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FOREWORD

Conservation of environment is essential to ensure the security of water, food and energy for human beings. The challenges of environmental pollution, climate change and disasters must be addressed carefully with integrated initiatives, enhanced awareness and research. For deltaic landmass with vast coastal areas, the peoples of Bangladesh are the main sufferers of climate change and natural disasters. Therefore, interdisciplinary researches are utmost important for the control, mitigation, adaptation and dissemination of experiences for sustainable environmental management.

The Rajshahi University Journal of Environmental Science (RUJES) is a multi-disciplinary journal to promote understanding of environmental issues includes environmental pollution, biodiversity loss, emission of carbon dioxide from fossil fuel, climate change and their impacts on air, water, soil and ecosystem. Thus, the journal offers a scientific platform for publishing the critical reviews and original research achievements through peer-review.

All the contributors and reviewers are highly acknowledged for their interest, efforts and co-operation. I would like to express my sincere appreciation to the members of editorial board and associates for their support in publishing the current volume of the journal. I also thanks to the employees of printing press for their necessary help. Any further suggestion for the improvement of the next issues will be highly appreciated. The Chief Editor and Members of the Editorial Board do not bear any responsibility of the views expressed in the papers. The online version of the journal is available at: http://ru.ac.bd/ies

Chief Editor

INSTRUCTIONS TO AUTHORS

Manuscripts: The manuscript must be sent in MS Word Document file format containing title of the paper, author's name(s), affiliation(s), author's full postal address and corresponding author's e-mail. Abstract should be within 250 words along with maximum of 5 keywords indicating the objectives, results or conclusion of the study. The text of the full paper should preferably be within 5000 words (max. 10 pages) having the following sub-titles:

- **1. Introduction**: Introduction should be concise and precise relevant to objectives of study.
- **2. Materials and Methods**: Standard and published methods should not be described rather only be cited as references. Any modification or new set up should be stated.
- **3. Results and Discussion**: Results should be presented with appropriate figures, tables, graphs, etc. with proper interpretation and justification by relevant previous studies.
- **4**. **Conclusion:** Concise form of results with concluding remarks.
- **Tables, Graphs and Figures**: The paper should contain maximum of 12 tables, graphs and figures all together. Figures, graphs and photographs should be given as attached file along with appropriate marking numbers in standard BMP format (uncompressed). Original illustrator, graphic or photo files must be supplied with finally accepted manuscript.
- **Acknowledgements (if any)**:
- **References.** Appropriate and relevant recent references must be cited following instruction given.

The following format needs to follow for preparation of manuscript:

1. Format Instructions

1.1. Instructions for Typists

Margins are to be set to a width of 15.2 cm, and each page must be typed in Times New Roman 11 points letter for the main text with a 13 points spacing between the lines. The footnotes to be typed in Times New Roman 10 points letter with an 11 points spacing between the lines. Each page must be typed in a page depth of 21.6 cm. On the first page, the title of the paper should start after three blank lines below the journal heading. New paragraphs should be started without any indentation. Title of paper should be typed in bold, 14 point all upper-case letters, with 6 and 12 points spaces above and below respectively. The headings used are:

2. First-Order Heading

These should be typed in bold, 12 point upper- and lower-case letters, with 6 points space above and below the heading. The text after the heading will begin at the left-hand margin (i.e., not indented as for new paragraph).

2.1. Second-Order Heading

This should be typed in 12 point bold with a capital initial for each word at the left-hand margin, 6 points space above and below the heading.

2.1.1. Third-Order Heading

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Special Attention

3.1. Tables

Put a table heading at the top of the table and skip one line above and below the tables. If table heading extends over one line, continue on the second and following lines immediately below the first letter of the heading. Do not use full stop at the end of each table caption. Use horizontal lines above tables, below column headings, and below tables. Use capitals for the first letter of column headings. As far as practicable, arrange the tables in the vertical direction just as in text. Tables and text may appear on the same page. Table 1 is an example of an acceptable table format.

Table 1. Annual rainfall and water table of the study area

Areas	Annual Rainfall (mm)		Water Table (m)	
	Wet Season	Dry Season	Wet Season	Dry Season
Rajshahi	20.4	27.4	90.0	20.4
Natore	30.6	38.6	34.6	31.6
Pabna	45.9	46.9	45.0	43.9

3.2. Figures

Skip 6 points space above and below the figures. Put a figure caption at bottom of the figure and leave 6 points space between figure and caption, and use a full stop at end of the caption. Start second and subsequent lines immediately below the first letter of caption. Skip 6 points space after caption. Figures and text may appear on the same page. Legends, scales, etc. must be large enough to be legible. Give the consecutive numbers for tables and figures, respectively. You can break a paragraph for placing the figure. Try to avoid blank spaces within the text.

3.3. Equations

Equations should be numbered sequentially as follows: Use 1 line spacing instead of a 13 points spacing for the lines from just above to just below the equation.

$$\nabla^2\phi = 0 \qquad (1)$$

3.4. References

In the text, author's last name should be followed by the year of publication; e.g. "(Islam, 2016; Mostofa *et al.*, 1997; Redwan and Shafiuzzaman, 2015) or "Azad (1998) showed that …". In the list of references, arrange authors' last names in alphabetical order with 0.5 cm indentation for the second and following lines of each reference. When two or more references by the same author are listed, the earlier work should appear first. All references must be cited in the text.

Style of References

For Journal:

Mostafa MG, Chen YH, Jean JS, Liu CC and Lee YC. 2011. Kinetics and Mechanism of Arsenate Removal by Nanosized Iron Oxide-coated Perlite. *J. Hazardous Mat.*, **187**: 89-95.

Sen I, Parua DK, Bera S, Islam MS and Poole I. 2012. Contribution to the Neogene Fossil Wood Record and Palaeoecological Understanding of Bangladesh. *Palaeontographica, Abteilung B: Palaophytologie, Palaeobotany-Palaeophytology,* **288(1-4)**: 99-133.

For Book:

Blanford WT and Godwin-Austen HH. 1908. *The Fauna of British India, including Ceylon and Burma, Mollusca*: Testacellidae and Zonitidae: Taylor and Francis, London. 311p.

For Book Chapter:

Islam MB and Islam MS. 2006. Floods in Bangladesh: A Combined Interaction of Fluvio-anthropogenic Processes in the Sourse-sink Region, *In*: (Alphen JV, Beek EV and Taal M; eds): *Floods, From Defence To Management*. Taylor and Francis Group, London, England. P:589-595.

For Book Edited:

Kumar A and Bidhan D. 1989. *A Text Book of Environmental Science* (eds). (3rd edt) University Press, Dhaka, 525p.

For Dissertation/Thesis:

Mostafa MG. 2000. Thermodynamic Simulation of Cobalt-carbonate Aqueous System. *PhD Dissertation* (unpubl). Faculty of Engineering, Ehime University, Matsuyama, Japan, 200p.

For Report:

WDATCP (Wisconsin Department of Agriculture, Trade, and Consumer Protection). 1991. Report to the State Legislature: Agricultural Clean Sweep Demonstration Projects, *Madison, WI: Agricultural Resource Management Division*.

For Regulation:

USEPA (United States Environmental Protection Agency). 1995. Water Quality Standards-Revision of Metals Criteria, *Fed. Reg.*, **60**: 229-240.

For Proceedings:

Krewitt W, Trukenmueller A, Mayerhofer P and Freidrich R. 1995. An Integrated Tool for Environmental Impact Analysis. *In:* (Kremers H and Pillmann W) *Environmental Information Systems*, (eds), *pp* :90-97.

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Mutton D and Haque CE. 2004. Human Vulnerability, Dislocation and Resettlement: Adaptation Processes of River-bank Erosion-induced Displacees in Bangladesh. *Disasters*, **28(1)**: 4-62(22), March. http://www.ingentaconnect.com/content/bpl/disa/2004/028/001/art0,03;jsionid=2hcpbncdh3r.alice?format=pri. Cite the date of visit the web pages.

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Climate Change and Groundwater Depletion Induced Agricultural Drought: An Empirical Investigation from Central Barind Tract of Bangladesh

Mousumi Akando Mou[1*], Jannatul Naim[1] and Shitangsu Kumar Paul[1]

[1]Department of Geography and Environmental Studies, University of Rajshahi, Rajshahi-6205, Bangladesh.

Abstract

Climatic variability is one of the major factor influencing the agricultural drought in north-western part of Bangladesh especially the central Barind region. The objective of this paper is to analyze the climatic variability of temperature, rainfall and the groundwater to investigate the intensity of drought in two drought-prone villages of Godagari and Tanore Upazila of Rajshahi district in the north-western Bangladesh.The secondary data of rainfall and temperature were collected from Bangladesh Meteorological Department (BMD) of four weather stations (Rajshahi, Bogura, Dinajpur and Rangpur) to depict the climate change and to compare the climatic variables among the four districts of Greater Barind region. On the other hand, Godagari and Tanore upazila of Rajshahi district were also selected to collect the groundwater level data from Barind Multi-purpose Development Authority (BMDA) as a main focus area of this study. The present study finds that both maximum and minimum temperature have increased, rainfall pattern become irregular and despite of rainfall the level of maximum and minimum groundwater have been decreasing day by day due to the over exploitation for irrigation in the study area. For this reason, agricultural droughts have become more frequent phenomena in the central Barind tract especially in the study villages of Rajshahi district.The present study can guide the farmers about the perception of climate change, preparedness and awareness rising to combat the impact of agricultural drought intensity in near future in the central Barind region of Bangladesh.

Keywords: Climate change; Groundwater level; Agricultural drought; Central Barind Tract; Bangladesh.

1. Introduction

Climate change is now one of the most burning issue in the world contest. Bangladesh is also recognized as a vulnerable zone to climate change by the international community as well as the most disaster prone country of the world (IPCC, 2014).The global circulation model (GCM) predicts that the average temperature increase in Bangladesh due to climate change will be 1.0°C by 2030 and 1.4°C by 2050 (Ahmed and Alam, 1998; Huq *et al*., 2003; Islam, 2009). Another modelling of temperature and rainfall variability suggests that mean global temperature of Bangladesh may rise by 1.5°C to 1.8°C by 2050 (Ahmed and Alam, 1998). In addition, the mean annual temperature of Bangladesh has already been increased during the period of 1895-1980 at 0.31°C (Kates *et al.,* 1985; ADB, 1994; Burton, 1997). Besides, monsoon precipitation is likely to increase 6.8% by 2050 (Selvaraju *et al*., 2006). Likewise, Agarwala *et al.* (2003) reported that the future climate change projections show increased rainfall during monsoon season and reduced rainfall in winter months. On the basis of existing studies, it can be said that present climate is rather different from the past and rapid change is being taking place gradually.

Based on the climate change scenarios and projections, Paul (1998) described in his study that Bangladesh (especially western part) will be at risk of drought under climate change conditions. Due to the rapid climate change, it may accelerate the frequency of extreme drought events in the Barind region of north-western Bangladesh (Selvaraju and Baas, 2007). Besides, bio-physical systems and eventually the rural livelihoods are influenced by one of the major factor of climatic variability in the drought-prone areas of Bangladesh (Paul *et al*., 2014). In Bangladesh, about 13.65% of the country's GDP comes from agriculture sector and more than 40.6% engage in agricultural labor force (BBS, 2019). The crop production of the country is also highly dependent on seasonal characteristics and climatic variables such as temperature, rainfall, humidity, day length etc. (MOEF, 2009). High temperature and high rates of evapotranspiration with the distribution pattern of precipitation during the growing season will create further water stress and reduce the agricultural production in the drought-prone areas (Paul, 1998; Huq *et al*., 2003). So, the agriculture often falls in high risk during summer and winter due to

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agricultural drought in the north western part of Bangladesh. Thus, the end results of drought usually first appear on agriculture and then it impacts on food production, water resources and farmer's life and livelihood (Alam *et al*., 2013; Paul *et al*., 2013; Mahmoud *et al*., 2016). On the other hand**,** water shortage is gradually becoming a grave concern in the drought-prone Barind region due to the excessive extraction of groundwater for irrigation and it may create further pressure to drought-prone environment as well as it is considered as a major crop production risk factors (Selvaraju *et al*., 2006). Due to the over-exploitation of groundwater for irrigation purposes, the water level declines and these areas are increasing with abstraction of more ground water irrigation in the dry season.Under the condition of climate change, it is very important to detect the trend of temperature and rainfall variability, declining the ground water level and fluctuation range situation of the groundwater to investigate the correlation between climate change and drought of the study area in the central Barind tract of Bangladesh.

