VARIABILITY OF RAINY DAYS IN BANGLADESH DURING 1950-1999

M. Phil Thesis

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Abstract

The impact of climate change on annual rainy days has received a great deal of attention by scholars worldwide. Many studies have been conducted to illustrate that changes in annual rainy days is becoming evident on a global scale. In the present study fifty years (1950-1999) daily rainfall data of 13 meteorological stations of Bangladesh Meteorological Department (BMD) have been used. Seasonal, yearly and decadal trend of variation of rainy days are studied. The whole country is divided into four regions named: South-East (SE), South-West (SW), North-East (NE) and North-West (NW). Variation of three threshold rainy days named: Moderated Heavy, Heavy and Very Heavy are studied. During pre-monsoon period in Bangladesh all the stations show increasing trend of rainy days except Srimongal. In monsoon, all the stations show increasing trend of rainy days except Dhaka, Chittagong, Cox's Bazar, Srimongal and Rangpur. Dhaka, Chittagong, Srimongal and Bogra stations show negative trend of rainy days during post-monsoon period and all other stations show positive trend. During winter season, all stations show positive trend. All the stations show positive trend of yearly variation of rainy days except Srimongal during 1950-1999 in Bangladesh. All the stations also show positive trend of decadal variation of rainy days except Srimongal. All the stations show increasing trend of moderate heavy rainy days except Srimongal and Comilla during 1950-1999. For heavy rainy days, all the stations show positive trend except Comilla and Satkhira during 1950-1999. For very heavy rainy days, all the stations show positive trend except Mymensing, Rangpur, Bogra and Dinajpur during 1950-1999. All the four regions of Bangladesh show positive trend of variation of rainy days during pre-monsoon and monsoon periods. Among four regions, SW and NW regions show positive trend of variation of rainy days whereas SE and NE shows negative trend during post-monsoon period. All regions show positive trend of variation of rainy days during winter period. The yearly averaged rainy days in the SE, SW, NE and NW region is 115, 101, 129 and 98 days, respectively. The 50 years averaged rainy days in the pre-monsoon, monsoon, post-monsoon and winter periods is 19, 74, 16, 04 days, respectively. All the four regions show the positive trend of yearly variation of averaged rainy days with maximum and minimum in the SW and SE regions, respectively. The yearly averaged rainy days in the wet region (120 days) is higher than that of dry region (103 days) of the country. The country averaged seasonal, yearly and decadal variation of rainy days as well as three threshold rainy days show positive trend. The yearly averaged increase of rainy days is found 0.36 days/year.

CHAPTER 01

Introduction

1.1 Prelude

Rainfall is the most dominant element of the climate in Bangladesh, which has strong impact on life and economy. Excessive of rainfall causes widespread flooding, flash flooding and on the other hand its lack leads to drought. Timely and well-distributed rainfall is essential for better crop production while the erratic behavior of rainfall has an adverse effect. One of the most important parts of the water resource comes from rainfall. Determining the rainfall in monsoon and out of monsoon is necessary for everyday management of water resources such as rivers and reservoirs, irrigation and water forecasting. Two-thirds of the global precipitation occurs in the tropics. It has been well documented that rainfall on the Earth’s surface varies greatly in both time and space. The south Asian monsoon system, in terms of rainfall, is of great importance to climate researchers for understanding its variability at different space and time scales. In recent years interest has increased in learning about precipitation variability and predictability. Another important aspects of rainfall is to changes in climate extremes (e.g., floods, droughts, etc.) since these events have the strongest impact on society. It has been documented that even a small change in the mean condition can cause a large change in extreme statistics [1]. Consequently, the degree to which climate change affects society will more likely depend on changes in climate variability and particularly, in the intensity, frequency, spatial and temporal distribution of climate extremes [2].

In Bangladesh, the agricultural economy with large growing population is closely linked with the behavior of rainfall distribution. The inter-annual variability of rainfall is very high, which significantly affects the agricultural activities and other water based enterprises in Bangladesh. Abnormalities of rainfall may be manifest in several forms like as less rain, rain not commencing in time due to delay in the onset of summer monsoon or early cessation due to early withdrawal of monsoon season. Few research works have done about the characteristics of cloud mechanism, precipitation systems and rainfall estimation in Bangladesh by using rain gauge, radar and satellite data [3-8] studied the details characteristics of precipitation systems by using the Bangladesh Meteorological Department radar data. Wahid et al., [9] estimate rainfall in the northern part of Bangladesh use satellite data. Islam et al., [10] worked on characteristics of precipitation system. Same author also in the same year analyzed spatial and temporal variations of precipitation in and around Bangladesh. Devkota [11] studied on rainfall over SAARC region with special focus on teleconnections and long range forecasting of Bangladesh monsoon Rainfall. Matsumoto, J., [12] studied on Synoptic features of heavy monsoon rainfall in 1987. They found a inter relation of rainfall variability over Bangladesh and Nepal comparison with India by Kripalani et al., [13]. Dhar et al. [14] studied on precipitation in the neighborhood of Mount Everest on the other hand Arkin studied on the relationship between the fractional coverage of high cloud and rainfall accumulations during Gate over the B-Scale array. Rainfall distribution is an important factor which causes floods and other rainfall related problems. Matsumoto et al., [15] measured rainfall distribution over the Indian subcontinent during 1987 and 1988 severe floods in Bangladesh. Ahmed et al., [16] studied El-Nino southern oscillation and rainfall variation over Bangladesh. Islam et al., [17] compared rainfall and rainy days using TRMM 3B42 and rain gauge data for the period 1998-2002. Out of 274 days, averaged for 5 years rainfall over 31 stations, 97.08% and 98.91% days are detected as rainy days by TRMM and RNG respectively. Rainy days detected by TRMM matched 95.99% of same detected by RNG. On an average, TRMM can determine about 98.24% of the RNG rainfall. The TRMM overestimates rainfall during pre-monsoon and underestimates during monsoon while alike during post-monsoon period.

However still to date it is not clear the long term variability of rainy days and extreme rainfall days which is the indicators to monitor climate change impact in Bangladesh.

1.2 Objectives of the research

Since the variability of rainy days and extreme rainfall days may be used as an indicator to monitor climate change impact in Bangladesh. So the focal objectives of this research work are to:

(i) determine the monthly, seasonal (pre monsoon, monsoon, post monsoon, winter), yearly and decadal variability of rainy days.

(ii) determine the regional variability of rainy days.

(iii) determine the variability of extreme rainfall days such as moderate rainy days, heavy rainy days and very heavy rainy days.

CHAPTER 02

Literature Review

2.1 Geographical description of Bangladesh

Bangladesh extends from 20^0-45'N to 26^0-40'N and 88^0-05'E to 90^0-40'E. Most of the country is flat except for hills in the southeastern parts.

Fig.2.1. Geographical map of Bangladesh

It is surrounded on the west, north and east by Indian territories. To the south lies the Bay of Bengal. The area of Bangladesh is 1, 44,000 square kilometers or 55,600 square miles. It is divided into six divisions and 64 districts. It has a population of about 155 million. In point of the size of population, it is the tenth largest state in the world. The physical features of Bangladesh are mainly a plain land criss-crossed by a network of rivers and canals. In the eastern and south-eastern regions there are only a few hilly tracts. Places like Paharpur, Mahasthangar and Mainamati and numerous historical monuments and relics give evidence to our glorious pasts, rich culture and high civilization. The country is bounded in the west Bengal. West Bengal, Asam and Meghalaya (hill area of Khashi and Joyonti hills) in the North; to the east by Tripura and Assam (hilly states of India) together with Myanmar, and South by the Bay of Bengal. The Himalayas demarcated the northern border of the Bengal basin while Shilong plateau and Tripura hills defined the northeastern and eastern boundaries, respectively and Chhotanagar plateau delineate western boundary. Bangladesh is a revering country within mighty drainage systems (Ganges, Brahmaputra and Meghna) along with its innumerable tributaries which originates in the Himalayas Mountains is largely responsible for the hydro-meteorological cycles of the whole Indian subcontinent including Bangladesh. It has a small border with Myanmar in the southeastern side.

Bangladesh is often called a land of natural calamities. Flood, cyclone, storm and heavy downpour and drought often visit the country. People here work and live fighting against recurring natural calamities. Bangladesh lies in the tropical region and its land is low. Almost every year cyclone or storm hits the land in summer or in the late autumn. Torrential rains and rush of water from the upper north bring about flood almost every year. On no other country of the world has Natural bestowed so much beauty as on Bangladesh. Its beauties consist in bounty and variety. The tropical climate brings for its abundance of sunshine, on the one hand and copiousness of cloud and rain, on the other hand. The country is frequently hit by the tropical cyclones, which affect the coastal zone by storm surges and wind actions. Salinity intrusion is a major problem in the coastal zone during the dry season. Floods frequency occurs in Bangladesh due to heavy monsoon rainfall in the country and also in the upper catchments of GBM outside the country. Nearly 22% of the area of Bangladesh gets flooded in a normal monsoon year. The floods like those of 1988, 1998 and 2004 occur once in 10 years, which are highly destructive to live and properties.

2.2 Rainfall

Bangladesh has an average rainfall of about 2300 mm, ranging from 1250-5000 mm. Mean annual rainfall is lowest in the centre-west (1250 mm). It increases towards the north, east and south, reaching more than 2500 mm in the extreme north-west, near and within the northern and eastern hills, and near the coast, and exceeding 5000 mm in the extreme north- east. In all areas, about 85-90 percent of the annual total occurs between mid-April and end-September. Totals vary considerably between years. This is mainly because of the yearly variability in pre-monsoon rainfall and the irregular incidence of heavy rainfall events within the monsoon season. Ahasan M.N. et al. [18] studied on “Variability and trends of summer monsoon rainfall over Bangladesh” and found annual country averaged rainfall is 2456.38 mm and summer monsoon rainfall 1769.14 mm and annual rainfall trend is 1.92 mm/year. Winter rainfall, when it occurs may be either from local thunderstorms or from depressions crossing northern India. Pre-rainfall may give more than 100 mm in a day. There are two regions in Bangladesh: wet region and dry region (Islam and Uyeda, 2007). The rainfall amount in the wet region is more than the dry region. The northern and southern coastal part of the country received maximum rain from mid-night to early morning (03-06 LST) with an afternoon 18 LST peak in the southeast-southwest region of Bangladesh, Islam et al., 2005a [19], Islam et al., 2005b [20]. V. Krishnamurthy and J. Shukla [21] found that the major drought years are characterized by large-scale negative rainfall anomalies covering nearly all of India and persisting for the entire monsoon season. It is found that the nature of the intraseasonal variability is not different during the years of major drought or major floods.

The heavy rainfall between May and September comes at a time when the major rivers are bringing in large volumes of water from the upper catchments areas outside Bangladesh. The high river levels block drainage of rainwater from the land. Because of this, most floodplain areas monsoon thunderstorms usually give rainfall of high intensity. Shamsuddin Shahid [22] studied on “Trends in extreme rainfall events of Bangladesh” and found a significant increase of annual and pre-monsoon rainfall in

Bangladesh. In general, an increasing trend in heavy precipitation days and decreasing trends in consecutive dry days are observed. Significant change in most of the extreme rainfall indices are observed in Northwest Bangladesh. Periods of heavy monsoon are submerged by rainwater in the monsoon season. In Bangladesh, there is a difference between flooding and flood. Flooding implies inundation of the land by water, such as floodplain inhabitants expect in 'normal' years and on which farmers base their traditional cropping patterns. On the other hand, flood implies abnormal submergence of the land, which may cause damage or loss of crops, property and lives.

2.3 Rainfall Estimation Techniques

Measuring precipitation is traditionally measured using various types of rain gages such as the non-recording cylindrical cont ainer type or the recording weighing type, float type and tipping-bucket type. One of the critical components of the Earth's hydrological cycle is precipitation. Rainfall is essential for providing the fresh water that sustains life. Some say the first rain gauge was invented more than 2,000 years ago when rulers of the Choson Dynasty (now Korea) decreed that all villages were to engage in measuring precipitation. The rainfall data was then incorporated into a formula to determine the potential harvest of each farm.

Generally, standard gauges measure precipitation at or near the ground, and are observed at least once a day. The sizes of the gauges are made big enough to collect more than the average one-day or maximum 1-2 hour precipitation which differs according to various climatic conditions. The standard gauges are also commonly used to measure both rain and snow, and the latter affects fundamentally the form and dimensions of a particular national gauge (snow gauges are bigger). Thus, in countries with negligible snowfall but much rain or where different gauges are used for rain and snow , the height of the gauge orifice varies between zero and more than 1 meter above the ground.

There are electronic rain gauges that measures rain fall, and are also self emptying and frost proof. The basic idea is the rain collector's measuring spoon being automatically tipped and emptied when the pre-adjusted water weight has been reached. Small units have a funnel measurement around 5 x 10 cm, and the rain is registered with a resolution of 1 mm. The rain runs through the funnel of the rain collector into a self-emptying spoon which automatically tips and is emptied as soon as there is a certain quantity of water in the rain collector for which it has been adjusted. The spoon is fitted with a magnet kept in position by an anchor and the spoon is emptied by a quick tip – returning immediately to collecting position for collection of a new portion of water.

Weather radar is a type of radar used to locate precipitation, calculate its motion, estimate its type and forecast its future position and intensity. Weather radars are mostly Doppler radars, capable of detecting the motion of rain droplets in addition to intensity of the precipitation. Both types of data can be analyzed to determine the structure of storms and their potential to cause severe weather.

Now day's weather satellites are used to monitor the weather and climate of the Earth. These meteorological satellites, however, see more than clouds and cloud systems. City lights, fires, effects of pollution, auroras, sand and dust storms, snow cover, ice mapping, boundaries of ocean currents, energy flows, etc are other types of environmental information collected using weather satellites.

2.4 Seasons of Bangladesh

Bangladesh is in the sub-tropical monsoon climate. Based on pressure, rainfall and temperature; the climate of this country can be described under the following four seasons:

1. Pre-monsoon or summer: March, April and May.
2. Monsoon: June, July, August and September.
3. Post-monsoon or autumn: October and November.
4. Winter: December, January and February.

2.4.1 Pre-monsoon Season

The mean temperature during the pre-monsoon remains 23^0-30^0 C. April and May are the hottest months. The highest temperature ranging from 38^0-41^0C is attained in the northern and north-western districts. Over rest of the country it ranges from 36^0-38^0C. Practically the highest temperature attains in the month of May. The winter anti cyclonic pressure regime starts changing of a summer heat low from March onwards. The low heat develops over Bihar and adjoining central India when the pressure system over Bangladesh forms a part of the resultant trough. In the northern and central districts the surface wind changes from northerly in the winter to south-westerly and it becomes southerly to south-easterly over rest of the country. The southerly low level circulation brings in considerable amount of moisture from the Bay of Bengal over the country causing sultry weather towards late afternoon and evening. Such inflow of moisture causes local thunderstorms in the late afternoon and early night. These local pre-monsoon thunder storms are usually called Nor'westers as because they move across the country mainly from the north-westerly to northerly direction.

2.4.2 Monsoon Season

The summer low over the northwest India and Pakistan intensifies in June and extends its trough to Bangladesh and adjoining North of the Bay of the Bengal. The surface wind changes to southerly direction over the southern and the central districts and to southeasterly to easterly over the northern districts of the country. Wind speed is light to moderate. Monsoon normally reaches the coastal districts of the country by the last week of May to first week of June and progressively engulfs the whole country through June. On the average there are 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 district of Sylhet and the southeastern districts if Chittagong and Chittagong Hill Tracts. Over the central districts, the rainfall is 250-380 mm per month in the two months. As the season advances the rainfall over the country decreases gradually. 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 [23].

With the advent of the monsoon the summer extreme temperatures fall appreciably throughout the country. Although the mean temperature falls hardly by one degree, the maximum temperature falls by 2-5^{0}C over most parts pf the country except the coastal districts where the fall is by 5-6^{0}C [23]. Tropical depressions and storms form in the Bay of Bengal during the season and generally more to the northwest or north towards India and Bangladesh coasts. Storms however seldom attain hurricane intensity in this season.

2.4.3 Post-Monsoon Season

October and November are consisting of post monsoon season. This is the transitional season from summer, monsoon to the winter. Tropical cyclones form over the Bay of Bengal in the Post-monsoon season. Some of these storms in this season may attain hurricane intensity. There is a general rise of pressure and the monsoon pressure structure breaks down over the country. The monsoon low over the central India weakens and shifts towards the Bay of Bengal with its though extending over the coastal Bangladesh. The surface wind is very light and variable. Rainfall decreases considerably in October and in November the dry period starts setting in over the country. The district of Sylhet gets 200-250 mm of rain in October and the rest of the country gets about 100-170 mm. In November the amount of rainfall over the southeastern coastal districts amount to 25-65 mm whereas the rest of the country gets only about 10-20 mm of rain. In October there are 4-10 days of rainfall over the country and only 1-3 days in the month of November. The mean temperature falls from 28-29^{0}C in September to 26-27^{0}C in October and to 23-25^{0}C in November. The highest maximum temperature hardly exceeds 29^{0}C and the lowest minimum does not fall below 10^{0}C throughout the country [23].

2.4.4 Winter Season

The season is characterized by mainly an anti-cyclonic pressure system dominating the country except in February when a shallow trough of low makes its appearance over the northern districts. Very light northerly winds, mild temperature and dry weather with clear to occasionally cloudy skies over the country. Exceptionally some powerful western disturbance passes over the country. The mean temperature is in the ranges of 18-21^{0}C. In the south – western and the coastal districts the mean temperature range between 22 – 23^{0}C with its lowest ranging between 6 – 10^{0}C. The temperature occasionally goes down to less than 5^{0}C in the north – eastern parts of the country. The prevailing air mass is during 0900 to 1500hrs local time. The dryness of air is not evident from morning and late afternoon humidity trends. This is due to the reason that continuous evaporation takes place from numerous rivers, lakes and natural water – sheds during clear sunny days and the evaporated moisture show up in the form of high humidity during the cool hours of late evening and morning. This ultimately helps formations of mist during the late nights and early mornings. The effect is more pronounced in the Genetic central districts and the coastal district. After passing the western disturbance morning fog occurred. Rainfall over the country during winter is very scanty. But sometimes in winter Bangladesh receives rain or cloudy sky this particular system occurs when some powerful western disturbance approach from Mediterinan Sea to east giving rain in Iran, Pakistan, Northern India and then to Bangladesh, which is the only source of winter rain in Bangladesh coast. The driest month of the season is December when the northern and the western districts get hardly 3 – 10 mm of rainfall; the districts of greater Barisal, Noakhali, Chittagong and Chittagong Hill Tracts get 15 – 30 mm of rain.

2.5 Climate Change

The earth’s climate, by nature, is a complex system consisting of oceans, atmosphere, land surface and vegetation, which respond to influences of various time scales. Oceans are generally influenced on time scales of years to centuries, whereas atmosphere, which is defined as a blanket of air surrounding the earth, may change on a daily basis and vegetation changes on a seasonal time scale. Earth experiences changes in its climate continuously. Due to enormous increase in population and the advancement in the technology founded on carbon-based fuels there has been a significant change in global climate. Climate change is directly linked to the increase in the green house gas concentration, caused by human activities (IPCC, 2001, [24]). Climate change does not necessarily mean that all regions experience a uniform change with respect to the direction and magnitude, but there may be regional variations. Also climate change may not imply that all successive years will necessarily have the same trend of increase or decrease.

2.5.1 Evaluation of climate change

The most reliable tool for estimating climate change in the atmosphere is General Circulation Models (GCMs). GCMs are numerical models that analyze the atmosphere on an hourly basis which is very small time slots in all three spatial dimensions based on the atmosphere on an hourly basis which is very small time slots in all three spatial dimensions based on the law of conservation of mass, momentum and conservation of energy. These models are complex computer simulations describing the circulation of air and ocean currents and how the energy is transported within a climate system. The best available GCMs for estimating the climate show that the annual global surface air temperature may increase at a rate of 2.5K to 4.5K due to the doubling of carbon dioxide concentration in the atmosphere [25].

2.5.2 Effects of climate change

Prediction of weather is important because it gives us a snap shot picture of climate which is helpful in many ways. It helps agriculture, industries, and long term planning of hydraulic structures and also in planning large domestic construction projects, such as roads, bridges, etc. Furthermore it is helpful in quantifying global warming and in mitigating it. Until recent years green house gases in the atmosphere were attributed primarily to the emission of carbon dioxide generated by fuel, but in recent years the role of trace gases has been recognized to be equally important. The knowledge about the change in temperature offers an insight into the impact of increasing CO_2 concentrations. Estimates of possible regional changes in the climate due to the increase of atmospheric CO_2 are required to evaluate the impact on various social and economic activities. Global warming has become one of the most alarming issues these days. The global change adversely impacts terrestrial and aquatic ecosystems. Some of the most important economic resources, such as agriculture, forestry, fisheries and water resources may also be affected. Increased temperature, severe and frequent droughts and floods and sea level rise would have huge impacts on human life and economic well beings. Based on statistical evidence, the average global surface air temperature has increased by 0.6^0C between 1860 and 2000 (IPCC, 2001 [24]). The increased global carbon dioxide emissions are mainly due to the energy burnt to run automobiles, power factories and heat homes and businesses.

Measurements of seasonal variations in the surface air temperature are important for better understanding of the impact of climate change on human activities. Although natural factors may have contributed to the temperature increase in the 20th century, studies indicates that warming in the last 50 years may be due to increases in the greenhouse gas concentration [26]. The major contributing factor for the climate change may be anthropogenic changes, which result in the decrease in the extent of snow cover and sea-ice thickness. Direct information can also be obtained from the instrumental records, such as average temperature. It is also noted that due to the thermal expansion of oceans, over the past century, global average sea level has been increasing by about 1 to 2 millimeter per year [26]). Even without the influence of anthropogenic factors climate may vary from year to year due to natural reasons, such as volcanic eruptions. In the past, the main reason for the change in the ecosystem was considered to be the human intervention, but now the influence of climate change on the ecosystem has been established [27].

CHAPTER 03

Data and Methodology

3.1 Rain Gauge Data

Meteorologists and hydrologists uses rain gauge as common instrument to collect and

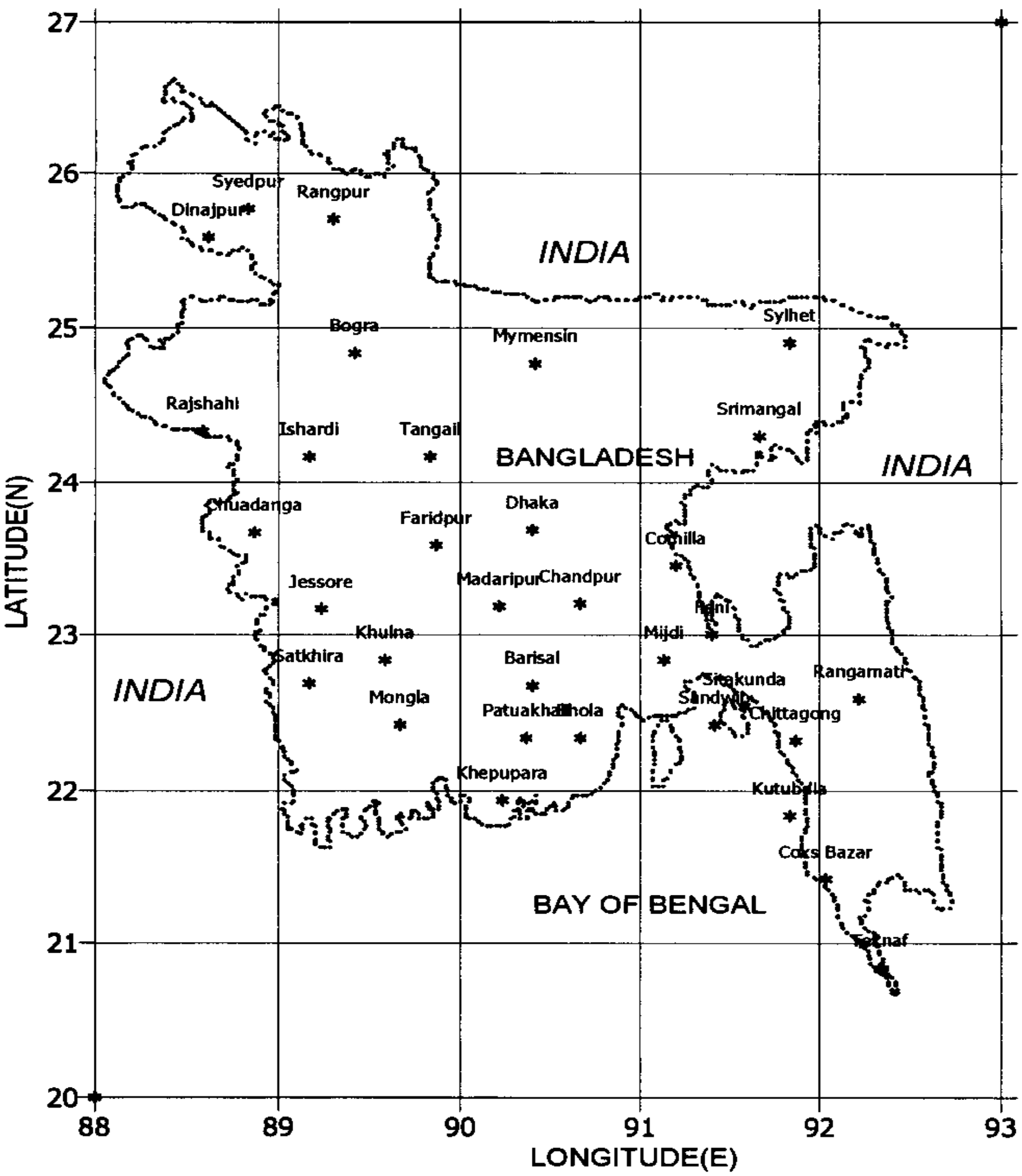


Fig.3.1. Rain gauge stations in Bangladesh

measure the amount of precipitation over a set period of time. Rain gauge generally measure precipitation in millimeters, inches or centimeters. In this study 24 hours rain gauge data is used to analyzed and comparison in order to getting rainy days variations.13 meteorological stations of Bangladesh Meteorological Department (BMD), Comilla, Chittagong, Cox's Bazaar, Khulna, Jessor, Satkhira, Sylhet, Mymensingh, Srimongal, Rangpur, Bogra, Dinajpur and Dhaka from 1950 to 1999 have been used in our study. Data have been collected from Bangladesh Meteorological Department, Agargaon, Dhaka.

3.2 Methods of analysis

Variations of rainy days were calculated for every year for individual station with 50 years rainfall data. Rainy days were calculated using command =COUNTIF(data range,">0") in the Microsoft Excel program. Rainy Days data considered for pre – monsoon, monsoon, post – monsoon, winter and decadal. 12 BMD stations were divided into South – East (SE), South – West (SW), North – East (NE), North – East (NE), North – West (NW). SE stations are, Comilla, Chittagong, and Cox's Bazaar. SW stations are Khulna, Jessor, Satkhira, NE stations are Sylhet, Mymensingh, Srimongal. NW stations are Rangpur, Bogra, Dinajpu.

Variations of SE, SW, NE, NW region calculated by taking average between three stations of every region. The time period divided 1950-1959 as Decade1, 1960 – 1969 as decade2, 1970 – 1979 as Decade3, 1980 – 1989 as decade4 and 1990 – 1999 as decade5 for every station, region and over country .

3.3 Threshold Rainfall

Intensity of rainfall measures by classification it in different ways. There are three threshold rainy days named Moderated Heavy, Heavy and Very Heavy.

3.3.1 Moderated Heavy Rain

This is very important to know which amount of rain comes in a day because of this amount play a role in flood and water management system. Moderated Heavy rain defined as 22 mm < M.Heavy ≤ 44mm. This threshold rainy days were calculated using command =SUMPRODUCT((data range>22)*(data range<45))

3.3.2 Heavy Rain

Rain gauge stations measure rain classified as Heavy when rain in 24 hours as 44mm < Heavy ≤ 88mm. This range of rain comes in generally beginning of monsoon and post-monsoon seasons. Sometimes this comes with Kal-Boishakhi and cyclone. This threshold rainy days were calculated using command =SUMPRODUCT((data range>44)*(data range<89))

3.3.3 Very Heavy Rain

Very Heavy rain defined as, V. Heavy >88 mm rain in 24 hours. This amount of rain comes in generally monsoon season which sometimes causes flood, over flow of rivers, erosion and with some others bad effects in earth. This threshold rainy days were calculated using command =COUNTIF(data range,”>0”).

CHAPTER 04

Results and Discussions

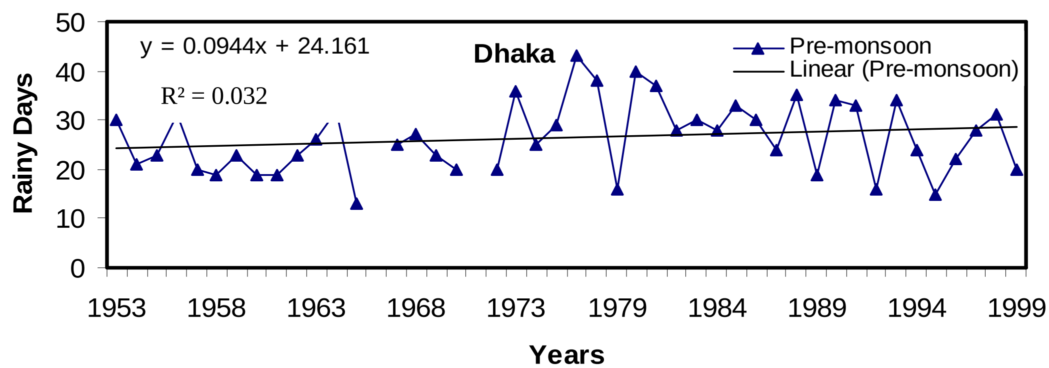
4.1 Seasonal variation of rainy days

Seasonal variations of rainy days for different stations are discussed in this section.

4.1.1 Pre-monsoon

Fig. 4.1(a-b) shows station wise variation of rainy days for pre-monsoon. Dhaka station (Fig.4.1 (a)) shows positive trend of rainy days with maximum value 43 in 1977 and minimum value 13 in 1965. Comilla station (Fig 4.1(b)) shows positive trend of rainy days with maximum value 38 in 1991 and minimum 07 in 1965.

(a



(b)

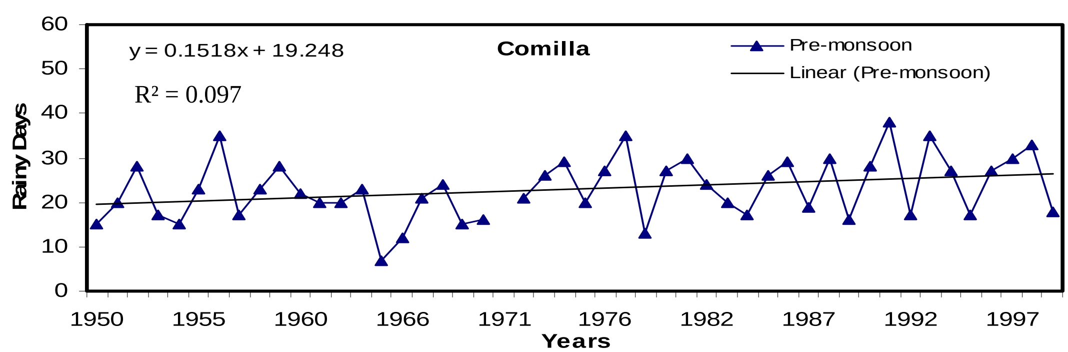
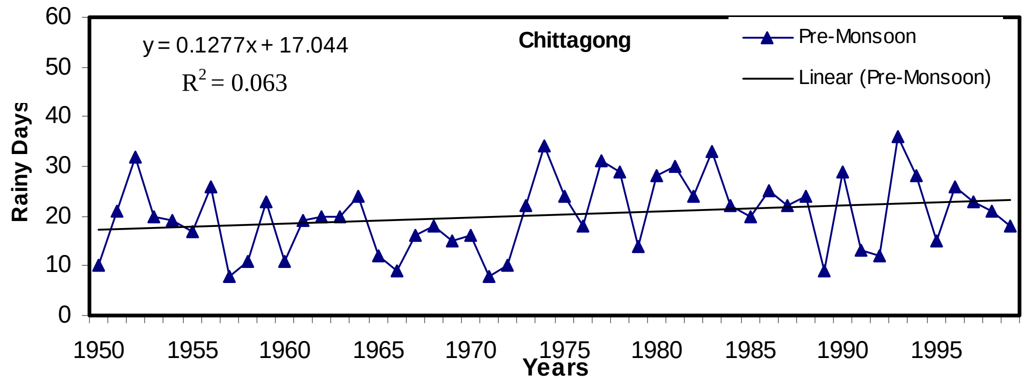


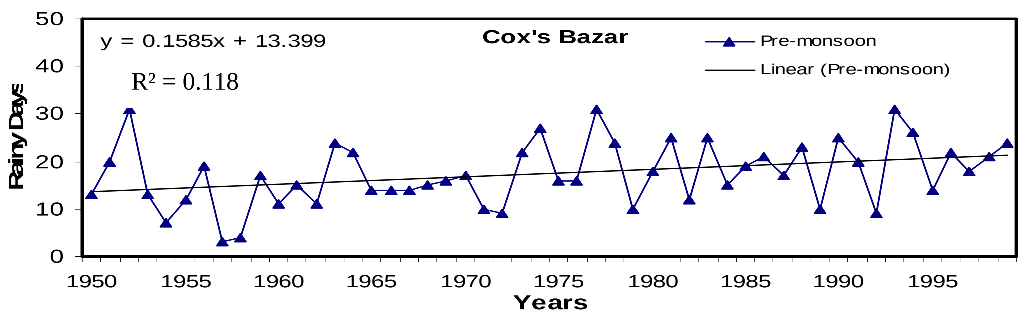
Fig.4.1. Variability of rainy days in pre-monsoon for the stations: (a) Dhaka, (b) Comilla.

