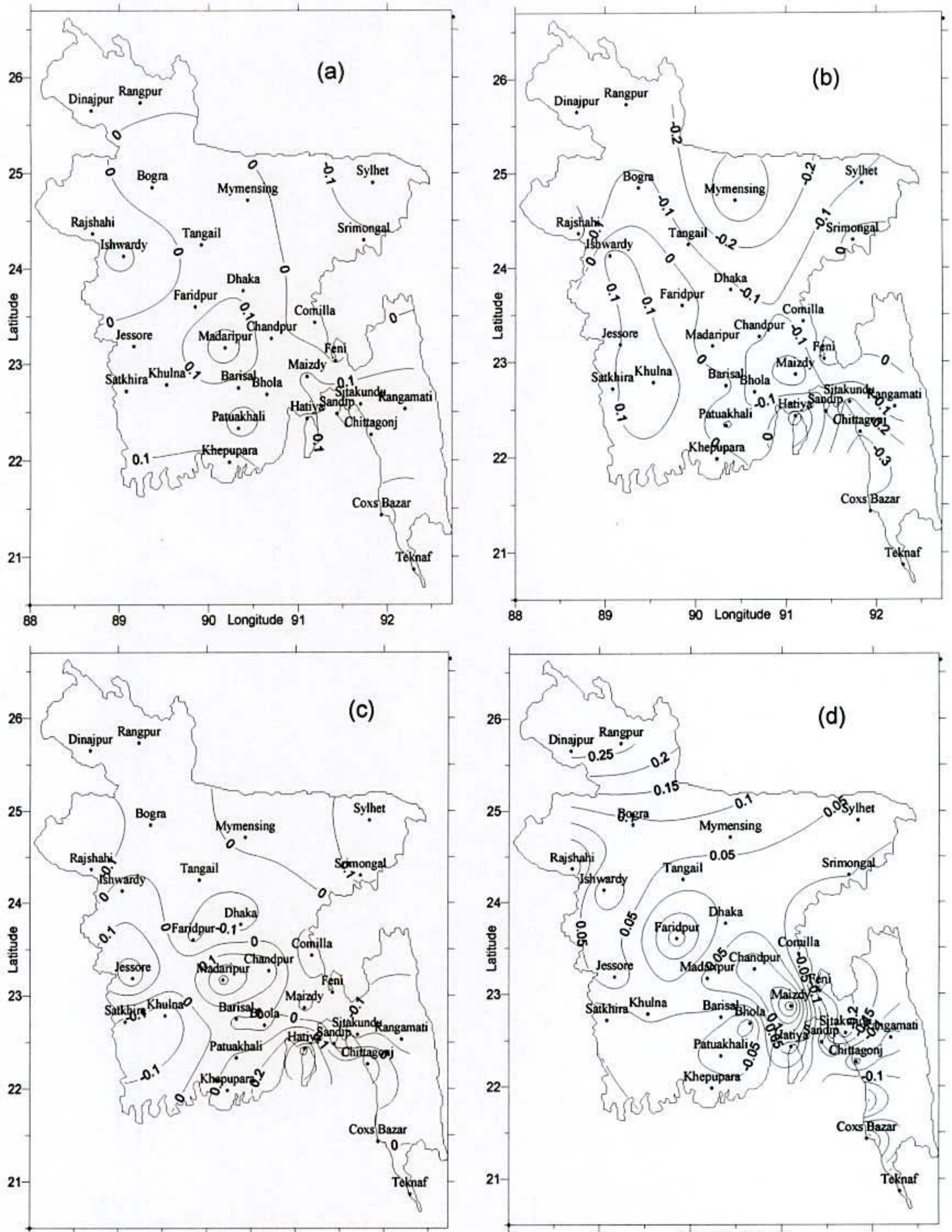

Fig 3.8.2: Correlation coefficient between the Maximum Temperature of April and Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

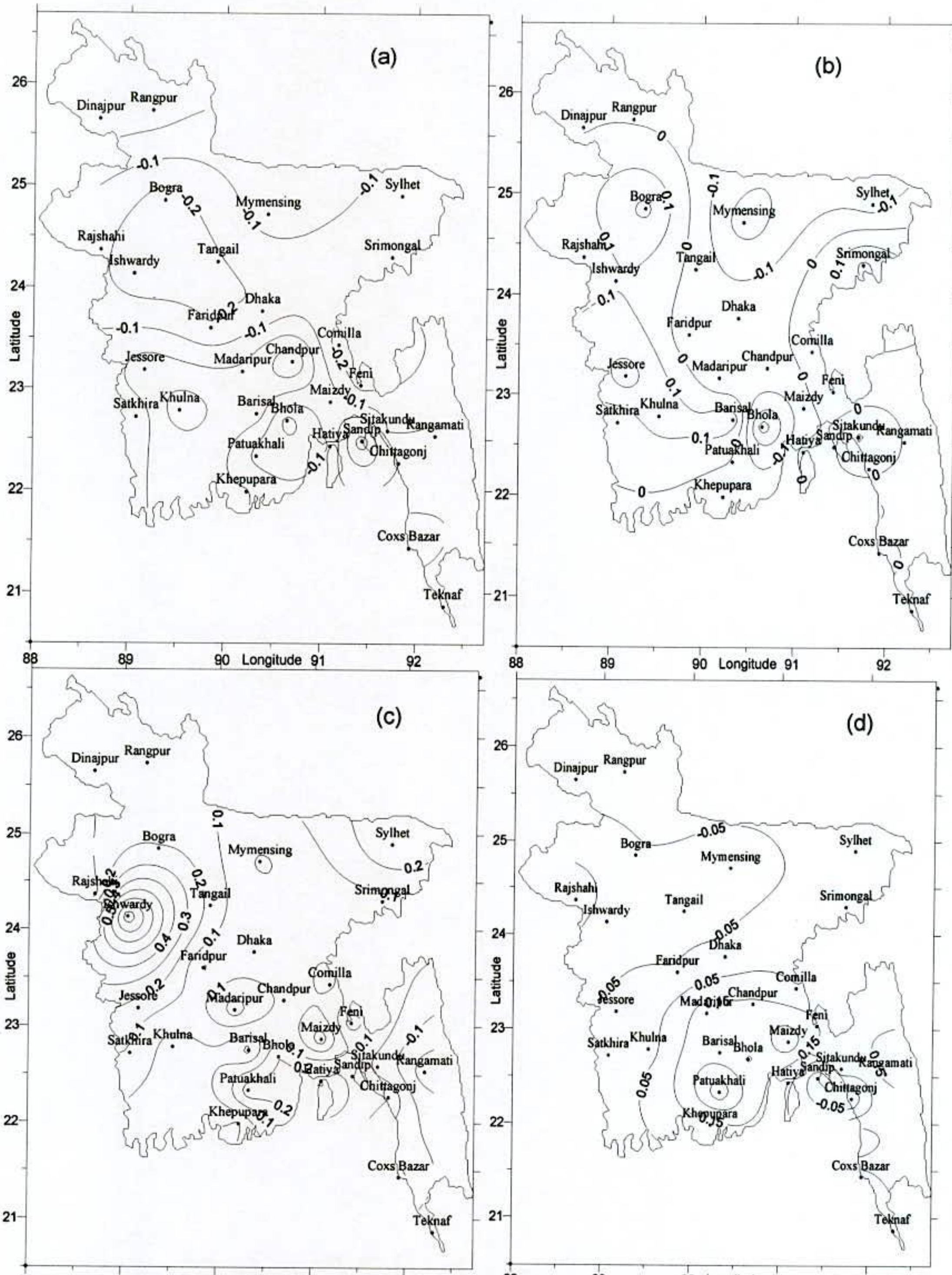

Fig 3.8.3: Correlation coefficient between the Maximum Temperature of May and the Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