However, a large number of studies have been conducted in the field of climate change and its sector-wise impacts, future projection. A number of studies have focused on vulnerability to climate change and impacts assessment in the context of Bangladesh (Kates *et al*., 1985; Erickson *et al*., 1993; ADB, 1994; Asaduzzaman *et al*., 1997; Burton, 1997; Ali, 1999; Hossain *et al*., 2014; Paul, 2014;).Some studies focused on adaptation to climatic variability and change (Ahmed and Alam, 1998; Smit *et al*., 2000; Huq *et al*., 2003; Uddin *et al*., 2014, Hossain *et al*., 2016).In addition, few studies also focused on drought risk assessment in Bangladesh (Chowdhury and Hussain, 1981; Wilhite, 1986; Brammer, 1987; Adnan, 1993; UN/ISDR, 2007; Shahid and Behrawan, 2008), impact of drought on agriculture (Jabbar *et al*., 1982; Karim *et al*., 1990; Saleh *et al*., 2000; Mazid *et al*., 2005) and drought induced crisis of water, it's use and management (Mather, 1984).Other researchers emphasized on assessment of groundwater resources (Rahman and Roehrig, 2006; Haque *et al*., 2012; Zahid and Uddin, 2013; Ashraf *et al*., 2017), groundwater development and sustainability (Dennehy *et al*., 2002; Michael and Voss, 2008; Ali *et al*., 2012), analysis of groundwater fluctuation (Akther *et at*., 2009; Ahmeduzzaman *et al*., 2012; Adhikary *et al*., 2014) and groundwater depletion (Rahman and Mahbub, 2012; Konikow 2015; MacDonald *et al*., 2016; Dalin *et al*., 2017).Few of them highlighted the analysis of groundwater table (Yousuf *et al*., 2009; Ahmadian and Chavoshian, 2012; Fan *et al*., 2013) and the recent trends of groundwater levels (Hoque *et al*., 2007; Shamsudduha *et al*., 2009).The review of existing literatures reveal that very limited studies have been conducted by giving in-depth insight on climatic variability of temperature, rainfall and analyze the groundwater depletion with fluctuation of groundwater level induced agricultural drought the context of the Barind region of Bangladesh. Therefore, to fill this research gap the present study intends to explore the climatic variability and the groundwater level condition to understand and identify the agricultural drought in the drought-prone areas of the central Barind region of the north-western Bangladesh.

2. Study Area

The Barind region has four weather stations in Rajshahi, Bogura, Dinajpur and Rangpur that were selected to collect rainfall and temperature data to compare the climate change of the Greater Barind region (Figure 1).More emphasis has been given on Rajshahi weather station to present the climatic variability of Godagari and Tanore upazila including study areas due to absence of weather station in Godagari and Tanore upazila.

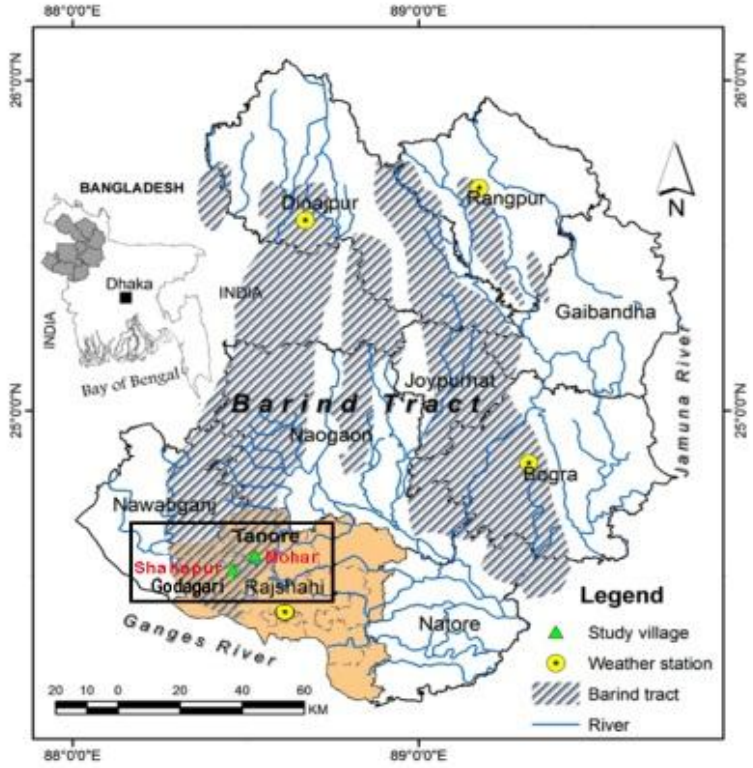

Figure 1. Location map of the study area and weather stations.

Therefore, data were used in the study as the adjacent weather station to present climatic variability of the area. Likewise, Godagari and Tanore upazila were also selected to collect the groundwater level data from Barind Multi-purpose Development Authority (BMDA). To conduct the present study, Shahapur and Mohar villages were selected purposively from Godagari and Tanore upazila respectively of Rajshahi district considering their severity of drought impacts. Godagari is located in between 24°21' and 24°36' north latitudes and in between 88°17' and 88°33' east longitudes. Tanore is located in between 24°29' and 24°43' north latitudes and in between 88°24' and 88°38' east longitudes (Figure 1). Both Godagari and Tanore upazila are severe drought-prone areas in the central Barind region of Bangladesh (Paul, 1998; Iqbal and Ali, 2001; Shahid and Behrawan, 2008; Alam *et al*., 2013; Alauddin and Sarker, 2014; Islam *et al*., 2014; Alam, 2015; Alamgir *et al*., 2015). The areas have been also selected because of high population nature and most of them engage in agriculture.

3. Materials and Methods

Secondary data was the main tools of data collection in this present study. To analyze the climatic pattern of the study area, meteorological data were collected from Bangladesh Meteorological Department (BMD) for the year of 1979-2017. On the other hand, to investigate the groundwater level of selected study areas (Godagari and Tanore), data was collected from Barind Multi-purpose Development Authority (BMDA) for the year of 1985-2017. For temperature analysis, first daily maximum and minimum temperature data were converted to yearly data and rainfall analysis, daily rainfall data were converted to annual total rainfall for the each weather station. The temperature and rainfall data of the selected weather stations were analyzed and presented graphically using Minitab (V.16) and MS Excel program to show its linear trend model of yearly maximum, minimum temperature and annual total rainfall. After the trend analysis, the anomalies were done to present the deviation of yearly maximum temperature, yearly minimum temperature and annual total rainfall data. Moreover, the present study have also shown and described that, how the maximum, minimum and average groundwater level fluctuates as well as deviatesin this area.To study the interrelationships among the variables, the correlations were also considered. Arc GIS 10.3 was exercised for making study area map.

4. Results and Discussion

The present study investigated climate change based on maximum and minimum temperature and annual total rainfall in Rajshahi, Bogura, Rangpur and Dinajpur weather stations to cover whole Barind region considering the data from 1979 to 2017 periods. Analyzed data indicates that climate is changingin the Barind region of Bangladesh at pre-monsoon season. This climate situation induced the drought hazards which is negatively impacted the agricultural production and groundwater level of the study area. In this study, an attempt has been also taken to detect the trend of groundwater level in Godagari and Tanore upazila and understand the correlation between climatic variability and groundwater level.

4.1.Changes in Temperature

This section portrays the long term linear trend models of yearly minimum and maximum temperature among the four weather stations (Rajshahi, Bogura, Dinajpur, and Rangpur) in Barind region of Bangladesh during the year of 1979 to 2017. To show the deviation, anomaly of minimum, maximum and mean temperatureare also given below:

4.1.1. Yearly Minimum Temperature

The lowest temperature of a particular day of a year is known as the yearly minimum temperature. Figure 2 represents the linear trend of the selected weather stations and it shows that the lowest minimum temperature was in Bogura station in 1983 (4.9°C), 2014 (4.5°C) and in Dinajpur station in 1995 (4.2°C). In Rajshahi station, the temperature was comparatively low in 1989 (4.6°C), 2015 (4.2°C) and 3.4°C was the lowest temperature recorded in 2003. By analyzing collected data it is found that all the stations show negative temperature trend. Figure 2 also presents that among the selected stations, the yearly minimum temperature was low in Rajshahi station. The trend of minimum temperature of Rajshahi station express the lowest negative temperature trend than the other selected stations of the Barind Region.

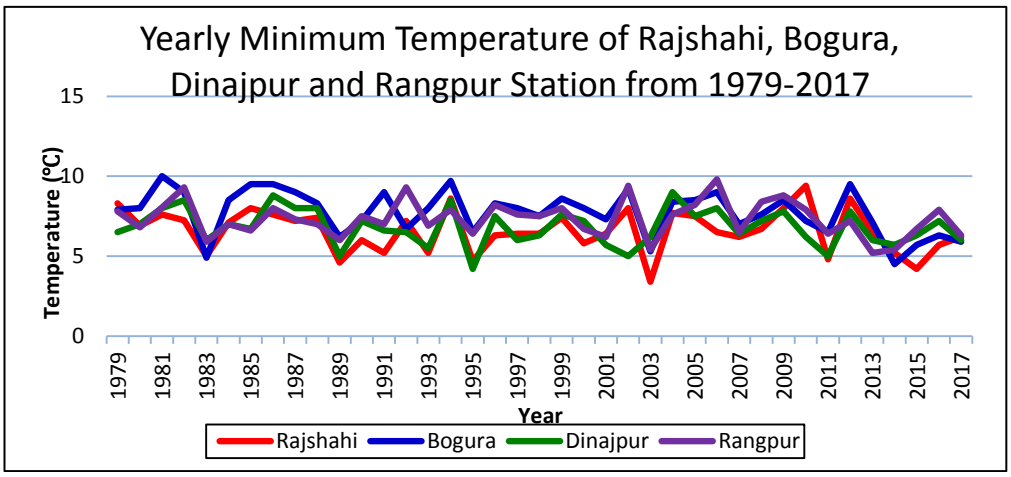

Figure 2.Trend of yearly minimum temperature in Rajshahi, Bogura, Dinajpur and Rangpur stations.

Figure 3 shows the anomaly of yearly minimum temperature and the mean temperature of Rajshahi, Bogura, Dinajpur and Rangpur stations have been calculated 6.59°C, 7.73°C, 6.81°C and 7.33°C respectively. In Rajshahi station, the temperature of 1983, 1989-1991, 1993, 1995-1998, 2000-2001, 2003, 2006-2007 and 2011 were higher than the mean minimum temperature in Figure 3. From 2013, the minimum temperature were also increased. Rest of the year of temperature was lower than the mean minimum temperature. On the other hand, Bogura, Dinajpur and Rangpur stationsshow the irregular pattern of minimum temperature and after 2013, the minimum temperature were increased than the average. So, the minimum temperature of the selected station did not follow the regular pattern and it was increased gradually during the last several years (except 2016 in Dinajpur and Rangpur station).