Chittagong station (Fig 4.2(a)) shows positive trend of rainy days with maximum value 36 in 1993 and minimum 08 in 1957. Cox's Bazar station (Fig. 4.2(b)) Shows positive trend of rainy days with maximum value 31 in 1952, 1977 and 1993 and minimum 03 in 1957, respectively. Khulna station (Fig. 4.2(c)) also shows positive trend of rainy days with maximum value 38 in 1981 and minimum value 04 in 1968.

(a)



(b)



(c)

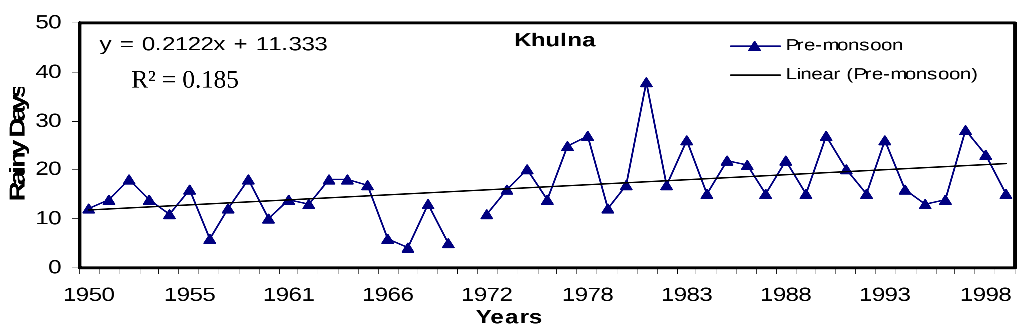
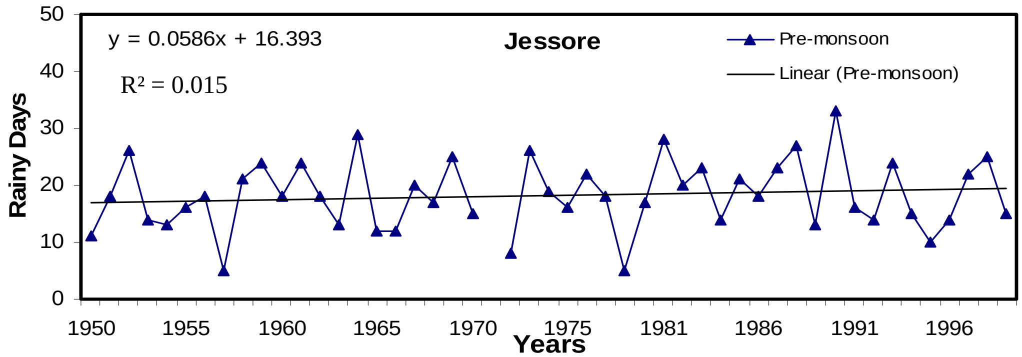


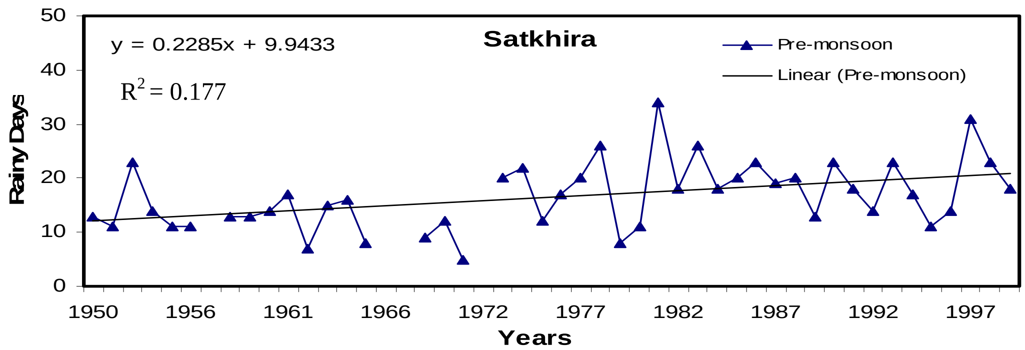
Fig.4.2. Same as fig.4.1 but for stations: (a) Chittagong, (b) Cox's Bazar, (c) Khulna.

Jessore station (Fig. 4.3(a)) shows positive trend of rainy days with maximum value 33 in 1990 and minimum value 05 in 1957 and 1979, respectively. Satkhira station (fig.4.3(b)) also shows positive trend of rainy days with maximum value 34 in 1981 and minimum value 05 in 1971. Sylhet station Fig. 4.3(c) shows positive trend of rainy days with maximum value 54 in 1977 and minimum value 33 in 1979.

(a)



(b)



(c)

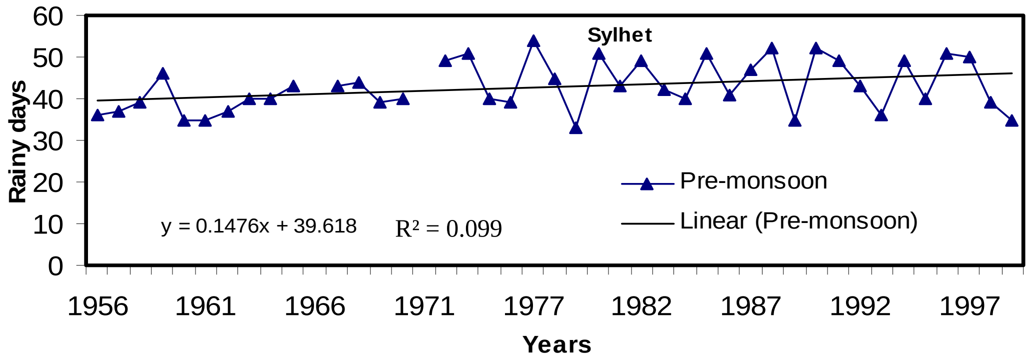
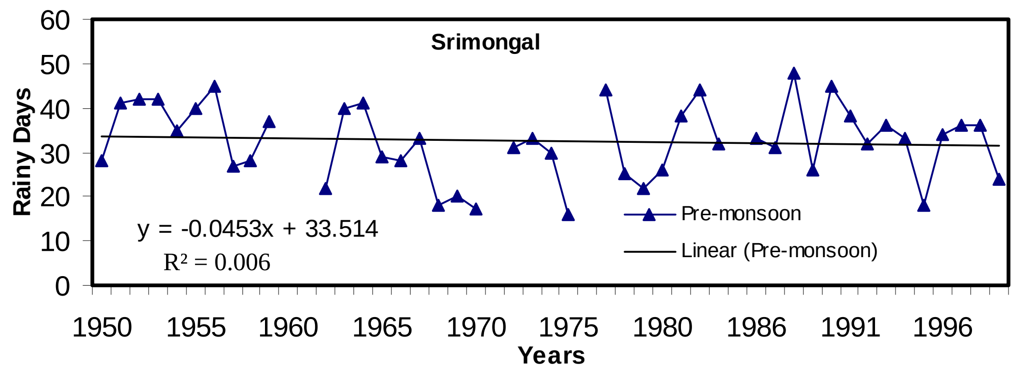


Fig.4.3 Same as fig.4.1 but for stations: (a)Jessore, (b)Satkhira (c) Sylhet.

Mymensing station (Fig. 4.4(a)) also shows positive trend with maximum value 42 in 1990 and minimum value 09 in 1966. Srimongal station (Fig. 4.4(b)) shows negative trend of variation of rainy days with maximum value 48 in 1988 and minimum value 16 in 1975. Fig. 4.4(c) shows variation of rainy days for Rangpur station. This station shows positive trend with maximum value 35 in 1990 and minimum value 07 in 1954.

(a)



(b)

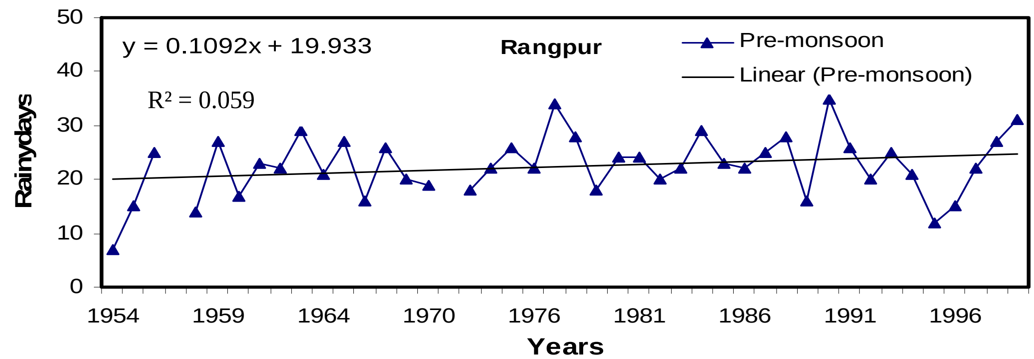
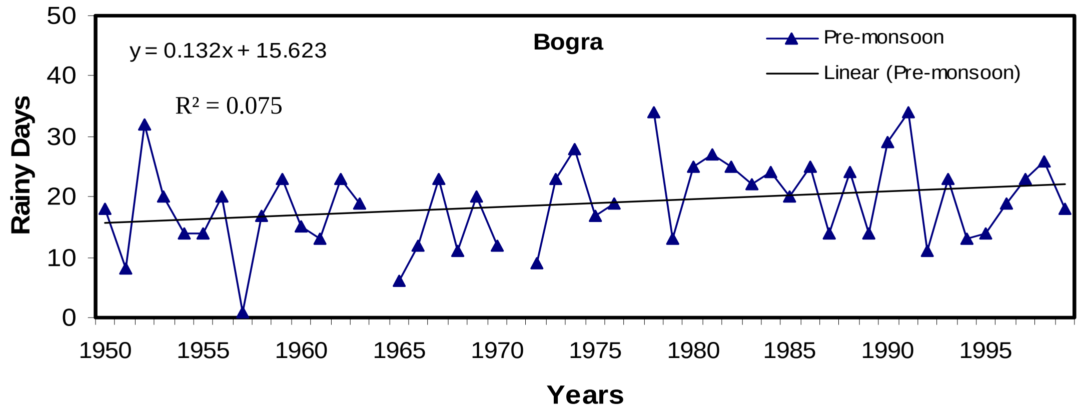


Fig.4.4. Same as fig.4.1 but for: (a) Mymensing, (b) Srimongal, (c) Rangpur.

Bogra station (Fig. 4.5(a)) shows positive trend with maximum value 34 in 1978 and minimum value 01 in 1957. Dinajpur station (Fig. 4.5(b)) also shows positive trend with maximum value 30 in 1990 and minimum value 00 in 1951.

All the stations shows increasing trend of rainy days except Srimongal during pre-monsoon period in Bangladesh. The highest positive trend of value 0.2455 is observed for the station of Dinajpur and lowest is 0.0586 for Jessore station. The negative trend of rainy days of value -0.0453 is observed for the station of Srimongal during pre-monsoon period in Bangladesh.

(a)



(b)

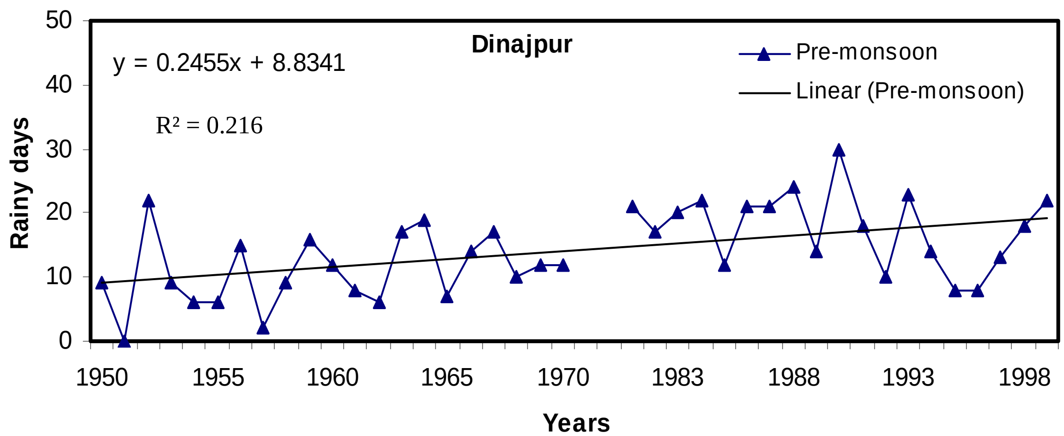
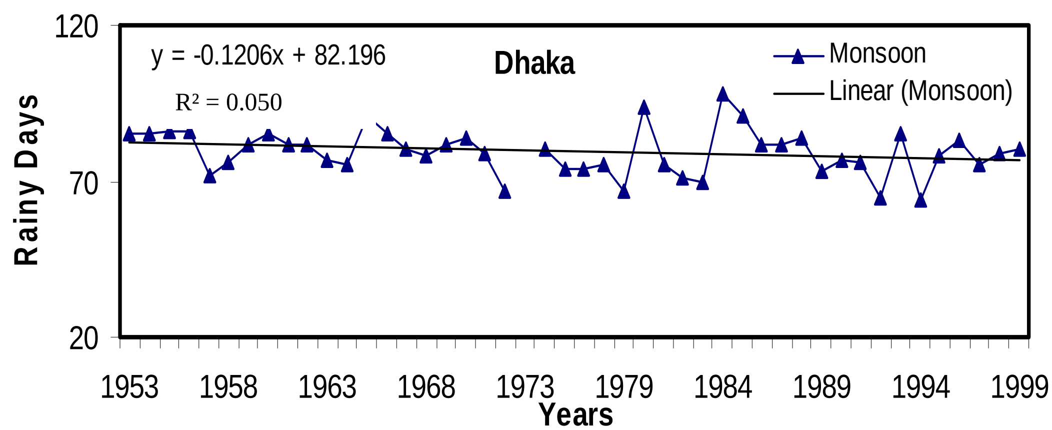


Fig.4.5. Same as fig.4.1 but for stations. (a) Bogra, (b) Dinajpur.

4.1.2 Monsoon

Fig. 4.6 (a-b) shows station wise variation of rainy days for monsoon in different rain gauge stations. Dhaka station (Fig.4.6 (a)) shows negative trend of rainy days with maximum value 98 in 1984 and minimum value 64 in 1994. Comilla station (Fig 4.6 (b)) shows positive trend of rainy days with maximum value 90 in 1955 and minimum value 36 in 1970.

(a)



(b)

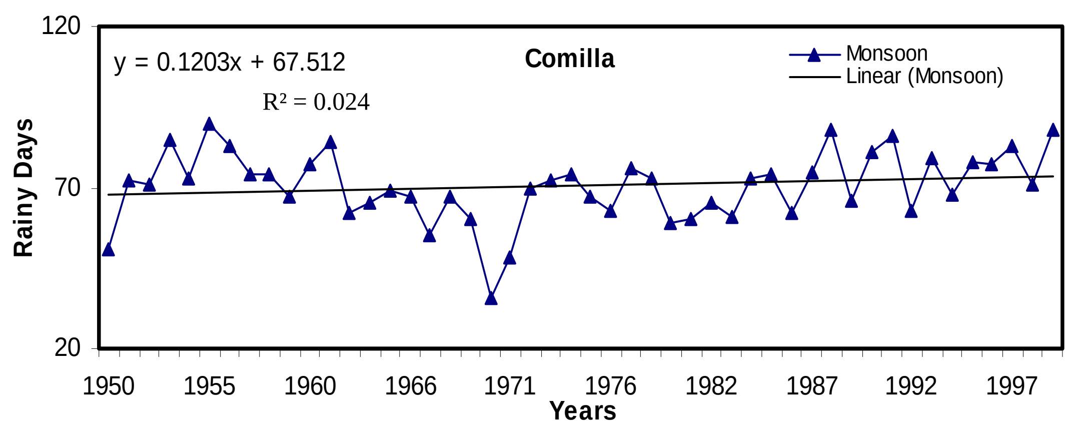
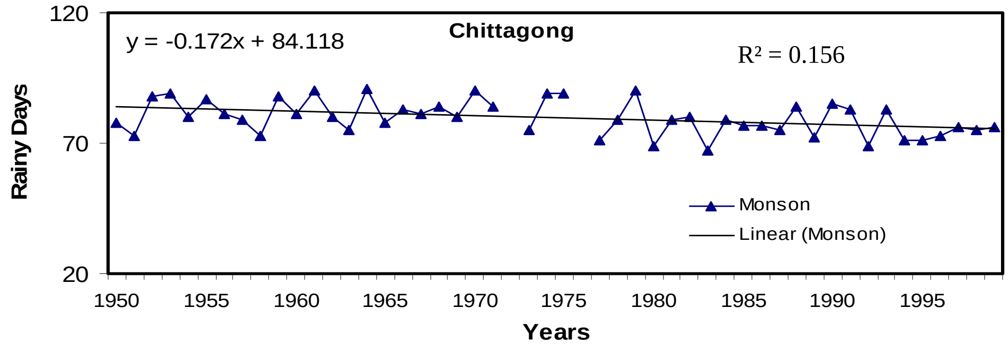


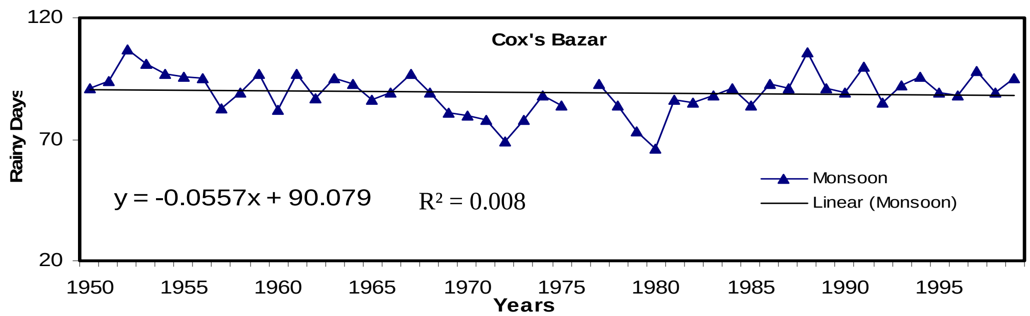
Fig.4.6. Variability of rainy days in monsoon for the stations: (a) Dhaka, (b) Comilla.

Chittagong station (Fig 4.7 (a)) shows negative trend of rainy days with maximum value 91 in 1964 and minimum value 67 in 1983. Cox's Bazar station (Fig. 4.7 (b)) Shows negative trend of rainy days with maximum value 107 in 1952 and minimum value 66 in 1980. Khulna station (Fig. 4.7 (c)) shows positive trend of rainy days with maximum value 90 in 1984 and minimum value 28 in 1973.

(a)



(b)



(c)

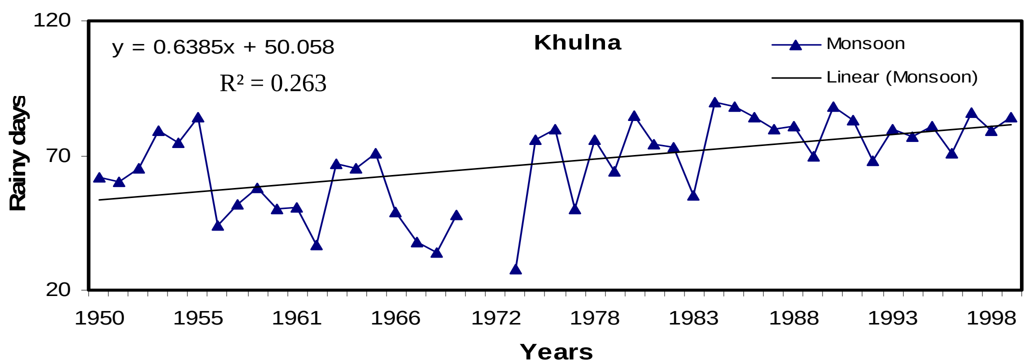
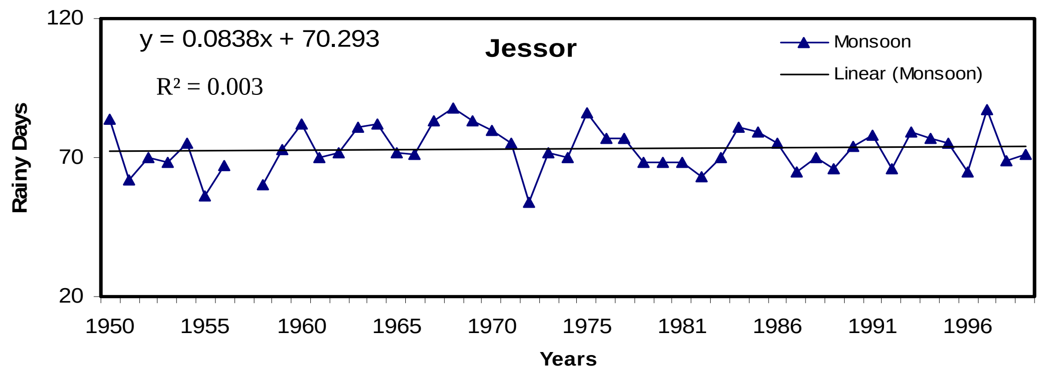


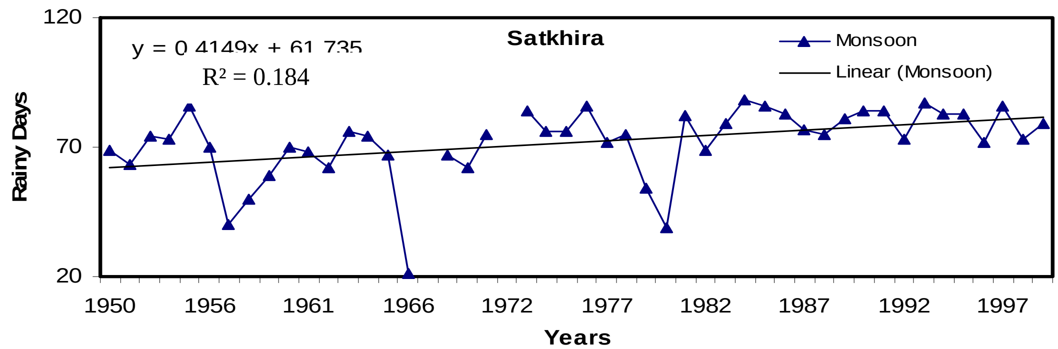
Fig.4.7. Same as fig.4.6 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Jessore station (Fig.4.8 (a)) Shows positive trend of rainy days with maximum value 88 in 1968 and minimum value 54 in 1972. Satkhira station (Fig.4.8 (b)) shows positive trend with maximum value 88 in 1984 and minimum value 21 in 1966. Sylhet station (Fig.4.8 (c)) Shows also positive trend with maximum value 108 in 1968, 1983 and 1989 where minimum value 80 in 1972 and 1978 respectively.

(a)



(b)



(c)

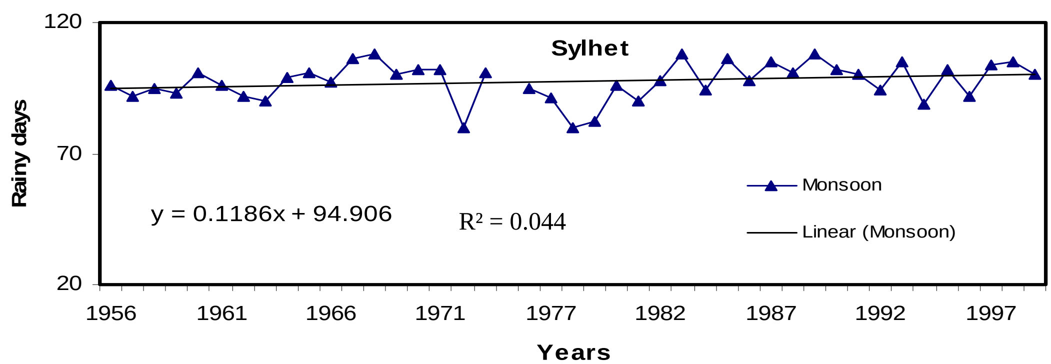
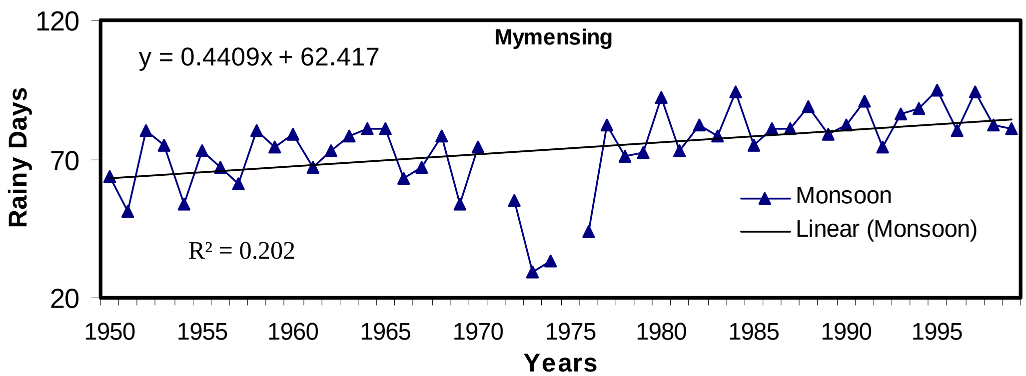


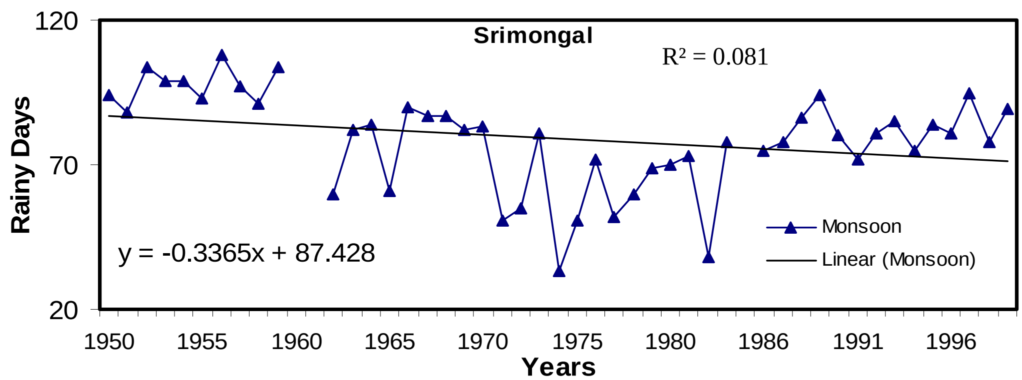
Fig.4.8. Same as fig. 4.6 but for stations: (a) Jessore, (b) Satkhira,(c) Sylhet.

Mymensing station (Fig.4.9 (a)) Shows positive trend of rainy days having maximum value 95 in 1995 and minimum value 29 in 1973. Srimongal shows (Fig.4.9 (b)) negative trend with maximum value 108 in 1956 and minimum value 33 in 1974. Rangpur station (Fig.4.9 (c)) Shows negative trend with maximum value 89 in 1987 and minimum value 53 in 1972.

(a)



(b)



(c)

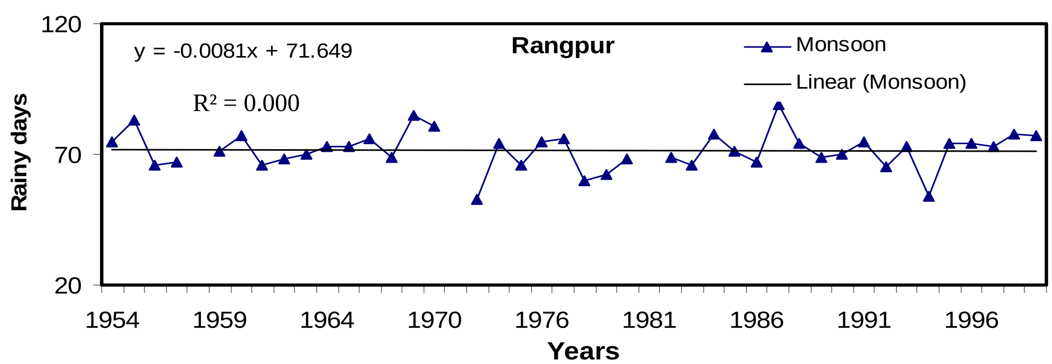
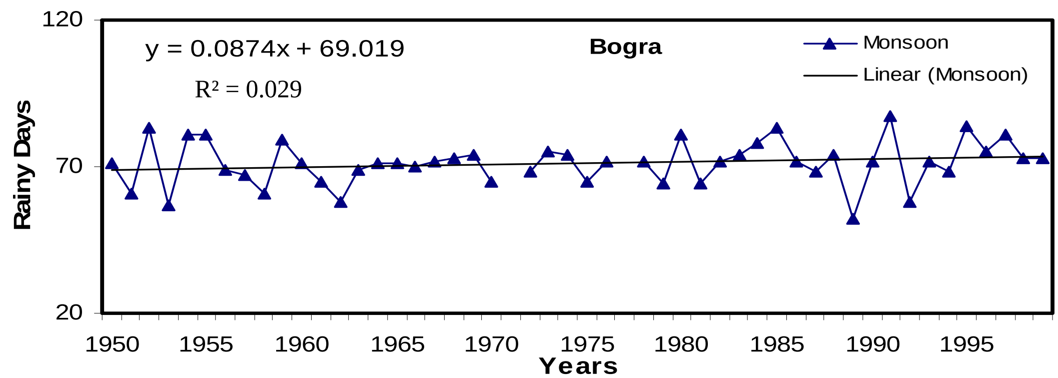


Fig.4.9. Same as fig. 4.6 but for stations: (a) Mymensing, (b) Srimongal, (c) Rangpur.

Bogra station (Fig.4.10 (a)) Shows positive trend with maximum value 87 in 1991 and minimum value 52 in 1989. Dinajpur station (Fig.4.10 (b)) shows positive trend with maximum value 89 in 1987 and minimum value 44 in 1961.

All the stations shows increasing trend of rainy days except Dkaka, Chittagong, Cox's Bazar, Srimongal and Rangpur, during monsoon period in Bangladesh. The highest positive trend of value 0.6385 is observed for the station of Khulna and lowest is 0.0838 for Jessore station. The negative trend of rainy days of value -0.3365 is observed for the station Srimongal and -0.0081 for Rangpur station during monsoon period in Bangladesh.

(a)



(b)

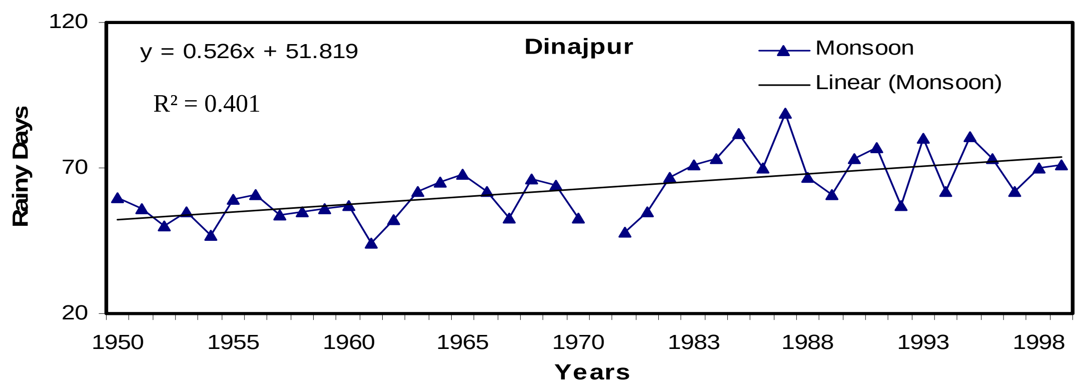
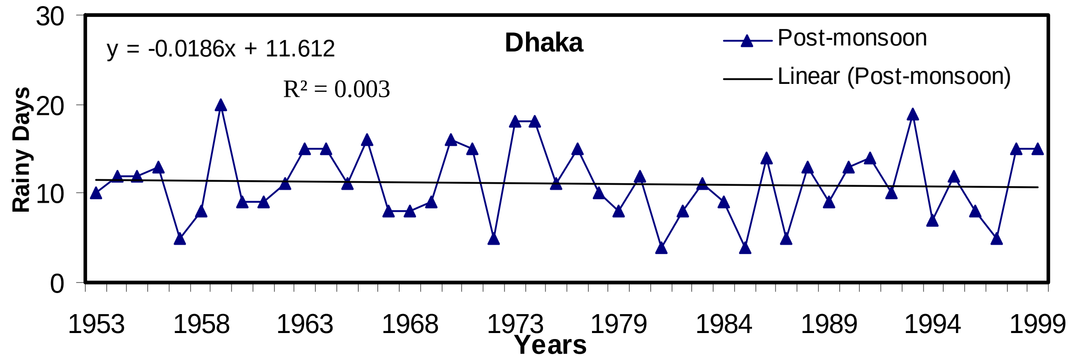


Fig.4.10. Same as fig. 4.6 but for stations: (a) Bogra, (b) Dinajpur.