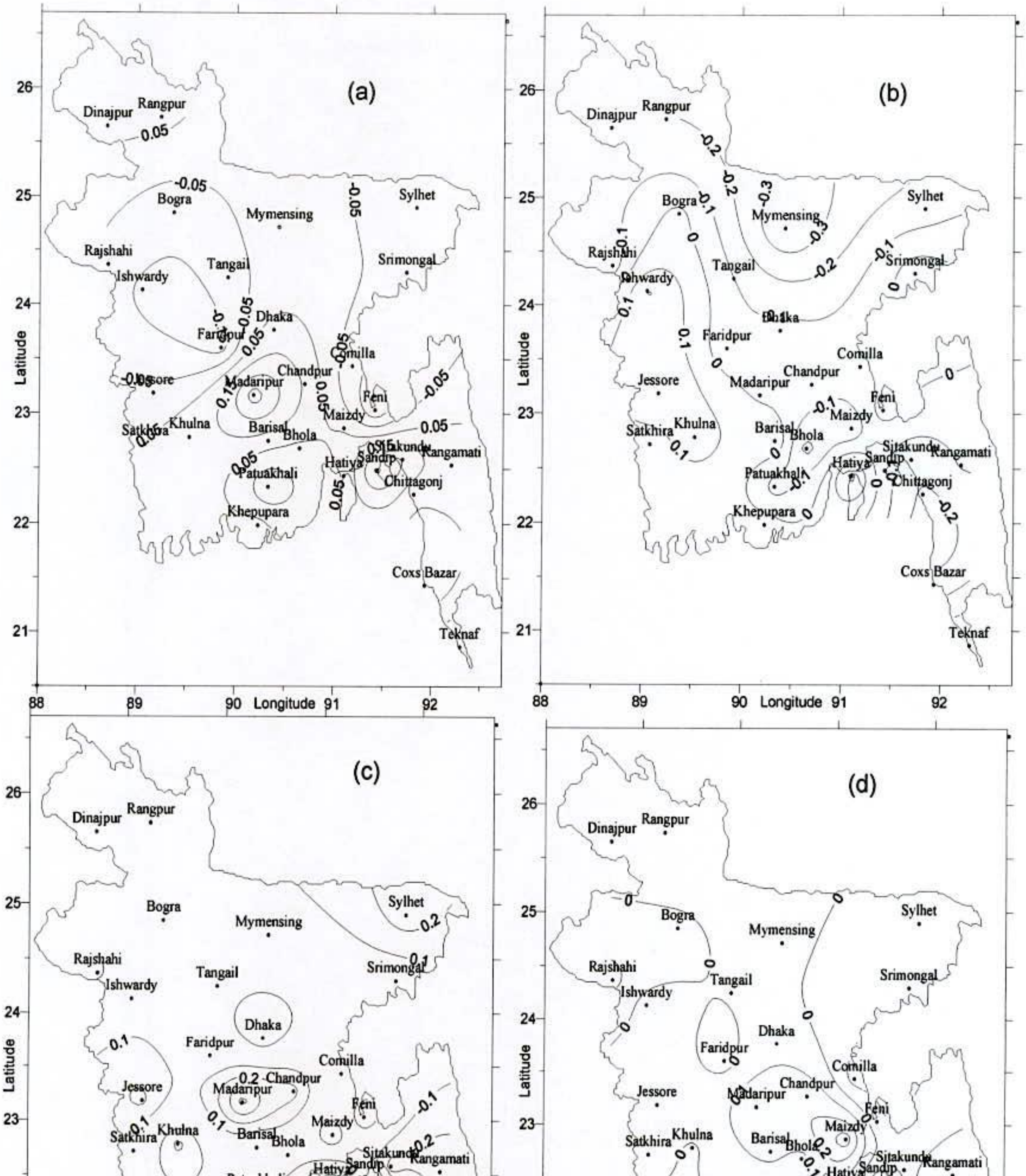

Fig 3.8.4: Correlation coefficient between Pre-monsoon Maximum Temperature and Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

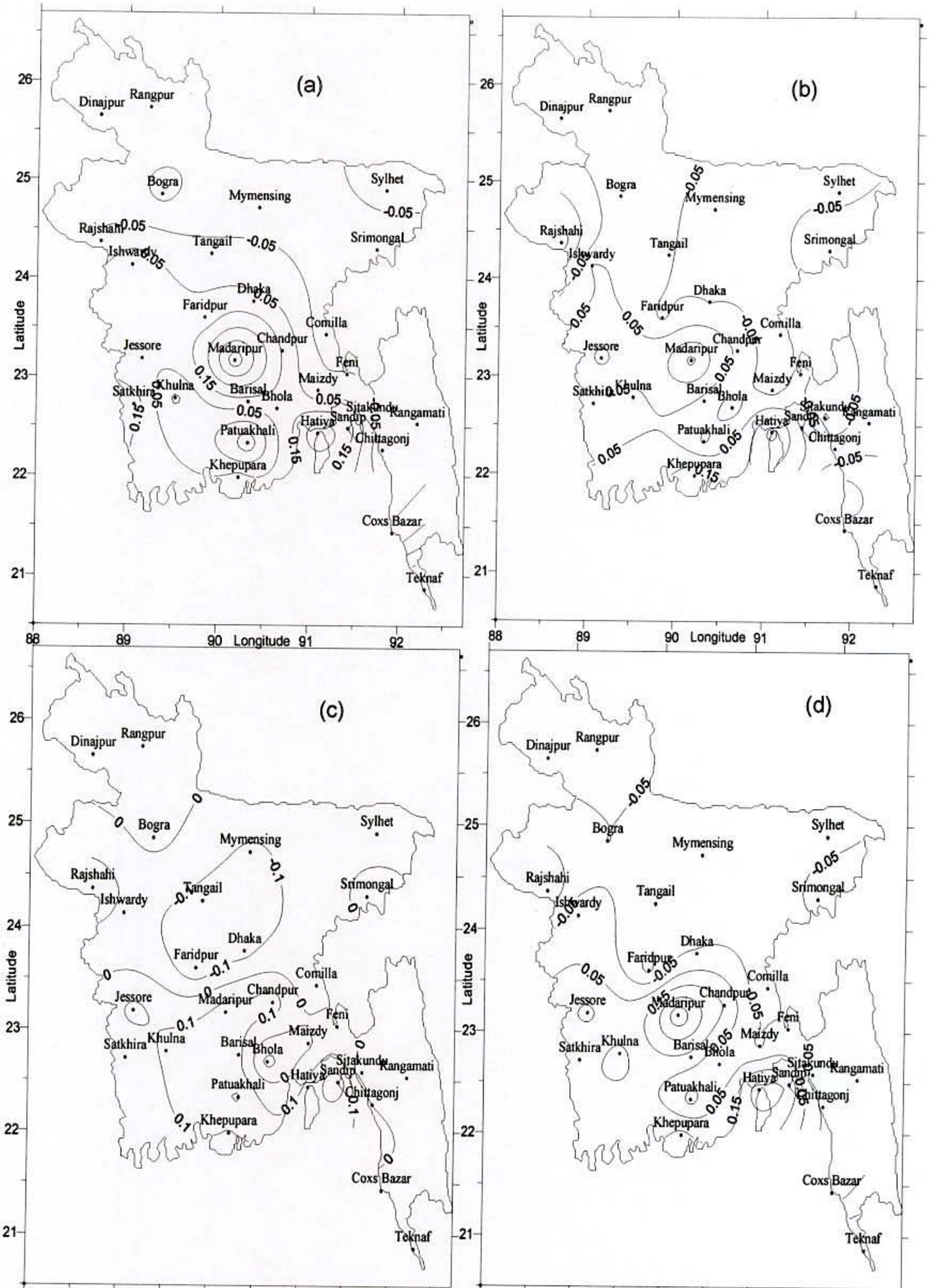

Fig 3.8.5: Correlation coefficient between monsoon rainfall and MaxT of March (b) April and (c) May, (d) the Pre-monsoon season.

Table-3.3: Correlation coefficients between MaxT (of March, April, May and Pre-monsoon season) and Rainfall (of June, July, August, September and Monsoon Season).

Correlation Coefficients between	Number of stations where CC is positive
MaxT(March)-Rain(June)	23
MaxT (March)-Rain(July)	09
MaxT(March)-Rain(August)	15
MaxT (March)-Rain(September)	18
MaxT(March)-Rain(Monsoon)	13
MaxT(April)-Rain(June)	20
MaxT(April)-Rain(July)	10
MaxT(April)-Rain(August)	13
MaxT(April)-Rain(September)	16
MaxT(April)-Rain(Monsoon)	16
MaxT(May)-Rain(June)	09
MaxT(May)-Rain(July)	15
MaxT(May)-Rain(August)	19
MaxT(May)-Rain(September)	15
MaxT(May)-Rain(Monsoon)	15
MaxT(Pre-monsoon)-Rain(June)	18
MaxT(Pre-monsoon)-Rain(July)	11
MaxT(Pre-Monsoon)-Rain(August)	20
MaxT(Pre-Monsoon)-Rain(September)	18
MaxT(Pre-Monsoon)-Rain(Monsoon)	12

3.9 Correlation coefficients between WBT of March-May and Rainfall of June-September

3.9.1 Distribution of the CC between WBT of March and rainfall of June-September

The distribution of CC between the WBT of March and the rainfall of June is shown in Fig 3.9.1(a). From this distribution we see that the CC is positive all over the country except few places. It is negative at many places of the southern part of the country, Bogra and Mymensing region. The maximum positive and negative CC is observed at Chandpur and Satkhira and is 0.27 and -0.20, respectively. The CC is significant about 95% level at Satkhira region.

The distribution of CC between the WBT of March and the rainfall of July is shown in Fig 3.9.1(b). The figure shows that the distribution of CC is positive at Jessore-Faridpur-Satkhira region. It is also positive at most of the places of the southern part of Bangladesh. The CC is negative at the north-eastern part and the eastern part of the country. It is also negative at many of the northern part including the extreme north. The maximum positive and negative CC is observed at Jessore and Rajshahi and is 0.35 and -0.25, respectively. The CC is significant about 99% level at Jessore.

The distribution of CC between the WBT of March and the rainfall of August is shown in Fig 3.9.1(c). The figure shows that the distribution of CC is negative at Dinajpur-Rangpur-Rajshahi-Bogra zone and eastern and southern part of the country whereas it is positive at Mymensing-Sylhet zone. It is also positive at Ishwardi-Faridpur-Jessore-Khulna-Satkhira belt. The maximum positive and negative CC is observed at Jessore and Dhaka and is 0.33 and -0.26, respectively. The CC is significant about 95% level at Jessore region.

The distribution of CC between the WBT of March and the rainfall of September is shown in Fig 3.9.1(d). The figure shows that the distribution of CC is positive at northern, north-eastern, southern and south western part of the country. The CC is negative at the central and south-eastern part of the country. The maximum positive and negative CC is observed at Srimongal and Ishwardi and is 0.36 and -0.34, respectively. The CC is significant about 99% level at Srimongal and Ishwardi region.