4.1.2. Yearly Maximum Temperature

The highest temperature of a specific day of a year is known as the yearly maximum temperature. Figure 4 represents that in Rajshahi and Bogura stations, 44°C was the highest maximum temperature in 1980 and 1989 respectively. Figure 4 also presents that from 2011, the maximum temperature of Rajshahi station was increased gradually. Among the selected stations, the yearly maximum temperature was highest in Rajshahi station and the trend of maximum temperature shows the highest upward trend than the other selected stations of the Barind Region.

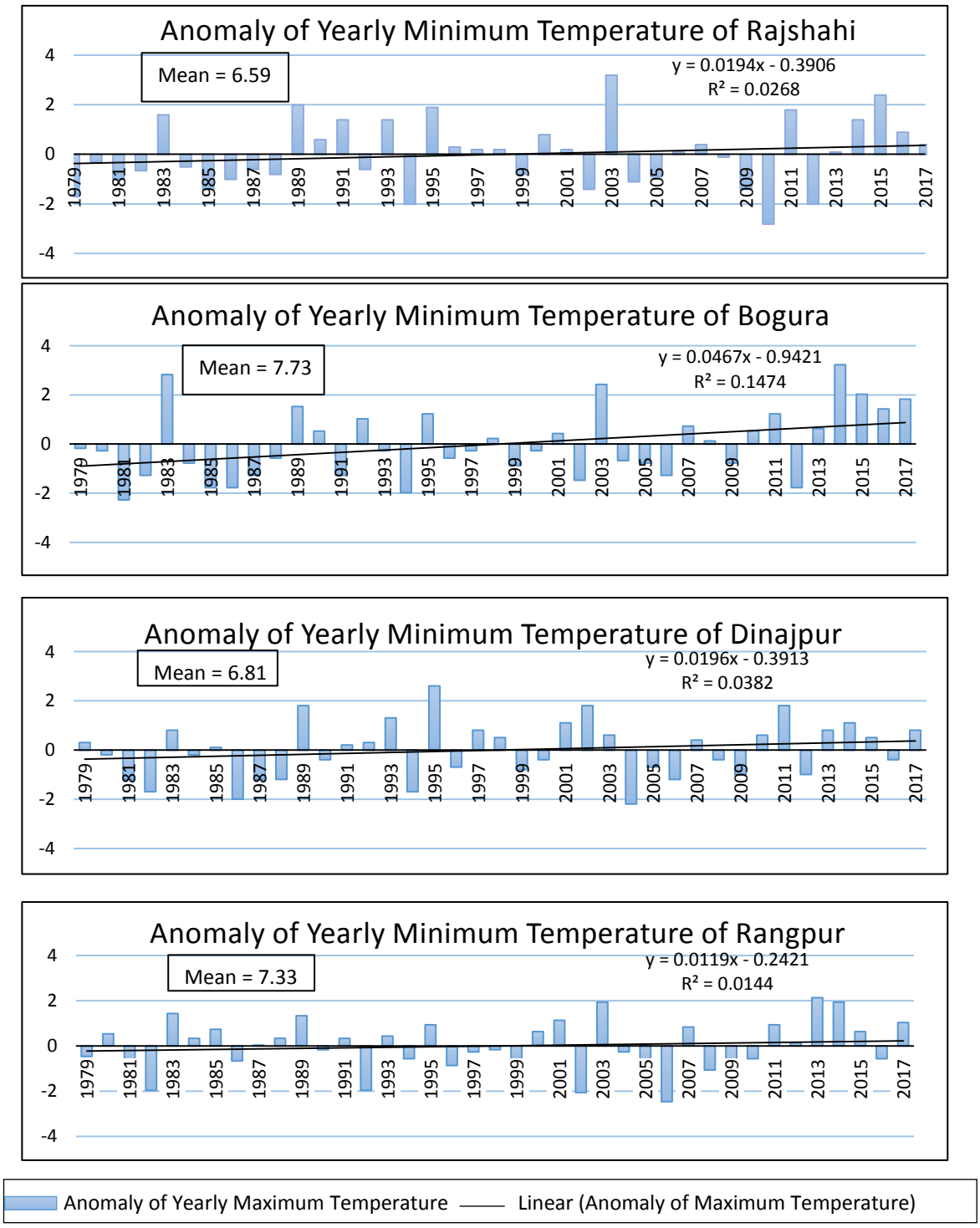

Figure 3. Anomaly of yearly minimum temperature of selected weather stations from 1979-2017.

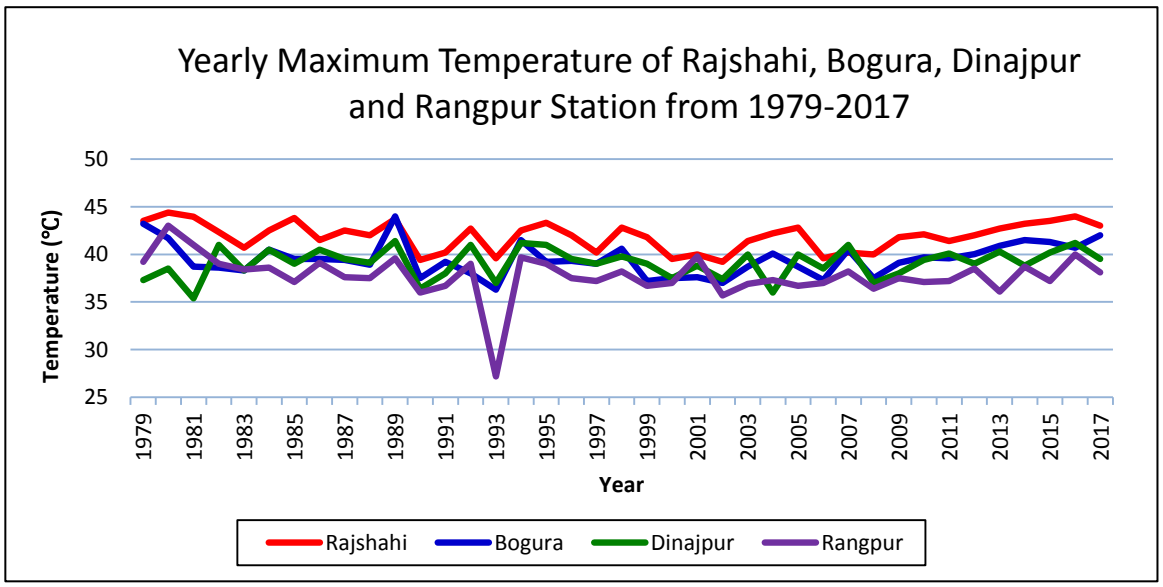

Figure 4. Trend of yearly maximum temperature in Rajshahi, Bogura, Dinajpur and Rangpur stations.

Figure 5 shows the anomaly of maximum temperature and the mean temperature of Rajshahi, Bogura, Dinajpur and Rangpur stations have been calculated 41.89°C, 39.48°C, 39.1°C and 37.76°C respectively.In Rajshahi station, the temperature of 1983, 1986, 1990-1991, 1993, 1997, 2000-2003, 2006-2009 and 2011 were higher than the mean maximum temperature in Figure 5. Rest of the year of temperature was low and from 2013, the maximum temperature was almost below than the average.On the other hand, Bogura, Dinajpur and Rangpur stations show the irregular pattern of maximum temperature. The trend line of Rajshahi and Rangpur stations show the upward trend and Bogura and Dinajpur stations show the downward trend. So, the maximum temperature of the selected station did not follow the regular pattern and it was increased gradually except Bogura and Dinajpur stations of the Barind region of Bangladesh.

Based on the analysis of yearly minimum and maximum temperature ofselected four weather stations, the result observed that in Barind region, the minimum and maximum temperature was lowest and highest respectively in Rajshahi station. So, Rajshahi is the driest and warmest place among any other area of the Barind region. It has been clearly found that temperature of pre-monsoon (March-May) season has been raised much higher rate than the post-monsoon (November-February) season. The present study also finds that pre-monsoon and during monsoon temperature has been increased over the last 30 years in Rajshahi region. Such finding of this study is consistent with Islam (2009). Therefore, relatively higher temperature increases evapotranspiration, lowers ground water aquifer, dries the agricultural land and creates drought situation in the Barind region in the pre-monsoon period.For this reason, drought is the most common natural disaster in the central Barind tract specially Rajshahi district. The temperature of this region is increasing day by day and the climate become more unfavorable. Its causes drought and fall negative impact on agriculture as well the overall livelihood in the central Barind tract of Bangladesh.

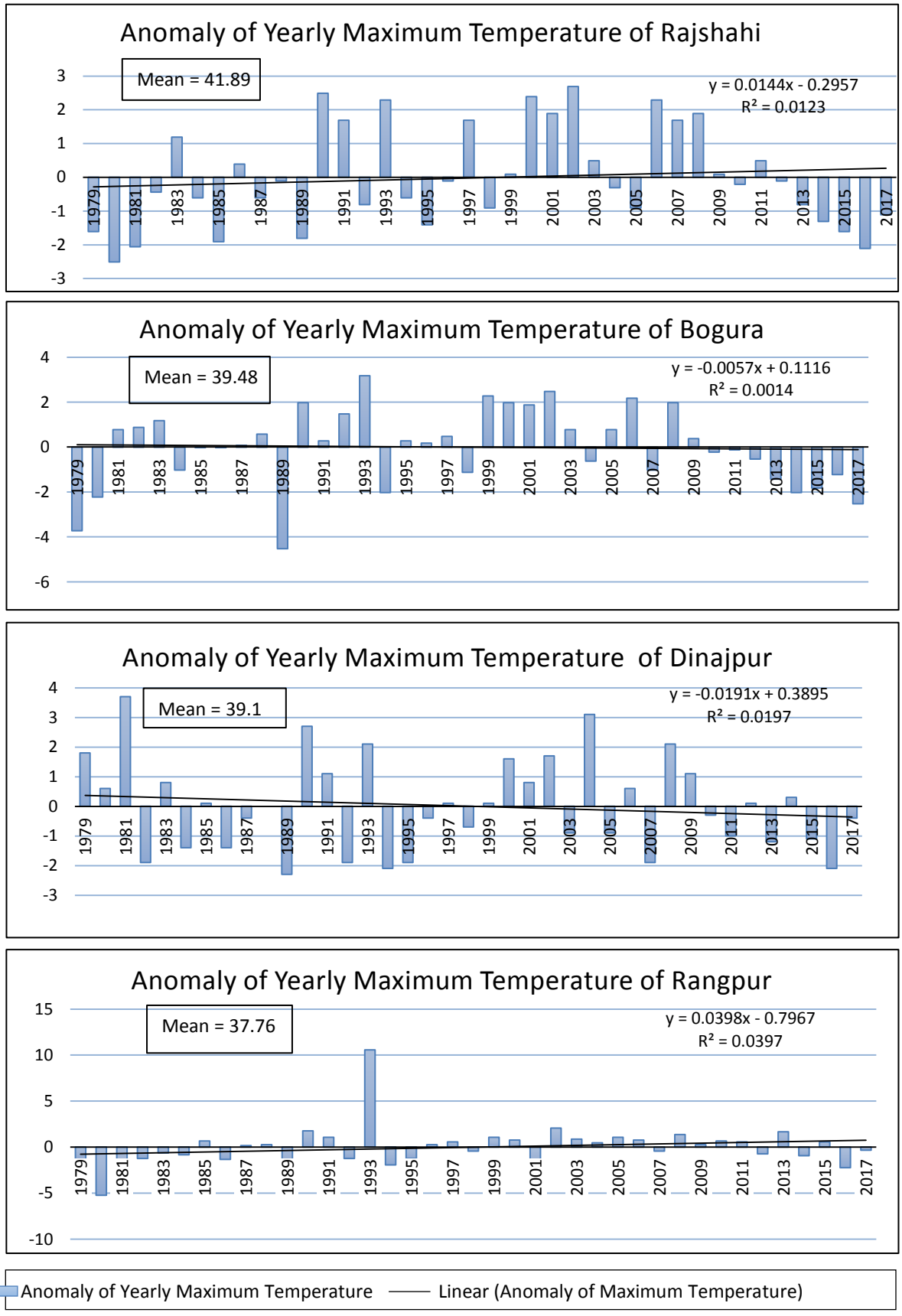

Figure 5. Anomaly of yearly maximum temperature of selected weather stations from 1979-2017.