4.1.3 Post-monsoon

Fig.4.11 (a-b) shows station wise variation of rainy days for post-monsoon season in different rain gauge stations. Dhaka station (Fig.4.11 (a)) shows negative trend of rainy days with maximum value 20 in 1959 and minimum value 4 in 1981, 1985 respectively. Comilla station (Fig.4.11 (b)) shows positive trend of rainy days with maximum value 18 in 1973 and minimum value 00 in 1981.

(a)



(b)

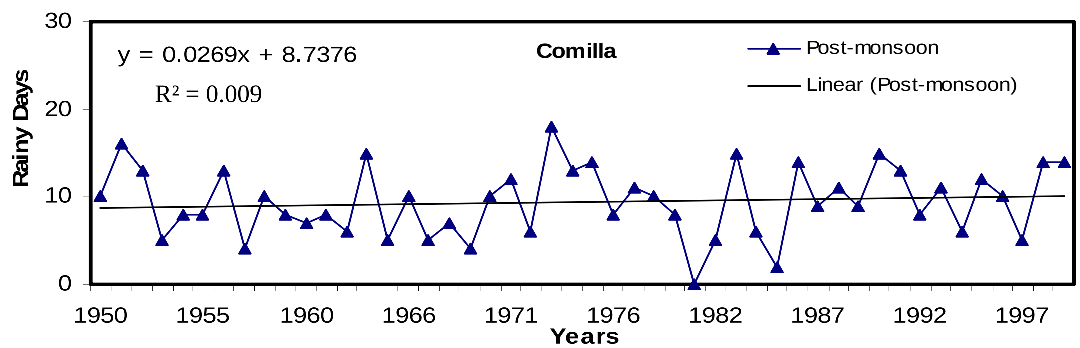
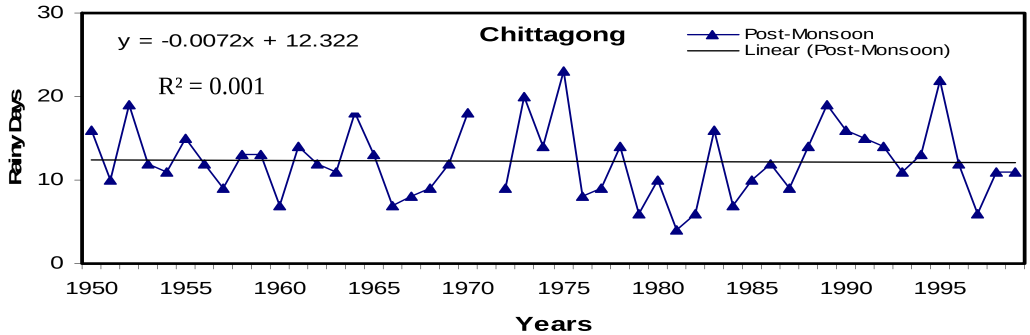


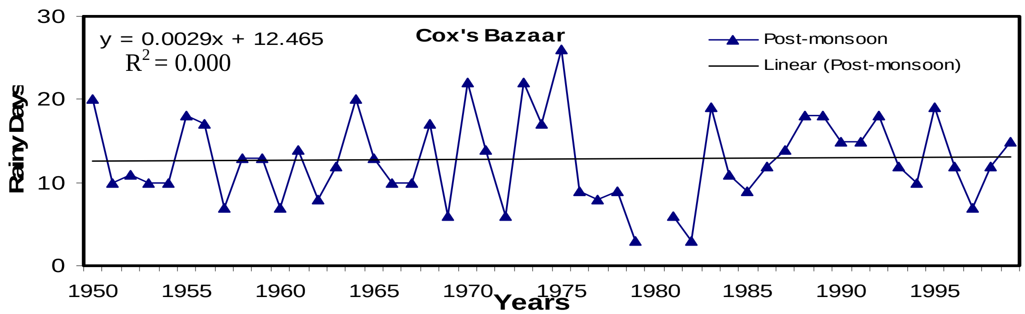
Fig.4.11. Variability of rainy days in post- monsoon for the stations: (a) Dhaka, (b) Comilla.

Chittagong station (Fig.4.12(a)) shows negative trend of rainy days with maximum value 23 in 1975 and minimum value 04 in 1981. Cox's Bazar station (Fig.4.12 (b)) shows positive trend of rainy days with maximum value 26 in 1975 and minimum value 03 in 1979 and 1982 respectively. Khulna station (Fig.4.12 (c)) shows also positive trend of rainy days with maximum value 20 in 1999 and minimum value 00 in 1973.

(a)



(b)



(c)

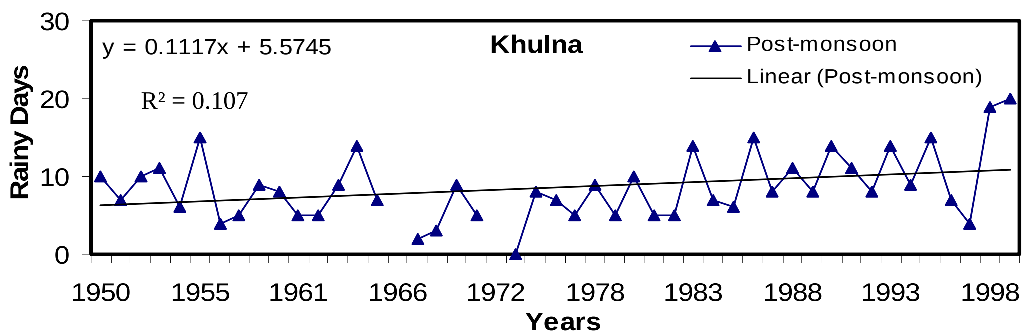
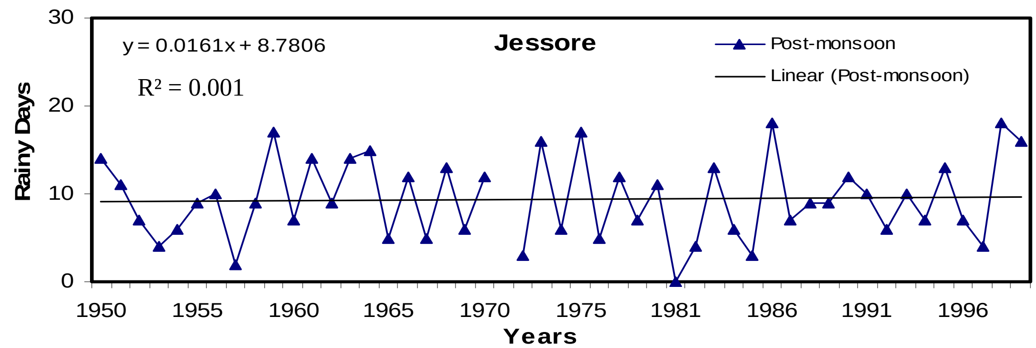


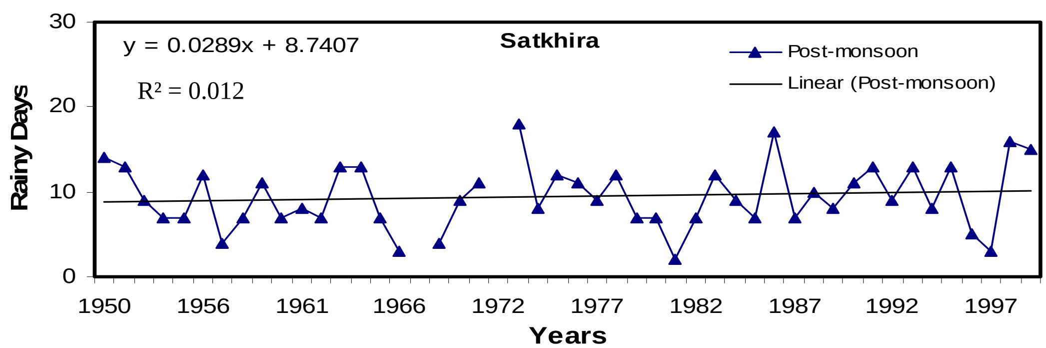
Fig.4.12. Same as fig. 4.11 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Jessore station (Fig. 4.13(a)) shows a positive trend of rainy days with maximum value 18 in 1986, 1998 and minimum value 00 in 1981 respectively. Satkhira station (Fig.4.13 (b)) shows increasing tendency of rainy days with maximum value 18 in 1973 and minimum value 02 in 1981. Sylhet station (Fig.4.13 (c)) also shows positive trend of rainy days with maximum value 18 in 1959, 1971, 1995 and minimum value 04 in 1981, 1982 respectively.

(a)



(b)



(c)

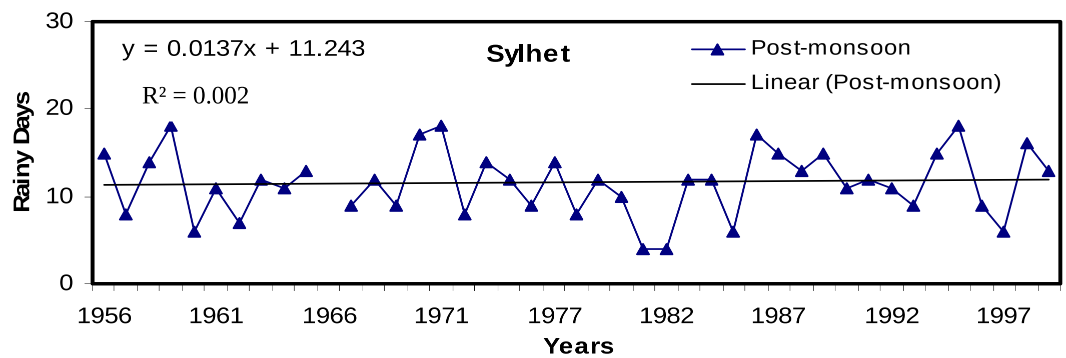
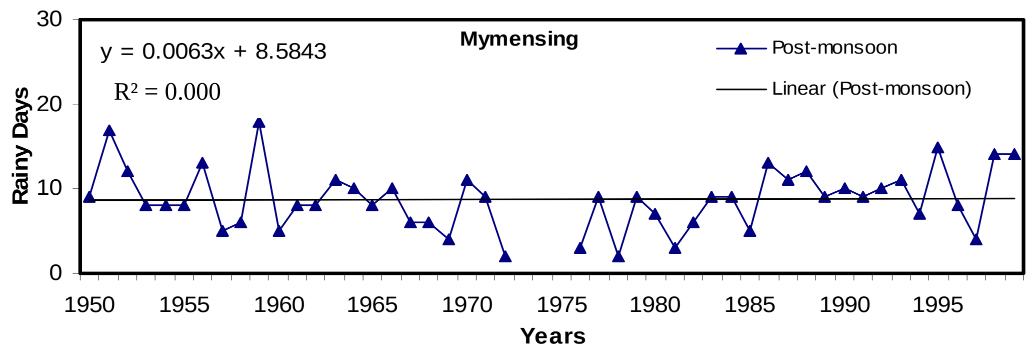


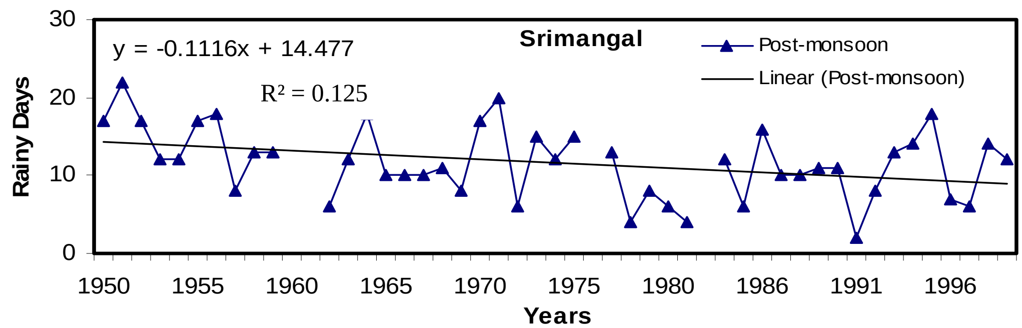
Fig.4.13. Same as fig. 4.11 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Mymensing station (Fig.4.14 (a)) shows positive trend of rainy days with maximum value 18 in 1959 and minimum value 2 in 1972, 1978 respectively. Srimongal station (Fig.4.14 (b)) shows negative trend of rainy days with maximum value 22 in 1951 and minimum value 02 in 1991. Rangpur station (Fig.4.14 (c)) shows positive trend of rainy days with maximum value 17 in 1986 and minimum value 04 in 1955, 1957, 1978, 1982, 1997 respectively.

(a)



(b)



(c)

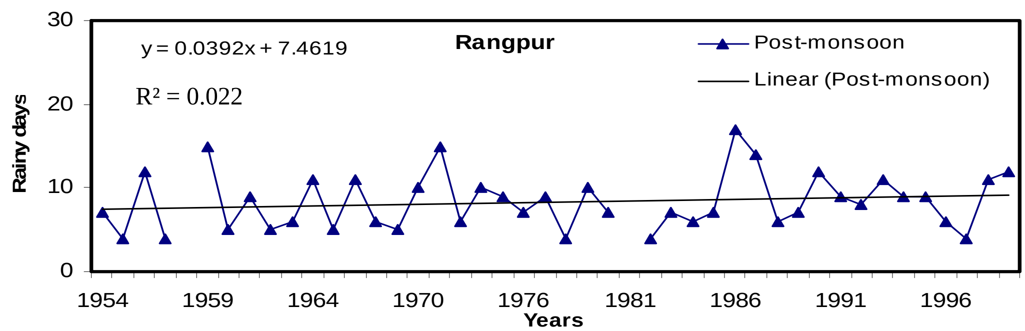
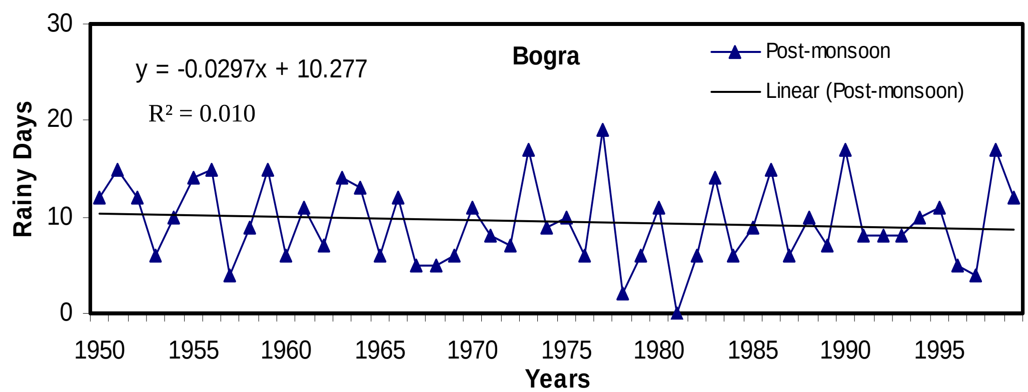


Fig.4.14. Same as fig. 4.11 but for stations:(a) Mymensing, (b) Srimongal, (c) Rangpur.

Bogra station (Fig.4.15 (a)) shows negative trend of rainy days with maximum value 19 in 1977 and minimum value 00 in 1981. Dinajpur station (Fig.4.15 (b)) shows positive trend of rainy days with maximum value 12 in 1990 and minimum value 00 in 1950.

Dkaka, Chittagong, Srimongal and Bogra stations show negative trend of rainy days. All other stations show positive trend during post-monsoon period. The highest positive trend of value 0.1117 is observed for the station of Khulna and lowest is 0.0029 for Cox's Bazar station. The negative trend of rainy days of value -0.1116 is observed for the station Srimongal and -0.0072 for Chittagong station during post-monsoon period in Bangladesh.

(a)



(b)

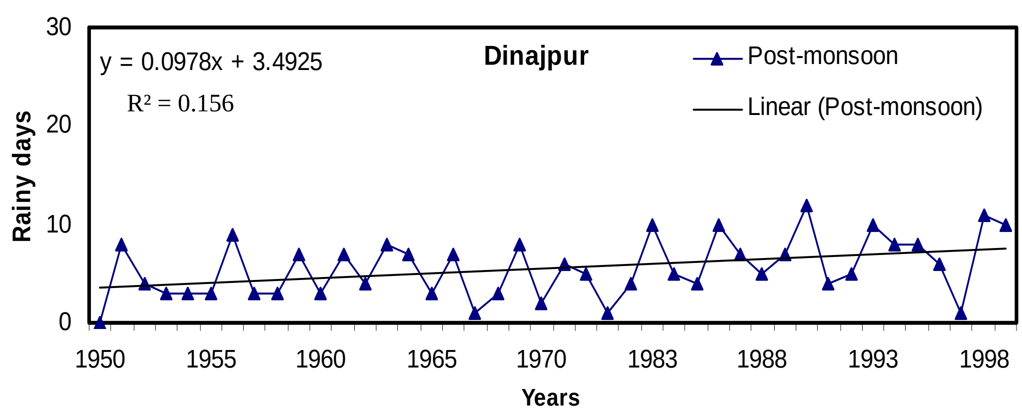
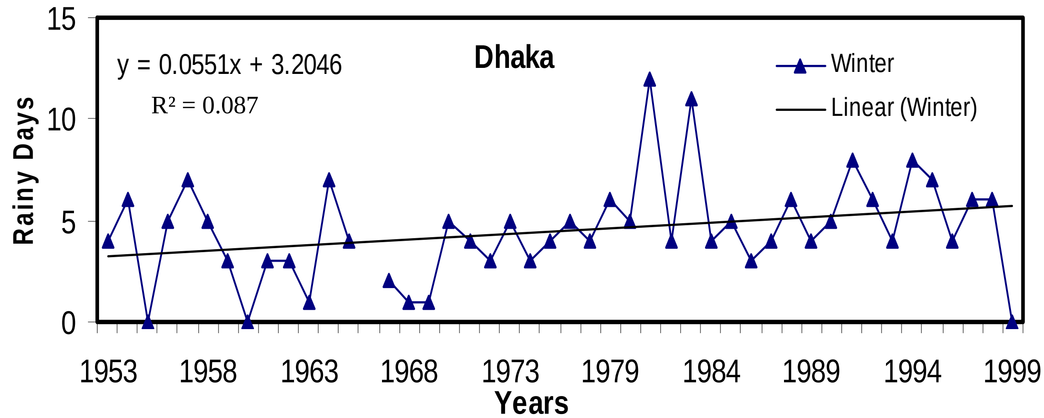


Fig.4.15. Same as fig. 4.11 but for stations: (a) Bogra, (b) Dinajpur.

4.1.4 Winter

Fig.4.16 (a-b) shows station wise variation of rainy days for winter season in different BMD rain gauge stations. Fig.4.16 (a) shows positive trend of rainy days with maximum value 12 in 1981 and minimum value 00 in 1955, 1960, and 1999 respectively for Dhaka station. Comilla station (Fig.4.16 (b)) shows positive trend of rainy days in winter with maximum value 10 in 1997 and minimum value 00 in 1951, 1955, 1960, 1967, 1972, 1974, and 1999 respectively.

(a)



(b)

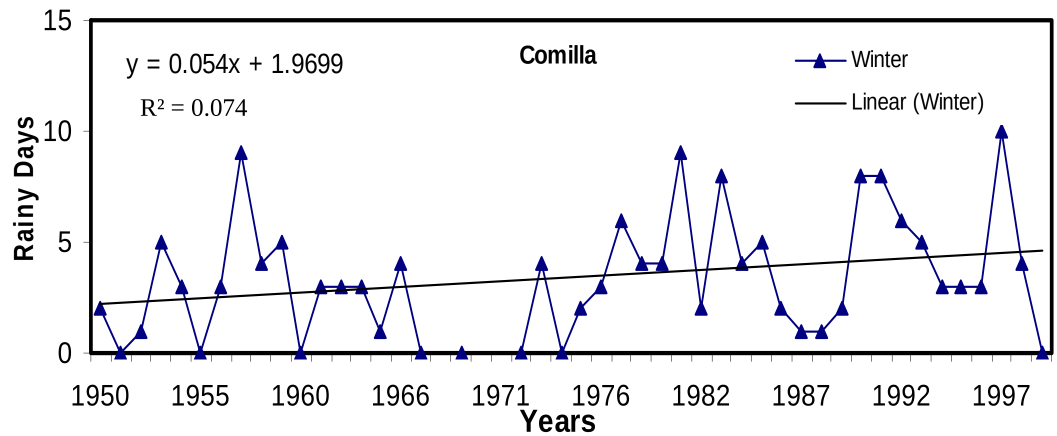
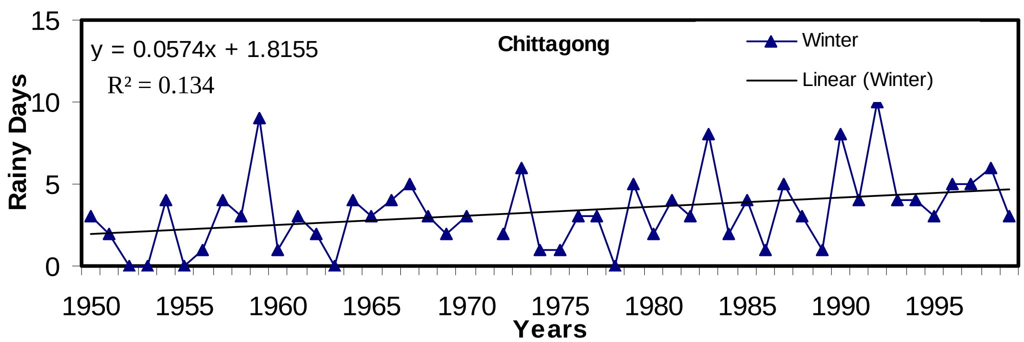


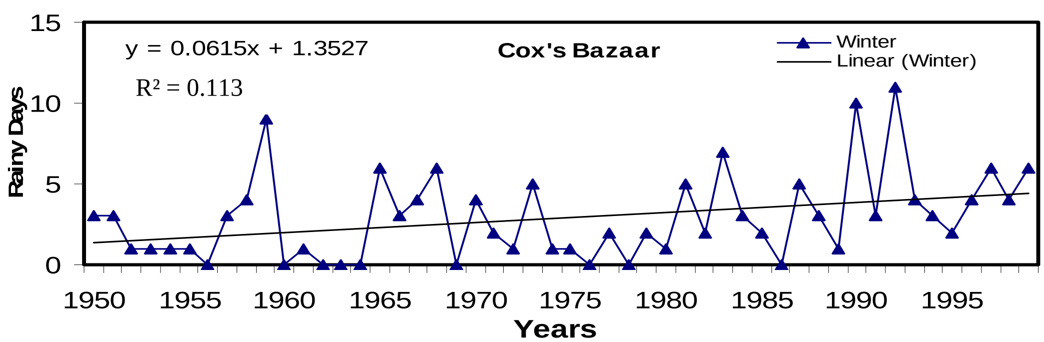
Fig.4.16. Variability of rainy days in winter for the stations: (a) Dhaka, (b) Comilla.

Chittagong station (Fig.4.17 (a)) shows positive trend of rainy days with maximum value 10 in 1992 and minimum value 00 in 1952, 1953, 1955, 1963 and 1978 respectively. Fig.4.17 (b) shows positive trend of rainy days in winter for Cox's bazaar station with maximum value 11 in 1992 and minimum value 00 in 1956, 1960, 1962, 1963, 1964, 1969 and 1978 respectively. Khulna station (Fig.4.17 (c)) shows positive trend of rainy days with maximum value 11 in 1992 and minimum value 00 in 1951, 1954, 1955, 1958, 1960, 1962, 1963, 1972 and 1999 respectively.

(a)



(b)



(c)

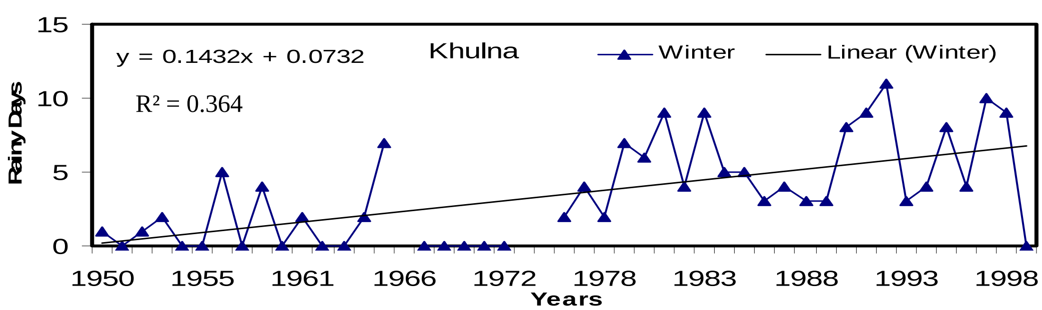
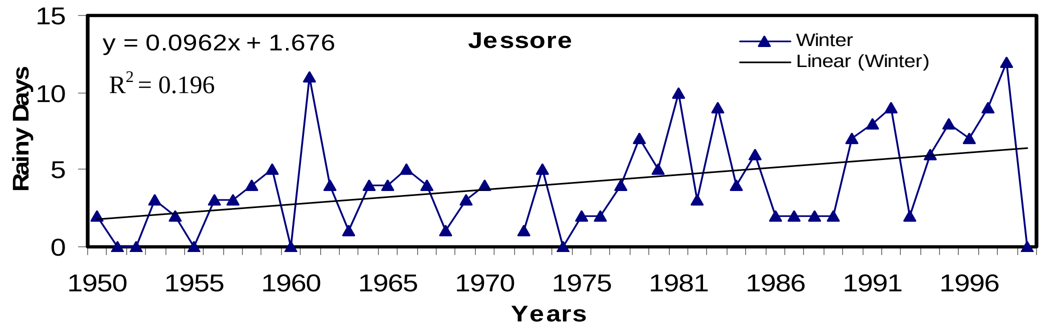


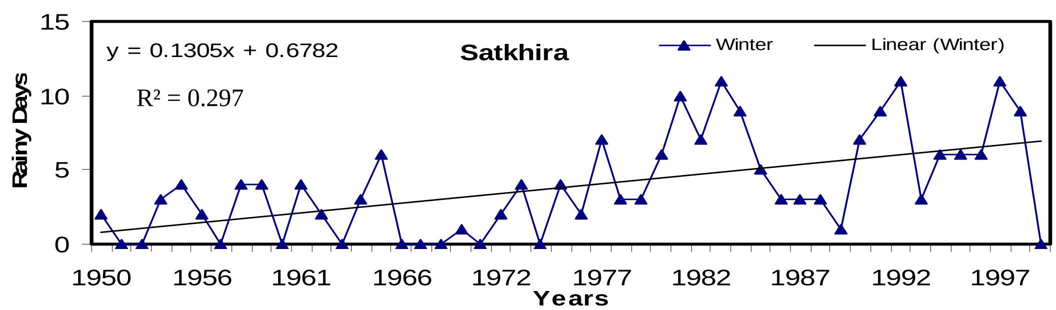
Fig.4.17. Same as fig. 4.16 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Fig.4.18 (a) shows positive trend of rainy days for Jessore station with maximum value 12 in 1998 and minimum value 00 in 1951, 1952, 1955, 1960, 1974, and 1999 respectively. Satkhira station (Fig.4.18 (b)) shows increasing trend of rainy days with maximum value 11 in 1983, 1992, 1997 and minimum value 00 in 1951, 1952, 1957, 1960, 1963, 1969 and 1999 respectively. Sylhet station (Fig.4.18 (c)) shows positive trend of rainy days with maximum value 18 in 1959, 1971, 1995 and minimum value 04 in 1981 and 1982 respectively.

(a)



(b)



(c)

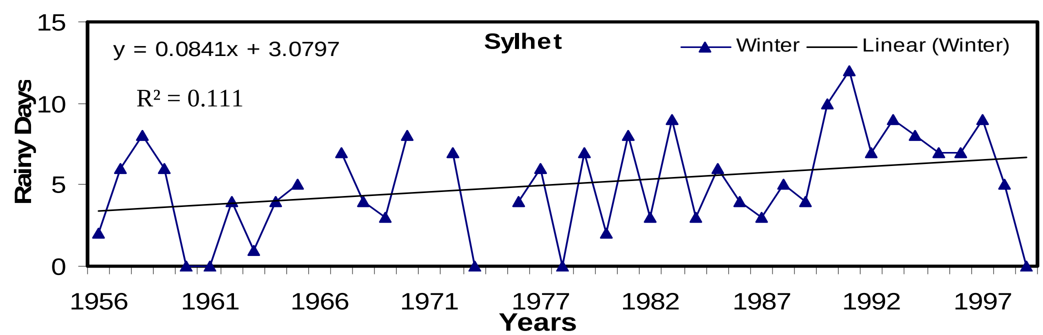
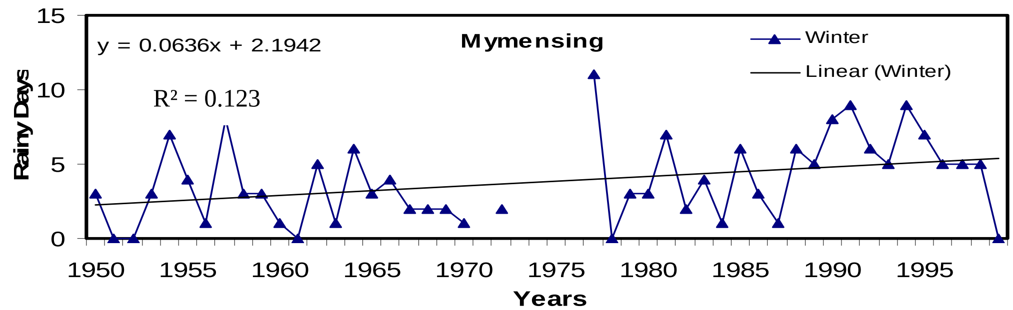


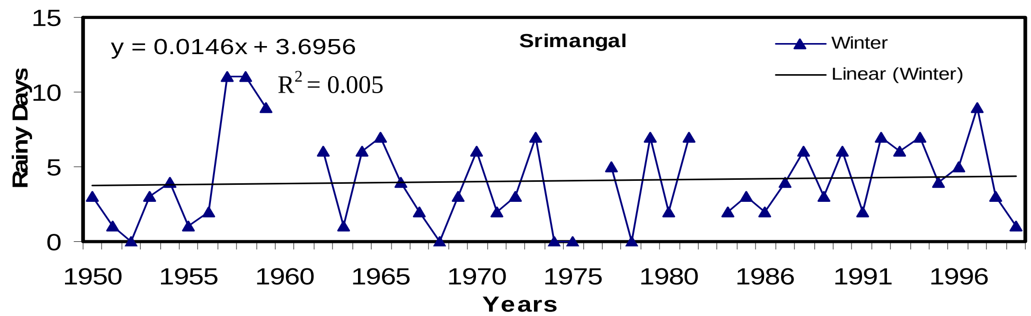
Fig.4.18. Same as fig. 4.16 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Mymensing station (Fig.4.19 (a)) shows positive trend equation of rainy days with maximum value 18 in 1959 and minimum value 02 in 1972 and 1978 respectively. Srimongal station (Fig.4.19 (b)) shows positive trend of rainy days with maximum value 11 in 1957, 1958 and minimum value 00 in 1952, 1968, 1974 and 1978 respectively. Fig.4.19 (c) shows positive trend of rainy days for Rangpur station with maximum value 08 in 1955, 1973, 1997 and minimum value 00 in 1957, 1960, 1963, 1976, 1978 and 1999 respectively.

(a)



(b)



(c)

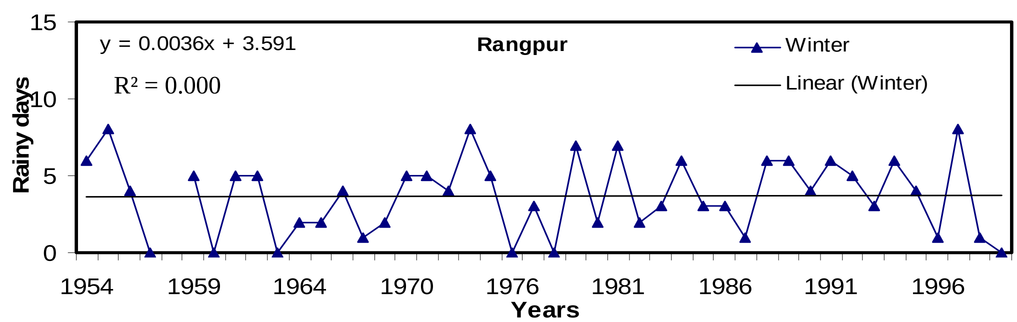
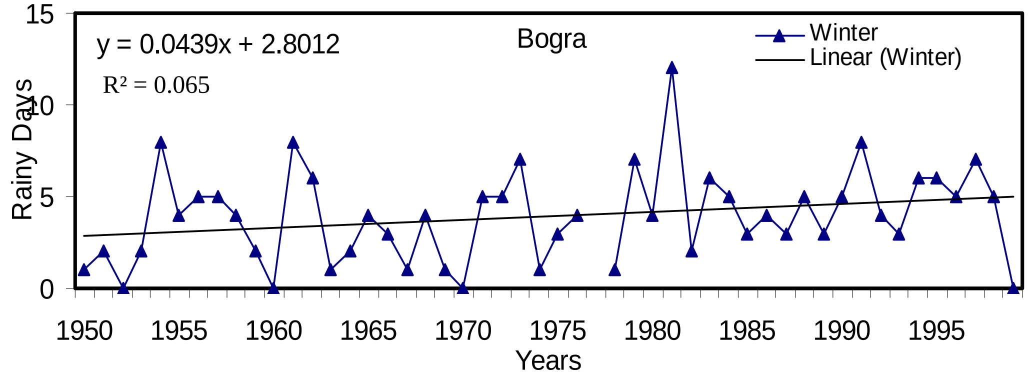


Fig.4.19. Same as fig. 4.16 but for stations:(a) Mymensing, (b) Srimongal. (c) Rangpur.