3.9.2 Distribution of the CC between WBT of April and rainfall of June-September

The distribution of CC between the WBT of April and the rainfall of June is shown in Fig 3.9.2(a). The figure shows that the distribution of CC is positive at all of the places over Bangladesh except Mymensing and southern region. The maximum positive and negative CC is observed at Jessore and Patuakhali and is 0.35 and -0.33, respectively and is significant about 99% level at Jessore.

The distribution of CC between the WBT of April and the rainfall of July is shown in Fig 3.9.2(b). The figure shows that the distribution of CC is negative throughout the northern and eastern region of the country. The CC is positive at south-western and southern part of Bangladesh. The maximum positive CC is observed at Satkhira which is 0.34 and negative CC is observed at Chandpur is -0.27. The CC has 99% level of significance at Satkhira.

The distribution of CC between the WBT of April and the rainfall of July is shown in Fig 3.9.2(c). The figure shows that the distribution of CC is positive at north-west, north-east, south, south-west and south-eastern region of the country. The CC is negative at the central and eastern belt of the country. The maximum positive and negative CC is observed at Jessore and Sitakundu and is 0.20 and -0.18, respectively.

The distribution of CC between the WBT of April and the rainfall of September is shown in Fig 3.9.2(d). The figure shows that the distribution of CC is positive starting from middle to western except Ishwardi and negative in the eastern region. The maximum positive CC is observed at Patuakhali which is 0.39 and negative at Teknaf is -0.35.

3.9.3 Distribution of the CC between WBT of May and rainfall of June-September

The distribution of CC between the WBT of May and the rainfall of June is shown in Fig 3.9.3(a). From the distribution pattern we see that the CC is positive all over the country except south-eastern region. The maximum negative CC is observed at Sitakundu which is -0.31 and positive at Mymensing and is 0.27. The CC is 95% significant at Mymensing and Sitakundu region.

The distribution of CC between the WBT of May and the rainfall of July is shown in Fig 3.9.3(b). The figure shows that the CC is positive at Mymensing-Sylhet-Srimongal and Jessore-Faridpur-Dhaka belt and in the southern region. It is negative at north-western, eastern and south-eastern region. Again CC is positive in the southern region and negative in the eastern and south-eastern region. The maximum positive CC is found to be 0.32 with a significance of 95% at Srimongal. The minimum CC is observed at Bhola which is -0.36 with a significance of 95%.

The distribution of CC between the WBT of May and the rainfall of August is shown in Fig 3.9.3(c). The figure shows that the CC is positive all over the country except extreme south of the country where the CC is negative. The maximum negative CC is measured at Patuakhali which is -0.36. The maximum positive CC is observed at Bogra and is 0.34 and significant at 99% level.

The distribution of CC between the WBT of May and the rainfall of September is shown in Fig 3.9.3(d). This figure shows that the distribution of CC is positive from the middle part towards the northern and north-western part of the country. At the extreme north and the north-eastern part the CC is negative. The CC is mostly positive at the southern part of the country. The maximum positive CC is found to be 0.18 at Maizdy Court and Chittagong. The maximum negative CC is observed at Feni and is -0.28.

3.9.4 Distribution of the CC between Pre-monsoon WBT and rainfall of June-September

The distribution of CC between the average pre-monsoon WBT and the rainfall of June is shown in Fig 3.9.4(a). The figure shows that the distribution of CC is positive everywhere except southern and south-eastern part of the country. The maximum negative CC has been observed at Patuakhali and Sitakundu and is -0.26. The maximum positive CC is measured at Jessore which is 0.33. The CC is 95% significance at Jessore.

The distribution of CC between the average pre-monsoon WBT and the rainfall of July is shown in Fig 3.9.4(b). It has been found from this distribution pattern that the CC is negative everywhere at the northern, north-eastern, north-western, eastern and southern part of Bangladesh. The positive CC is observed in Faridpur, Jessore and Satkhira regions. The maximum negative CC has been observed at Feni and is -0.31. The maximum positive CC is measured at Jessore which is 0.38. The CC at Jessore is observed with 99% level of significance.

The distribution of CC between the average pre-monsoon WBT and the rainfall of August is shown in Fig 3.9.4(c). The figure shows that the distribution of CC is positive at the extreme northern part, most of the central, south-western and southern part of the country. The other parts of the country have negative CC distribution. The maximum negative CC has been measured at Feni and is -0.23 and positive CC at Jessore which is 0.36. The measured CC is 99% significant at Jessore.

The distribution of CC between the average pre-monsoon WBT and the rainfall of September is shown in Fig 3.9.4(d). It has been found from this distribution pattern that the CC is positive at the northern, north-eastern and north-western part of Bangladesh except Ishwardi and Sylhet. The CC is negative at the eastern, central and the extreme southern part of the country. Many of the remaining part have a positive CC. The maximum negative CC is found at Madaripur which is -0.18. The maximum positive CC has been observed at Patuakhali with a significance of 95% which is 0.33.

3.9.5 Distribution of the CC between average monsoon rainfall and WBT of March-May and Pre-monsoon season itself

The distribution of CC between the WBT of March and the monsoon rainfall is shown in Fig 3.9.5(a). From the distribution pattern we see that there is a zero correlation co-efficient at many places over the country. The extreme northern, western and extreme southern part has a positive CC. Many of the southern part have a negative CC. The maximum positive CC has been measured at Hatiya which is 0.26

The distribution of CC between the WBT of April and the monsoon rainfall is shown in Fig 3.9.5(b). From the distribution pattern we see that the CC distribution is positive throughout the western and north-western part of Bangladesh. The eastern and northern part has mostly a negative CC distribution. Except Chittagong and Rangamati the entire southern belt has a negative CC. The maximum positive CC has been observed at Satkhira which is 0.29. The maximum negative CC has been observed at Sitakundu and is -0.28. The observed CC at Satkhira and Sitakundu is about 95% significant.

The distribution of CC between the WBT of May and the monsoon rainfall is shown in Fig 3.9.5(c). The CC distribution is positive at the northern, north-eastern and north-western part of the country except Rajshahi and Ishwardi. The south-western part and the extreme southern part of the country have mostly negative CC. The maximum positive CC is observed at Jessore and Srimongal which is 0.22. The maximum negative CC is observed at Patuakhali and is -0.28.

The distribution of CC between the Pre-monsoon WBT and the monsoon rainfall is shown in Fig 3.9.5(d). The CC distribution is positive at the extreme northern part of Bangladesh whereas it is negative at the north-western and north-eastern part of the country. At the southern part the CC is mostly negative. The maximum positive CC is observed at Jessore which is 0.40. The maximum negative CC is observed at Feni which is -0.25. The CC has about 99% level of significance at Jessore.