4.2. Changes in Rainfall

The average annual total rainfall of the north-western part of Bangladesh varies from 1400 to1600 mm (Selvaraju *et al*. 2006). The rainfall exceeds the potential evapotranspiration in the monsoon period and becomes less in the remaining months. The present study finds that about 80% of rainfall occurs during the monsoon period in the selected four weather stations. It is mentionable that normal rainfall in the Barind region is 1410 mm.The linear trend line and anomaly of annual total rainfall have been analyzed among the four weather stations (Rajshahi, Bogura, Dinajpur, and Rangpur) in the Barind tract of Bangladesh. Attempt has been made to analyze the annual total rainfall in study area from 1979 to 2017are given below:

4.2.1. Annual Total Rainfall

Generally annual total rainfall refers to the amount of rainfall occurs in a region each year. Figure 6 represents that the rate of rainfall recorded in each station has decreased significantly than preceding time. A negative trend line was seen in the weather stations of Rajshahi, Bogura, Dinajpur and Rangpur. Although average negative value was not high but during recent years the amount of rainfall has decreased rapidly compared to previous years. The amount of rainfall of Rajshahi in the year of 1982 (1103mm), 1992 (843mm), 2009 (1043mm) and 2010 (792mm) was very negligible clearly shows in Figure 6. On the other hand, rainfall was comparatively low in the year of 1982 (1223mm), 2006 (1106mm) and 2015 (1376mm)in Bogura station.Figure 6 also shows that among the selected stations, the annual total rainfall was highest in Rangpur station and the lowest in Rajshahi station.

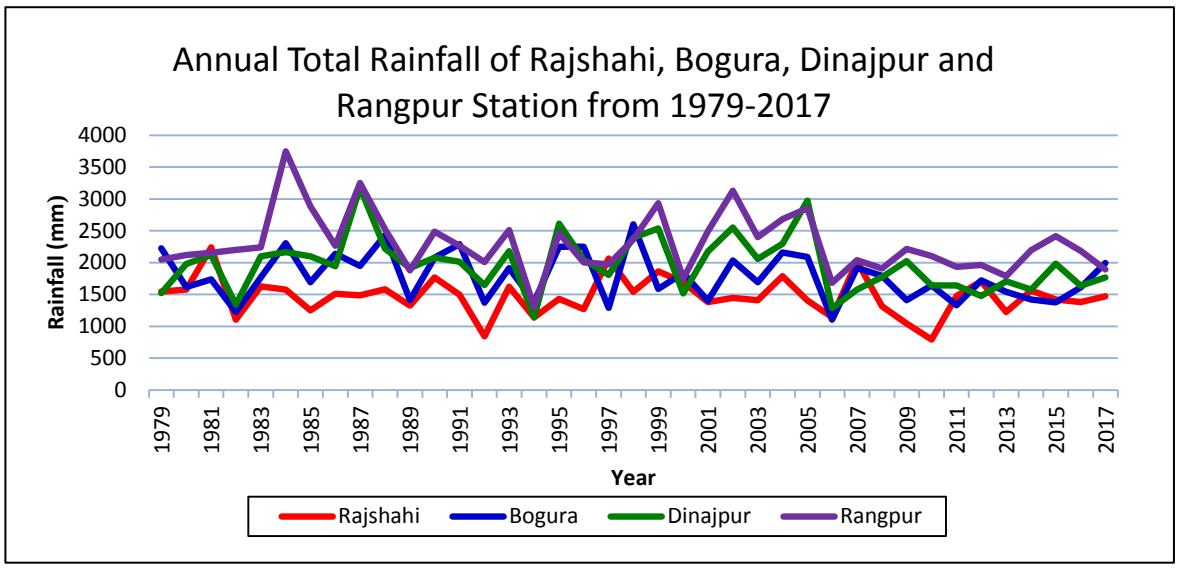

Figure 6. Trend of annual total rainfall in Rajshahi, Bogura, Dinajpur and Rangpur stations.

Figure 7 display that how much the rainfall was deviating from the mean rainfall pattern from the year of 1979 to 2017 in the selected four weather stations. It has been calculated that the mean rainfall of Rajshahi, Bogura, Dinajpur and Rangpur stations were 1475mm, 1784mm, 1967mm and 2288mm respectively. In Rajshahi station, the rainfall was very high in 1982, 1985, 1989, 1992, 1994-1996, 2001-2003, 2005-2006, 2008-2010, 2013, 2015-2017, and rest of the year were lower in than the mean annual rainfall.

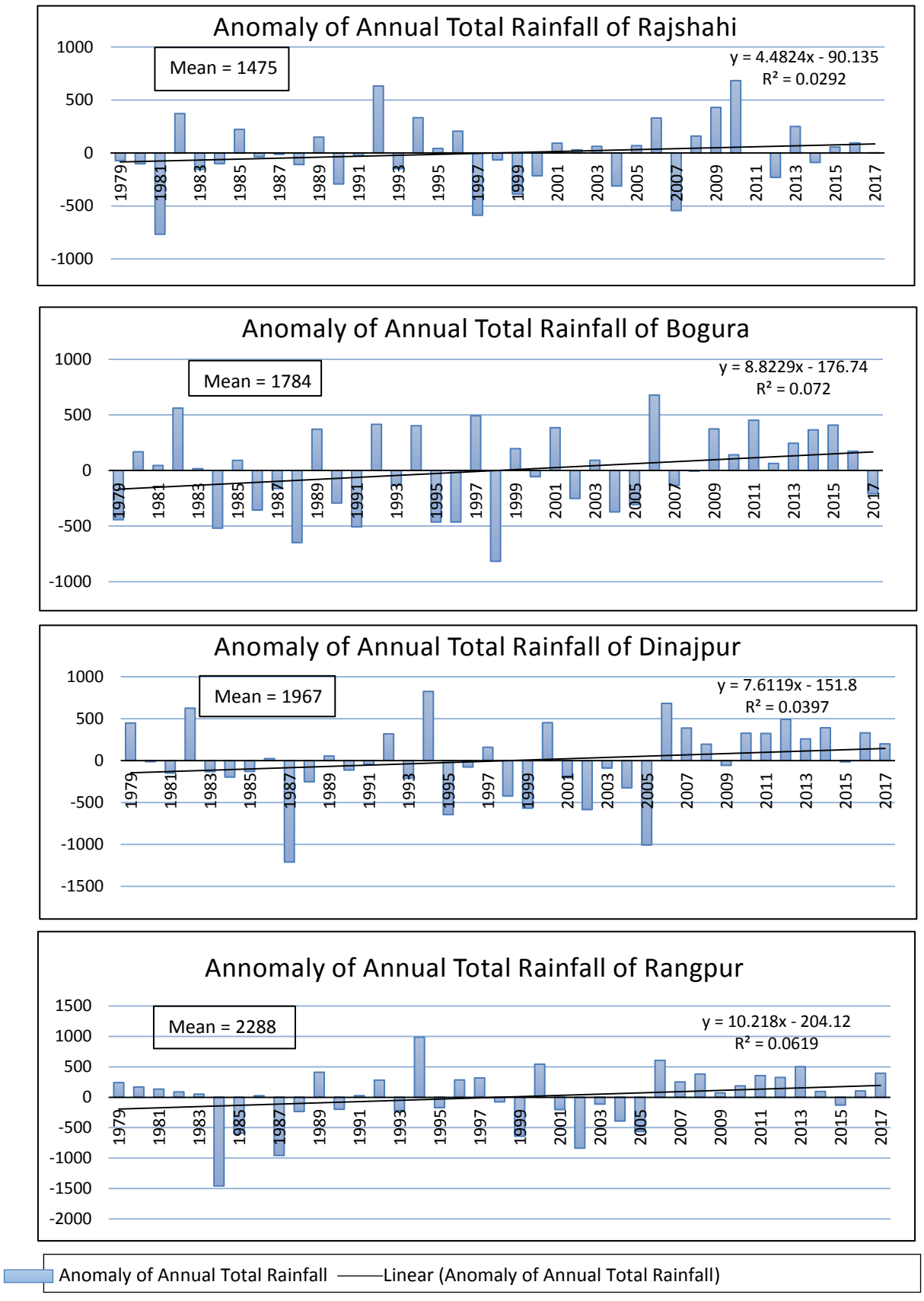

Figure 7. Anomaly of annual total rainfall of selected weather stations from 1979-2017.

On the other hand, in the station of Bogura, Dinajpur, Rangpur also show the irregular pattern from the year of 1979 to 2005 and from 2006, it was increased gradually almost during the last several years than the average (Figure 7). Based on the analysis of annual total rainfall, the present study finds that Rajshahi station express the lowest downward trend than the other selected stations of the Barind Region.Rajshahi station receives the lowest rainfall and the deviation of annual total rainfall of Rajshahi station was become irregular.For this reason, Rajshahi becomes the driest region among the Barind weather stations of Bangladesh. However, low rainfall in this region was associated with long dry spells throughout the season. Moreover, such climate change further aggravate drought situation in the central Barind region as well as the study villages.

4.3.Changes of Groundwater Level (GWL)

In Bangladesh groundwater level rise in wet season due to monsoon rain and flooding in the main river and reach in minimum level in August to September. After the wet season it starts to fall and reach in maximum level in the pre-monsoon months of April to May. In this study, an attempt has been made to analyze the anomaly and detect the trend of declining the groundwater level in Godagari (Shahapur village) and Tanore (Mohar village) upazila of Rajshahi district with the data of groundwater level from 1985 to 2017. The changes of ground water level, its fluctuation range and the deviation of groundwater level from the average of the study area are given below:

4.3.1.Maximum, Minimum and Fluctuation of Groundwater Level (GWL)

Long-term linear trend analysis and anomaly of groundwater level (GWL) are observed by the groundwater observation well data from 1985 to 2017 in the two study villages of Godagari and Tanore upazila. However, this present study have shown and described that, how the groundwater level is declining in this area during the last several years. The analysis also depicted the fluctuation range, average, maximum-minimum fluctuation and the deviation from the average of groundwater level.

4.3.1.1. In Shahapur Village (Godagari Upazila)

Figure 8 represents the long-term trend of yearly maximum, minimum, average and fluctuation of the GWL of Shahapur village from 1985-2017. The study finds that, the overall GWL of Shahapur village was within a range of 4.52m (1985) to 26.6m (2014) in the year of 1985 to 2017.The highest minimum GWL was 23.11m in 2014 and the lowest GWL was 4.52m in 1985.On the other hand**,** the highest maximum GWL was 26.06m in 2014 and the lowest GWL was 12.17m in 1985.The present study also reveals that the minimum fluctuation of GWL of Shahapur village was 1.92m in 2011 and the maximum fluctuation of GWL was 11.31m in the year of 2000. Therefore, it can be said that the trend of GWL of Shahapur village of Godagari upazila was declining gradually.