Fig. 4.20 (a) shows positive trend of rainy days in winter for Bogra station with maximum value 12 in 1981 and minimum value 00 in 1952, 1960, 1970 and 1999 respectively. Dinajpur station (Fig.4.20 (b)) also shows positive trend with maximum value 10 in 1991 and minimum value 00 in 1950, 1951, 1952 and 1999 respectively.

All stations show positive trend of rainy days during winter season. The highest positive trend of value 0.1432 is observed for the station of Khulna and lowest is 0.0036 for Rangpur station.

(a)



(b)

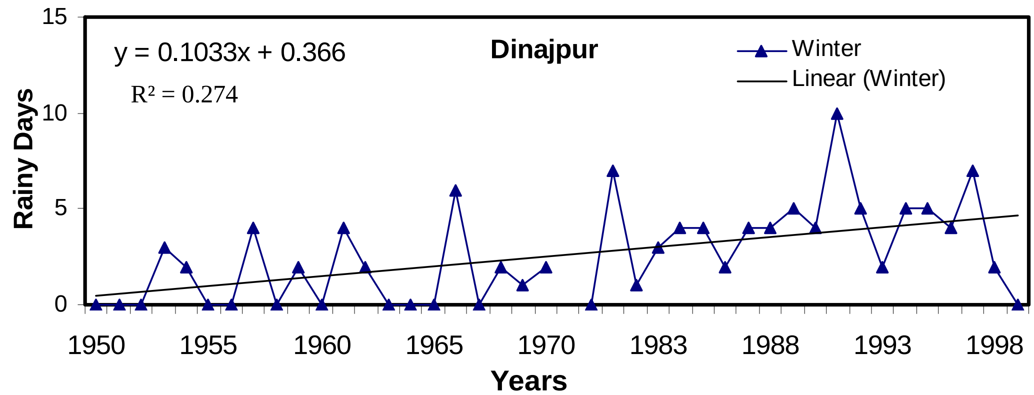


Fig.4.20. Same as fig. 4.16 but for stations: (a) Bogra, (b) Dinajpur.

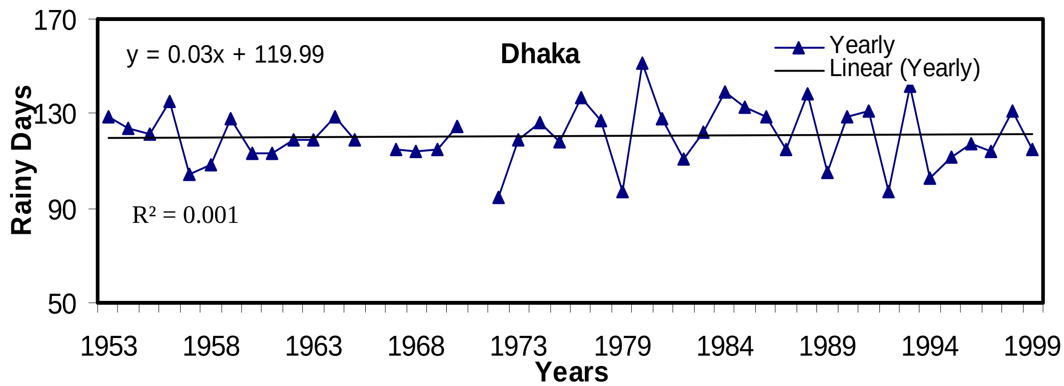
4.2 Yearly variation of rainy days

Yearly variation of rainy days for different rain gauge stations during the period from 1950 to 1999 is discussed in this sub-section.

Fig.4.21 (a-b) shows yearly variation of rainy days of different rain gauge stations in Bangladesh.

Dhaka station (Fig.4.21 (a)) shows positive trend of rainy days with maximum value 1951 in 1980 and minimum value 95 in 1972. Comilla station (Fig.4.21 (b)) shows positive trend of yearly variation of rainy days with maximum value 145 in 1991 and minimum 78 in 1950.

(a)



(b)

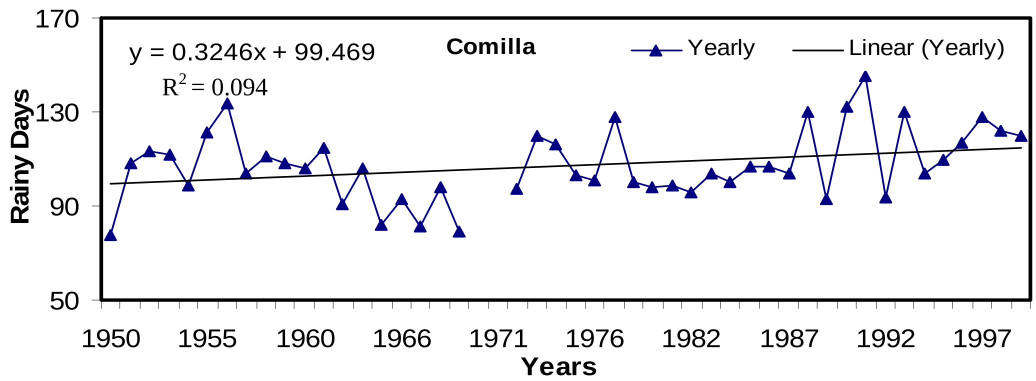
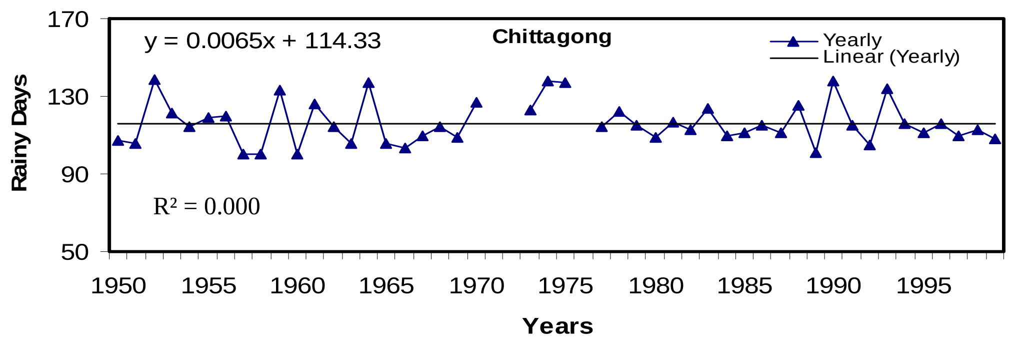


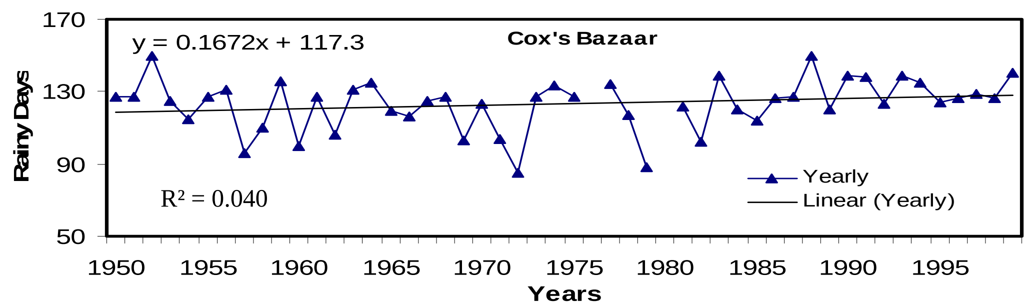
Fig.4.21. Yearly variation of rainy days for the selected stations: (a) Dhaka, (b) Comilla.

Chittagong station (Fig.4.22 (a)) Shows positive trend of rainy days in yearly variation with maximum value 139 in 1952 and minimum value 100 in 1960. Cox's Bazar station (Fig. 4.22 (b)) shows positive trend of rainy days with maximum value 150 in 1952 and minimum value 85 in 1972. Fig. 4.22(c) also shows positive trend of rainy days for Khulna station with maximum value 137 in 1990 and minimum value 50 in 1969.

(a)



(b)



(c)

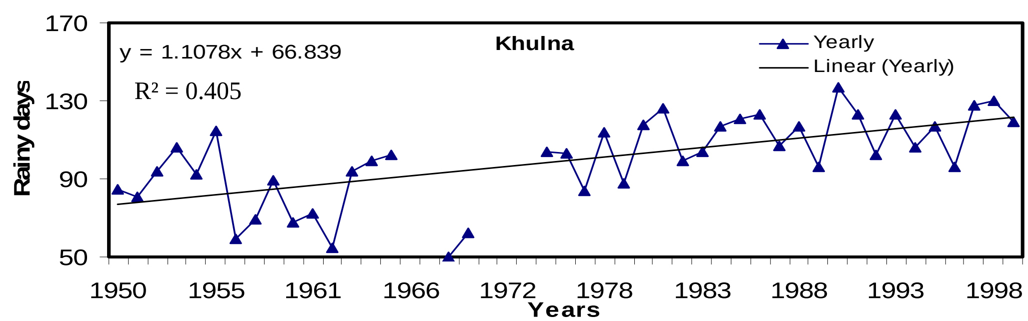
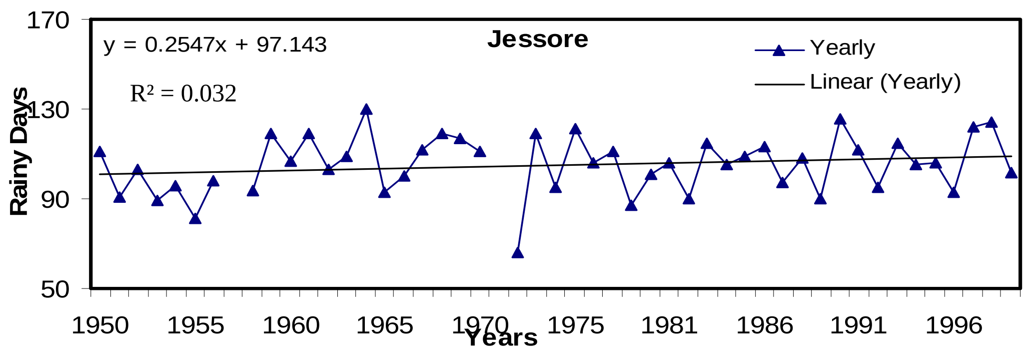


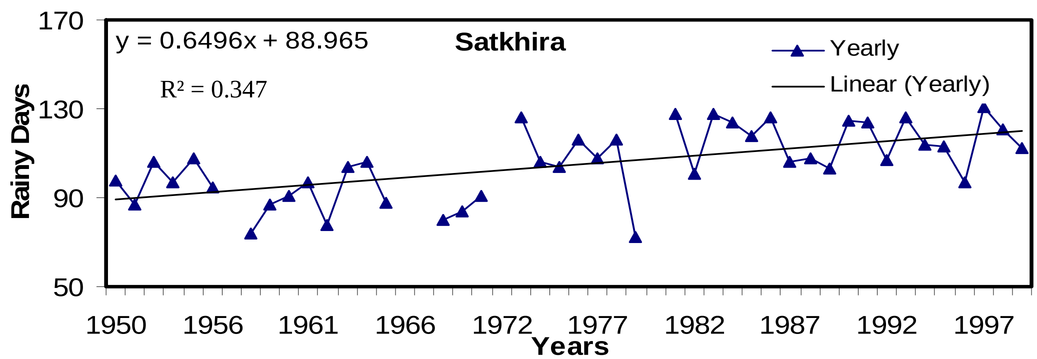
Fig.4.22.Same as fig. 4.21 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Fig. 4.23 (a) shows positive trend of rainy days for Jessore station with maximum value 130 in 1964 and minimum value 66 in 1972. Satkhira station (Fig.4.23 (b)) shows positive trend of rainy days with maximum value 131 in 1997 and minimum value 72 in 1979. Fig. 4.23 (c) shows positive trend of rainy days for Sylhet station with maximum value 175 in 1990 and minimum value 131 in 1975.

(a)



(b)



(c)

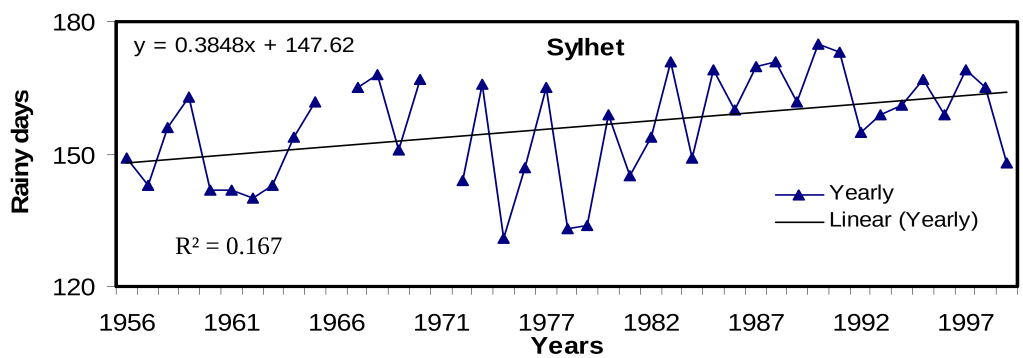
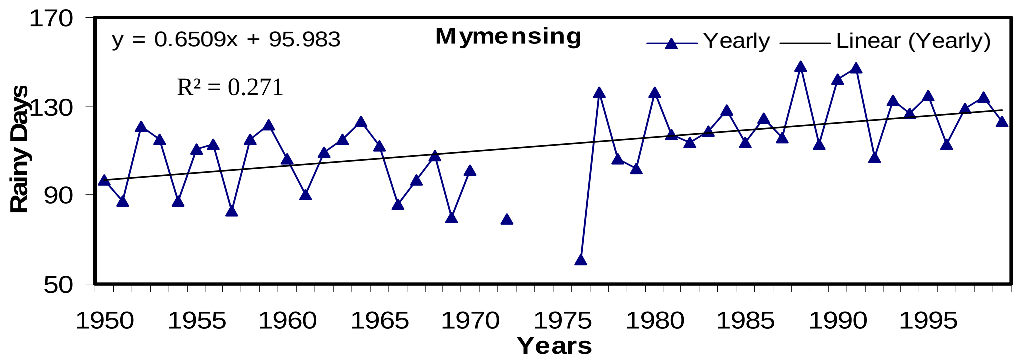


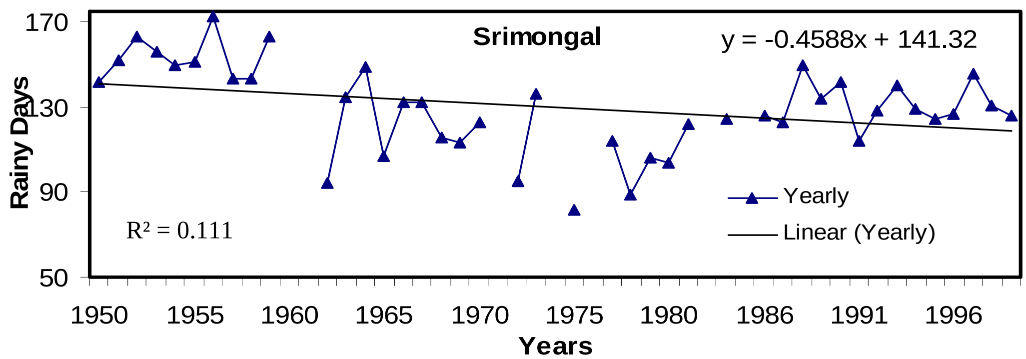
Fig.4.23. Same as fig. 4.21 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Mymensing station (Fig.4.24 (a)) shows positive trend of rainy days in yearly variation with maximum value 148 in 1988 and minimum value 61 in 1976. Fig. 4.24 (b) shows negative trend of rainy days for Srimongal station with maximum value 173 in 1956 and minimum value 82 in 1975. Fig. 4.24 (c) shows positive trend for Rangpur station with maximum value 129 in 1987 and minimum value 81 in 1972.

(a)



(b)



(c)

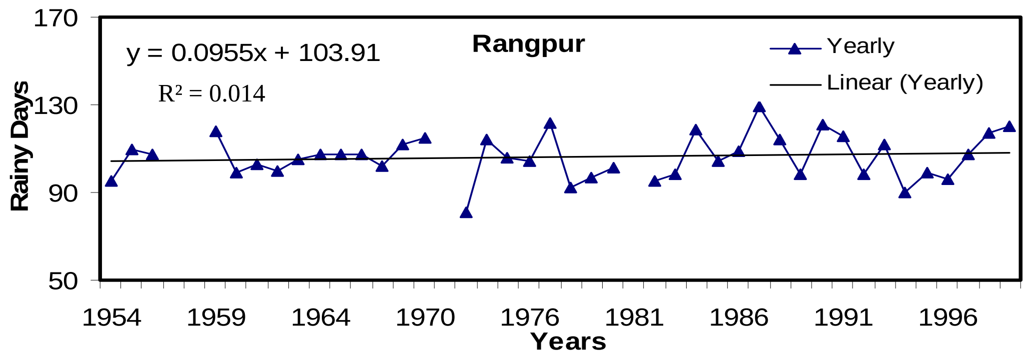
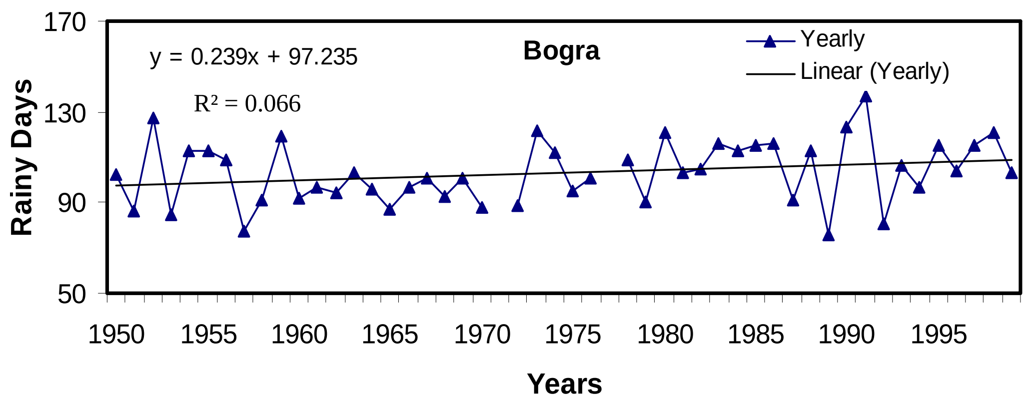


Fig.4.24. Same as fig. 4.21 but for stations: (a) Mymensing, (b) Srimongal. (c) Rangpur.

Fig. 4.25(a) shows positive trend yearly rainy days variation for Bogra station, with maximum value 137 in 1991 and minimum value 76 in 1989. Fig. 4.25 (b) also shows positive trend of rainy days with maximum value 121 in 1987 and minimum value 58 in 1954 for Dinajpur station.

All the stations show increasing trend of yearly variation of rainy days except Srimongal during 1950-1999 in Bangladesh. The highest positive trend of value 1.1078 is observed for the station of Khulna and lowest is 0.0065 for Chittagong station. The negative trend of yearly variation of rainy days of value -0.04588 is observed for the station of Srimongal.

(a)



(b)

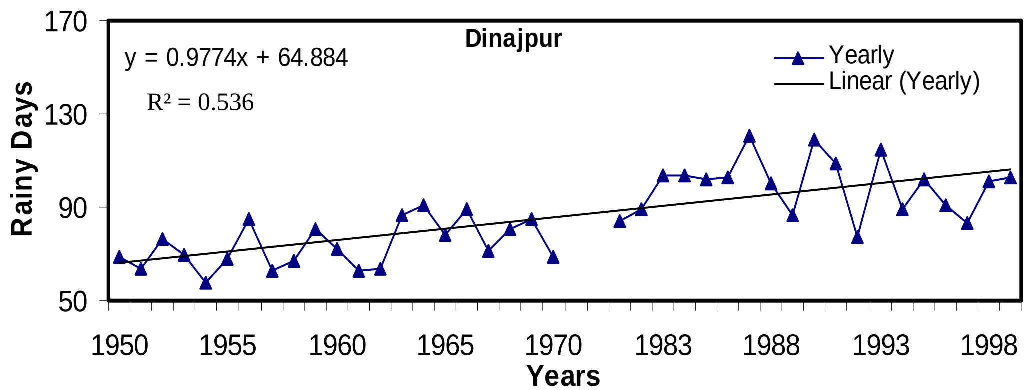
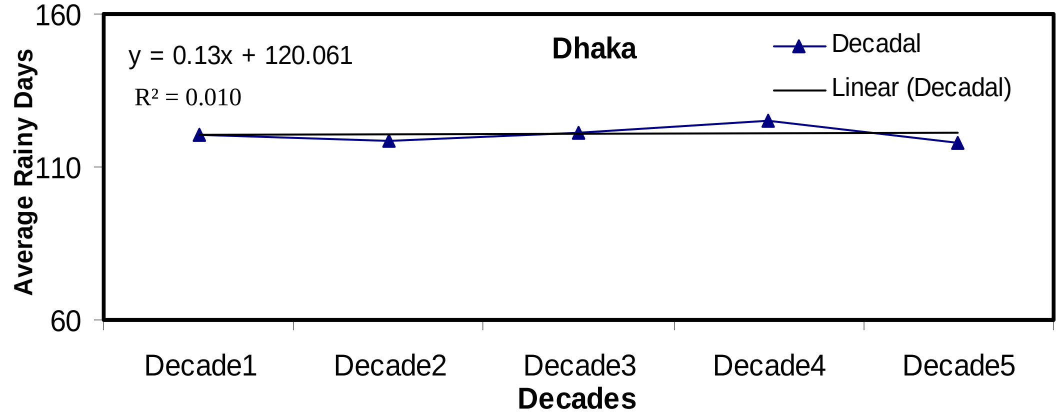


Fig.4.25. Same as fig. 4.21 but for stations: (a) Bogra, (b) Dinajpur.

4.3 Decadal variation of rainy days

Fig. 4.26 (a-b) shows decadal variation of averaged rainy days for different BMD rain gauge stations. Fig.4.26 (a) shows positive trend of rainy days for Dhaka station with maximum value 124 in Decade4 (1980-1989) and minimum value 118 in Decade5 (1990-1999). Fig. 4.26 (b) shows positive trend of decadal variation of rainy days for Comilla station with maximum value 118 in Decade5 (1990-1999) and minimum value 93 in Decade2 (1960-1979).

(a)



(b)

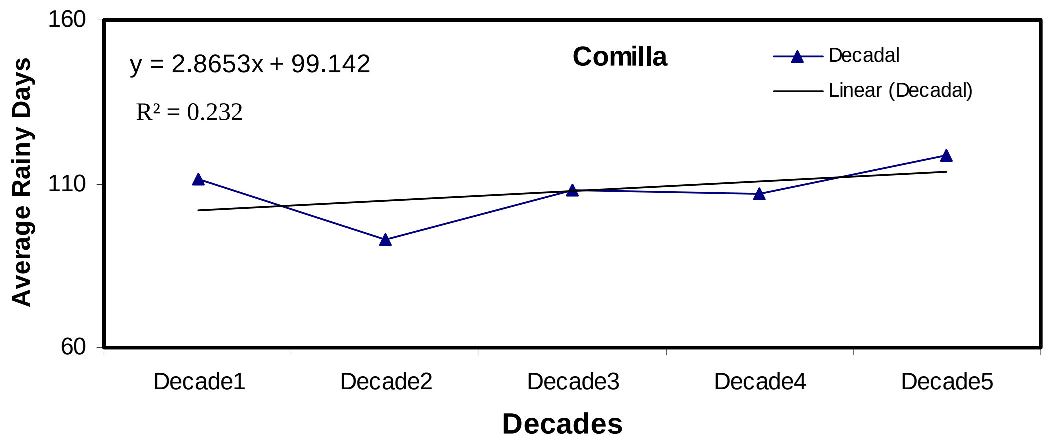
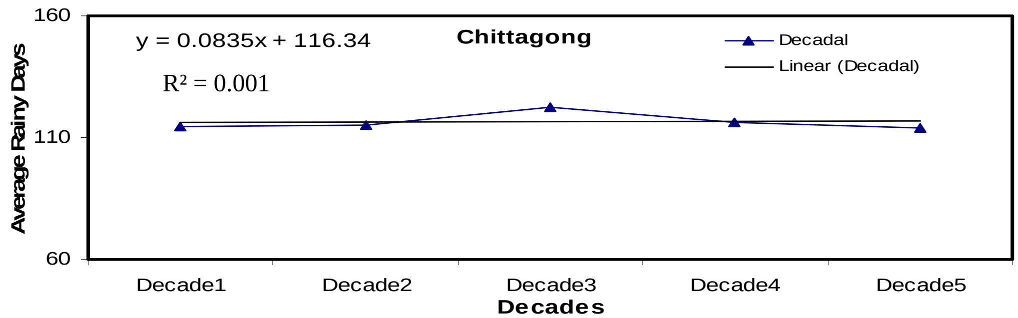


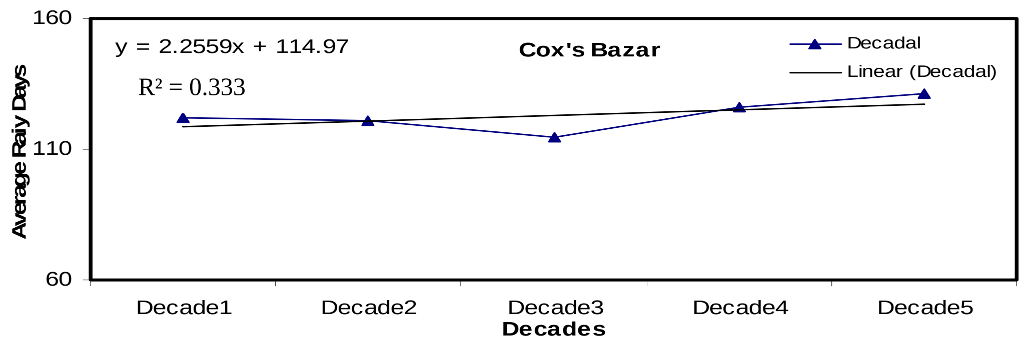
Fig.4.26 Decadal variation of rainy days for the selected stations: (a) Dhaka, (b) Comilla.

Fig. 4.27(a) shows positive trend of decadal variation of rainy days for Chittagong station, where maximum value is 122 in Decade3 (1970-1979) and minimum value is 114 in Decade5 (1990-1999). Cox's bazar station also shows positive trend of decadal variation of rainy days with maximum value 131 in Decade5 (1990-1999) and minimum value 114 in Decade3 (1970-1979) in (Fig.4.27 (b)). Fig. 4.27(c) shows positive trend of decadal variation of rainy days for Khulna station with maximum value 116 in Decade5(1990-1999) and minimum value 76 in Decade2(1960-1969).

(a)



(b)



(c)

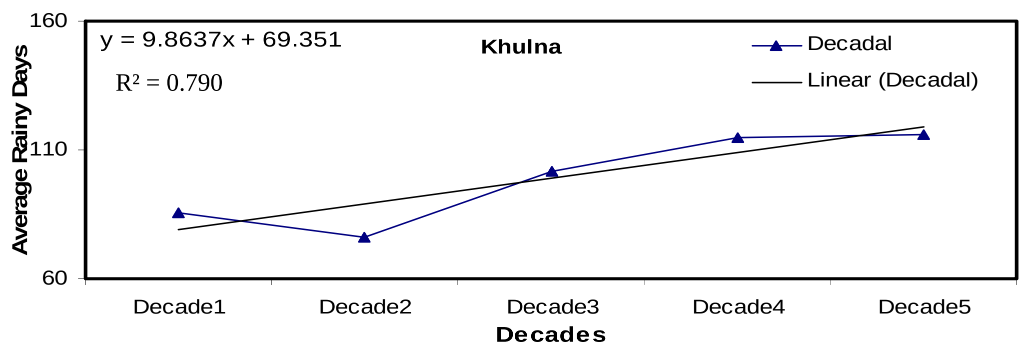
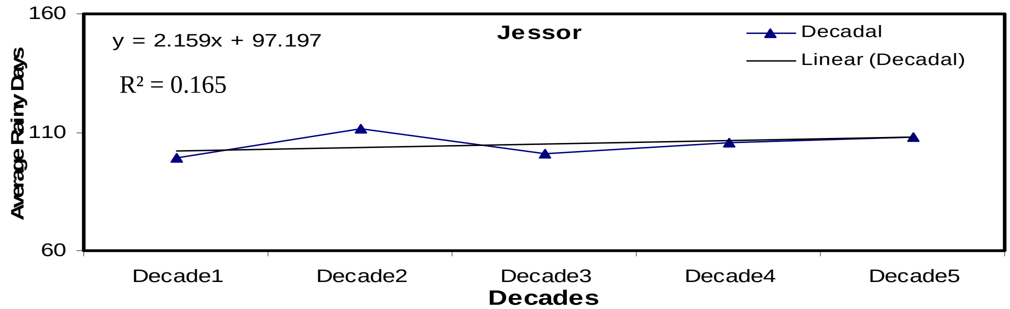


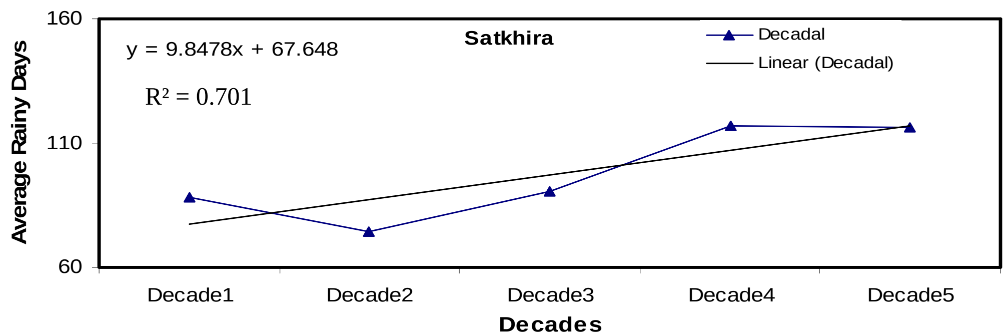
Fig.4.27. Same as fig. 4.26 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Fig. 4.28(a) shows positive trend of decadal variation of rainy days for Jessore station having maximum value 111 in Decade2 (1960-1969) and minimum value 100 in Decade3(1970-1979). Satkhira station (Fig. 4.28(b)) also shows positive trend of decadal variation of rainy days with maximum value 116 in Decade4(1980-1989) and minimum value 74 in Decade2(1960-1969). Fig. 4.28 (c) shows positive trend of decadal variation of rainy days for Sylhet station, where the maximum value 162 in Decade4(1980-1989) and minimum value 147 in Decade3(1970-1979).

(a)



(b)



(c)

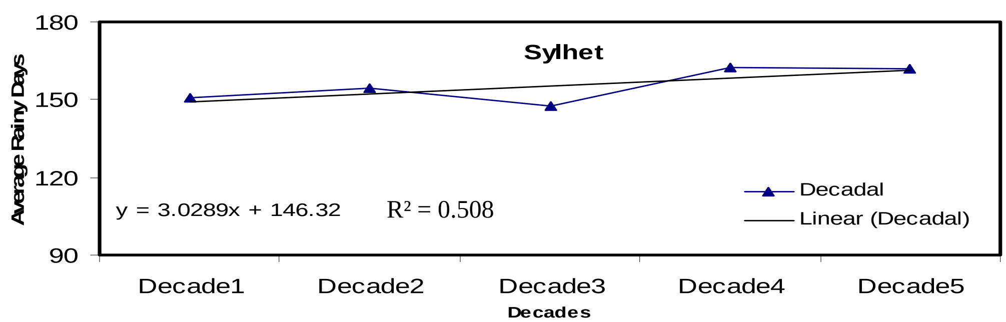
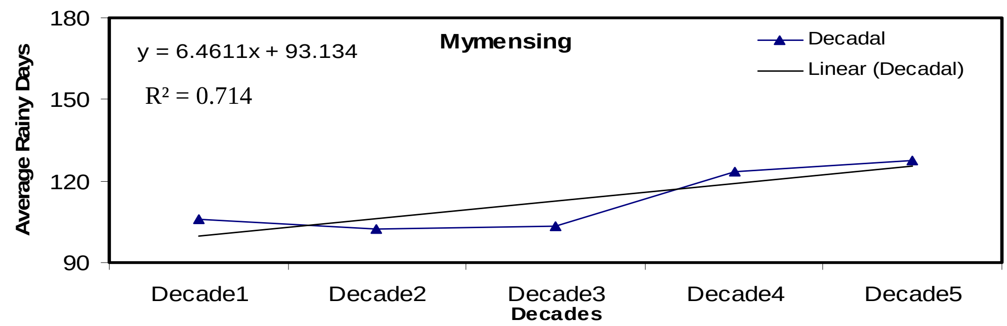


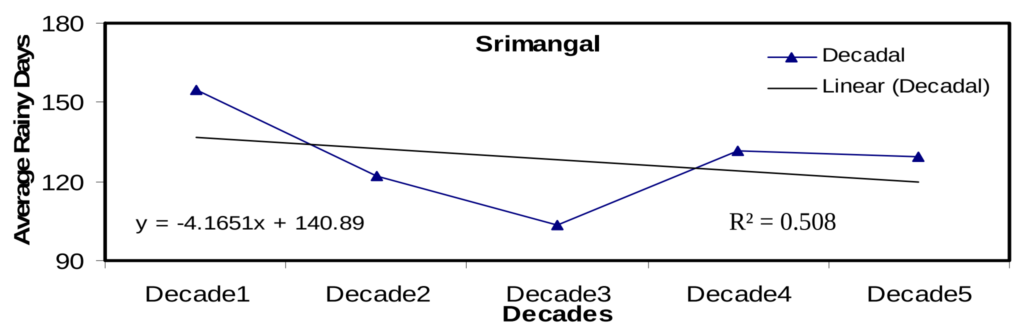
Fig.4.28. Same as fig. 4.26 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Fig. 4.29 (a) shows positive trend of decadal variation of rainy days for Mymensing station having maximum value 127 in Decade5(1990-1999) and minimum value 102 in Decade2(1970-1979). Srimongal station (Fig.4.29 (b)) shows negative trend of decadal variation of rainy days with maximum value 154 in Decade1(1950-1959) and minimum value 103 in Decade3(1980-1989). Fig. 4.29(c) shows decadal variation of rainy days for Rangpur station, where the maximum value is 109 in Decade4(1980-1989) and minimum value is 102 in Decade3(1970-1979).