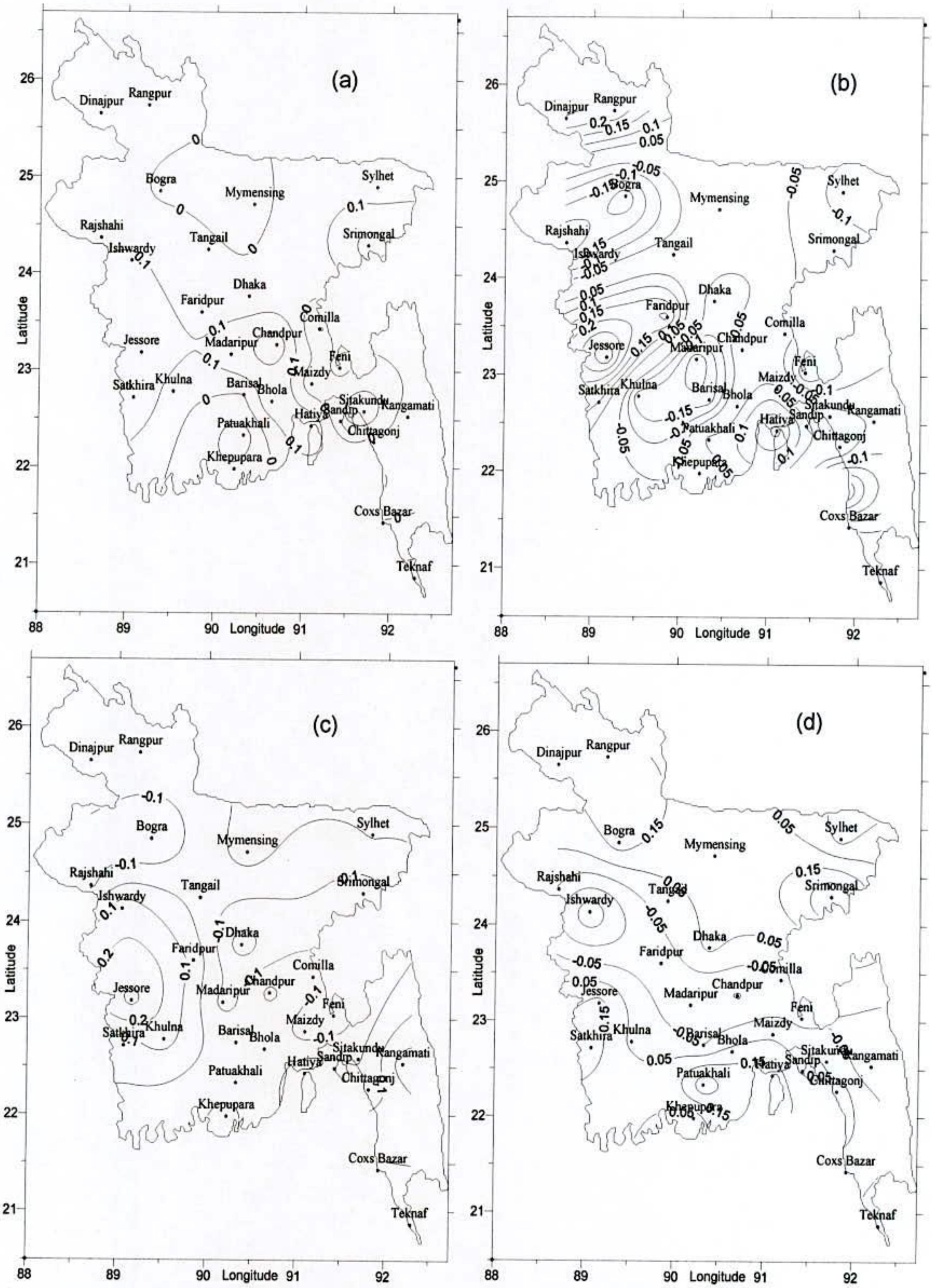

Fig 3.9.1: Correlation coefficient between the WBT of March and the rainfall of (a) June, (b) July, (c) August and (d) September respectively.

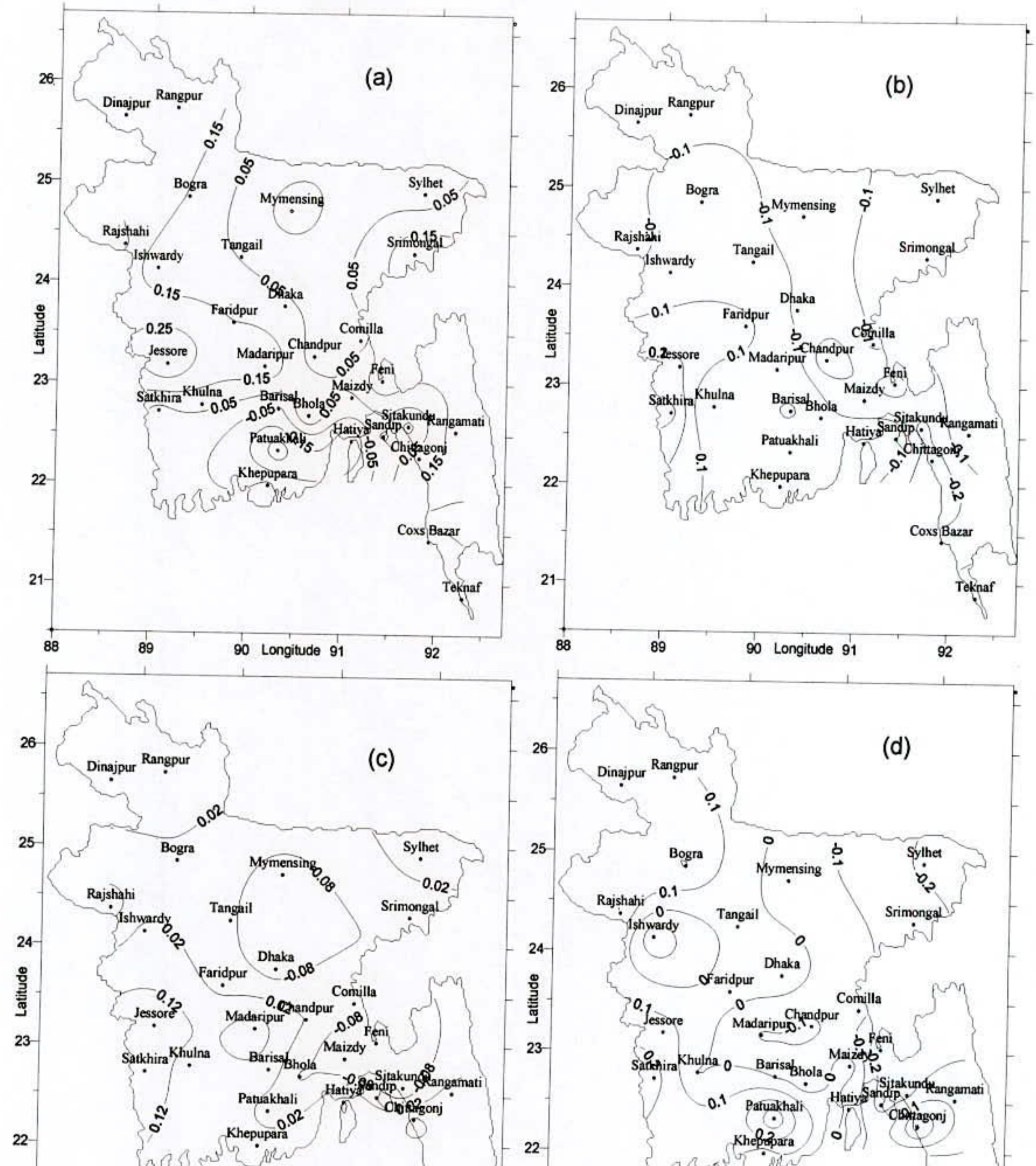

Fig 3.9.2: Correlation coefficient between the WBT of April and the rainfall of (a) June, (b) July, (c) August and (d) September respectively.

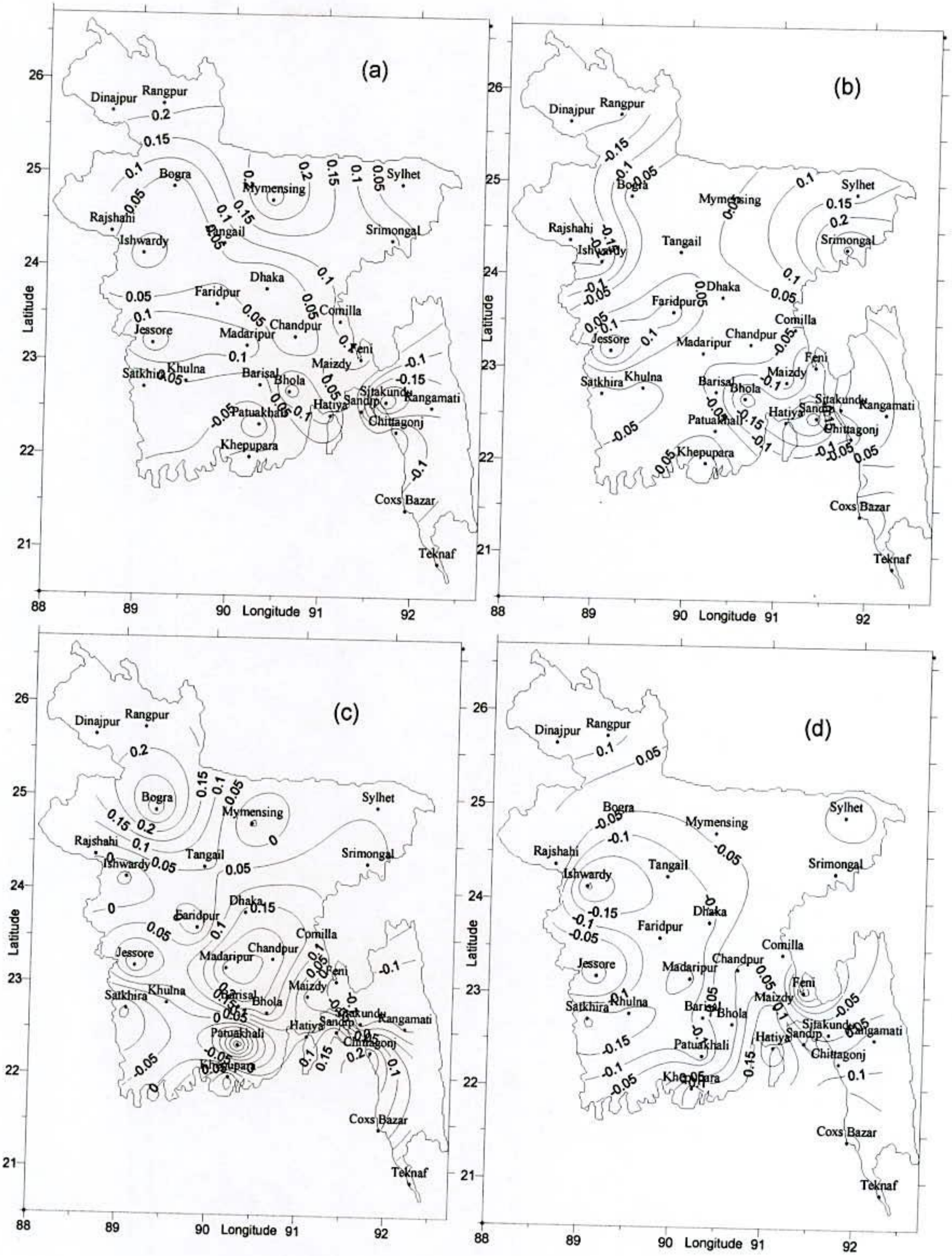

Fig 3.9.3: Correlation coefficient between the WBT of May and the rainfall of (a) June, (b) July, (c) August and (d) September respectively.