Figure 9 represents the deviation of yearly maximum (mean=19.32m) and minimum (mean=12.30m) GWL from the year of 1985 to 2017. The result shows that the maximum GWL was high in 1985-1994, 1997-1998, 2006-2007, and was lower in 1995-1996, 1999-2005 than the mean maximum GWL, and after 2008, the maximum GWL of this village decreased day by day. Similarly, it also reveals that the minimum GWL was high in 1985-2002, 2006, and was lower than the mean minimum GWL in 2003-2005, 2007-2017. So, the anomaly of maximum and minimum GWL represent that the level of groundwater was decreasing gradually during the last several years in Shahapur village.

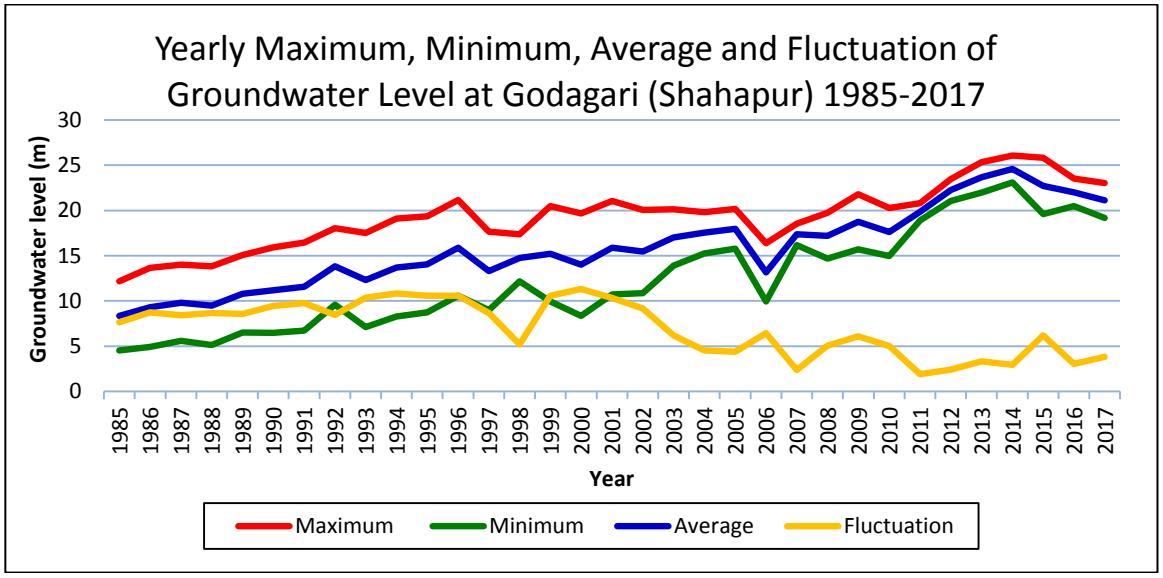

Figure 8. Trend of yearly maximum, minimum and average GWL and fluctuation at Shahapur.

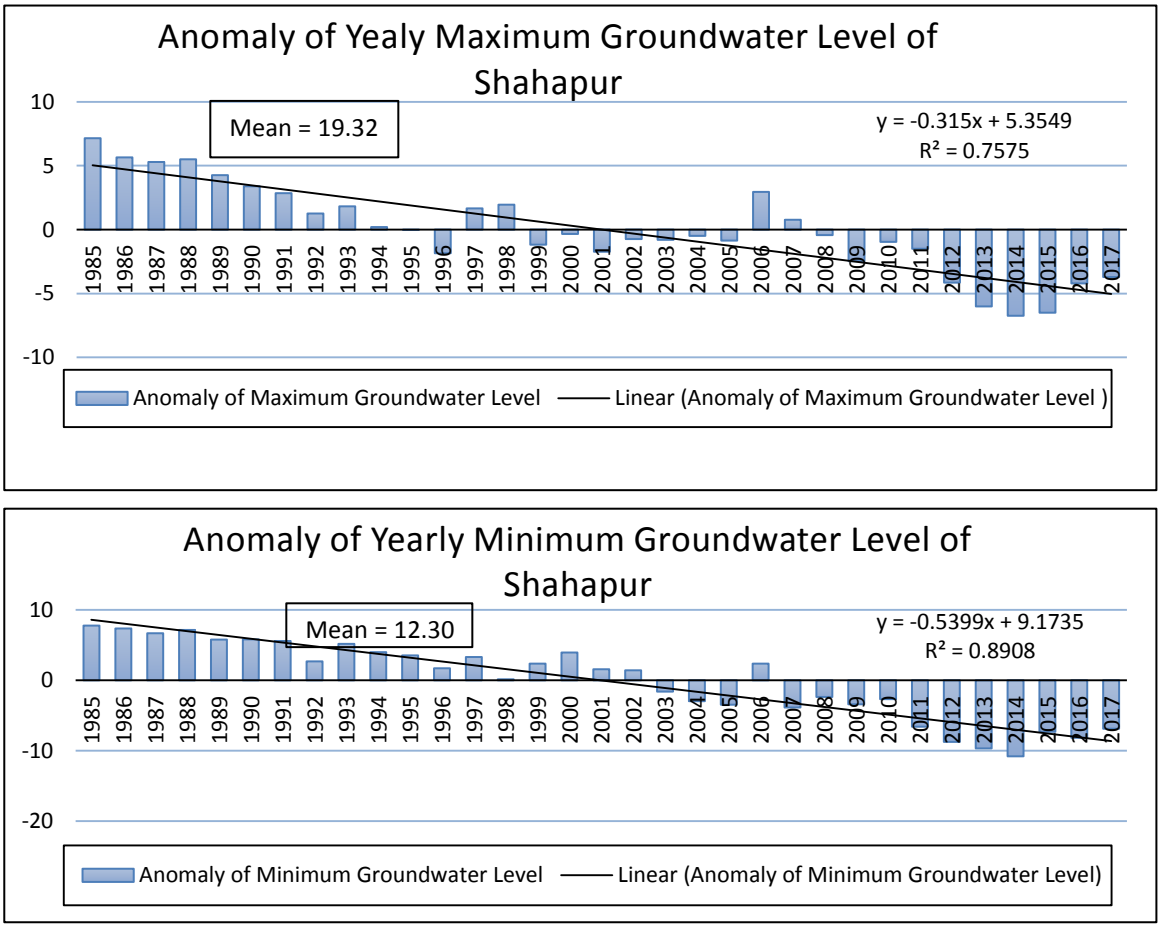

Figure 9. Anomaly of yearly maximum and minimum GWL of Shahapur village from 1985-2017.

4.3.1.2. In Mohar Village (Tanore Upazila)

The trend of yearly maximum, minimum, average GWL and fluctuation from 1985 to 2017 of Mohar village has given in the Figure 10. The Figure finds that the overall GWL of Mohar village was within a range of 0.91m

(1987) to 16.97m (2017) in the year of 1985-2017. The highest minimum GWL was 15.16m in 2017 and the lowest GWL was 0.91m in 1987. On the other hand, the highest maximum GWL was 16.97m in 2017 and the lowest GWL was 6.55m in 1986.The present study also reveals that the minimum fluctuation of GWL of Mohar village was 0.70m in 2013 and the maximum fluctuation of GWL of Mohar village was 6.16m in 2009. Therefore, the result observed that, the trend of GWL of Mohar village of Tanore Upazila was declining gradually. So it can be concluded that the maximum, minimum and average GWL and fluctuation was comparatively higher in Shahapur than Mohar village.

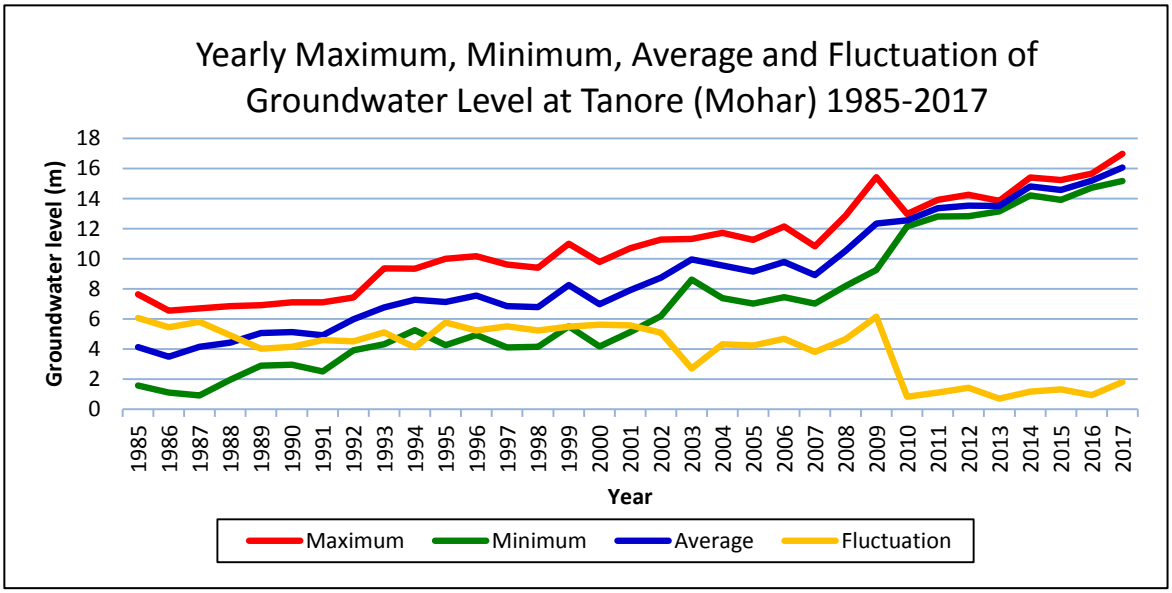

Figure 10. Trend of yearly maximum, minimum and average GWL and fluctuation at Mohar.

In Mohar village, data of last 33 years' from 1985 to 2017 were used to show the deviation of GWL as well as Shahapur village. It was calculated that the mean maximum GWL was 10.93m and the mean minimum GWL was 6.96m in Figure11, which shows that the maximum GWL was higher in 1985-1998, 2000-2001, 2007, and was lower than the mean maximum GWL in 1999, 2002-2006, 2008-2017. Similarly, the minimum GWL was higher in 1985-2002 than the mean minimum GWL. After 2003, the minimum GWL of this village decreased day by day. So the anomaly of maximum and minimum GWL represent that the level of groundwater was decreasing gradually during the last several years in Mohar village as well as Shahapur village.