(a)



(b)



(c)

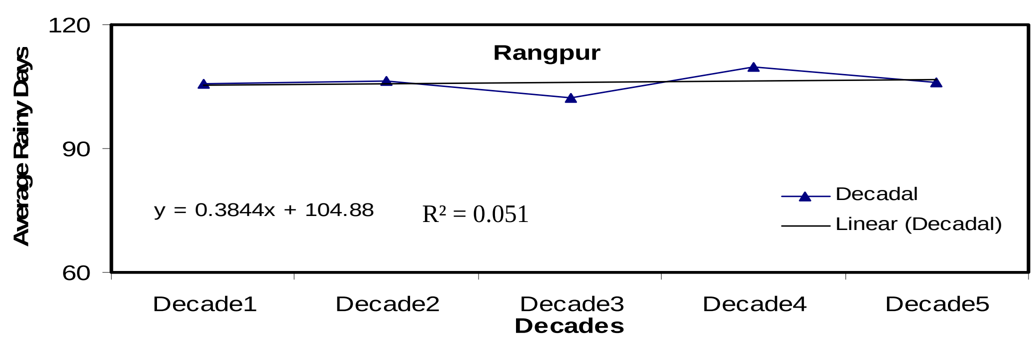
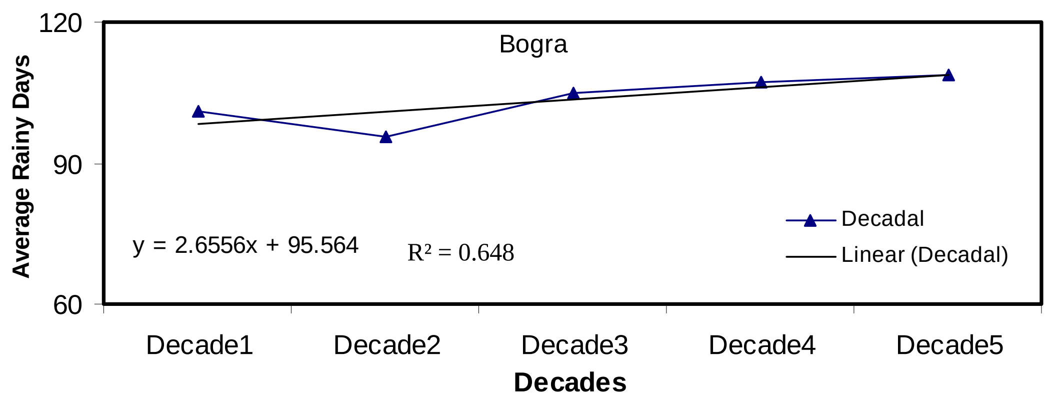


Fig.4.29. Same as fig. 4.26 but for stations:(a) Mymensing, (b) Srimongal, (c) Rangpur.

Fig. 4.30 (a) shows increasing tendency of decadal variation of rainy days for Bogra station with maximum value 108 in Decade5(1990-1999) and minimum value 95 in Decade2(1970-1979). Fig. 4.30 (b) also shows positive trend of decadal variation of rainy days for Dinajpur station with maximum value 101 in Decade4(1980-1989) and minimum value 70 in Decade1(1950-1959).

All the stations show positive trend of Decadal variation of rainy days except Srimongal station during 1950-1999 in Bangladesh. The highest positive trend of value 9.8637 is observed for the station of Khulna and lowest is 0.0835 for Chittagong station. The negative trend of Decadal variation of rainy days of value -4.1651 is observed for the station of Srimongal.

(a)



(b)

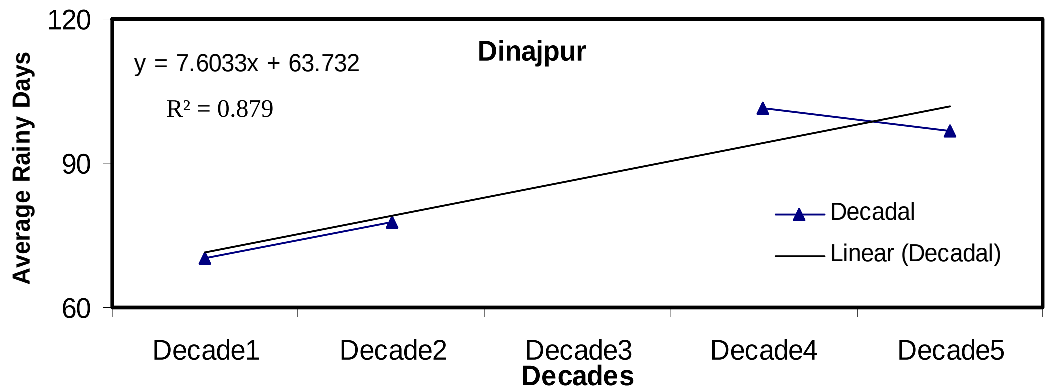


Fig.4.30. Same as fig. 4.26 but for stations: (a) Bogra, (b) Dinajpur.

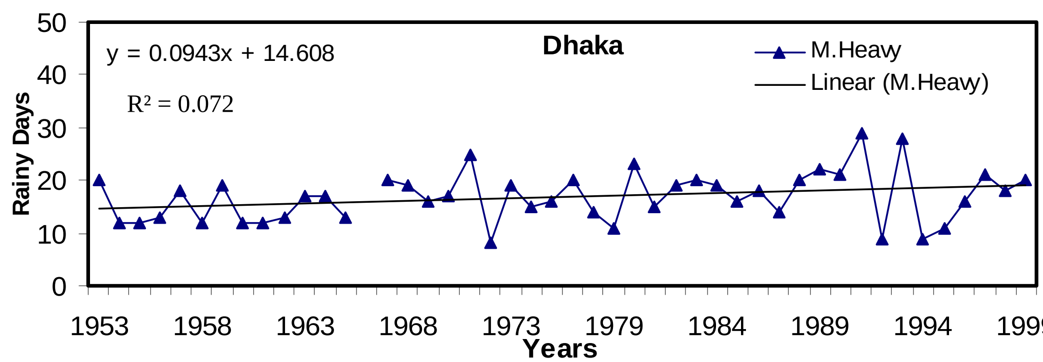
4.4 Variation of extreme rainfall days

As mentioned earlier that the variation of three extreme rainfall days named: Moderate heavy, Heavy and Very heavy are discussed in this sub-section.

4.4.1 Moderate heavy rainy days

Fig. 4.31 (a-b) shows variability of moderate heavy rainy days for different rain gauge stations during 1950-1999. Fig.4.31 (a) shows positive trend of moderated heavy rainy days with maximum value 29 in 1991 and minimum value 08 in 1972. Fig. 4.31 (b) shows negative trend of moderate heavy rainy days having maximum value 29 in 1954 and minimum value 08 in 1979 for Comilla station.

(a)



(b)

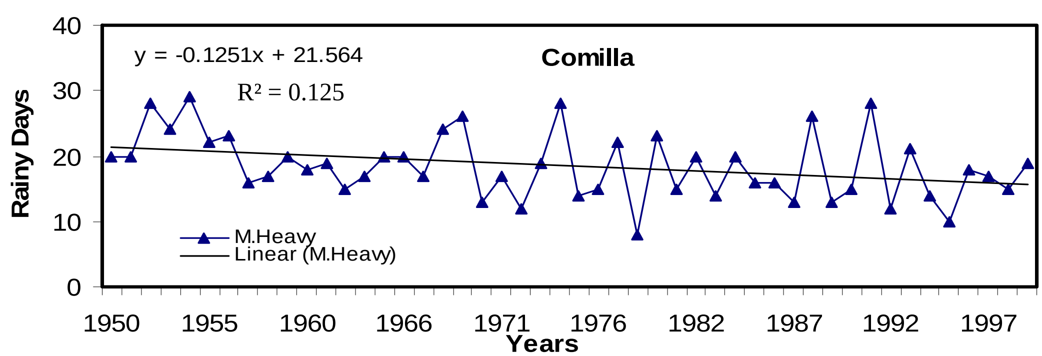
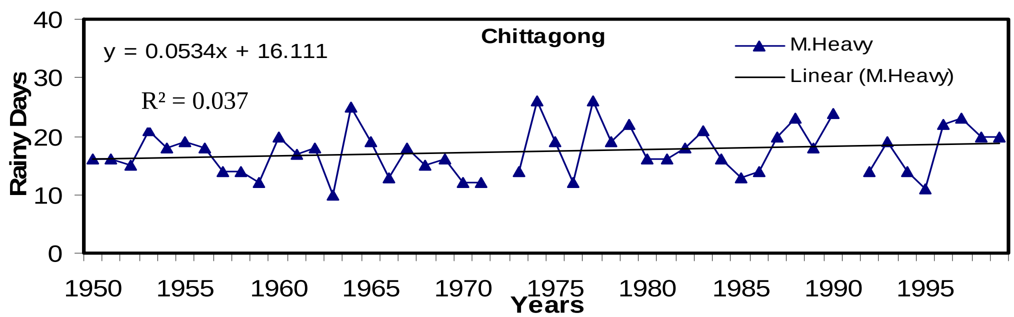


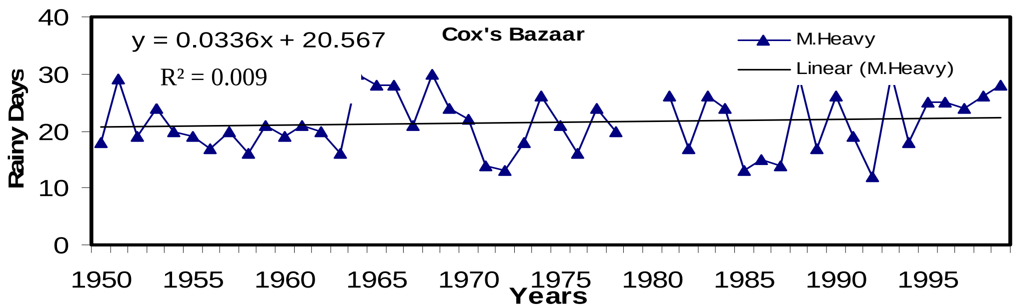
Fig.4.31 Moderated Heavy rainy days variation for the selected stations: (a) Dhaka, (b) Comilla.

Fig. 4.32 (a) shows positive trend of moderate heavy rainy days for Chittagong station having maximum value 26 in 1974, 1977 and minimum value 10 in 1963. Cox's bazar station shows positive trend (Fig. 4.32 (b)), where the maximum value is 30 in 1964, 1968, 1993 and minimum value is 12 in 1992, respectively. Fig. 4.32 (c) also shows positive trend of moderate heavy rainy days for Khulna station with maximum value 26 in 1970, 1974 and minimum value 06 in 1971.

(a)



(b)



(c)

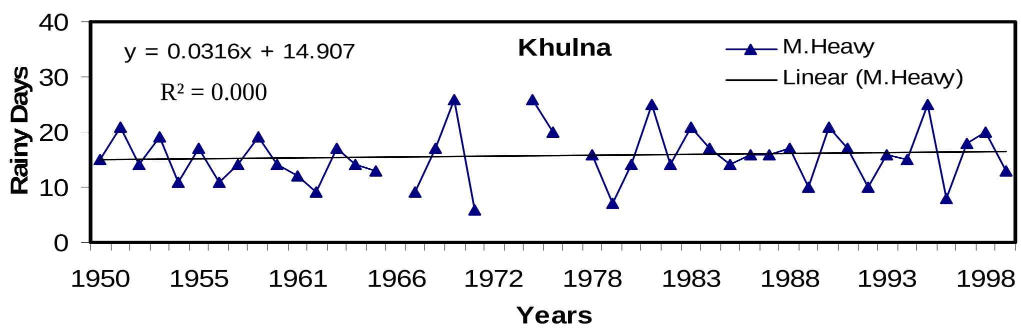
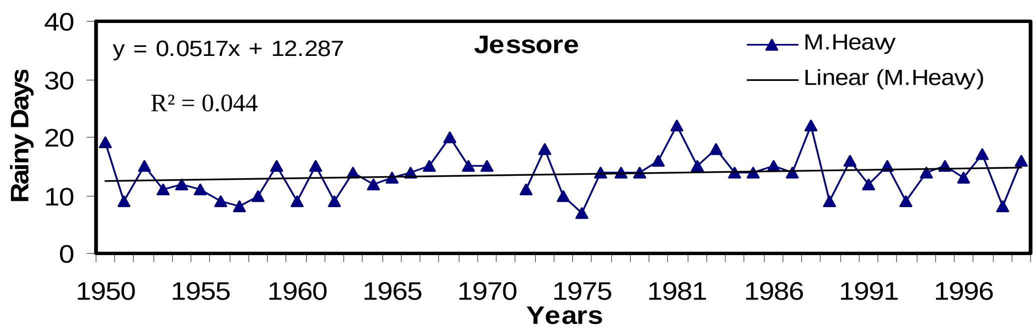


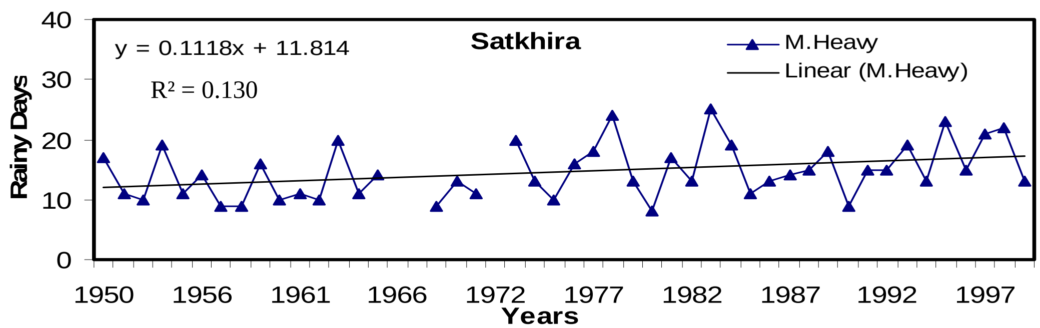
Fig.4.32. Same as fig. 4.31 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Fig. 4.33 (a) shows increasing tendency of moderate heavy rainy days for Jessore station with maximum value 22 in 1981, 1988 and minimum value 07 in 1975. Fig. 4.33 (b) also show positive trend of moderate heavy rainy days for Satkhira station with maximum value 25 in 1983 and minimum value 8 in 1980. Fig. 4.33 (c) shows positive trend of moderate heavy rainy days for Sylhet station with maximum value 42 in 1964, 1981 and minimum value 18 in 1966.

(a)



(b)



(c)

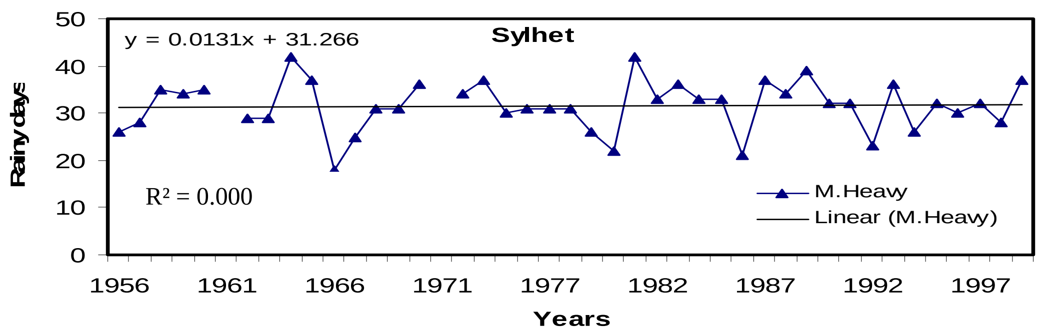
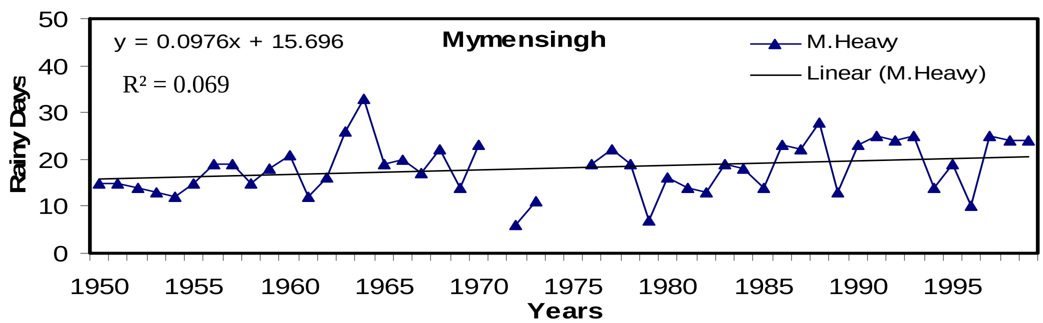


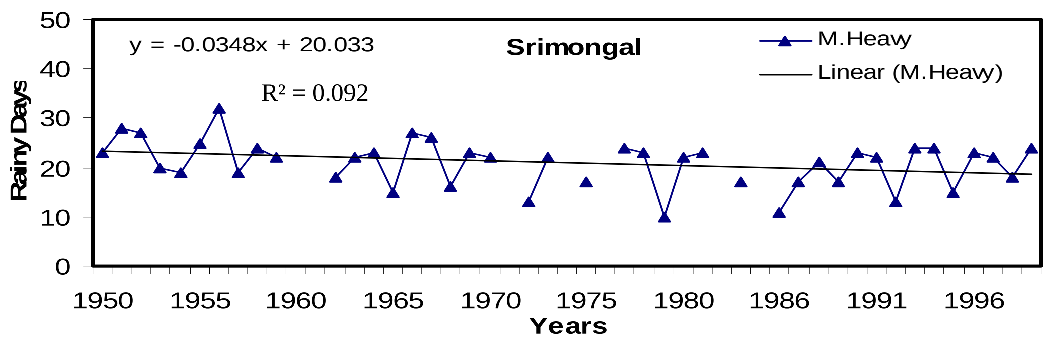
Fig.4.33. Same as fig. 4.31 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Fig.4.34 (a) shows positive trend of moderate heavy rainy days for Mymensing with maximum value 33 in 1964 and minimum value 06 in 1972. Fig.4.34 (b) shows negative trend of moderate heavy rainy days for Srimongal station, where the maximum value is 32 in 1956 and minimum value is 10 in 1979. Fig. 4.34 (c) shows positive trend of moderate heavy rainy days for Rangpur station having maximum value 31 in 1984 and minimum value 08 in 1960.

(a)



(b)



(c)

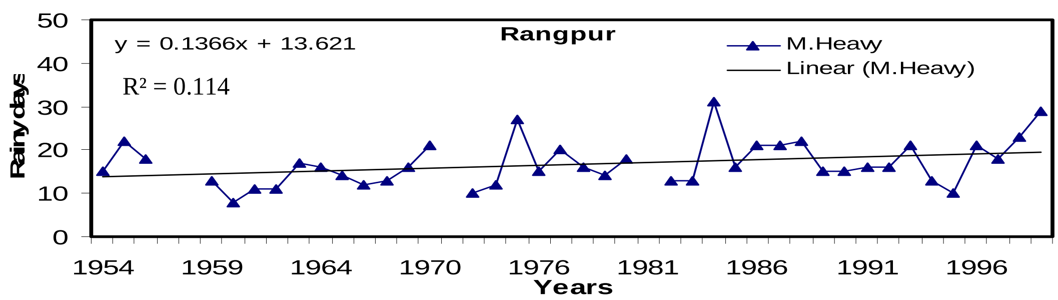
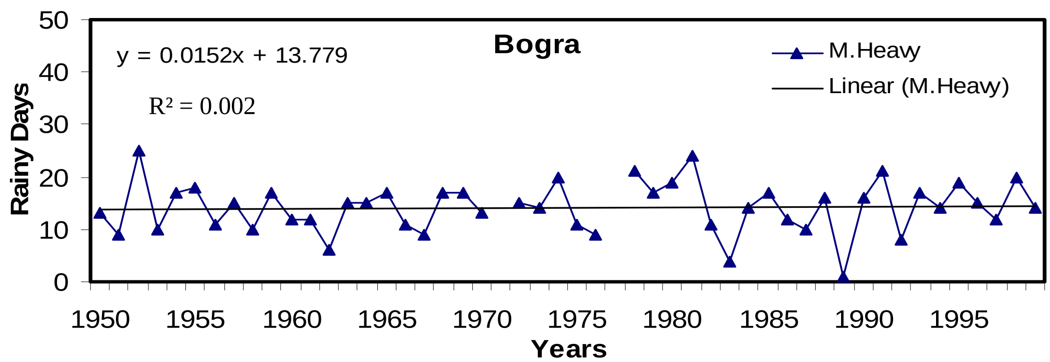


Fig.4.34. Same as fig. 4.31 but for stations. (a) Mymensing, (b) Srimongal, (c) Rangpur.

Fig. 4.35 (a) shows positive trend of moderate heavy rainy days for Bogra station with maximum value 25 in 1952 and minimum value 01 in 1989. Fig. 4.35 (b) also shows positive trend of moderate heavy rainy days for Dinajpur station with maximum value 24 in 1958 and minimum value 06 in 1992, 1994, respectively.

All the stations shows increasing trend of moderate heavy rainy days except Srimongal and Comilla during 1950-1999. The highest positive trend of value 0.1366 is observed for the station of Rangpur and lowest is 0.0131 for Sylhet station. The negative trend of rainy days of value -0.0348 and -0.01251 is observed for the station of Srimongal and Comilla during 1950-1999, respectively.

(a)



(b)

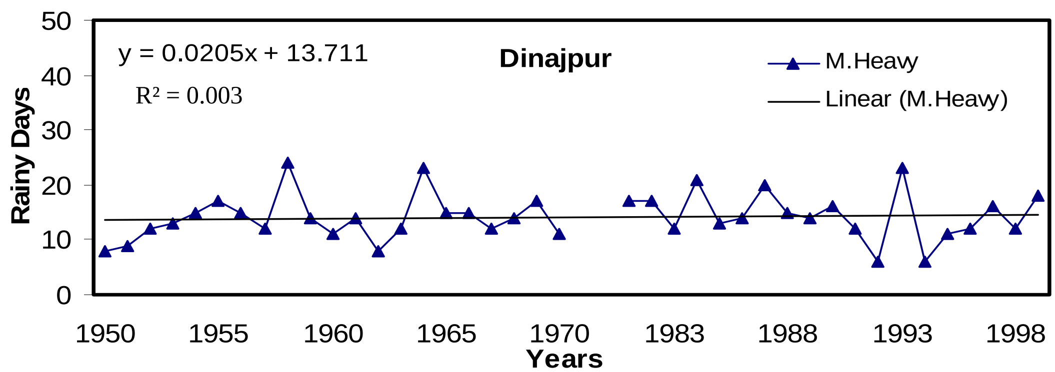
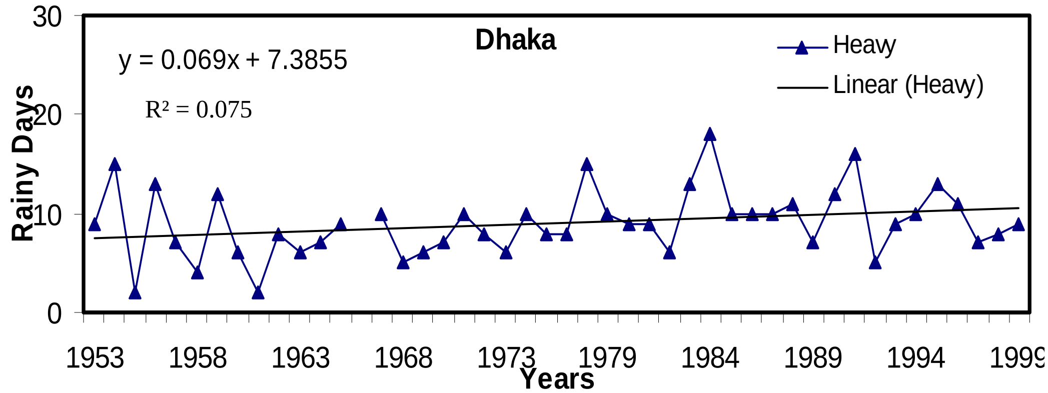


Fig.4.35. Same as fig. 4.31 but for stations: (a) Bogra, (b) Dinajpur.

4.4.2 Heavy rainy days

Fig.4.36 (a-b) shows variability of Heavy rainy days for different rain gauge stations. Fig.4.36 (a) shows positive variation of Heavy rainy days for Dhaka station with maximum value 18 in 1984 and minimum value 02 in 1955 and 1961 respectively. Comilla station (Fig.4.36 (b)) shows negative trend of heavy rainy days with maximum value 27 in 1951 and minimum value 03 in 1994.

(a)



(b)

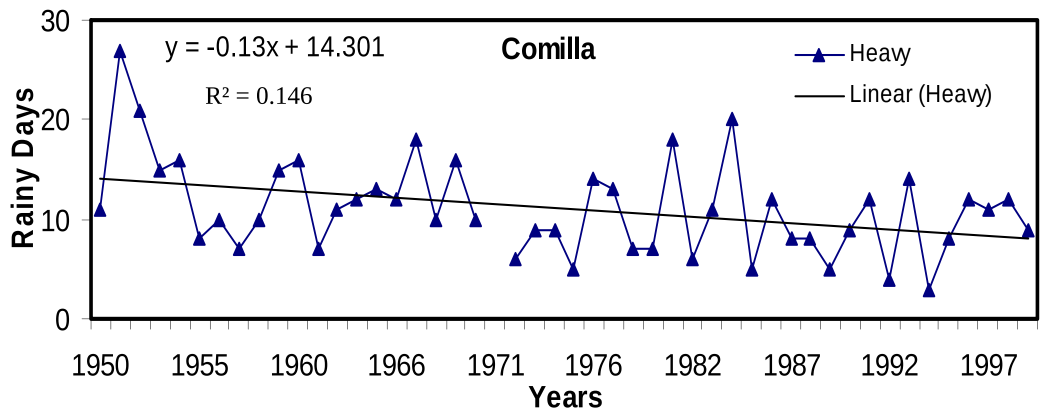
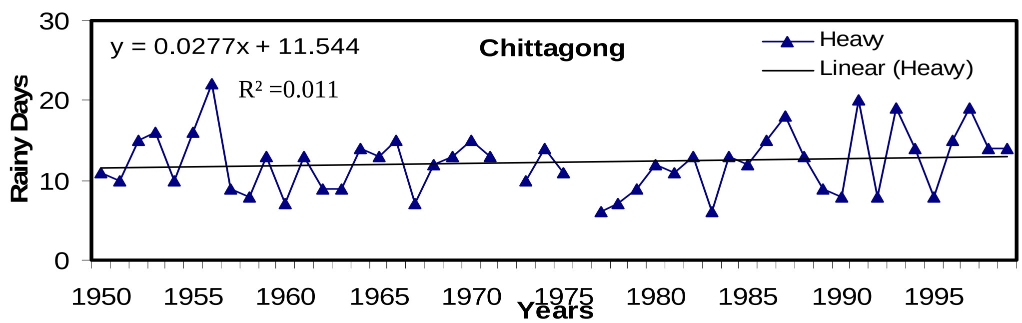


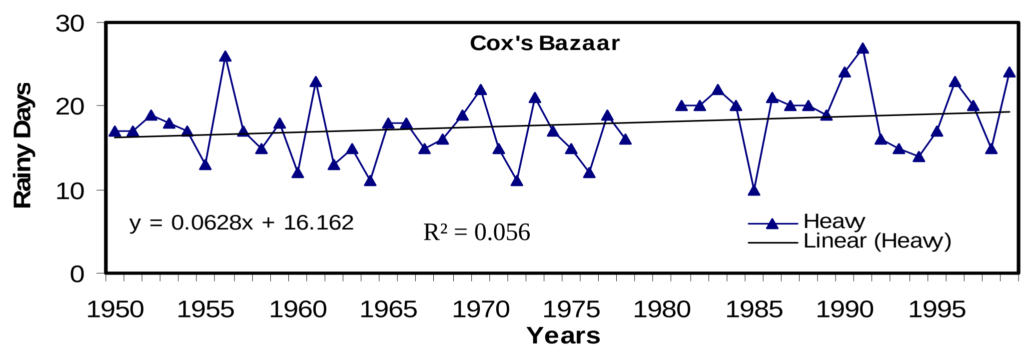
Fig.4.36. Heavy rainy days variation for the selected stations: (a) Dhaka, (b) Comilla.

Fig.4.37 (a) shows positive trend of heavy rainy days for Chittagong station with maximum value 22 in 1956 and minimum value 06 in 1977 and 1983 respectively. Cox's bazar station (Fig.4.37 (b)) shows positive trend with maximum value 27 in 1991 and minimum value 10 in 1985. Fig.4.37 (c) also shows positive trend of rainy days for Khulna station with maximum value 15 in 1974 and minimum value 01 in 1985 and 1994 respectively.

(a)



(b)



(c)

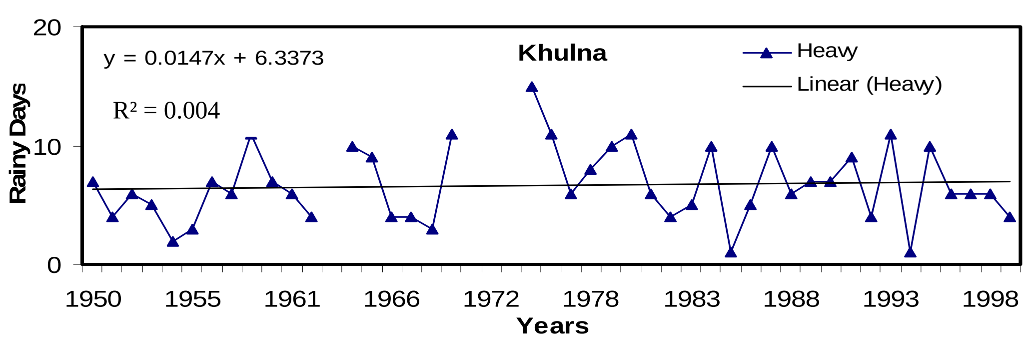
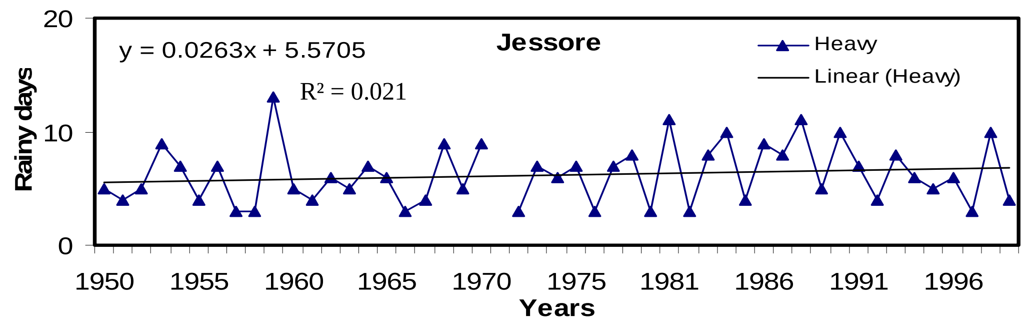


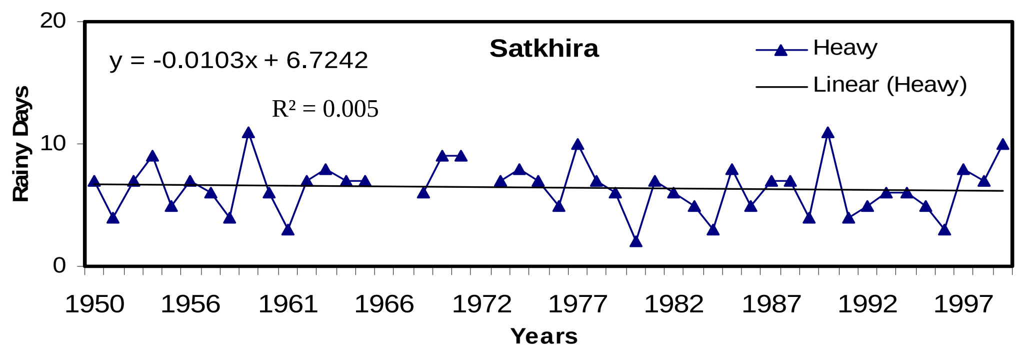
Fig.4.37. Same as fig. 4.36 but for stations: (a) Chittagong, (b) Cox's Bazaar, (c) Khulna.