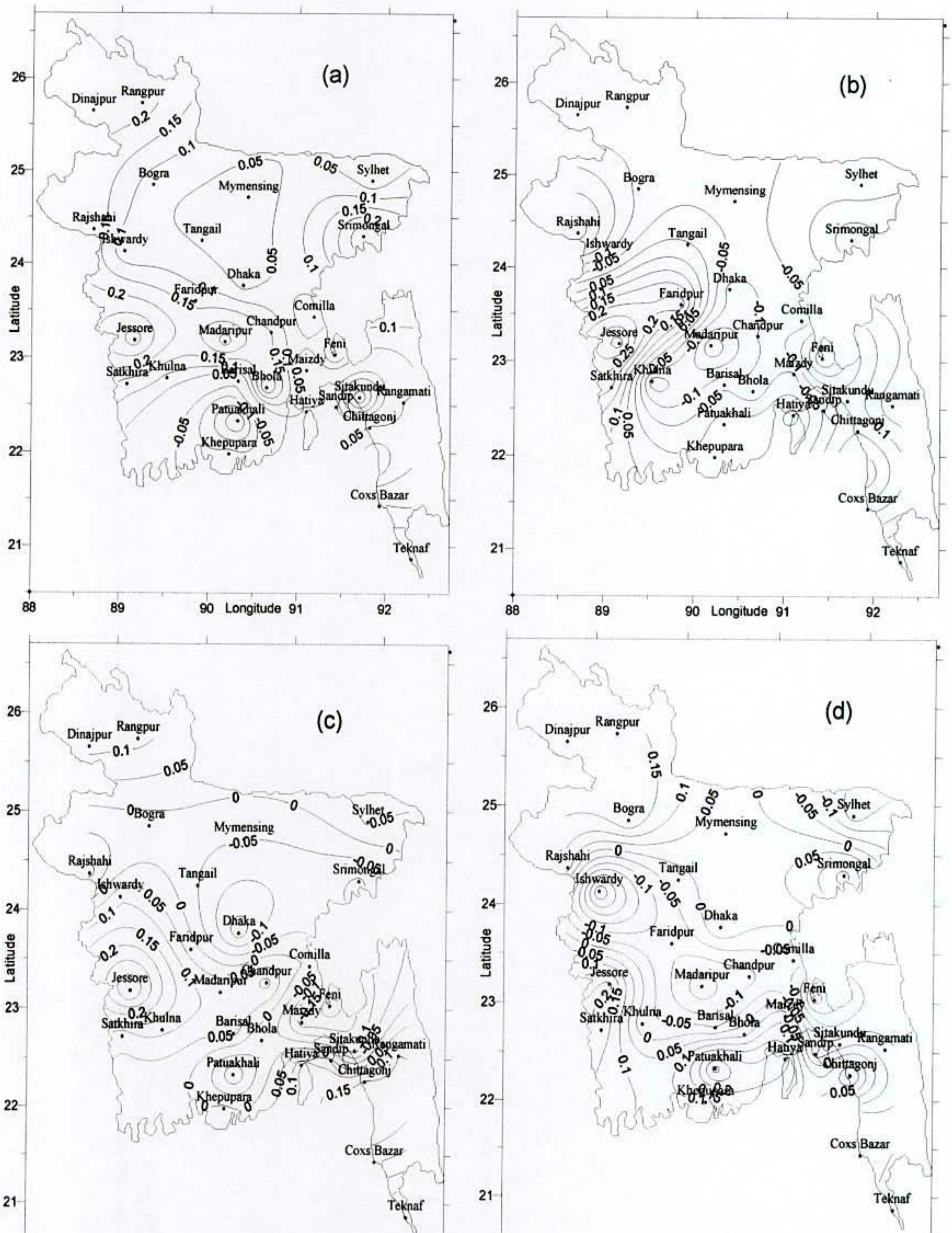

Fig 3.9.4: Correlation coefficient between Pre-monsoon WBT and rainfall of (a) June, (b) July, (c) August and (d) September rsepectively.

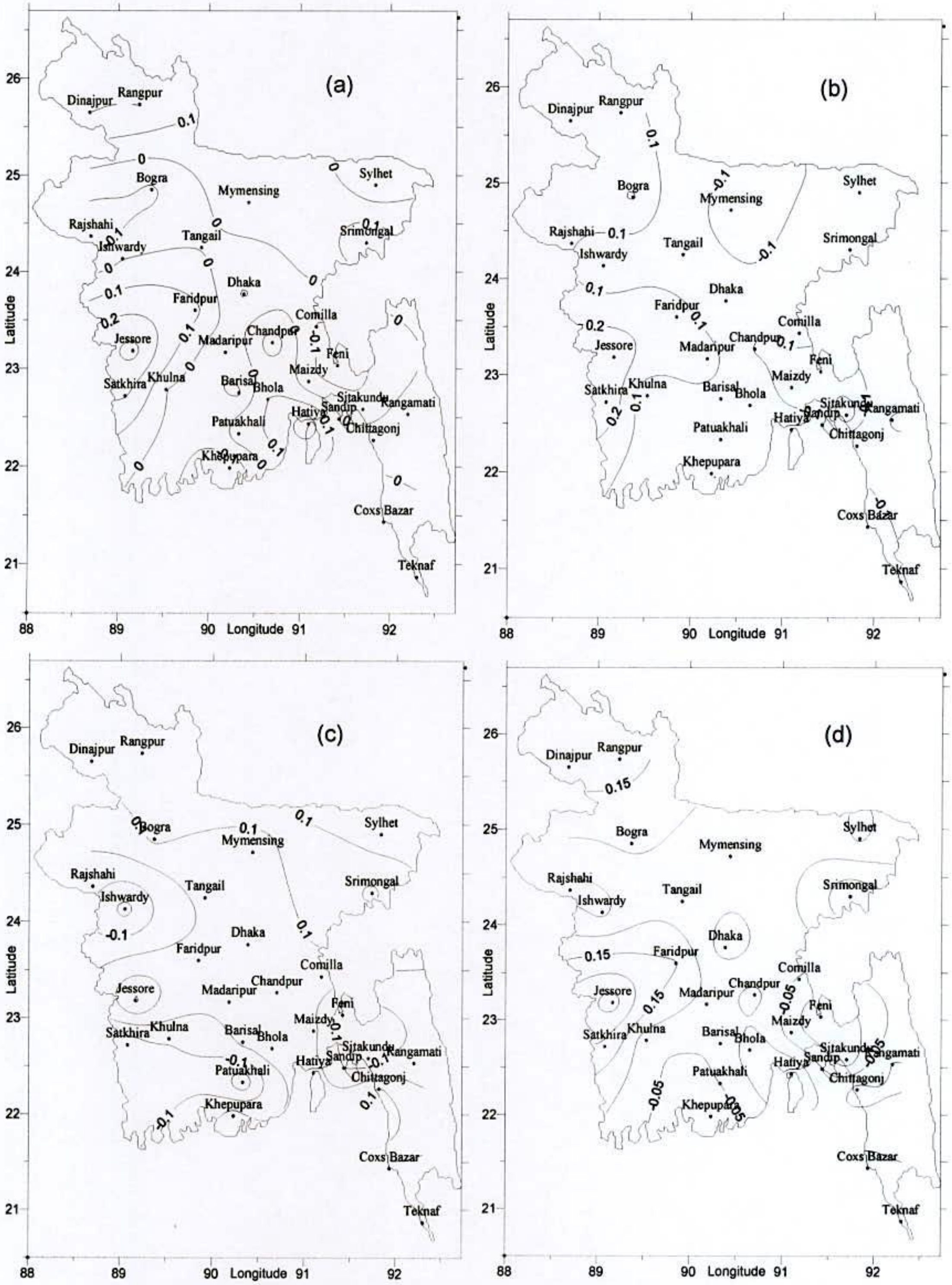

Fig 3.9.5: Correlation coefficient between Monsoon rainfall and WBT of (a) March, (b) April, (c) May and (d) Pre-Monsoon season.

Table-3.4: Correlation coefficients between WBT (of March, April, May and Pre-monsoon season) and Rainfall (of June, July, August, September and Monsoon Season).

Correlation Coefficients between	Number of stations where CC is positive
WBT(March)-Rain(June)	19
WBT(March)-Rain(July)	14
WBT(March)-Rain(August)	14
WBT(March)-Rain(September)	17
WBT(March)-Rain(Monsoon)	15
WBT(April)-Rain(June)	22
WBT(April)-Rain(July)	10
WBT(April)-Rain(August)	17
WBT(April)-Rain(September)	12
WBT(April)-Rain(Monsoon)	15
WBT(May)-Rain(June)	16
WBT(May)-Rain(July)	12
WBT(May)-Rain(August)	19
WBT(May)-Rain(September)	15
WBT(May)-Rain(Monsoon)	20
WBT(Pre-monsoon)-Rain(June)	21
WBT(Pre-monsoon)-Rain(July)	8
WBT(Pre-Monsoon)-Rain(August)	18
WBT(Pre-Monsoon)-Rain(September)	15
WBT(Pre-Monsoon)-Rain(Monsoon)	13

3.10 Multiple Correlation Coefficients (MCC) between Rainfall of Monsoon and 4 parameters of Pre-Monsoon

3.10.1 Distribution of the MCC between Rainfall of different months of Monsoon and DBT, WBT, MinT and MaxT of March

The distribution of MCC between the rainfall of June and the DBT, maximum temperature, minimum temperature and WBT of March is shown in Fig 3.10.1(a). From the distribution pattern we see that the MCC is positive all over the country. The most of the southern part of Bangladesh has an MCC 0.35 to 0.4. The northern part of the country has an MCC 0.13 to 0.22. The maximum positive MCC has been measured at Srimongal is 0.61 with 99% level of significance. At Madaripur and Sandwip the MCC of 0.58 and 0.44, respectively observed with a significance of 99%.