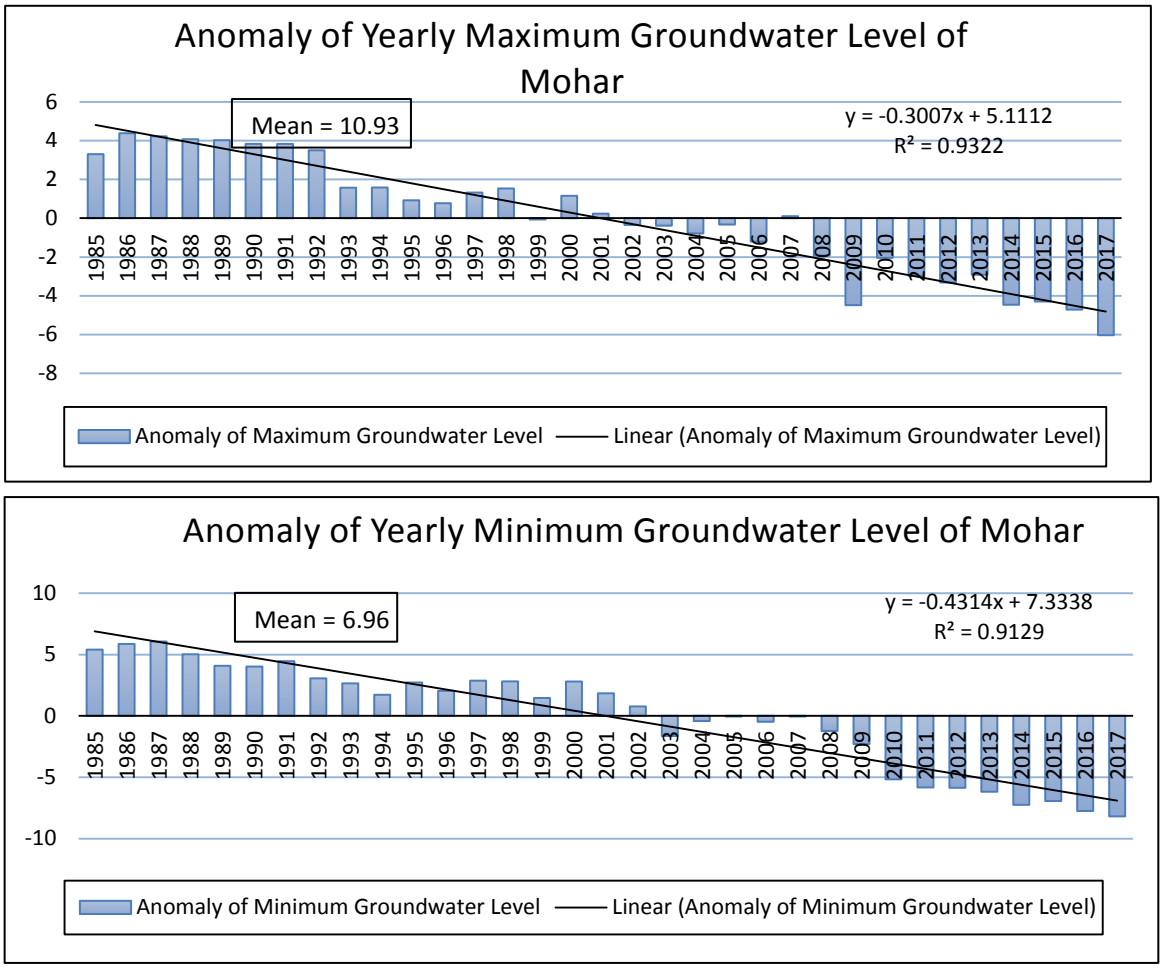

Figure 11. Anomaly of yearly maximum and minimum GWL of Mohar village from 1985-2017.

4.4. Correlation between Different Climatic Variable and Groundwater Level

Table 1 represents the correlation between different variable of temperature, rainfall and GWL of the study villages. It reveals that the correlation of the yearly minimum temperature with the minimum, maximum and average GWL have negative correlation. It indicates that the decreasing of GWL with the increasing of minimum temperature in the area have opposite relation. When the minimum temperature is increasing then the level of groundwater of the study area is decreasing from the minimum, maximum and average level. Table 1 also represents that the correlation between the annual total rainfall and GWL of the study villages have negative correlation. It indicates that the insufficient rainfall occurs in the area and the soil characteristics is hard clay which is less permeable to infiltration the rainwater. Besides, over exploitation for irrigation system, insufficient rainfall to refill the aquifer as it working as a reservoirs and increasing the maximum temperature are responsible for decreasing the level of groundwater in the area. So the despite of rainfall, the minimum, maximum and average GWL of the study villages is decreasing day by day. Due to extensive underground exploitation of water for irrigation purpose, the groundwater could not recharge properly in spite of having sufficient monsoon rainfall and it induced agricultural drought in the study villages.

Table 1.Correlation between different climatic variable and groundwater level

Study villages	Climatic variables (Rajshahi station)	Groundwater Level (GWL)of the study villages	Correlation (R)
Shahapur	Yearly Minimum Temperature	Minimum GWL	-0.104
		Maximum GWL	-0.164
		Average GWL	-0.131
	Annual Total Rainfall	Minimum GWL	-0.038
		Maximum GWL	-0.066
		Average GWL	-0.051
Mohar	Yearly Minimum Temperature	Minimum GWL	-0.113
		Maximum GWL	-0.061
		Average GWL	-0.107
	Annual Total Rainfall	Minimum GWL	-0.150
		Maximum GWL	-0.111
		Average GWL	-0.142

6. Conclusions

The present study finds that in Barind region, among the selected weather stations the maximum and minimum temperature is respectively highest and lowest in Rajshahi station in last three decades. The present study also reveals that during recent years, the amount of rainfall has decreased rapidly compared to previous years and the trend of annual total rainfall of Rajshahi station presents the rapid downward trend than other selected stations of the Barind tract. For this reason, Rajshahi becomes the driest region among the other weather stations of Barind area and the effect of it is noticeable. Raising of temperature and decreasing of rainfall lead the severe drought situation in the study area .It also cause of crop production failure and reduce the crop productivity in the area. For this reason, agricultural droughts have become more frequent phenomena in the central Barind tract especially in the study area of Rajshahi district. On the other hand, after analyzing the fluctuation and trend of GWL in the study area, it found that GWL is reducing and as well as the depth of tube well is also declining. Moreover, the analyzing data is indicated the decreasing trends of GWL in the study area and it revealed that over exploitation of groundwater through irrigation is mainly responsible for declining the GWL. Low rainfall, increasing of maximum-minimum temperature and unsustainable use of groundwater are other causes of decreasing of GWL. Due to the growth rate of population, it is important to increase crop production to fulfil the demand of feeding the population. In this case, irrigation is a parameter to increase the production of crops. Therefore, the amount of expulsion of groundwater is increased but there is no rainfall occur equally in all months in a year of our country. It is examined that in Godagari and Tanore upazila, rainfall is so insufficient and soil is normally hard clay which is less permeable to infiltration. Due to the result of climatic variability, drought appears as determining factor of crop production, fish cultivation, poultry and livestock rearing in the study area. The drought is considered to be strongly related to the agricultural food production system and that why the result of agricultural drought destroys the food chain, the food stock and the agro-based production system of the Barind region. The present study can guide the farmer's about their perception of climate change, preparedness and awareness rising for the initiation of adaptation practices. The results of the study may help the researchers as well as government, NGOs and the other policy makers to take appropriate agricultural drought adaptation policy thus facilitating farmers in sustaining their livelihoods against drought in the near future.

Acknowledgements

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Urban Geology of Rajshahi City Corporation, Rajshahi, Bangladesh: Implication for Land Use pattern

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Abstract

Investigation of the subsurface condition according to the geological and engineering geological aspects was carried out in the Rajshahi City Corporation, Rajshahi, Bangladesh. The study was undertaken based on the data of subsurface for the urban sustainability and development of the rapidly expanding Rajshahi City Corporation. New structures are being constructed everywhere, however, ignoring the proper existing urbanization regulations to meet the increasing demands of accommodation, commerce, trade, administration, and other municipal facilities. Unplanned urbanization and town development without considering geological, engineering geological information create the geoenvironmental problems that hindered sustainable development. Especially, four stratigraphic units have been identified in the study area. The subsurface lithology of the area mainly consists of fine sand (unit-D), silt (unit-C), clay (unit-B), and medium sand (unit-A). The standard penetration test (SPT) value ranges from 2 to 44 showing that the values are high at greater depth and low at the near-surface for all bore logs. Four SPT contour maps were prepared at the depth of 3m, 7.5m, 12m, and 15m. By combining four contour maps and lithological data, an urban sustainability map was prepared. It is found that Zone A (southwest) is suitable in lower degree for settlement, Zone B (north and north-east) suitable in a moderate degree, Zone C (north to south-central) suitable in good degree, and Zone D (north central) most suitable for the excellent degree of urban settlement. The groundwater contour map indicates the suitable position of the waste disposal site should be constructed at the southwest part of the study area.

Keywords: Urban geology; Borelog SPT; Groundwater Level; Zoning Map; Rajshahi City Corporation

1. Introduction

The development of the urban area and the construction of new settlements need the right land as well as proper study (Kashem *et al.*, 2007). In this respect, geological information is used to select the proper size for the growth of new cities. Urban geology is the application of geologic knowledge to the planning and management of metropolitan areas (Bathrellos, 2007). An assessment of the geological and engineering properties of the soil (lithology)is considered to identify restrictions to urban expansions (Adhikari *et al.*, 2006). However, these issues are generally addressed through environmental geology and generally include the identification of geotechnical assessment and investigation of geological phenomena. The basic parameters are affecting land use in urban planning are geography, geological nature, hydrogeological conditions, climate, and geotechnical properties of underlying materials. The range and complexity of these parameters increase concerning the engineering aspect in the urban environment (Martin, 2014).

Initially, urban geology came up with few considerations, however, recently urban geology plays a vital role in the growth of urbanization and provide knowledge to the solution of construction in urban areas (Karrow and White, 1998). However, geologists are involved worldwide in working in cities along side engineers (Legget 1973 and 1982). A geotechnical investigation has been carried out in and around the Rajshahi City Corporation by the detailed subsurface investigation programmed which includes nine boring execution of the standard penetration test (SPT) of secondary data and thirteen boring execution of groundwater level data. Geographically, the study area comprises the northwestern part of Bangladesh within the Barind Tract of 23m above sea level. Rajshahi City lies at latitude 24°22′26" N and longitude 88°36′04" E (Figure 1). It is bounded on the east, north, and west by Paba Upazila of the Rajshahi district and south by the Padma River.

Urban planning and town development in the study area is going on without the consideration of geoscientific information properly. As a result, the area is being suffered from drainage congestion, flooding, water logging, groundwater contamination and waste disposal problems, etc. This research work aims to identify the engineering

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properties of each soil unit, to investigate the groundwater level and the subsurfacelitho-stratigraphy, and finally, to prepare the potential zoning map for urban development. The results of this research work provide geomorphic information to the urban planner for the management of urban growth.

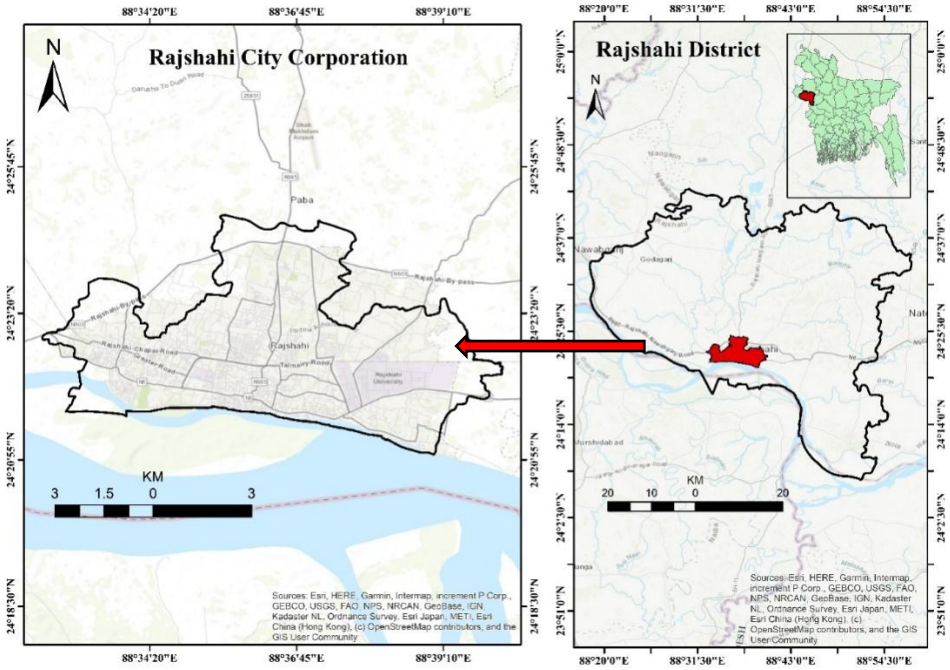

Figure 1. Location Map of Study Area

2. Geological Setting

The study area is situated in the shelf area of Bangladesh. Tectonically, it includes the active Bogra slope nearest to the Hinge Zone. Aeromagnetic Survey has revealed that the basement is crisscrossed by numerous fault terraces (Alam, 1972). The fault has vertical displacement trending N-S, E-W, and NNE-SSW. The structural activity of this region is mainly differential vertical movement. The relative displacements along the basement fault have resulted in the horst and graben features and the inducement of contrasted relief (Evans, 1964). No sediments are older than the Pleistocene Barind Clay formation are exposed in the study area. The subsurface of the stable region including the Bogra slope sedimentary rock ranging in age from Permian (286 million years to 245 million years ago) to Recent (0.1 million years ago till today) are laid down on the Precambrian Basement (Curray and Moore, 1971).