Fig. 4.38 (a) shows positive trend of heavy rainy days for Jessore station with maximum value 13 in 1959 and minimum value 03 in 1957, 1958, 1982 and 1997 respectively. Satkhira station (Fig. 4.38 (b)) shows negative trend of heavy rainy days with maximum value 11 in 1959 and minimum value 02 in 1980. Fig.4.38 (c) shows positive trend of heavy rainy days for Sylhet station with maximum value 31 in 1968 and minimum value 07 in 1960.

(a)



(b)



(c)

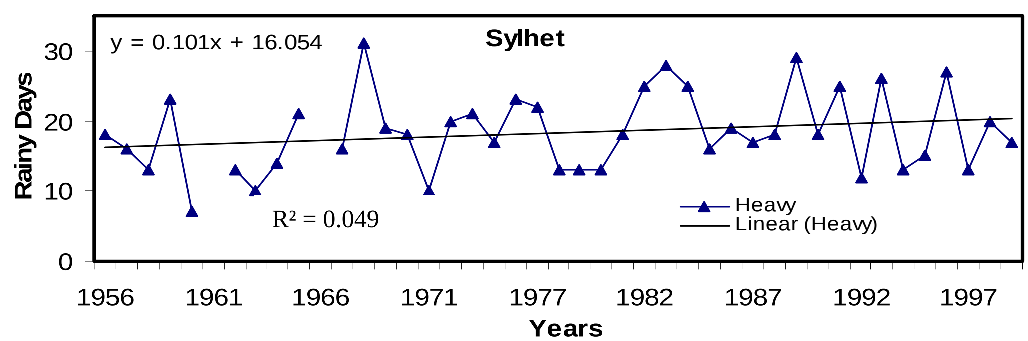
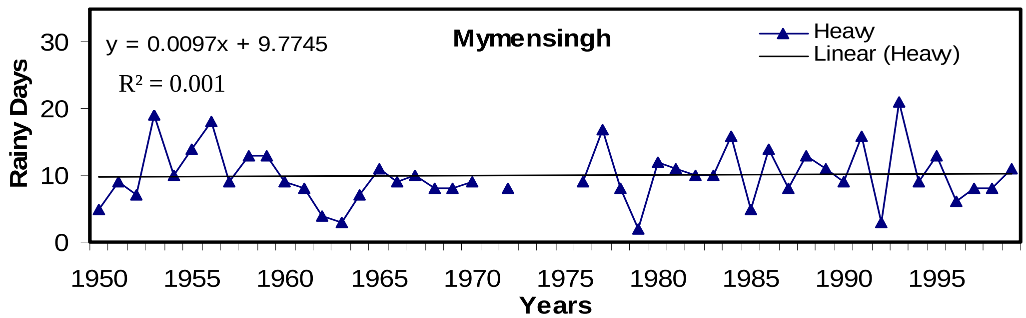


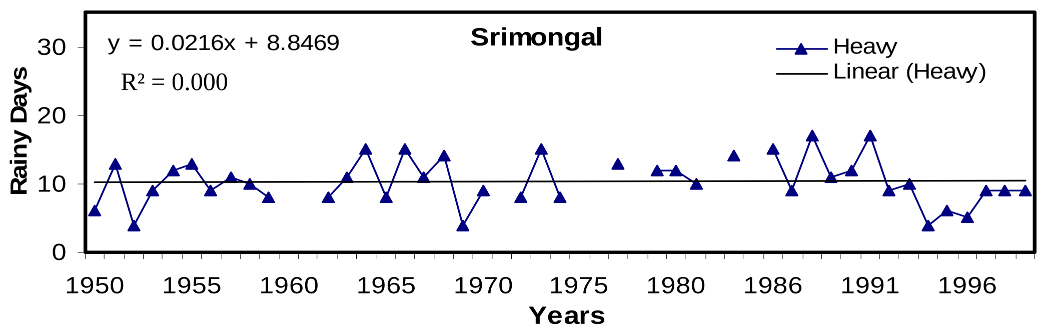
Fig.4.38. Same as fig. 4.36 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Fig.4.39 (a) shows positive trend of heavy rainy days for Mymensing station with maximum value 21 in 1993 and minimum value 02 in 1979. Srimongal station (Fig.4.39 (b)) shows positive trend of heavy rainy days where maximum value 17 in 1988, 1991 and minimum value 04 in 1952, 1969 and 1994 respectively. Rangpur station (Fig.4.39 (c)) also shows positive trend of heavy rainy days with maximum value 19 in 1990 and minimum value 03 in 1975.

(a)



(b)



(c)

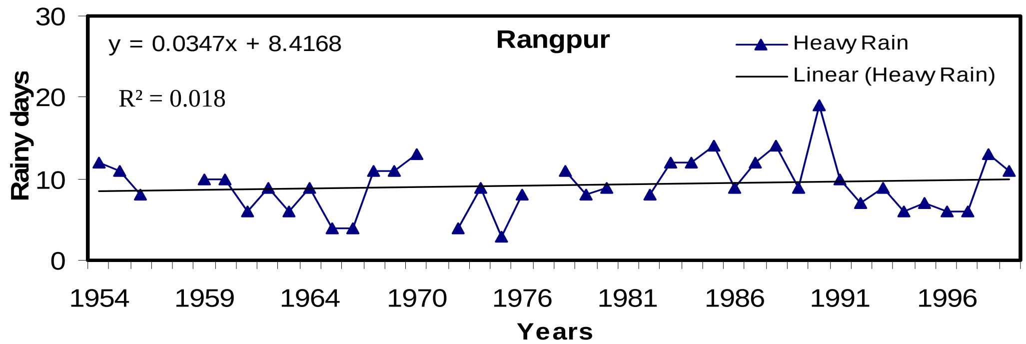
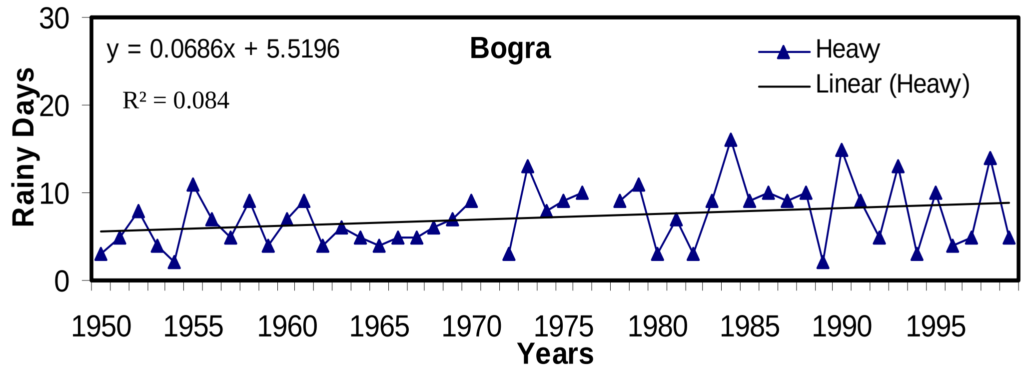


Fig.4.39. Same as fig. 4.36 but for stations: (a) Mymensing, (b) Srimongal, (c) Rangpur.

Fig.4.40 (a) shows positive trend of heavy rainy days for Bogra station with maximum value 16 in 1984 and minimum value 02 in 1954 and 1989 respectively. Dinajpur station (Fig.4.40 (b)) also shows positive trend of heavy rainy days with maximum value 14 in 1998 and minimum value 02 in 1951.

All the stations shows positive trend of heavy rainy days except Comilla and Satkhira during 1950-1999. The highest positive trend of value 0.101 is observed for the station of Sylhet and lowest is 0.0097 for Mymonsing station. The negative trend of heavy rainy days of value -0.130 and -0.0103 is observed for the stations of Comilla and Satkhira respectively during 1950-1999.

(a)



(b)

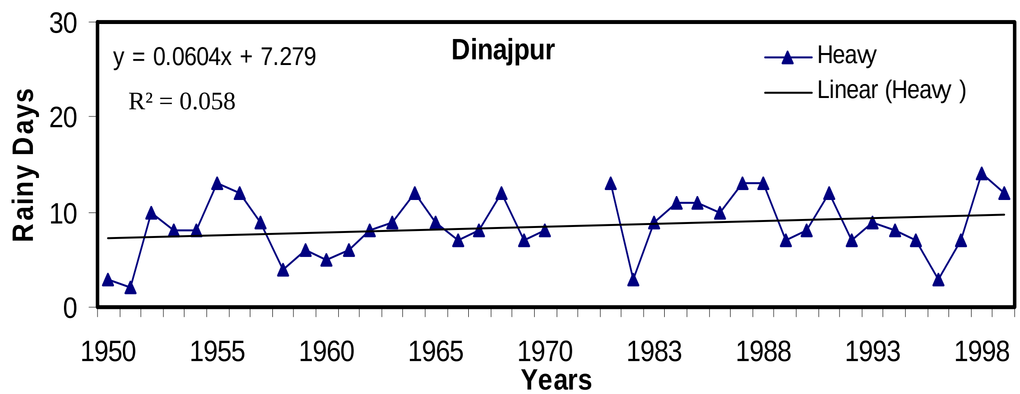


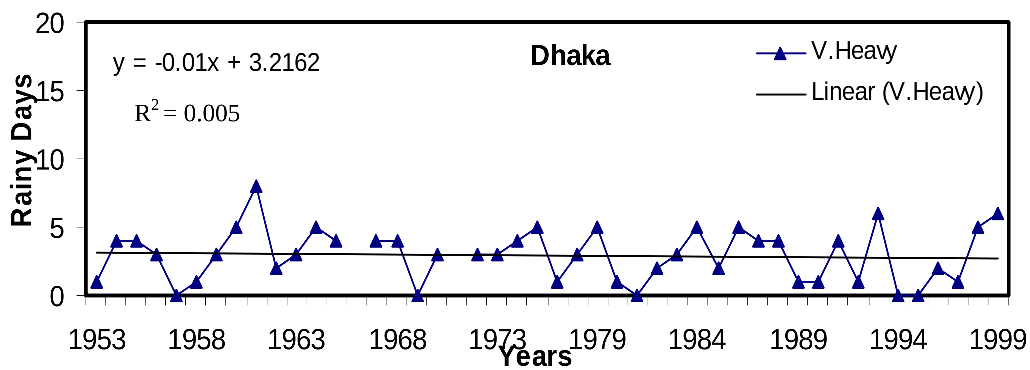
Fig.4.40. Same as fig. 4.36 but for stations: (a) Bogra, (b) Dinajpur.

4.4.3 Very heavy rainy days

Fig.4.41 (a-b) shows variability of Very Heavy rainy days for different rain gauge stations.

Fig.4.41 (a) shows negative trend of very heavy rainy days with maximum value 08 in 1961 and minimum value 00 in 1957, 1969, 1981, 1994 and 1995 respectively. Comilla station (Fig.4.41 (b)) also shows negative trend of very heavy rainy days with maximum value 13 in 1964 and minimum value 01 in 1957.

(a)



(b)

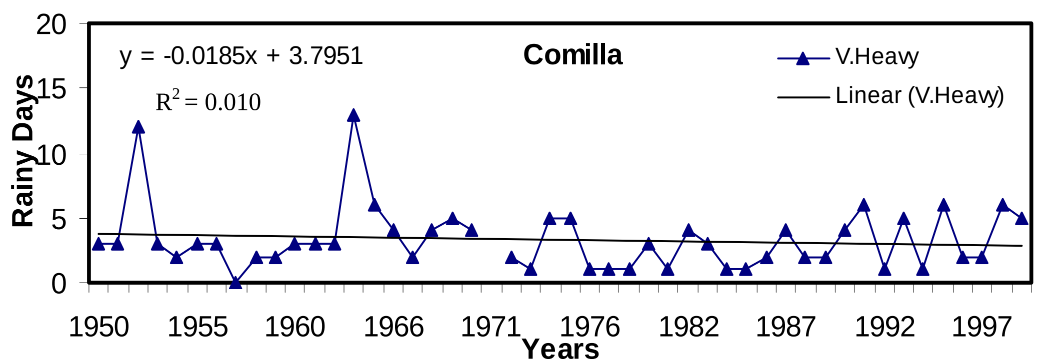
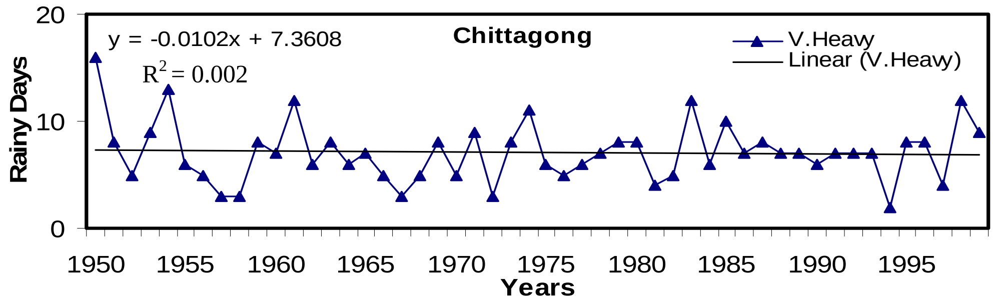


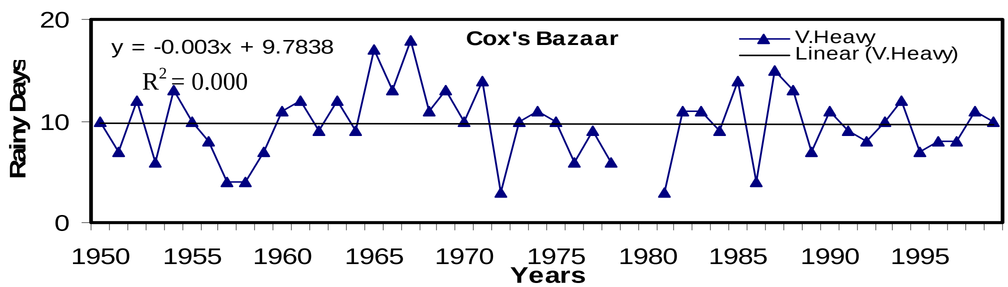
Fig.4.41 Very Heavy rainy days variation for the selected stations: (a) Dhaka, (b) Comilla.

Fig.4.42 (a) shows negative trend of very heavy rainy days for Chittagong station with maximum value 16 in 1950 and minimum value 02 in 1994. Cox's bazaar station (fig.4.42 (b)) shows negative trend of very heavy rainy days with maximum value 18 in 1967 and minimum value 03 in 1972, 1981 respectively. Fig.4.42 (c) also shows negative trend of rainy days for Khulna station with maximum value 06 in 1959 and minimum value 00 in 1950, 1957, 1958, 1964, 1991, and 1992 respectively.

(a)



(b)



(c)

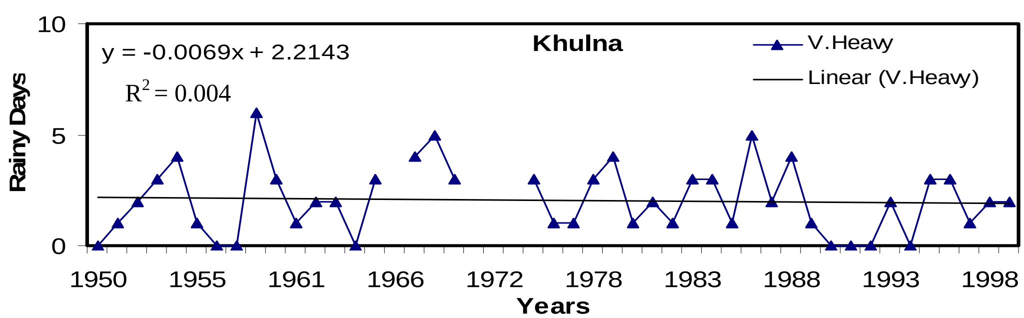
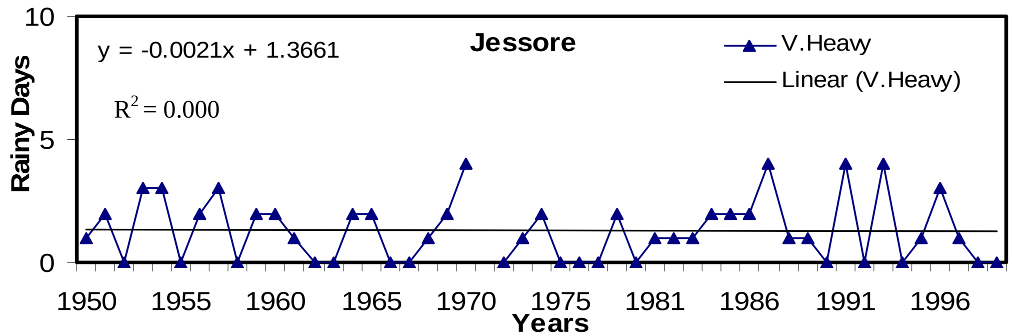


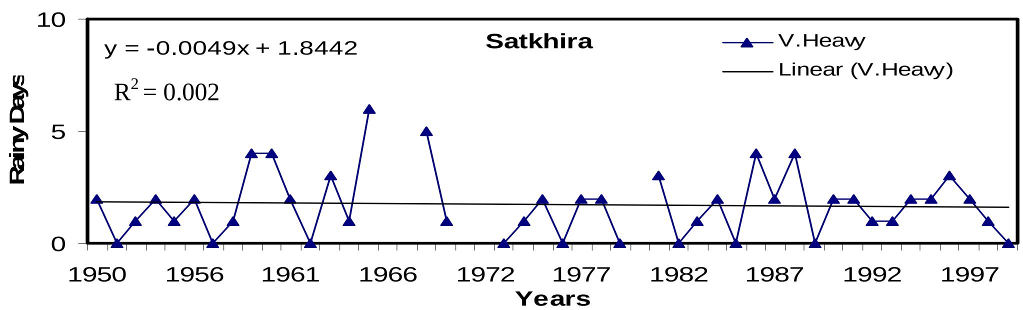
Fig.4.42. Same as fig. 4.41 but for stations: (a) Chittagong, (b) Cox's Bazar, (c) Khulna.

Fig.4.43 (a) Shows negative trend of very heavy rainy days for Jessore station with maximum value 04 in 1970, 1987, 1991, 1993 and minimum value 00 in 1952, 1955, 1958, 1992, 1994, 1998 respectively. Satkhira station (Fig.4.43 (b)) shows negative variation of very heavy rainy days with maximum value 06 in 1965 and minimum value 00 in 1951, 1957, 1962, 1973, 1976 and 1999 respectively. Fig.4.43 (c) also shows negative trend of very heavy rainy days variation for Sylhet station with maximum value 18 in 1988 and minimum value 03 in 1965, 1999 respectively.

(a)



(b)



(c)

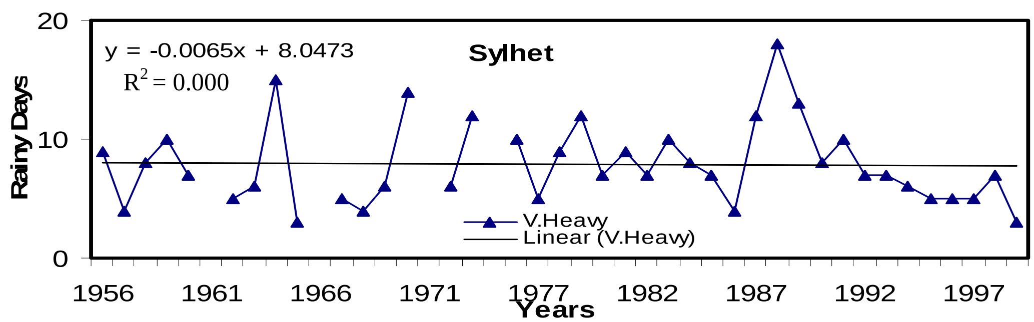
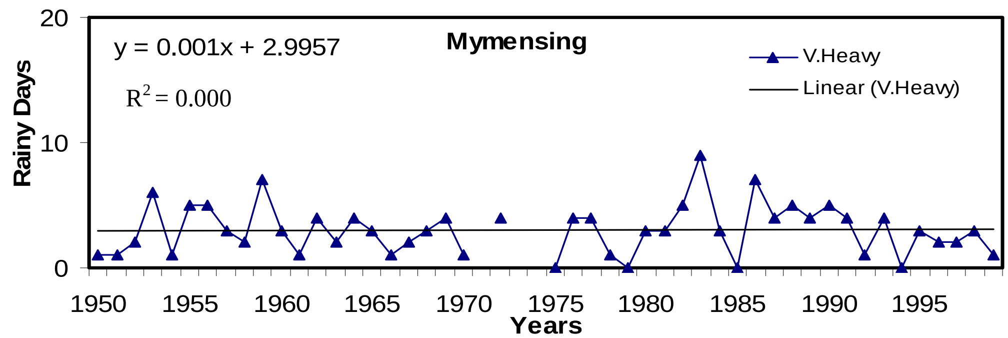


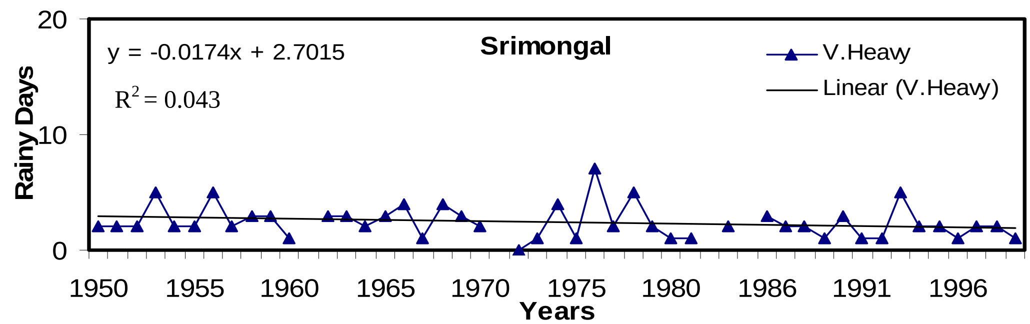
Fig.4.43. Same as fig. 4.41 but for stations: (a) Jessore, (b) Satkhira, (c) Sylhet.

Fig.4.44 (a) shows positive trend of very heavy rainy days for Mymensing with maximum value 09 in 1983 and minimum value 00 in 1975, 1979, 1985 and 1994 respectively. Fig.4.44 (b) shows negative trend of very heavy rainy days for Srimongal station with maximum value 07 in 1976, 1991 and minimum value 00 in 1972. Fig.4.44 (c) Shows Positive trend for Rangpur station with maximum value 10 in 1984 and minimum value 00 in 1966, 1967, 1975 and 1994 respectively.

(a)



(b)



(c)

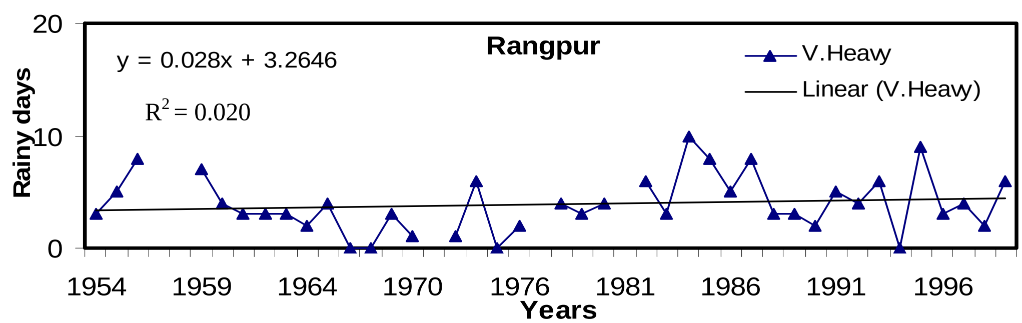
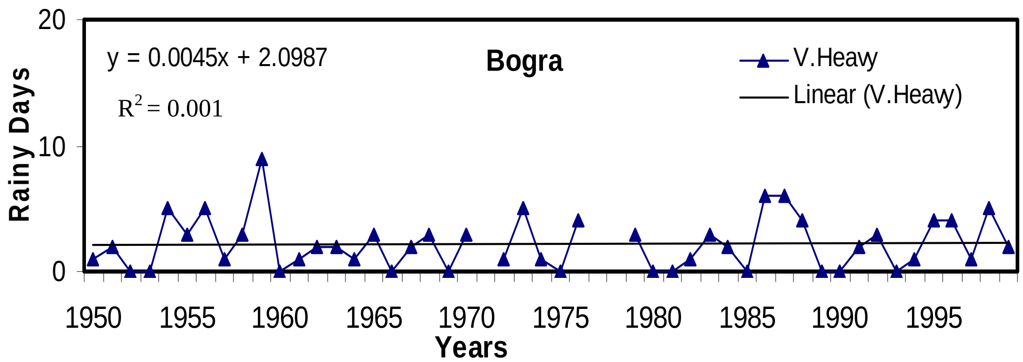


Fig.4.44. Same as fig. 4.41 but for stations: (a) Mymensing, (b) Srimongal, (c) Rangpur.

Fig.4.45 (a) shows positive trend of very heavy rainy days for Bogra station with maximum value 09 in 1959 and minimum value 00 in 1952, 1953, 1960, 1966, 1969 and 1975 respectively. Dinajpur station (Fig.4.45 (b)) also shows positive trend of very heavy rainy days with maximum value 09 in 1987 and minimum value 00 in 1957, 1961, 1966 and 1994 respectively.

All the stations shows negative trend of very heavy rainy days except Mymensing, Rangpur, Bogra, Dinajpur during 1950-1999. The highest positive trend of value 0.053 is observed for the station of Dinajpur and lowest is 0.001 for Mymonsing station. The negative trend of heavy rainy days of value -0.0185 observed for the station Comilla and -0.003 is observed for the stations of Cox's Bazar during 1950-1999.

(a)



(b)

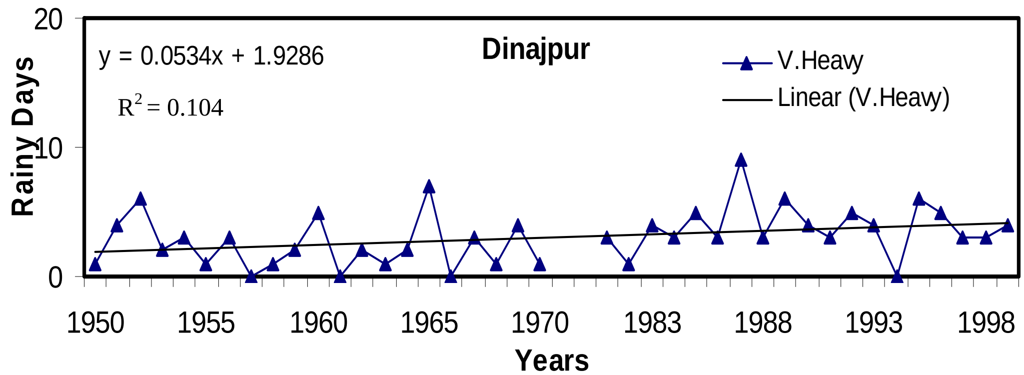


Fig.4.45. Same as fig. 4.41 but for stations: (a) Bogra, (b) Dinajpur.

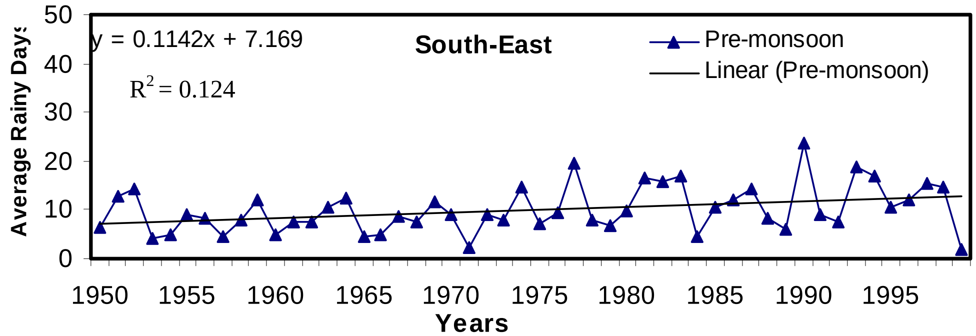
4.5 Regional variation of rainy days

Regional variations of rainy days are discussed in this sub-section. Bangladesh is divided into four regions name: south-east(SE), south-west(SW), north-east(NE) and north-west(NW).

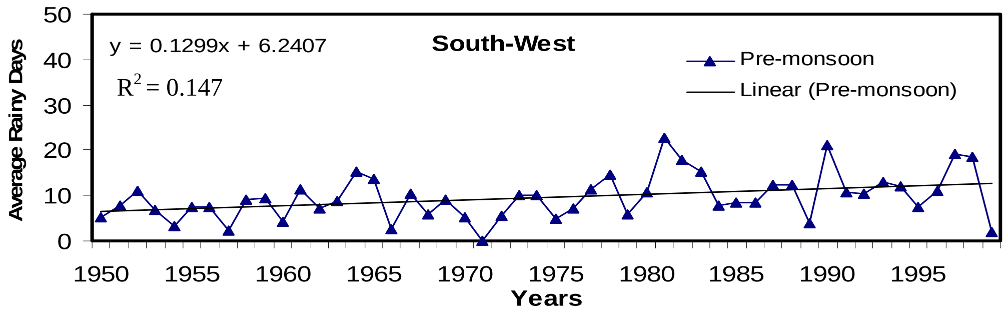
4.5.1 Pre-monsoon

Fig. 4.46 (a-d) shows variability of averaged rainy days for different regions during pre-monsoon period in Bangladesh. All the four regions shows positive trend of rainy days variation. The maximum value of averaged rainy days 23, 22, 47 and 31 is found in the SE, SW, NE and NW region in 1990, 1981, 1988, and 1990, respectively. The minimum value of averaged rainy days 02, 00, 05 and 13 is found in the SE, SW, NE and NW region in 1999, 1971, 1971 and 1965, respectively. The maximum increasing tendency 0.1762 is observed in the NW region and minimum 0.1142 is found in the SE region. This indicates that pre-monsoon rainfall in the NW side of Bangladesh increased more than that of in the SE side.

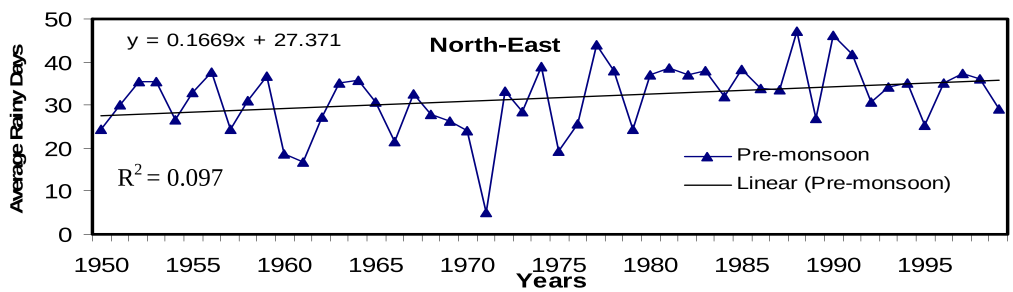
(a)



(b)



(c)



(d)

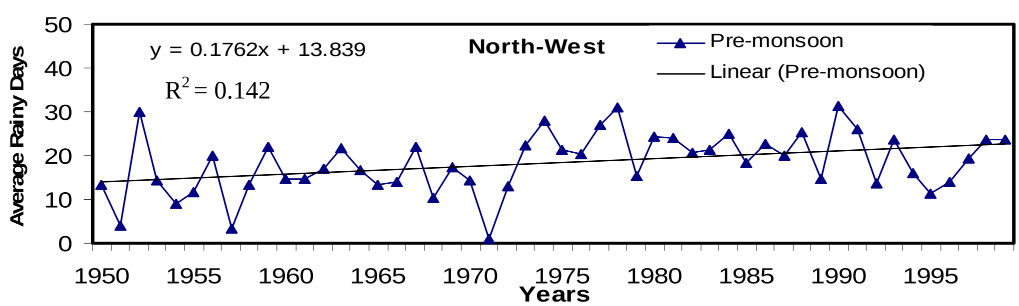
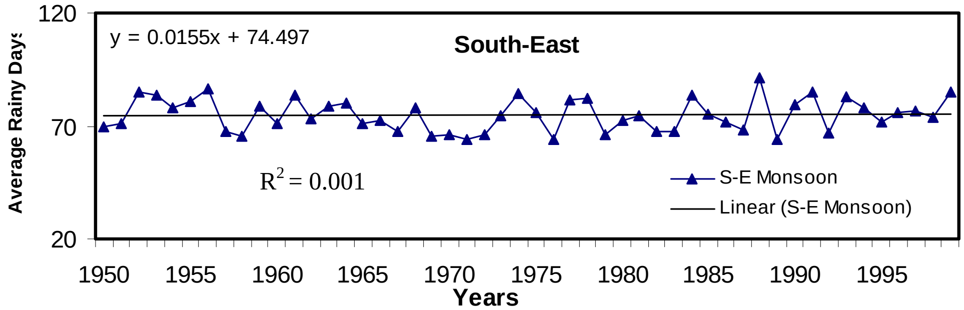


Fig. 4.46 Variability of average rainy days in Pre-monsoon: (a) South-East, (b) South-West, (c) North-East, (d) North-West.