The distribution of MCC between the rainfall of July and the DBT, maximum temperature, minimum temperature and WBT of March is shown in Fig 3.10.1(b). The figure shows that the MCC is positive all over the country. Rangpur-Dinajpur-Rajshahi-Jessore belt (i.e. the north-western part of the country) has an MCC 0.45 to 0.52 which are significant at 99% level. The central part of the country has an MCC 0.2 to 0.3. The maximum positive MCC has been measured at Teknaf and is 0.59. The minimum positive MCC is measured at Bhola which is 0.07. The measured MCC has 99% significance level also at Teknaf.

The distribution of MCC between the rainfall of August and the DBT, maximum temperature, minimum temperature and WBT of March is shown in Fig 3.10.1(c). From the distribution pattern we see that the MCC is positive all over the country. The Sylhet-Mymensing zone and its surroundings have an MCC 0.1 to 0.2. Most of the southern part of Bangladesh has an MCC 0.2 to 0.3. The maximum positive MCC has been measured at Maizdy Court and is 0.54. The minimum positive MCC is observed at Dinajpur and Mymensing. At Maizdy Court and at Madaripur the MCC has 99% level of significance.

The distribution of MCC between the rainfall of September and the DBT, maximum temperature, minimum temperature and WBT of March is shown in Fig 3.10.1(d). The figure shows that the MCC is positive all over the country. Patuakhali-Khepupara and its surroundings have an MCC 0.45 to 0.50 and are significant at 99% level. The south-eastern part of the country has an MCC mostly in the range of 0.2 to 0.3. The northern part has an MCC in the range of 0.2 to 0.3. The maximum positive MCC has been measured at Madaripur and is 0.59. The minimum positive MCC is measured at Bhola which is 0.15. The measured MCC has 99% significance level also at Madaripur.

3.10.2 Distribution of the MCC between Rainfall of different months of Monsoon and DBT, WBT, MinT and MaxT of April

The distribution of MCC between the rainfall of June and the DBT, maximum temperature, minimum temperature and WBT of April is shown in Fig 3.10.2(a). From the distribution pattern we see that the MCC is positive all over the country. The minimum MCC is observed at Dhaka region, starting from the central part the MCC increases everywhere towards the boundary of the country. The maximum positive MCC has been observed at Teknaf which is 0.64. The MCC is 99% significant at Teknaf. The MCC at Jessore, Srimongal, Khepupara and Sitakundu are 0.50, 0.42, 0.65 and 0.54, respectively which are also significant at 99% level.

The distribution of MCC between the rainfall of July and the DBT, maximum temperature, minimum temperature and WBT of April is shown in Fig 3.10.2(b). From the distribution pattern we see that the MCC is positive all over the country. The northern, north-eastern and north-western part of the Bangladesh has an MCC between 0.2 to 0.3 except Mymensing and Bogra. From the central part the MCC increases towards the southern and south-western part of the country. The maximum positive MCC has been observed at Teknaf which is 0.59. The minimum positive MCC has been observed at Bogra and is 0.16. The MCC is 99% significant at Teknaf. The observed MCC at Mymensing, Satkhira, Chandpur, Jessore and Sitakundu are 0.46, 0.46, 0.49, 0.45 and 0.42, respectively which are also significant at 99% level.

The distribution of MCC between the rainfall of August and the DBT, maximum temperature, minimum temperature and WBT of April is shown in Fig 3.10.2(c). From the distribution pattern we see that the extreme northern part of the country has the lowest MCC. It then increases towards the south-eastern boundary of the country up to Jessore where it is 0.45. The maximum positive MCC has been measured at Hatiya and Feni and is 0.55. The MCC is 99% significant at Hatiya, Feni, Jessore and Sitakundu.

The distribution of MCC between the rainfall of September and the DBT, maximum temperature, minimum temperature and WBT of April is shown in Fig 3.10.2(d). The figure shows that the MCC is positive all over the country. From the central part the CC increases towards the north, south and western part of the country. The maximum positive MCC has been measured at Jessore and is 0.55 and the minimum is at Dhaka which is 0.14. The MCC is 99% significant at Jessore.

3.10.3 Distribution of the MCC between Rainfall of June-September and DBT, WBT, MinT and MaxT of May

The distribution of MCC between the rainfall of June and the DBT, maximum temperature, minimum temperature and WBT of May is shown in Fig 3.10.3(a). From the distribution pattern we see that the MCC is positive all over the country. Starting from the extreme north the MCC increases towards the south up to Rajshahi and Mymensing. The central part of the country has an MCC of about 0.2 to 0.3. The maximum positive MCC has been observed at Chandpur and Bhola and is 0.46. The minimum MCC is observed at Satkhira and is 0.08. At Chandpur, Maizdy Court and Bhola the MCC is observed with a significance of about 99%.

The distribution of MCC between the rainfall of July and the DBT, maximum temperature, minimum temperature and WBT of May is shown in Fig 3.10.3(b). From the distribution pattern we see that the MCC is positive all over the country. Hatiya-Sandwip-Sitakundu belt has an MCC of about 0.42. Ishwardi-Rajshahi belt also has an MCC of more than 0.4. The maximum positive MCC has been observed at Bhola which is 0.53. The minimum positive MCC has been observed at Chittagong and is 0.14. The MCC is 99% significant at Bhola, Hatiya, Sandwip, Sitakundu and Ishwardi-Rajshahi belt.

The distribution of MCC between the rainfall of August and the DBT, maximum temperature, minimum temperature and WBT of May is shown in Fig 3.10.3(c). From the distribution pattern we see that Khulna has an MC of 0.1. Then from Khulna the MCC increases towards south, east and west. At Chandpur the MCC is highest and it is 0.55. The minimum MCC is observed at Khulna and Rajshahi which is 0.1. The MCC is 99% significant at Chandpur and Khepupara region.

The distribution of MCC between the rainfall of September and the DBT, maximum temperature, minimum temperature and WBT of May is shown in Fig 3.10.3(d). The figure shows that the MCC is positive all over the country. The CC increases towards the south and western part starting from the central part of the country. The maximum positive MCC has been measured at Barisal and Madaripur and is 0.50. The minimum

MCC is observed at Srimongal which is 0.1. The MCC is 99% significant at Barisal and Madaripur.

3.10.4 Distribution of the MCC between the Rainfall of June-September and the average DBT, WBT, MinT and MaxT of Pre-Monsoon

The distribution of MCC between the rainfall of June and the average DBT, maximum temperature, minimum temperature and WBT of pre-monsoon is shown in Fig 3.10.4(a). From the distribution pattern we see that the MCC is positive all over the country. Starting from the middle part the MCC increases towards the south-west, east and north-east of the country. The maximum positive MCC has been measured at Sandwip 0.63. At Sandwip the MCC is observed with a significance of about 99%. At Jessore, Srimongal and Khepupara the observed MCC are 0.52, 0.61, and 0.50 respectively which are also significant at 99% level. The minimum positive MCC has been measured at Hatiya which is 0.11.

The distribution of MCC between the rainfall of July and the average DBT, maximum temperature, minimum temperature and WBT of pre-monsoon is shown in Fig 3.10.4(b). From the distribution pattern we see that the MCC is positive all over the country. Starting from the middle part the MCC increases towards the western part of the country. The maximum positive MCC has been observed at Maizdy Court is 0.53 which is significant at 99% level. The observed MCC at Jessore and Mymensing are 0.53 and 0.46, respectively which are also 99% significant. The minimum positive MCC has been observed at Dhaka, Bogra and Barisal. Chittagong and is 0.13.

The distribution of MCC between the rainfall of August and the average DBT, maximum temperature, minimum temperature and WBT of pre-monsoon is shown in Fig 3.10.4(c). From the distribution pattern we see that starting from the middle part the MCC increases towards south up to Madaripur and Chandpur. Similar pattern is also can be found from the south-western part towards Madaripur and Chandpur. The maximum MCC has been measured at Hatiya and Madaripur which are 0.53 and 0.51. The minimum MCC is observed at Dinajpur which is 0.13. The MCC is 99% significant at Hatiya and Madaripur.

The distribution of MCC between the rainfall of September and the average DBT, maximum temperature, minimum temperature and WBT of pre-monsoon is shown in Fig

3.10.4(d). The figure shows that the MCC is positive all over the country. From the central part the CC increases towards the north-east and western part of the country. The maximum positive MCC has been measured at Chandpur and is 0.48. The minimum MCC is observed at Dhaka which is 0.09. The MCC is 99% significant at Chandpur.