3. Materials and Methods

3.1. Materials

The data were collected from different sources to accomplish the research work. Different data from different sources are listed below:

1. Bangladesh Water Development Board (BWDB): Rainfall data of the study area.
2. Rajshahi WASA: Groundwater level data.
3. Paba Upazilla Complex: Borelog data.

3.2.Methodology

Urban development of the study area incorporates the collection of field data, various types of maps, SPT data, bore log data and groundwater data, published and unpublished reports and documents relevant to the study. It also includes the visual interpretation of geomorphologic elements of the area and the relation between surface and subsurface lithologic units to provide better ideas for future planning. By integrating with bore log data, two stratigraphic cross-sections and a panel diagram have

been prepared. Finally, morphologic units have been delineated and a land-use map has been prepared. The whole study was carried out using the SPT test which has been described below:

3.2.1. Standard Penetration Test (SPT)

The Standard Penetration Test datas used to measure the in-situ properties of the sub-soil. These tests are the best for cohesionless because a correlation has been established between the SPT values and the angle of internal friction of the soil. The tests consist of driving of a SPLIT SPOON SAMPLER having 50.80mm (2") outer diameter and 35mm (1-3/8") inner diameter. The split spoon is driven 450mm (18") into the ground using a 63.60kg (140Ibs) hammer falling freely from a height of 750mm (30") onto the drilling rod. The number of the hammer blows required to drive the sample for the 2nd 15cm (6") and 3rd 15cm (6") of penetration is called the Standard Penetration Test which is presented by N. The 1st 15cm (6") penetration of the sampler is discarded as seating drive. Refusal is said to have been reached when the sampler penetrates less than 25.40mm (1"0) under 50 blows.

The SPT test was performed at 1.50m intervals in all borelogs up to the final depth. The depth-wise SPT values have been presented in the form of curves in the respective bore logs (Odunyemi *et al*. 2016). In the study area, the observed SPT values concerning depth in different boreholes are given in (Table 1). The SPT value of the study area ranges from 3 to 50 and shows that the values are high at greater depth and low at the near-surface.

4. Result and Discussion

4.1. SPT Data Analysis

The study area is situated in the Barind Tract of Bangladesh. During the field investigation, deep tubewell bore log data and standard penetration test (SPT) data were collected and after that these data were analyzed.

Table 1. SPT values of different boreholes concerning depth.

Depth (m)	SPT Value								
	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9
1.5	2	5	2	4	2	5	5	8	8
3.0	3	2	2	4	2	11	6	10	10
4.5	4	6	6	7	6	8	7	10	10
6.0	4	4	6	6	6	10	9	14	14
7.5	4	8	11	12	11	9	11	6	6
9.0	7	8	5	13	5	9	25	9	9
10.5	6	5	9	13	9	25	35	15	15
12.0	9	15	12	28	12	22	34	15	15
13.5	13	8	17	19	17	23	32	7	7
15.0	44	27	8	20	8	-	40	12	12
16.5	7	-	9	-	9	-	-	15	15
18.0	15	-	10	-	10	-	-	35	35

(Source: Paba Upazilla Complex, Rajshahi, Bangladesh)

In borehole-1, the SPT value ranges from 2-44. At the depth of 15m, the SPT value is at the highest peak of 44 which is the suitable zone for moderate to high load-bearing structure (According to Terzaghi and Peck, 1967). In borehole-2, the SPT value ranges from 2-27. At the depth of 15m, the SPT value is at the highest peak of 27 which is suitable for low to the moderate load-bearing structure. In borehole-3, the SPT value ranges from 2-17. At the depth of 13.5m, the SPT value is 17 which indicates the suitable zone for low to moderate load-bearing structure. In borehole-4, the SPT value ranges from 4-28. At the depth of 12m, the SPT value is 28 which is suitable for a moderate load-bearing structure. In borehole-5, the SPT value ranges from 2-17. At the depth of 13.5m, the SPT value 17 is suitable for low to the moderate load-bearing structure.

In borehole-6, the SPT value ranges from 5-25. At the depth of 10.5m, the SPT value is at the highest peak of 25 which is suitable for a moderate load-bearing structure. In borehole-7, the SPT value ranges from 5-40. At the depth of 15m, the SPT value is at the highest peak of 40 which is suitable for moderate to the high load-bearing structure. In borehole-8, the SPT value ranges from 6-35. At the depth of 18m, the SPT value is at the highest peak of 35 which is suitable for moderate to high load-bearing structure. In borehole-9, the SPT value ranges from 6-35. At the depth of 18m, the SPT value is 35 which indicates the suitable zone for moderate to high load-bearing structure.

The SPT values suggested that upper soil (7-13.5m) is suitable for only light to medium load-bearing structure with proper methods and the lower soil below 13.5m depth is suitable for construction of medium to the high load-bearing structure.

4.2. Contour Map of SPT

The study area comprises the different SPT values at 15m depth (Figure 2). The contour map indicates that at 15m depth, the strength of soil is higher at the southwest central part of the city. The strength of the soil is poor at the southeastern part and the southwestern ended part of the city at 15 m depth (Figure 2). This value indicates that high buildings can be constructed to the red zone according to the contour map of 15m depth and should not be constructed to the green zone. Small buildings, parks or markets can be built in that green zone.

The study area represents that at 12m depth (Figure 3), the strength of soil is high to the northeastern part which is marked red. The strength of soil is medium to the eastern part and low to the western part of the city. In that certain depth, we can build a high-rise building to the northeastern part of the study area. The southwestern part is very weak to build high-rise buildings.

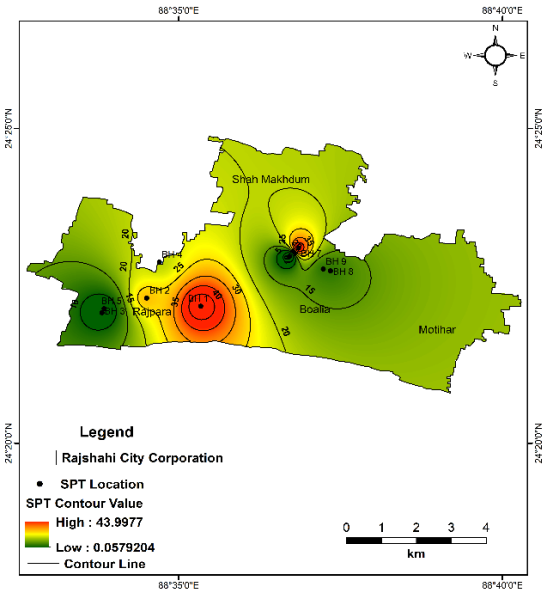

Figure 2. SPT Contour Map at 15m Depth

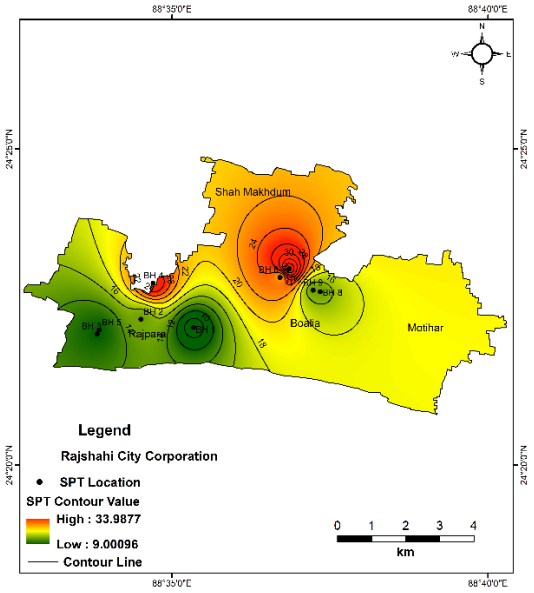

Figure 3. SPT Contour Map at 12m Depth

The study area represents that at 7.5m depth (Figure 4), the strength of soil is high to the western part which is marked red. The strength of soil is medium to the northern part and low to the southwestern central part of the city. In that certain depth, we can build a high-rise building to the western part of the study area. The southwestern central part is very weak to build high rise buildings.The study area represents that at 3m depth (Figure 5), the strength of soil is high from the north to the southeastern part which is marked red. The strength of soil is medium to the central part and low to the southwestern part of the city. In that certain depth, we can build a high-rise building from the north to the southeastern part of the study area. The western part is very weak to build high-rise buildings.

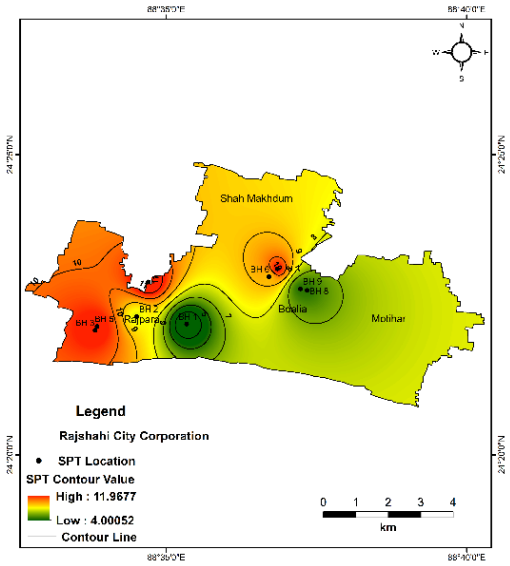

Figure 4. SPT Contour Map at 7.5m Depth

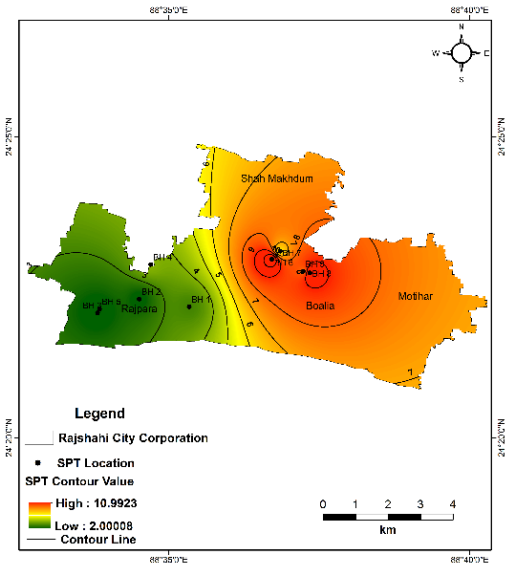

Figure 5. SPT Contour Map at 3m Depth

4.3. Borelog Stratigraphy and Morphological Panel Diagram

The borelog profiles and lithological panel diagram represents the lithostratigraphic correlation of the stratigraphy. This criterion helps to define the soil condition and shear strength of the soil. The subsurface geology of the study area was studied up to a depth of 22.5m based on borehole lithology (Figure 6). The stratigraphic panel diagram represents an overall view of the subsurface geologic formations in the area. It depicts that the sediments were deposited through paleochannels which were energetic enough for carrying finer materials and much deeper as well as wider nature indicating a meandering nature (Wang and Bhattacharya, 2018).