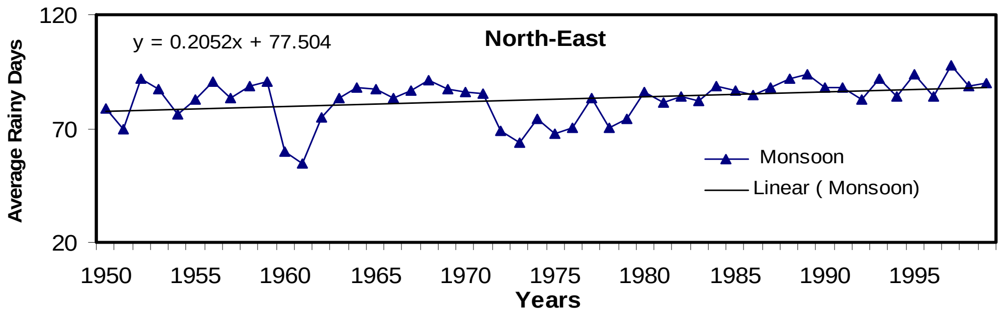
4.5.2 Monsoon

Fig. 4.47 (a-d) shows variability of averaged rainy days for different regions during monsoon period in Bangladesh. All the four regions show positive trend of rainy days variation. The maximum value of averaged rainy days 91, 80, 97 and 82 is found in the SE, SW, NE and NW region in 1988, 1984, 1997, and 1987, respectively. The minimum value of averaged rainy days 64, 36, 54 and 56 is found in the SE, SW, NE and NW region in 1971, 1957, 1961 and 1953, respectively. The maximum increasing tendency 0.3204 is observed in the SW region and minimum 0.0155 is found in the SE region. This indicates that monsoon rainfall in the SW side of Bangladesh increased more than that of all other sides.

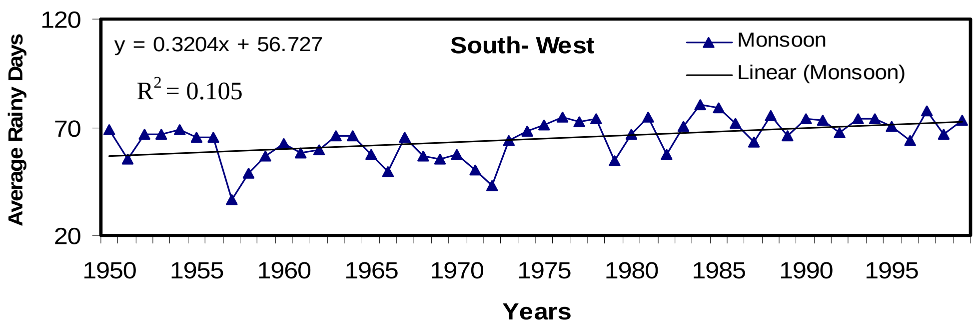
(a)



(b)



(c)



(d)

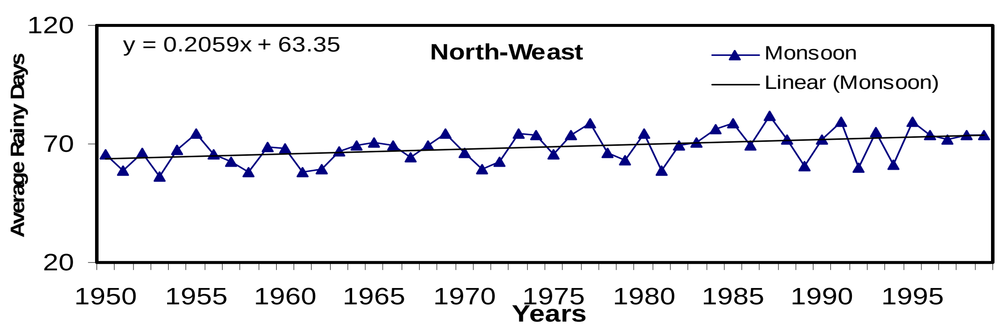
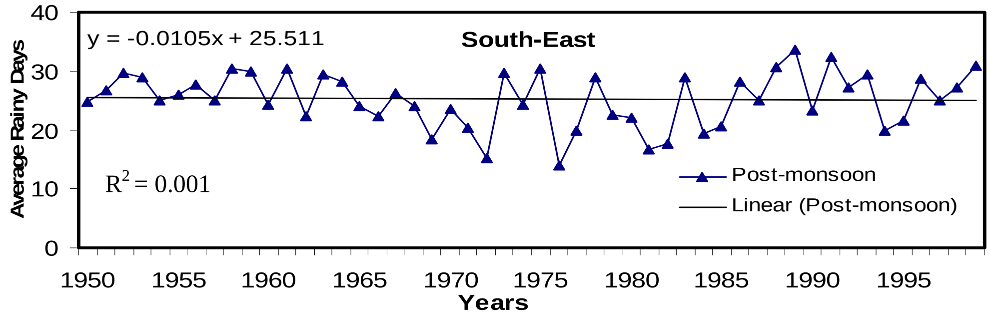


Fig. 4.47 Variability of average rainy days in monsoon: (a) South-East, (b) North-East, (c) South-West, (d) North-West.

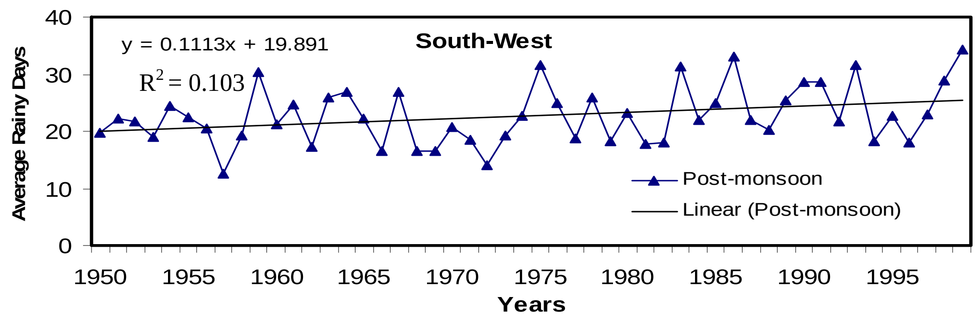
4.5.3 Post-Monsoon

Fig. 4.48 (a-d) shows variability of averaged rainy days for different regions during post- monsoon period in Bangladesh. Among four regions SW and NW shows positive trend of variation of rainy days, SE and NE shows negative trend of variation of rainy days. The maximum value of averaged rainy days 33, 34, 19 and 16 is found in the SE, SW, NE and NW region in 1989, 1999, 1951, and 1977, respectively. The minimum value of averaged rainy days 14, 12, 03 and 00 is found in the SE, SW, NE and NW region in 1976, 1957, 1981 and 1981, respectively. The maximum increasing tendency 0.1113 is observed in the SW region and minimum -0.0105 is found in the SE region. This indicates that post- monsoon rainfall in the SW side of Bangladesh increased more than that of all other sides.

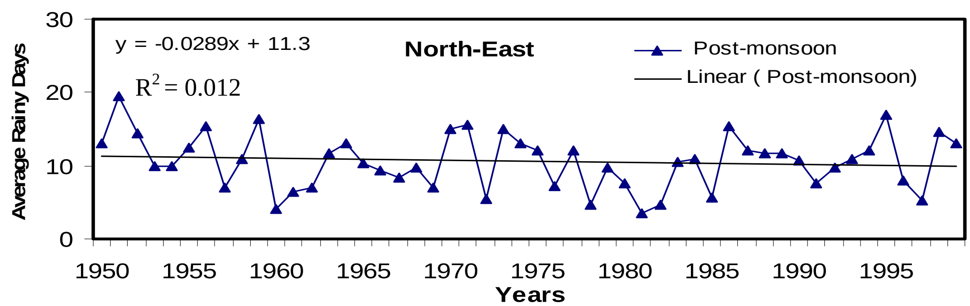
(a)



(b)



(c)



(d)

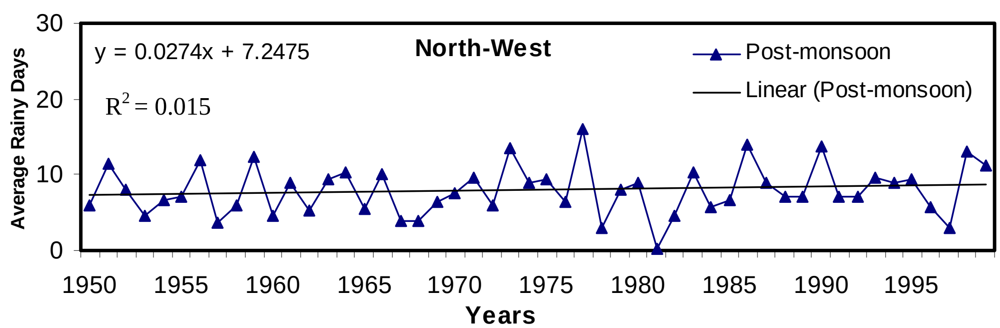
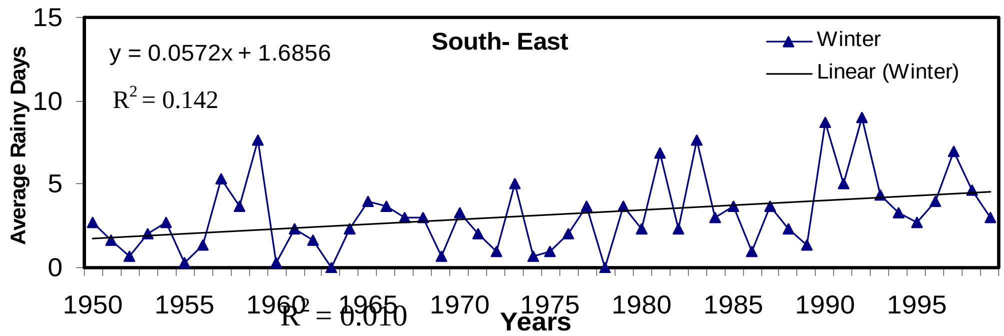


Fig. 4.48 Variability of average rainy days in post- monsoon: (a) South-East, (b) South-West, (c) North-East, (d) North-West.

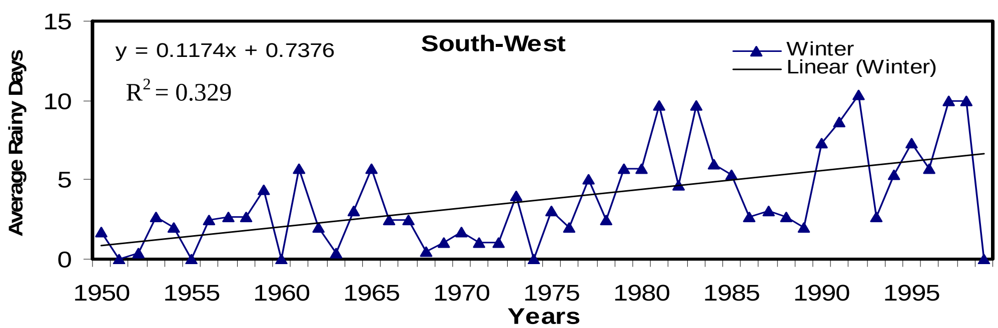
4.5.4 Winter

Fig. 4.49 (a-d) shows variability of averaged rainy days for different regions during winter season in Bangladesh. All regions shows positive trend of variation of rainy days. The maximum value of averaged rainy days 09, 10, 08 and 08 is found in the SE, SW, NE and NW region in 1992, 1992, 1957, and 1981, respectively. The minimum value of averaged rainy days 00 is found in the SE region in 1963 and 1978. The minimum value of averaged rainy days 00 is found in the region SW in 1955, 1960, and 1974. The same minimum value of averaged rainy 00 is found in the NE region in 1952, 1961, 1974 and 1978. The minimum value of NW region also 00 in 1956, 1960 and 1999. The maximum increasing tendency 0.1174 is observed in the SW region and minimum 0.05 is found in the NW region. This indicates that winter rainfall in the SW side of Bangladesh increased more than that of all other sides.

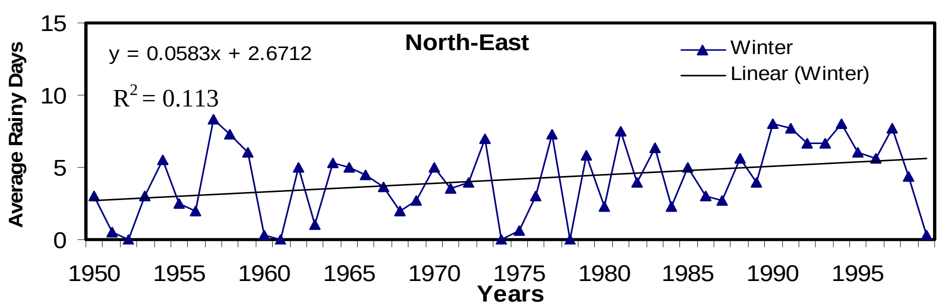
(a)



(b)



(c)



(d)

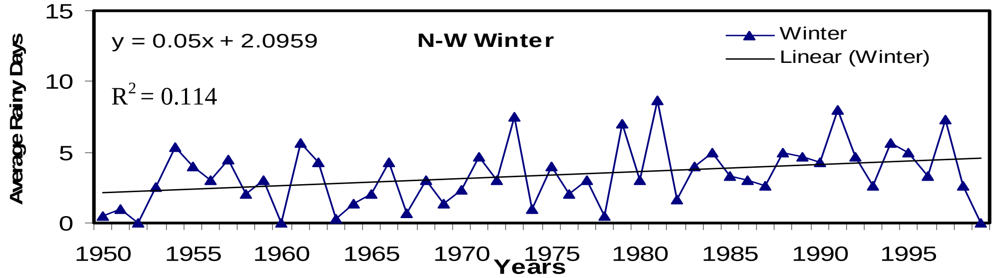
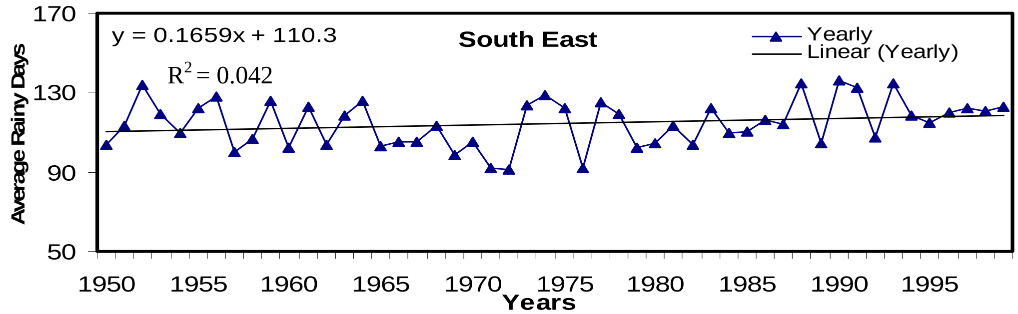


Fig. 4.49 Variability of average rainy days in winter : (a) South-East, (b) South-West, (c) North-East, (d) North-West.

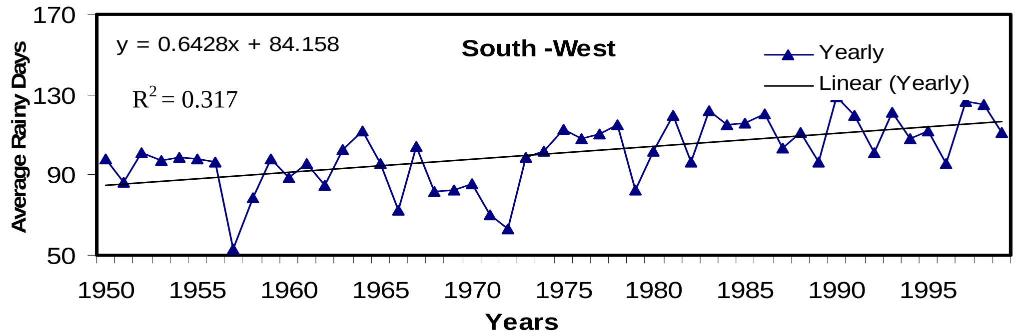
4.5.5 Yearly

Fig.4.50 (a-d) shows yearly variation of averaged rainy days for SE, SW, NE, and NW regions of Bangladesh. All the four regions show the positive trend of yearly variation of averaged rainy days. The maximum value of rainy days 136, 129, 156 and 124 is found in the SE, SW, NE and NW region in 1990, 1990, 1968 and 1977, respectively. The minimum value of rainy days 91, 53, 77 and 74 is observed in the SE, SW, NE and NW region in 1972, 1957, 1961 and 1957, respectively. The maximum increasing trend of rainy days 0.6428 is found in the SW region and the minimum increasing trend of rainy days 0.1659 is observed in the SE region. The yearly averaged rainy days in the SE, SW, NE and NW region is 115, 101, 129 and 98 days, respectively. The maximum and minimum yearly averaged rainy days is found in NE and NW regions, respectively. Rafiuddin et al. [26] showed that the scattered-type and arc-type precipitation systems is dominated in the NE and NW region, respectively.

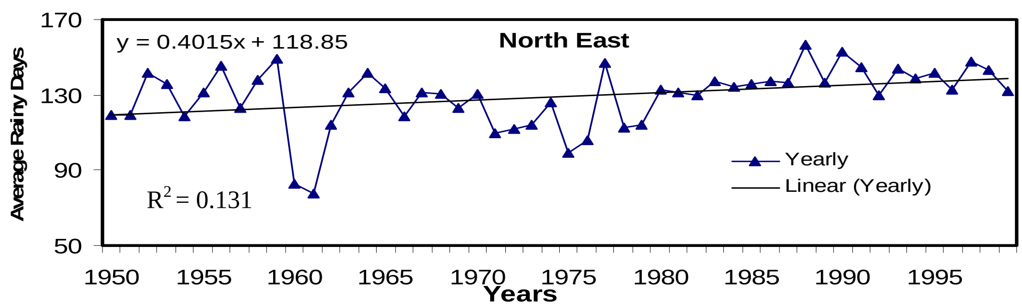
(a)



(b)



(c)



(d)

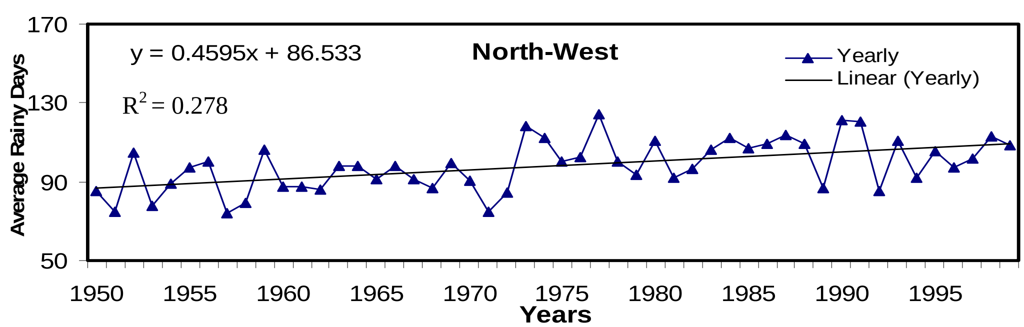


Fig. 4.50 Yearly variation of average rainy days for : (a) South-East, (b) South-West, (c) North-East, (d) North-West.

4.5.6 Decadal

Fig.4.51 (a-d) shows decadal variation of averaged rainy days for SE, SW, NE, and NW regions of Bangladesh. All the four regions show the positive trend of decadal variation of averaged rainy days. The maximum value of average rainy days 121, 113, 139 and 105 is found in the SE, SW, NE and NW region in D5, D5, D5 and D4 respectively. The minimum value of rainy days 110, 89, 117 and 89 is observed in SE, SW, NE and NW region in D3, D1, D3 and D1 respectively. The maximum increasing trend of rainy days 6.8939 is found in the SW region and the minimum increasing trend of rainy days 1.6998 is observed in the SE region.

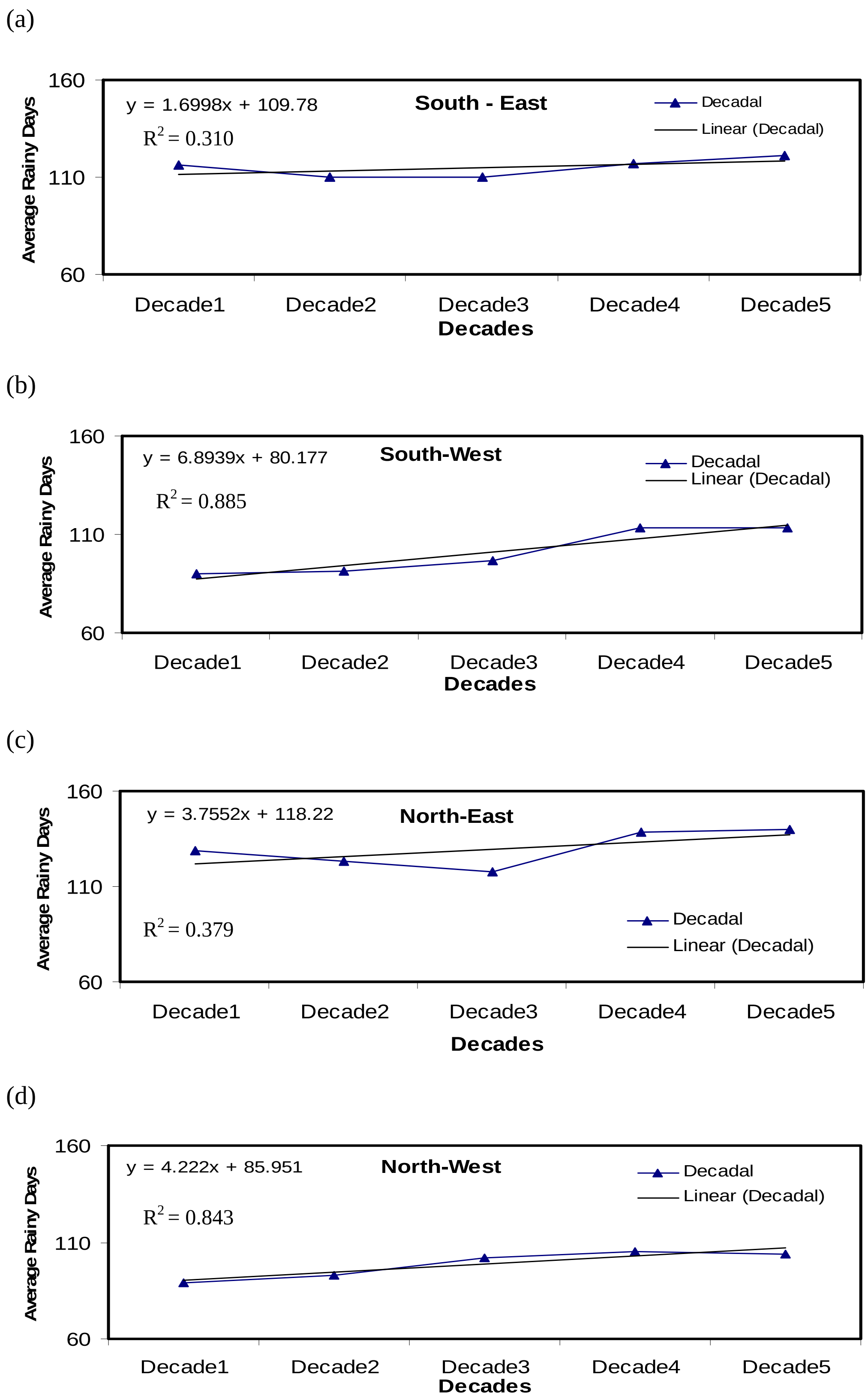


Fig. 4.51 Decadal variation of average rainy days for : (a) South-East, (b) South-West, (c) North-East, (d) North-West.

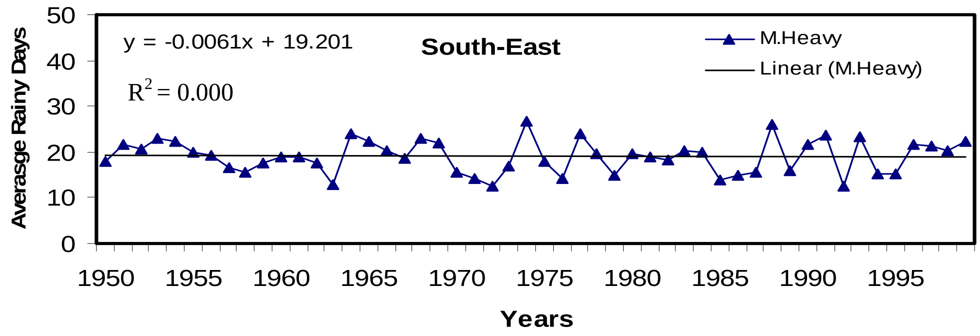
4.5.7 Variation of extreme rainfall days

Regional variations of three extreme rainfall days are discussed in this sub-section.

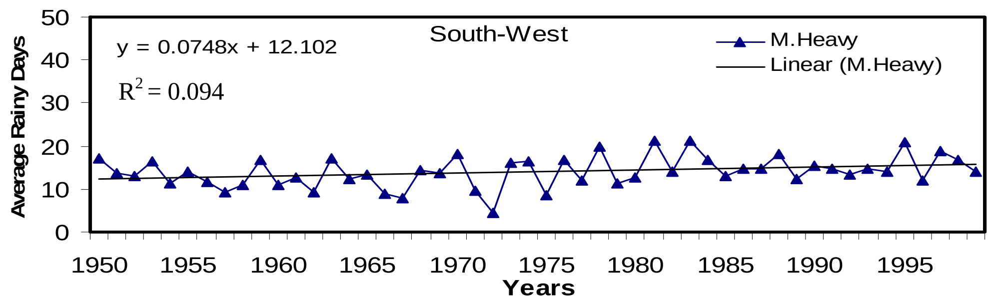
4.5.7.1 Moderate heavy rainy days

Fig. 4.52 (a-d) shows regional variability of averaged moderate heavy rainy days. All the region show the increasing tendency of moderate heavy rainy days except SE region. The maximum increasing tendency of moderate heavy rainy days of value 0.0748 is observed in the SW region and minimum 0.0683 is found in the NW region. The decreasing tendency of moderate heavy rainy days of value -0.0061 is observed in the SE region. The maximum value of moderate heavy rainy days 26, 21, 32 and 22 is found in the SE, SW, NE and NW region in 1974, 1981 and 1983, 1964 and 1984, respectively. The minimum value of moderate heavy rainy days 12, 04, 12 and 08 is observed in the SE, SW, NE and NW region in 1972, 1972, 1961 and 1962, respectively.

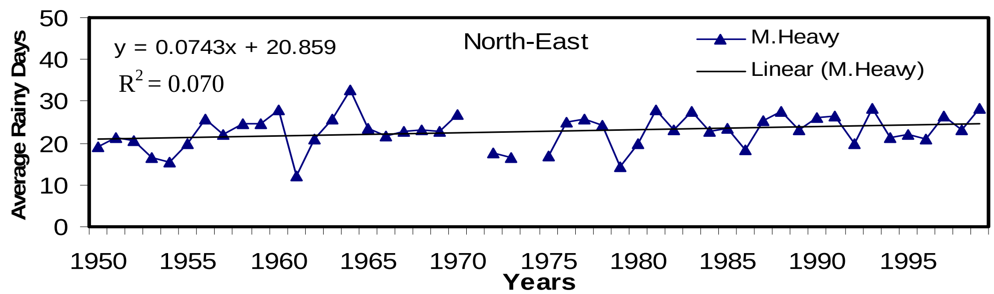
(a)



(b)



(c)



(d)

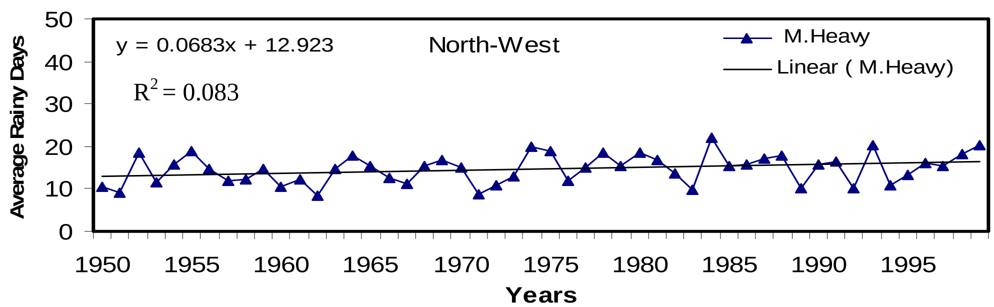


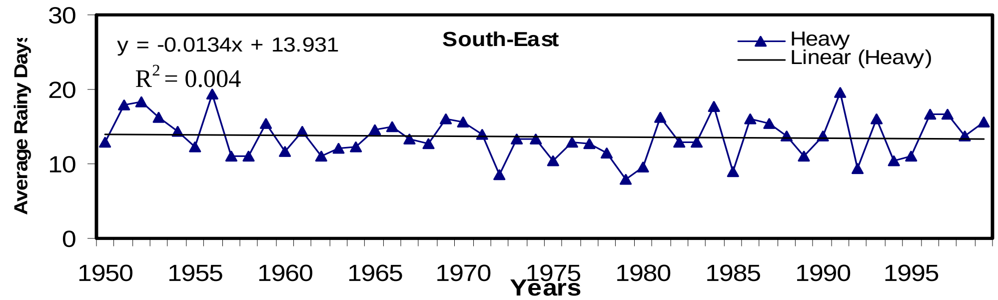
Fig.4.52 Variability of average rainy days in M.Heavy: (a) South-East (b) South-West, (c) North-East, (d) North-West.

4.5.7.2 Heavy rainy days

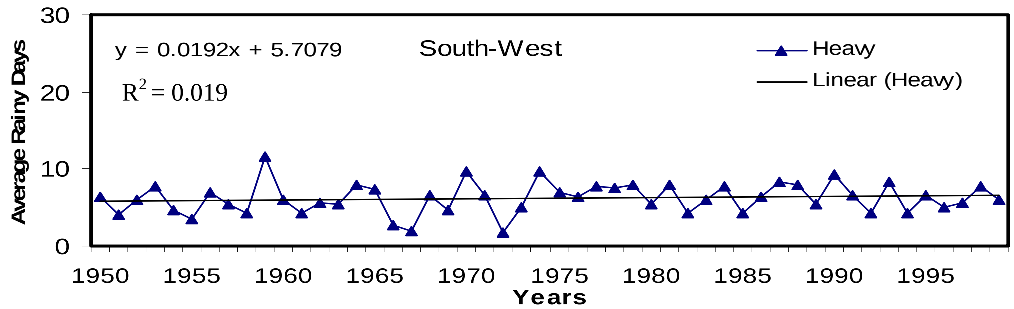
Fig. 4.53 (a-d) shows regional variability of averaged heavy rainy days. All the region show the increasing tendency of heavy rainy days except SE region. The maximum value of heavy rainy days 19, 11, 19 and 14 is found in the SE, SW, NE and NW region in 1991, 1959, 1991 and 1990 respectively. The minimum value of heavy rainy days 08, 01, 04 and 02 is observed in the SE, SW, NE and NW region in 1979, 1972, 1961 and 1977 respectively.

The maximum increasing tendency of heavy rainy days of value 0.0806 is observed in the SE region and minimum 0.0192 is found in the SW region. The decreasing tendency of heavy rainy days of value -0.0134 is observed in the SE region.