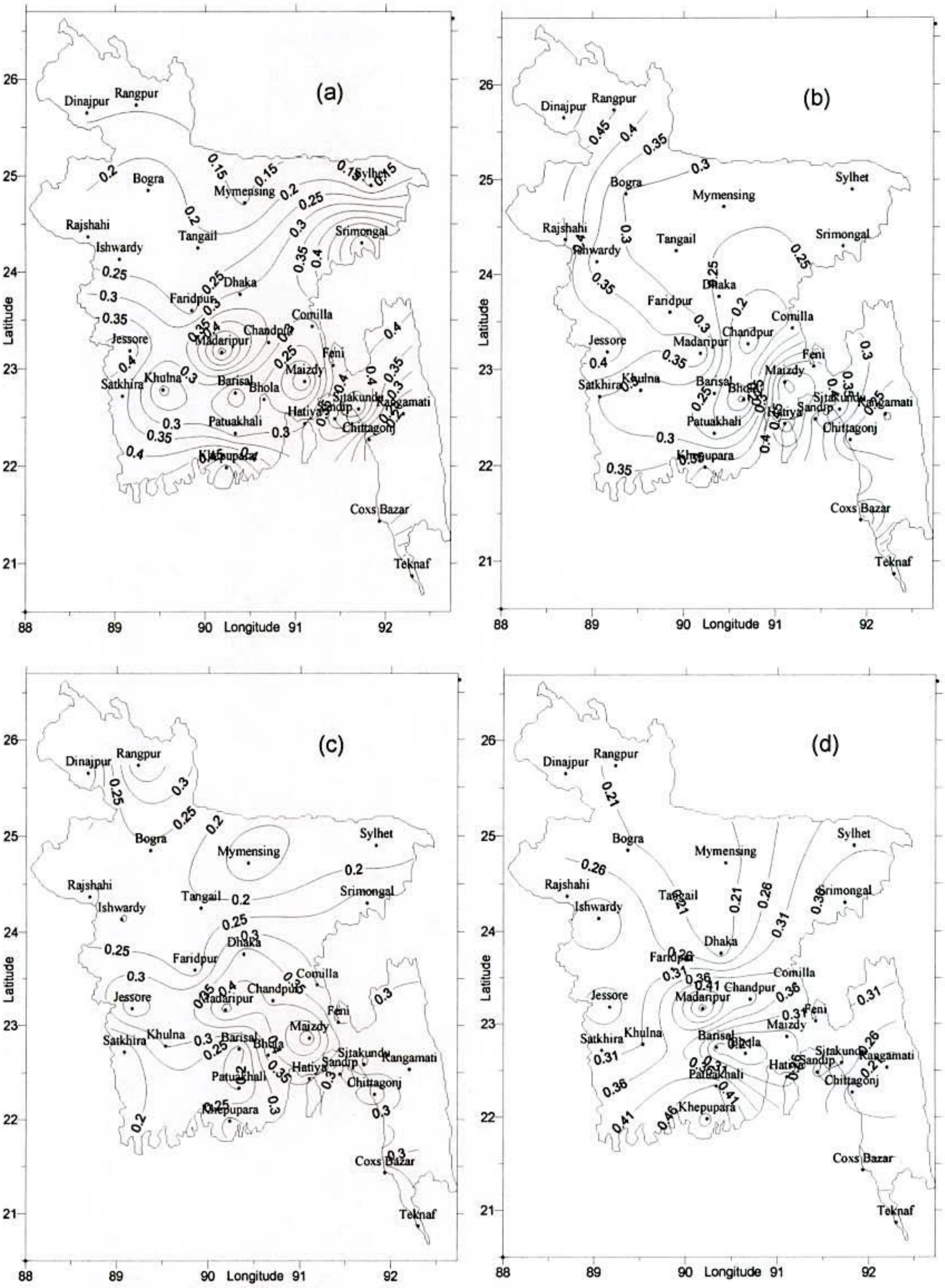

Fig 3.10.1: Multiple Correlation Coefficient between the MaxT, MinT, DBT and WBT of March and Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

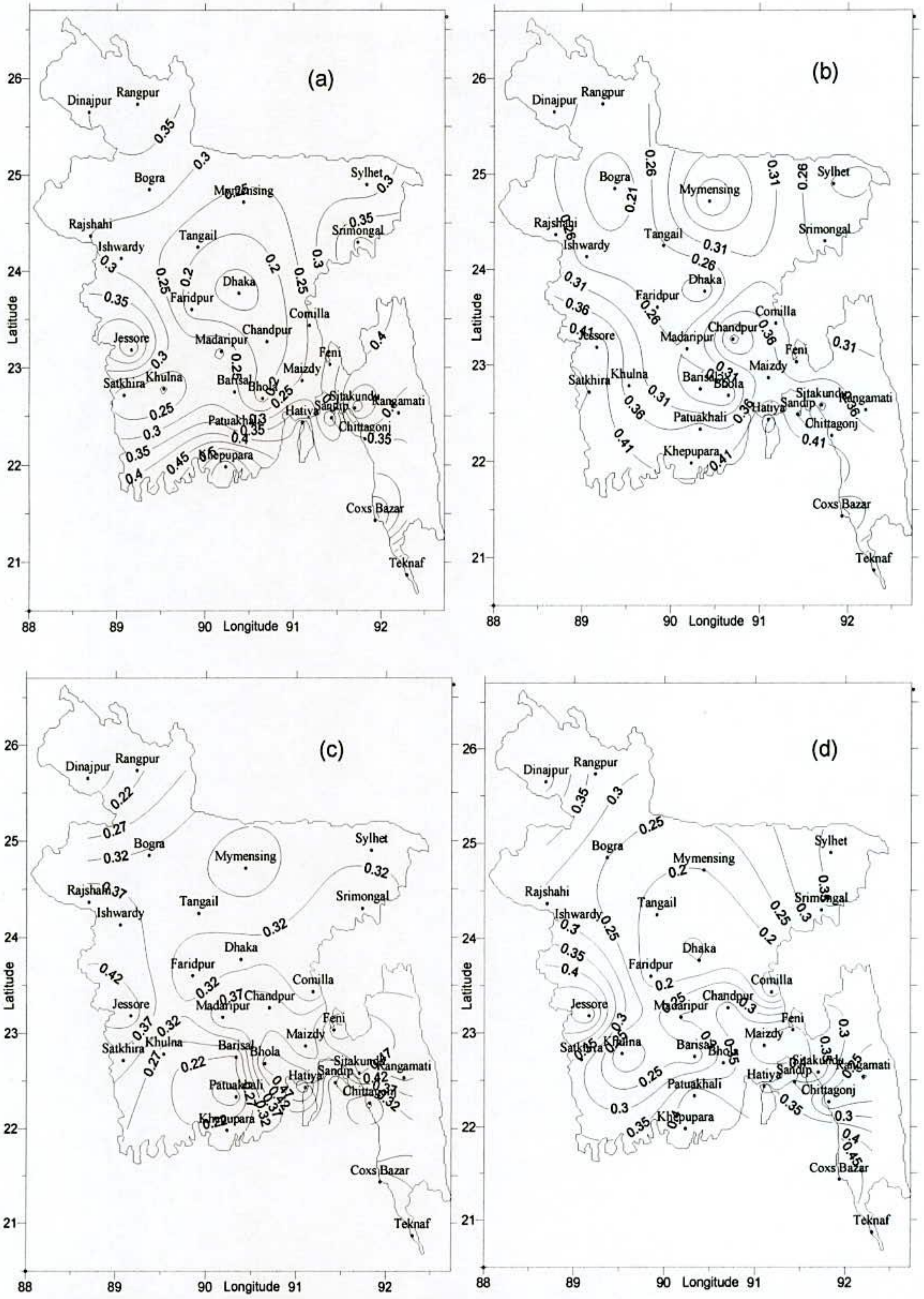

Fig 3.10.2: Multiple Correlation Coefficient between the MaxT, MinT, DBT and WBT of April and Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