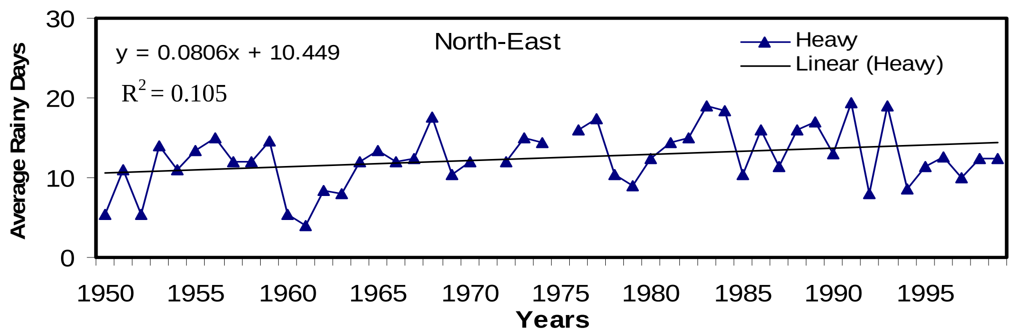
(a)



(b)



(c)



(d)

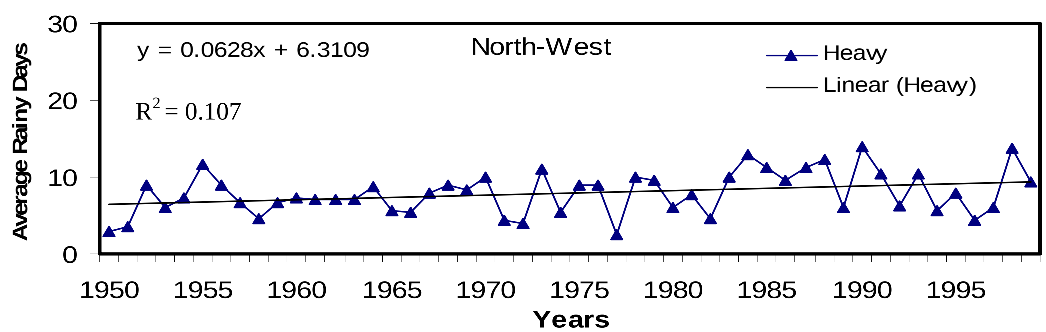


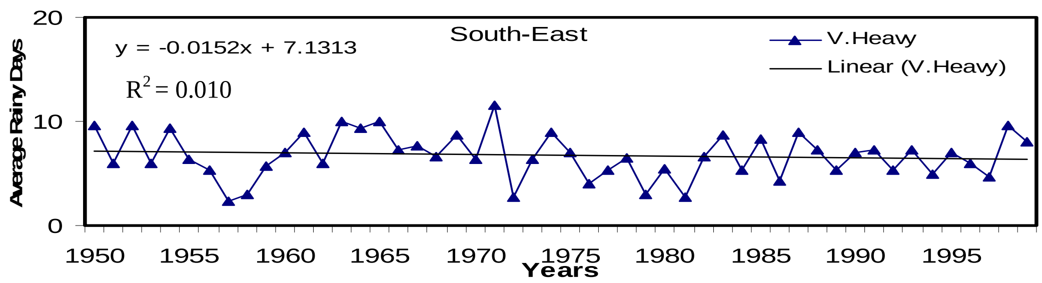
Fig.4.53 Variability of average Heavy rainy days in : (a) South-East (b) South-West, (c) North-East, (d) North- West.

4.5.7.3 Very heavy rainy days

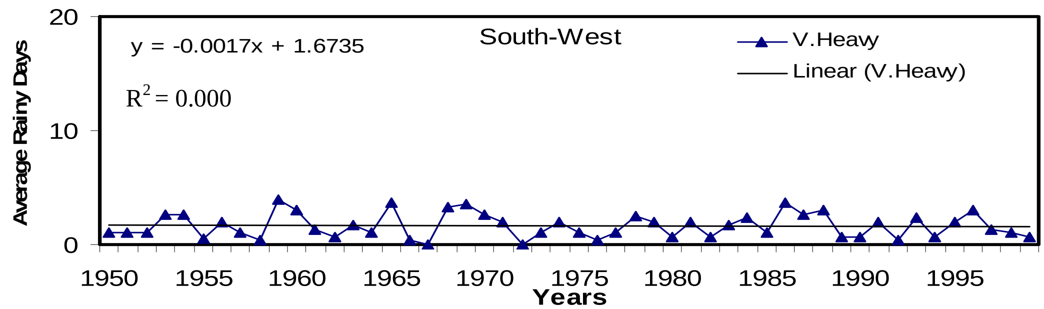
Fig. 4.54 (a-d) shows regional variability of averaged very heavy rainy days. SE and SW regions show negative trend of very heavy rainy days variation. NE and NW regions show positive trend of very heavy rainy days variation. The maximum value of very heavy rainy days 11, 04, 09 and 07 is found in the SE, SW, NE and NW region in 1971, 1959, 1983 and 1987 respectively. The minimum value of very heavy rainy days 02, 00, 00 and 00 is observed in the SE, SW, NE and NW region in 1957, 1967, 1961 and 1975 respectively.

The maximum increasing tendency of very heavy rainy days of value 0.0309 is observed in the NW region. The decreasing tendency of very heavy rainy days of value -0.0152 is observed in the SE region.

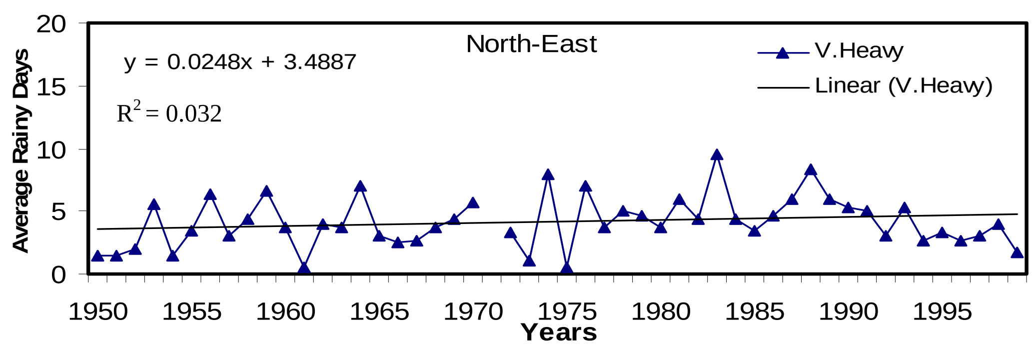
(a)



(b)



(c)



(d)

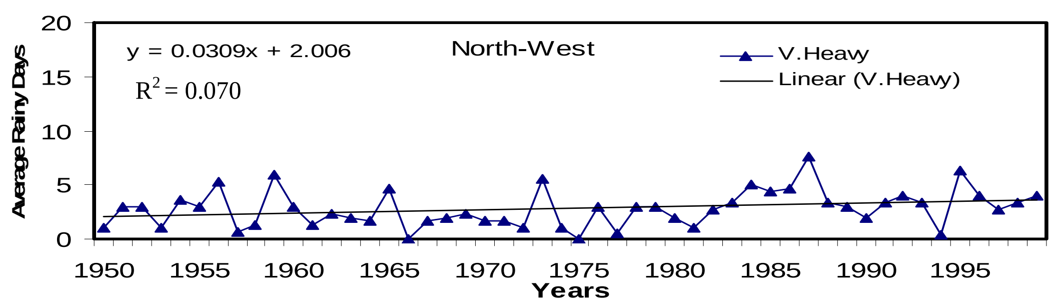


Fig.4.54 Variability of average very heavy rainy days in : (a) South-East (b) South-West, (c) North-East, (d) North- West.

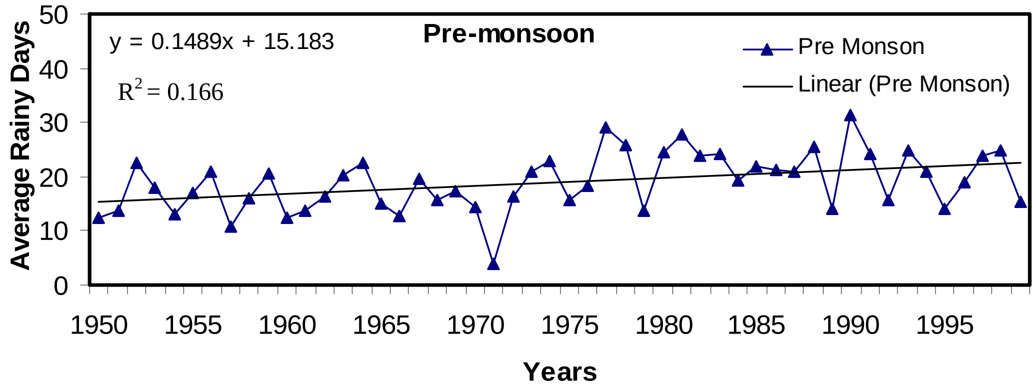
4.6 Country Average Variation of rainy days

Fig. 4.55 (a-i) show country averaged variation of rainy days for seasonal, yearly, decadal, moderate heavy, heavy and very heavy. Fig. 4.55 (a) shows positive trend of variation of rainy days for pre-monsoon season with maximum value 31 in 1990 and minimum value 04 in 1971. Fig. 4.55(b) also shows positive trend of variation of rainy days for monsoon, where the maximum value is found 85 in 1984 and minimum value is found 61 in 1972. Fig. 4.55 (c) shows positive variation of rainy days for post-monsoon with maximum value 21 in 1959 and minimum value 08 in 1981.

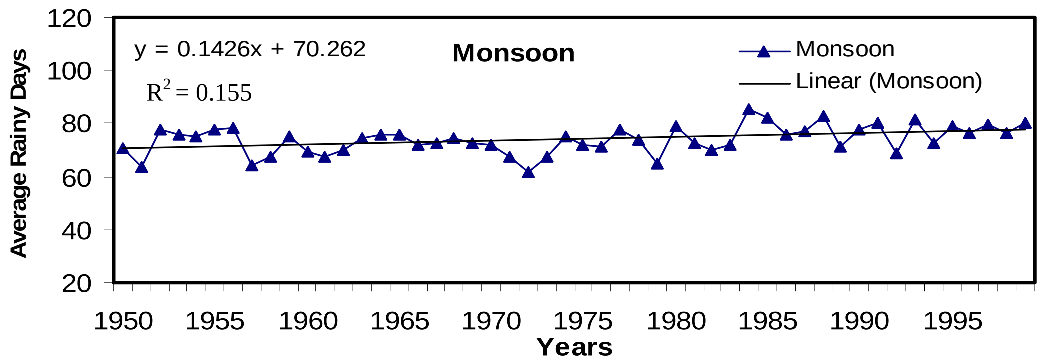
Fig. 4.55 (d) shows positive trend of rainy days for winter season with maximum value 09 in 1981 and minimum value 00 in 1960. Fig. 4.55 (e) shows increasing trend of the yearly variation of rainy days with maximum value 133 in 1990 and minimum value 89 in 1972. Fig. 4.55 (f) also shows positive trend of Decadal variation of average rainy days with maximum value 119 in Decade4 and minimum value 107 in Decade2

Fig.4.55 (g) shows positive trend Moderated Heavy rainy days with maximum value 25 in 1974 and minimum value 10 in 1972. Fig.4.55 (h) shows positive trend of Heavy rainy days with maximum value 15 in 1984 and minimum value 06 in 1961. Fig.4.55 (i) also shows positive variation of very heavy rainy days with maximum value 06 in 1987 and minimum value 01 in 1957.

(a)



(b)



(c)

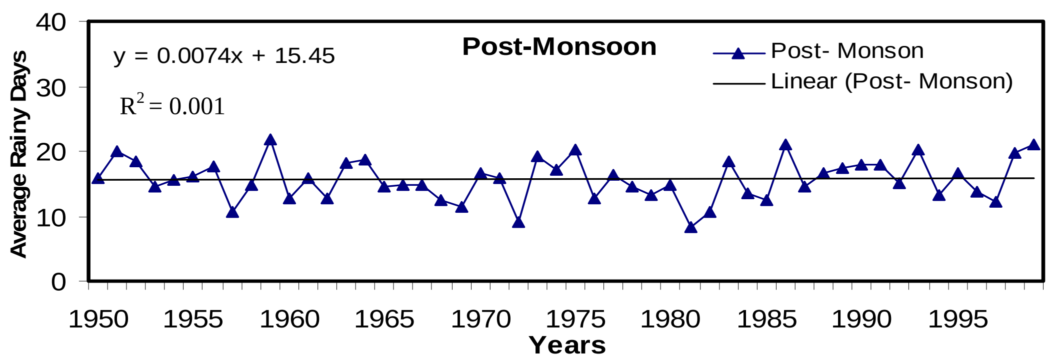
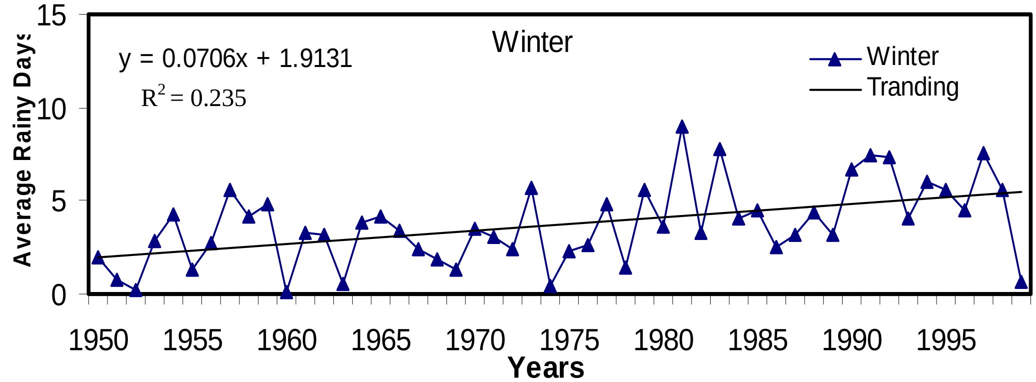
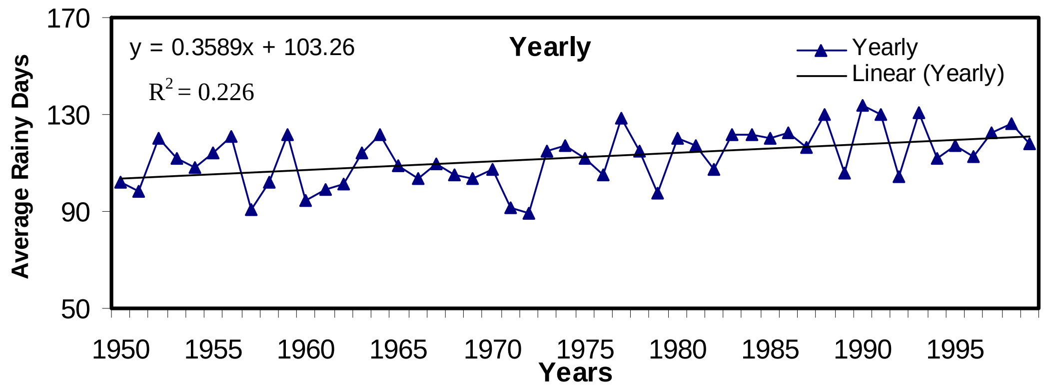


Fig. 4.55 Variability of country average rainy days: (a) Pre-monsoon, (b) Monsoon, (c) Post-monsoon.

(d)



(e)



(f)

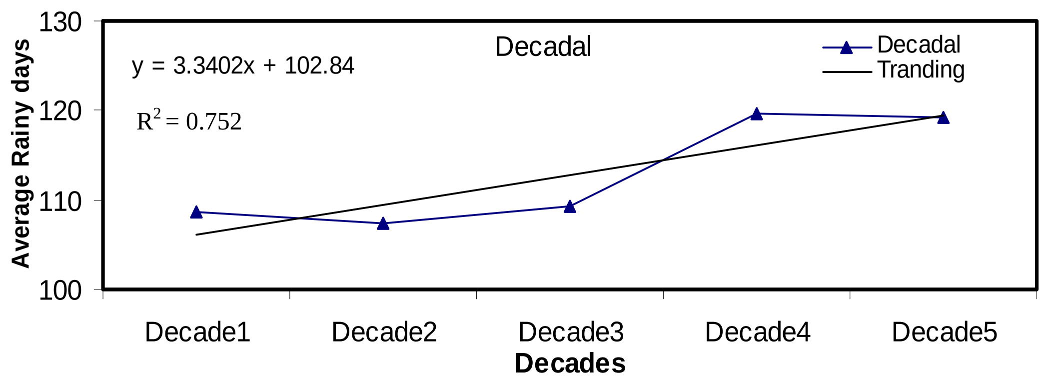


Fig.4.55. Continued: (d) Winter, (e) Yearly (f) Decadal.

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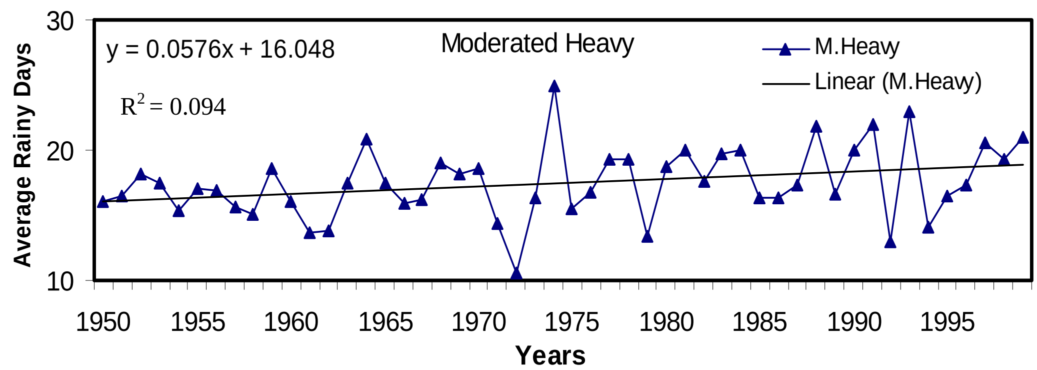
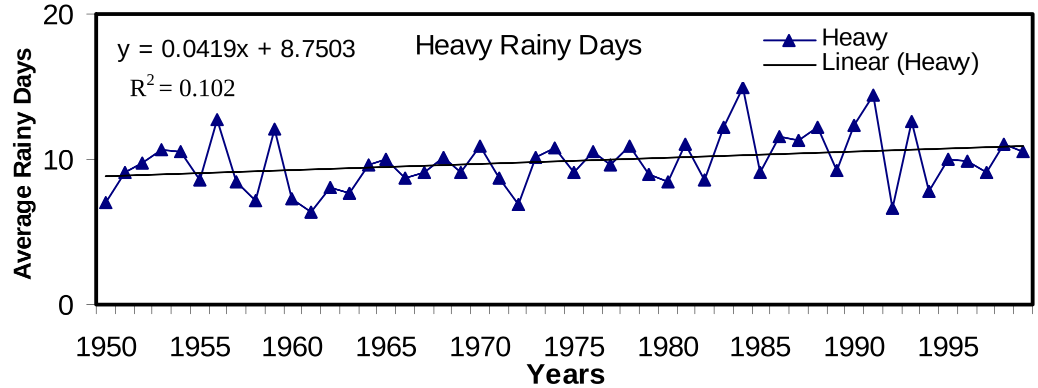
(g)



(h)



(i)

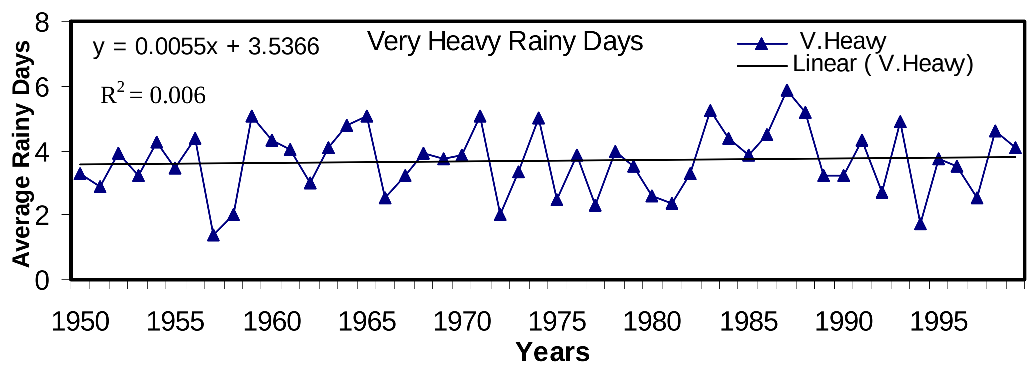


Fig.4.55. Continued: (g) Moderated Heavy, (h) Heavy (i) Very Heavy.

The averaged rainy days in different seasons for different stations and regions are given in the Table 4.1.

Table 4.1 Average rainy days in different seasons for different stations and regions.

Stations or regions	Pre-monsoon	monsoon	Post-monsoon	winter	yearly	decadal	M. Heavy	Heavy	V. Heavy
Dhaka	26.41	79.35	11.17	4.51	120.70	120.61	16.84	9.02	2.98
Comilla	22.98	70.46	9.39	3.4	107.47	107.74	18.5	11.11	3.34
Chittagong	20.30	79.73	12.24	3.31	116.21	116.59	17.46	12.25	7.10
Cox's Bazar	17.44	89.29	12.80	2.92	123.12	122.95	21.42	17.75	9.71
Khulna	16.72	67.55	8.62	3.55	99.86	98.94	15.67	6.70	2.05
Jessore	18.23	73	9.37	4.10	105.13	105.01	13.58	6.23	1.31
Satkhira	16.61	72	9.45	3.875	105.37	97.19	14.6	6.47	1.72
Mymensing	24.59	73.69	8.74	3.82	112.65	112.52	18.19	10.02	3.02
Srimongal	32.36	78.89	11.64	4.07	129.74	128.39	20.86	10.34	2.4
Sylhet	42.93	97.52	11.55	5.08	156.24	155.40	31.56	18.34	7.90
Rangpur	22.45	71.46	8.36	3.67	106.15	106.03	16.82	9.23	3.92
Bogra	19.02	71.25	9.52	3.91	103.33	103.53	14.167	7.27	2.21
Dinajpur	14.10	63.12	5.59	2.59	85.85	86.54	14.15	8.58	3.075
SE	10.08	74.89	25.24	3.14	114.52	114.87	19.05	13.59	6.74
SW	9.55	64.90	22.73	3.73	100.55	100.86	14.01	6.20	1.63
NE	31.63	82.74	10.56	4.16	129.08	129.49	22.76	12.51	4.12
NW	18.33	68.60	7.94	3.37	98.25	98.62	14.66	7.91	2.79
Country Average	18.98	73.90	15.63	3.71	112.41	112.86	17.52	9.82	3.67

4.7 Rainy Days Variation of Dry and Wet Regions

The whole country is divided in two regions: dry- and wet- region according to humidity anomalies as Islam and Uyeda [27] proposed. Fig. 4.56 shows the variation of rainy days in the dry region of Bangladesh. This figure shows that the rainy days are increasing. The 50 years average rainy days in the dry region is found 103 days. The maximum deviation -27 is observed in the year 1957.

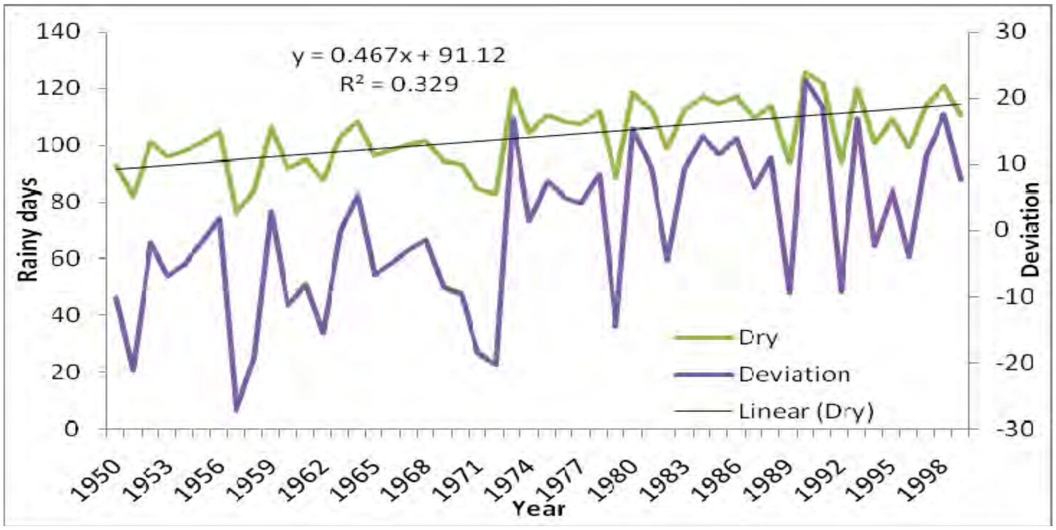


Fig.4.56 Variation of rainy days and deviation in dry region of the country.

Fig. 4.57 shows the variation of rainy days in the wet region of the country. This figure indicates that rainy days in the wet region are also increasing but increasing tendency is less than that of dry region. The 50 years average rainy day in the wet region is found 120 days. The maximum deviation -50 days is observed in the year 1971.

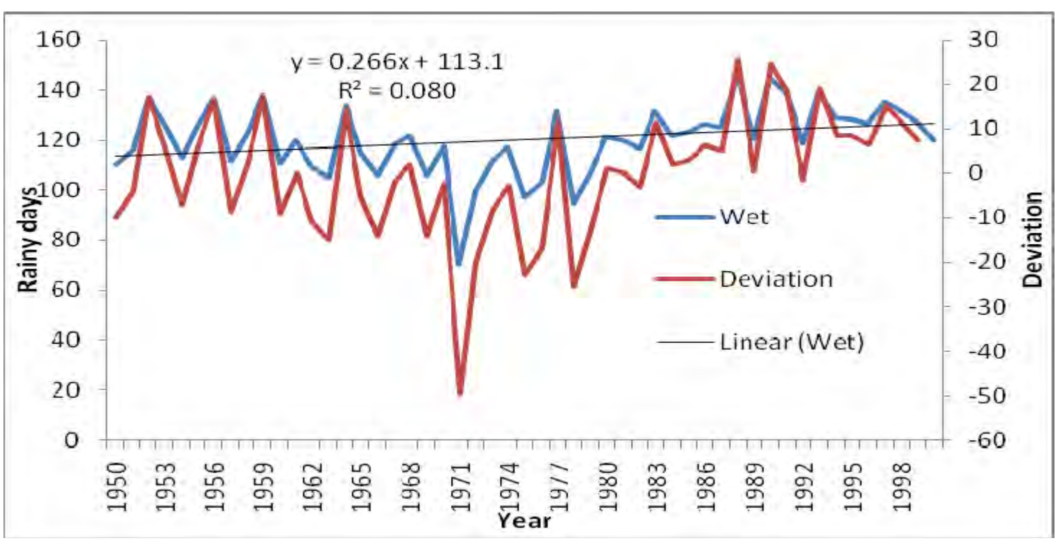


Fig.4.57 Variation of rainy days and deviation in wet region of the country.

CHAPTER 05

Summery and Conclusions

Fifty years (1950-1999) daily rainfall data of 13 metrological stations of Bangladesh Meteorological Department (BMD) have been used in this study. . Seasonal, yearly and decadal trend of variation of rainy days are studied. The whole country is divided into four regions named: South-East (SE), South-West (SW), North-East (NE) and North-West (NW). Variation of three threshold rainy days named by BMD: Moderated Heavy (22 mm < M. Heavy ≤ 44 mm), Heavy (44 mm <Heavy ≤ 88 mm)and Very Heavy (V. Heavy ≥ 88 mm) are studied.

During pre-monsoon period in Bangladesh except Srimongal all the stations show increasing trend of rainy days. The highest positive trend of value 0.25 is observed for the station of Dinajpur and lowest is -0.05 is observed for the station of Srimongal. In monsoon, all the stations show increasing trend of rainy days except Dhaka, Chittagong, Cox's Bazar, Srimongal and Rangpur. The highest positive trend of value 0.64 is observed for the station of Khulna and lowest negative trend of value -0.01 observed for the station Rangpur during monsoon period in Bangladesh. Dhaka, Chittagong, Srimongal and Bogra stations show negative trend of rainy days during post-monsoon period and all other stations show positive trend. The highest positive trend of value 0.11 is observed for the station of Khulna and lowest is 0.003 for Cox's Bazar station. The negative trend of rainy days of value -0.11 is observed for the station Srimongal and -0.01 for Chittagong station during post-monsoon period in Bangladesh. During winter season, all stations show positive trend. The highest positive trend of value 0.14 is found for the station of Khulna and lowest is 0.003 for Rangpur station. For yearly variation of rainy days all stations show positive trend except Srimongal during 1950-1999 in Bangladesh. The highest positive trend of value 1.11 is observed for the station of Khulna and lowest is 0.01 for Chittagong station. The negative trend of yearly variation of rainy days of value -0.05 is observed for the station of Srimongal. All the stations show positive trend of decadal variation of rainy days except Srimongal station during 1950-1999. The highest positive trend of value 9.86 is observed for the station of Khulna and lowest is 0.08 for Chittagong station. The negative trend of Decadal variation of rainy days of value -4.17 is observed for the station of Srimongal. All the stations shows increasing trend of moderate heavy rainy days except Srimongal and Comilla during 1950-1999. The highest positive trend of value 0.14 is found for the station of Rangpur and lowest is 0.01 for Sylhet station. The negative trend of rainy days of value -0.03 and -0.01 is observed for the station of Srimongal and Comilla during 1950-1999, respectively. For heavy rainy days except Comilla and Satkhira all other stations show positive trend during 1950-1999. The highest positive trend of value 0.10 is observed for the station of Sylhet and lowest is 0.01 for Mymonsing station. The negative trend of heavy rainy days of value -0.13 and -0.01 is observed for the stations of Comilla and Satkhira, respectively. For very heavy rainy days except Mymensing, Rangpur, Bogra, Dinajpur all other stations show positive trend during 1950-1999. The highest positive trend of value 0.05 is observed for the station of Dinajpur and lowest is 0.001 for Mymonsing station. The negative trend of heavy rainy days of value -0.02 observed for the station Comilla and -0.003 is observed for the stations of Cox's Bazar.

In the regional variation for pre-monsoon, four regions show positive trend of rainy days. The maximum increasing tendency 0.18 is observed in the NW region and minimum 0.11 is found in the SE region. For monsoon period all four regions show positive trend of rainy days variation. The maximum increasing tendency 0.32 is observed in the SW region and minimum 0.02 is found in the SE region. Among four regions SW and NW shows positive trend of variation of rainy days, SE and NE shows negative trend of variation of rainy days for post-monsoon period. The maximum increasing trend 0.11 is observed in the SW region and minimum -0.01 is found in the SE region. In winter all regions show positive trend of variation of rainy days. The maximum increasing trend 0.12 is observed in the SW region and minimum 0.05 is found in the NW region. All the four regions show the positive trend of yearly variation of averaged rainy days. The maximum increasing trend of rainy days 0.64 is found in the SW region and the minimum increasing trend of rainy days 0.17 is observed in the SE region. Decadal variation of averaged rainy days for SE, SW, NE, and NW regions of Bangladesh. All the four regions show the positive trend of decadal variation of averaged rainy days. The maximum increasing trend of rainy days 6.89 is found in the SW region and the minimum increasing trend of rainy days 1.70 is observed in the SE region.

For threshold rainy days variation of Moderated Heavy except SE region rest three regions show positive trend of averaged rainy days. SE region shows negative trend in case of Heavy rainy days variation. For Very Heavy rainy days variation NE and NW regions show positive trend on the other hand SE and SW region show negative trend.

In country averaged variation of rainy days for pre-monsoon season shows positive trend with maximum value 31 in 1990 and minimum value 04 in 1971. Monsoon season shows increasing trend of rainy days variation where the maximum value is found 85 in 1984 and minimum value is found 61 in 1972. Positive trend of averaged rainy days variation is found for post-monsoon season with maximum value 21 in 1959 and minimum value 08 in 1981. Positive trend of rainy days for winter season with maximum value 09 in 1981 and minimum value 00 in 1960. Increasing trend of the yearly variation of rainy days with maximum value 133 in 1990 and minimum value 89 in 1972. Positive trend of Decadal variation of average rainy days with maximum value 119 in Decade4 and minimum value 107 in Decade2.

Country averaged Moderated Heavy rainy days shows positive trend with maximum value 25 in 1974 and minimum value 10 in 1972. Heavy rainy days variation shows positive trend with maximum value 15 in 1984 and minimum value 06 in 1961. Country averaged Very Heavy rainy days variation also shows positive trend with maximum value 06 in 1987 and minimum value 01 in 1957.

The yearly averaged rainy days in the SE, SW, NE and NW region is 115, 101, 129 and 98 days, respectively. The 50 years averaged rainy days in the pre-monsoon, monsoon, post-monsoon and winter periods is 19, 74, 16, 04 days, respectively. All the four regions show the positive trend of yearly variation of averaged rainy days with maximum and minimum in the SW and SE regions, respectively. The yearly averaged rainy days in the wet region (120 days) is higher than that of dry region (103 days) of the country. The country averaged seasonal, yearly and decadal variation of rainy days as well as three threshold rainy days show positive trend. The yearly averaged increase of rainy days is found 0.3589 days/year.

It is apparent that rainy days are changing in different seasons, most of the stations, regions and country average show positive trend which lead to change our climate.

On fitting the linear trend line, it is observed that trend is increasing for all the stations, except for Srimongal. For Srimongal, the trend apparently is decreasing. The slope of the trend line is not very large in magnitude for all the stations, but it is positive. Based on the above results, it is of immense importance to discuss the ecological, economic, and social impacts that could result if increasing rainy days trends continue in these stations in the future. Excess rainy days could also lead to soil saturation as well as to runoff and soil erosion problems.

On the other hand, Srimongal experienced a decreasing rainy days trend during the 50 year time period of this study and if this trend continues in the future then it could have repercussions in the sustainability of surface water resources and groundwater recharge.

The linear trend line shows that there is an increase in rainy days for all stations except Srimongal. The study, therefore, offers remarkable insights and new perspective for policy makers and planners in helping them take proactive measures in the context of climate change. Timely measures and institutional changes can certainly help in reducing the irreparable damages that can be caused by climate change, since the trends in 50 year precipitation data do not deny climate change is occurring.

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