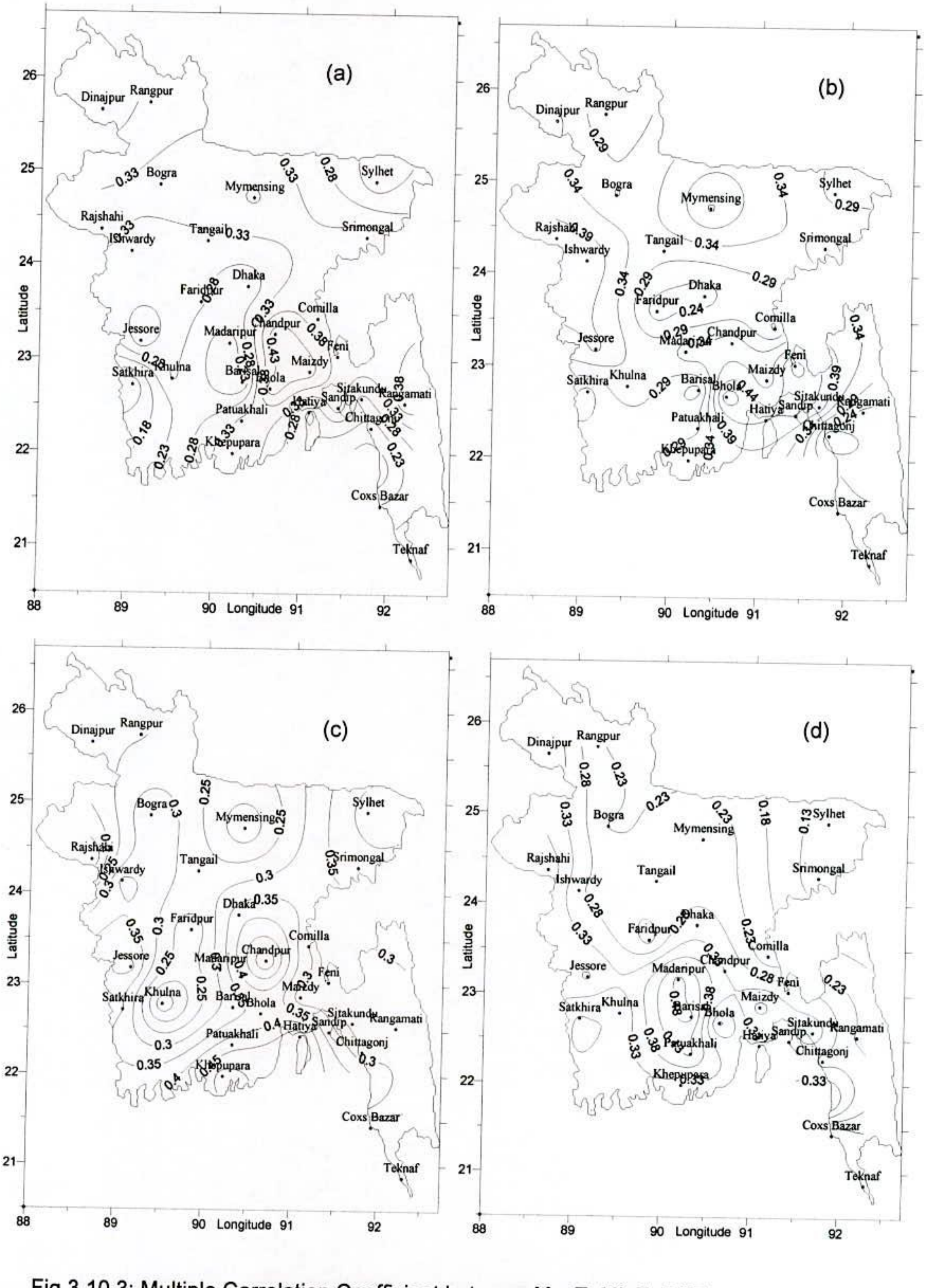

Fig 3.10.3: Multiple Correlation Coefficient between MaxT, MinT, DBT and WBT of May and the Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

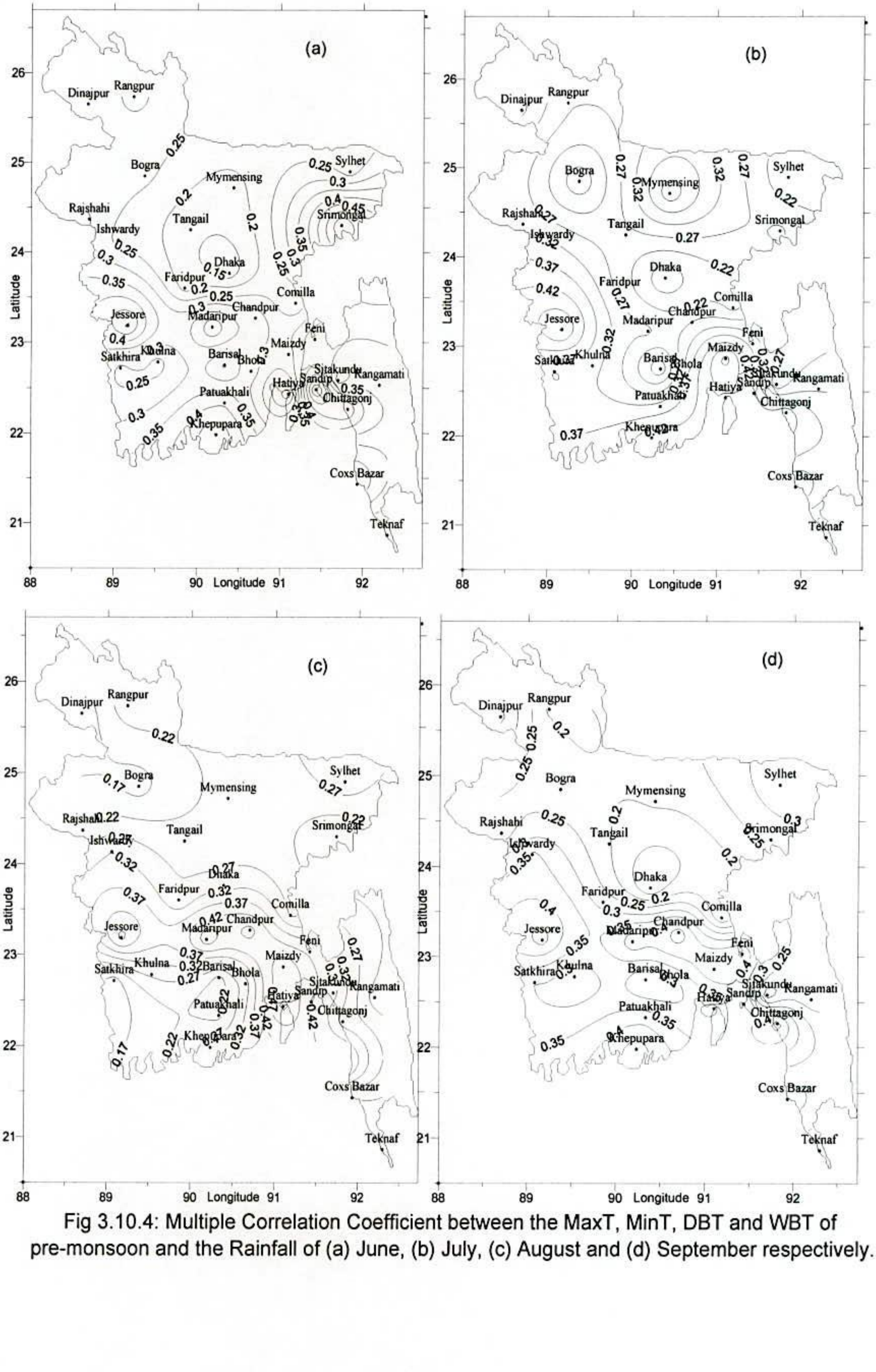

Fig 3.10.4: Multiple Correlation Coefficient between the MaxT, MinT, DBT and WBT of pre-monsoon and the Rainfall of (a) June, (b) July, (c) August and (d) September respectively.

CHAPTER IV

CONCLUSIONS

From this study and analysis the following conclusions can be drawn:

- The average DBT of the pre-monsoon season increases gradually from north-eastern to south-eastern part of the country. The highest and lowest values of the average DBT have been observed at Satkhira and Teknaf, respectively.

- The average WBT of the pre-monsoon season is found to be minimum at the northern part of the country and gradually increases towards the south.

- During pre-monsoon season the southern part of the country is warmer than the northern part and the western part is warmer than the eastern part of the country.

- The maximum amount of average rainfall is observed at the eastern side of the country and decreases gradually towards west during the pre-monsoon and monsoon season. During monsoon season the lowest rainfall is observed at Jessore and highest at Teknaf.

- The correlation co-efficient between the pre-monsoon WBT and pre-monsoon rainfall is positive mostly at the middle part and towards northeast and northwestern part of the country specially Ishwardi-Bogra-Mymensing area. The correlation co-efficient at this zone lies between 0.11 to 0.15.

- The CC between the pre-monsoon minimum temperature and pre-monsoon rainfall are positively correlated mostly at Khepupara, Cox's Bazar, Sylhet and Srimongal region.

- The pre-monsoon maximum temperature and pre-monsoon rainfall are positively correlated at Barisal, Khepupara and Feni and some of the other parts of the south and southwestern part of the country.

- It has been found that the correlation co-efficient between the pre-monsoon WBT and monsoon rainfall is positive mostly at the southern, southwestern and the extreme northern (especially Rangpur-Dinajpur-Bogra zone) part of the country. The correlation co-efficient at this zone lies between 0.11 to 0.19.

- It has also been observed that the correlation coefficient between the pre-monsoon maximum temperature and monsoon rainfall is positive at most of the places of the central (especially Chandpur and Madaripur), southwestern and a few places of the northern part of the country. The correlation co-efficient at Madaripur is 0.44.

- The rainfall of June are positively correlated in the NW, S, SE and SW part and negatively correlated in the eastern and western part of the country with the DBT of March, April and May. The DBT of March and April are negatively correlated with the rainfall of June, July, August and September in the northeastern part of the country.

- The minimum temperature of March and April are negatively (positively) correlated in the northern (southern) part with the rainfall of July and August.

- The rainfall for the month of June, July, August, September and monsoon season has positive correlation in the southern and southeastern part and negative correlation in the northern and northeastern part with the minimum temperature of March, April, May and pre-monsoon season. The rainfall of June is also positively correlated with the minimum temperature of March, April, May and average of pre-monsoon season with little anomalies.

- From this study it has been found that the multiple correlation co-efficient between the DBT, WBT, MinT and MaxT of pre-monsoon and the rainfall of monsoon has a positive value for all over the country.

Even though some positive correlations have been found with the monsoon rainfall and the four parameters of pre-monsoon season but the correlation co-efficients are so small that statistically it is not enough nor straightforward to make any prior prediction. It is therefore necessary to add more independent environmental variable to predict the monsoon rainfall beforehand.

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