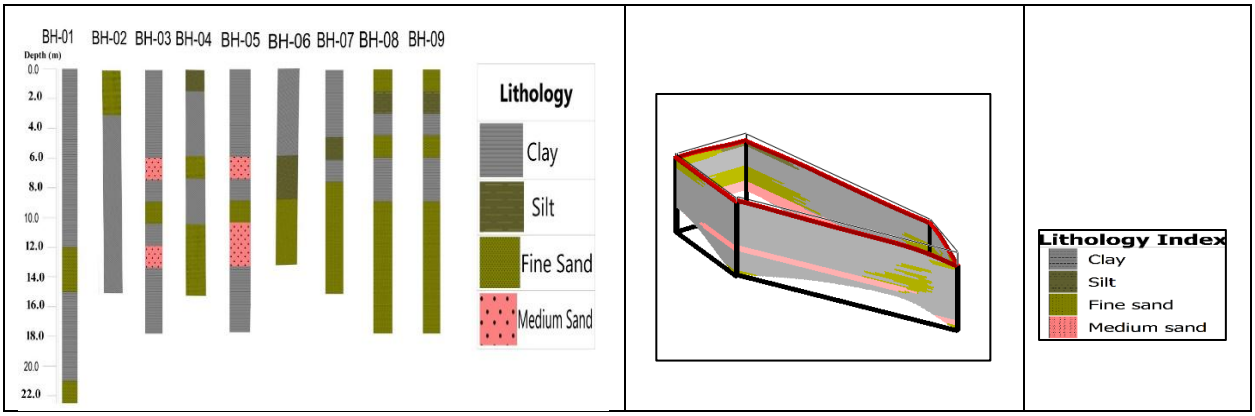

Figure 6. The Stratigraphic Succession of Borelogs and Panel Diagram of the Study Area

4.4. Groundwater Flow

Urbanization causes radical changes in the frequency and rate of groundwater recharge with a general tendency for volume to increase significantly and for quality to deteriorate substantially (Foster, 1990). These changes cannot be measured directly and are thus difficult to quantify. In terms, they influence groundwater levels and flow regimes in the underlying aquifers with equilibrium taking decades to be achieved. Most urbanization involves large imports of water except where local groundwater resources are adequate to provide the major contribution. When expressed in hydrological terms, the amount of water circulating in the distribution system is very significant compared to excess rainfall even in relatively humid climates (Foster, 1990). A spatial distribution map is produced by deep tube-well groundwater level data which indicates the groundwater flow direction. Here the groundwater flow direction is approximately from NE to SW region of the study area (Figure 7) (Source: Report on shrouded production tubewell, WASA Rajshahi, 2020). So, if a waste disposal site is to be made in Rajshahi City Corporation, it is a suitable location in the southwestern region of the study area due to the flow direction.

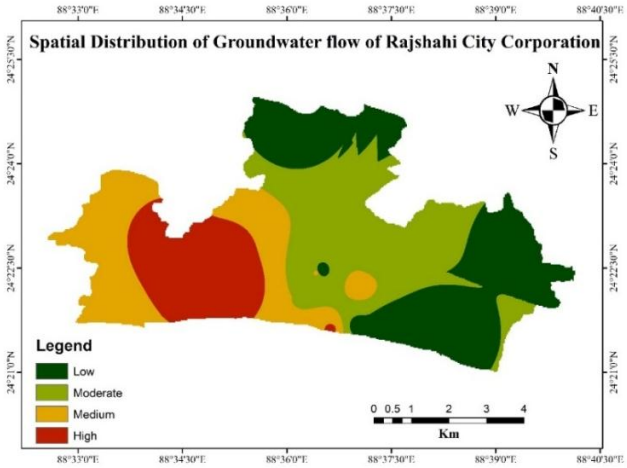

Figure 7. Groundwater level map of the study area

4.5. Land Use Pattern

Knowledge of land use and land cover is important for planning and management activities and is considered an essential element for modeling and understanding the earth as a system (Lillesand and Kiefer, 2000). Urban geology is the study of urban geologic environments to provide a scientific basis for rational land-use planning and urban development, which deals with major geotechnical and environmental problems arising from topography, geology, and soil types including their properties and areal distribution (Zervakou and Tsombos, 2010). According to the bore log data, the area can be divided into 4 zones for urban settlement. Such as-

Zone A: This zone is suitable for a low load-bearing structure. The subsurface lithology is composed of fine sand with few clays. SPT value of this region ranges from 5-17 at the depth range of 9-15m which indicates low suitability of settlement (after Terzaghi and Peck, 1967). The highest SPT value peak rises to 17 at the depth of 13.5m. In that certain depth, urbanization is suitable at a lower degree. The zone is found in the southeast corner of the study area (Figure 8). The settlement density is low but the communication system is good in this zone.

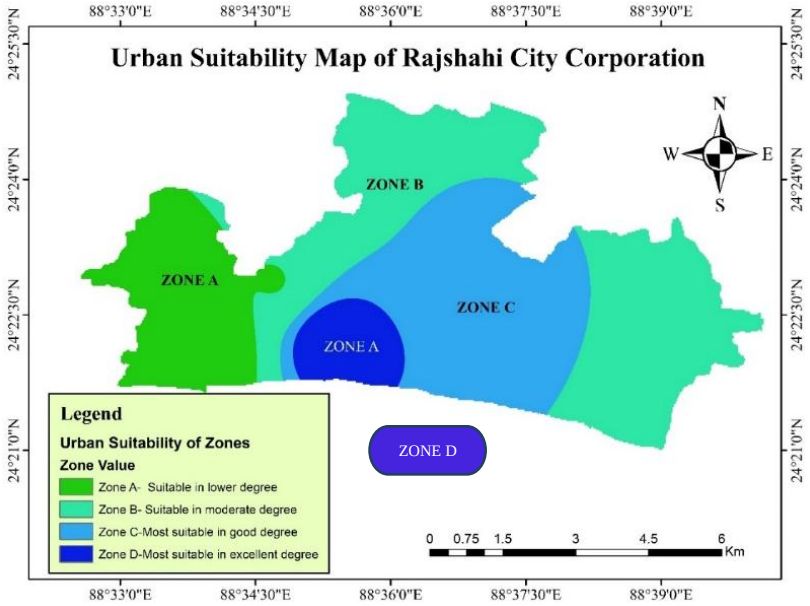

Figure 8. Zoning map of the study area

Zone B: The zone is suitable for a moderate degree of urbanization. This zone is more suitable than Zone A. The SPT bore log data shows the subsurface composed of stiff clay representing the SPT value of 13-28 at the depth of 10.5-13.5m. The highest peak of SPT rises up to 28 at 12m depth and this certain depth is suitable for moderate load-bearing structure of settlement (after Terzaghi and Peck, 1967). This zone is located in the central north part of the study area (Figure 8). The communication system is good and settlement density is medium.

Zone C: The zone is most suitable for good degree of urbanization. This zone is more suitable than Zone B. The SPT bore log data shows the subsurface composed of medium sand, stiff clay with few sands representing the SPT value of 35 at the highest peak of 10.5m depth within the depth of 7-13.5m range. So this zone is most suitable for moderate to high load-bearing structure (after Terzaghi and Peck, 1967). The area is located north to the south-central part of the study area (Figure 8). The communication system is good and settlement density is high.

Zone D: The zone is most suitable for excellent degree of urbanization. This zone is more suitable than Zone C. The SPT bore log data shows the subsurface composed of fine sand representing the SPT value of 7-44 at the depth of 13.5-16.5m. The highest peak of SPT rises up to 44 at 15m depth and this certain depth is suitable for the high load-bearing structure of settlement (after Terzaghiand Peck, 1967). This zone is located in the south-central part of the study area (Figure 8). The communication system is very good and settlement density is very high.

4. Conclusions

An important goal for urban geology is to assist planners in determining the optimal areas for development. The evaluation of results can assist planners in making decisions on land use alternatives. The results of the study in Rajshahi City Corporation described in the here give information relating to the distribution of soils and rocks and their associated geotechnical characteristics. The engineering geological units provide a general assessment of rock mass strength and weathering for each area. From the bore log data we find four stratigraphic units namely unit-A (medium sand), unit-B (clay), unit-C (silt), and unit-D (fine sand). The SPT value ranges from 2-44 shows that the values are high at greater depth and low at the near-surface for all bore logs. Four SPT contour maps have been prepared at the depth of 3m, 7.5m, 12m, and 15m. By combining four contour maps and lithological data, an urban sustainability map has been prepared. It is found that Zone A (southwest) is suitable in lower degree for settlement, Zone B (north and north-east) suitable in a moderate degree, Zone C (north to south-central) suitable in good degree, and Zone D (north central) most suitable for the excellent degree of urban settlement. The groundwater contour map also depicts if any solid waste disposal site is to be made, it has to construct at the southwestern part of Rajshahi City Corporation. Otherwise, the groundwater will be contaminated. Due to the urban development law, the analysis will help to maintain the suitability for urban settlement for this city with all geologic and engineering geologic aspects.

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Drought and Rainwater Deficit in Rangpur Division, Bangladesh

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Abstract

Drought in a region is first detected by a lack of rainfall. This work has studied drought and shortage of rainwater in Rangpur division of northwestern Bangladesh using drought index estimated from the monthly mean rainfall from 1988 to 2017. Computed indices have shown that moderate to severe drought occurred in the years 1994, 1995, 2000, 2006, and 2014. Mann–Kendall trend and the Sen's slope test analyses have shown that the number of draughts in the study area is growing. Therefore, the research area is expected to face increased droughts as a result of a lack of water due to a lack of rainfall, particularly during the monsoon season. This research has also estimated that Rangpur division has been suffering from shortage of rainwater, approximately 13%, in monsoon season. The volume of surface water along with recharging the groundwater is expected to be affected and it may cause the long-term irrigation to be distorted. Hence, this work will aid the region's watering system in order to provide a sustainable long-term irrigation system.

Keywords: Drought; Rainfall; Trends; Rangpur; Bangladesh.

1. Introduction

Drought is the most complex of chronic natural calamities that is characterized by the lack of precipitation over an extended period of below-normal precipitation and can cause substantial economic loss as well as human suffering (Rafiuddin *et al*., 2011). Rainfall is one of the most important factors of Bangladesh where the economy strongly based on agricultural. Agricultural sector suffers the most due to lack of precipitation and subsequent serious hydrological imbalance, making drought one of the most complex natural hazards (Heim 2002). Bangladesh experiences a dry weather because of low precipitation for a period of six months from November to April, and many parts of the country has already experienced an increasing number of droughts with varying severity in the recent years (Uddin *et al*., 2020; Alamgir *et al*., 2020; Hoque *et al*., 2020; Adhikary *et al*., 2013). The northern part of the country is highlighted as a severely drought prone area because of irregularity and high variability in rainfall (Uddin *et al*., 2020; Rahman *et al*., 2019; Shahid and Behrawan, 2008). Agricultural production in the northern part plays important role in overall economy of the country. Most of the surface waterbodies including rivers and cannels dry up during the dry season. To meet irrigation, approximately 75% of water demand were sourced from groundwater which led a sharp rise in the ratio of surface to ground water (Shahid and Hazarika, 2010; Rahaman *et al*., 2016; Bari and Anwar, 2000), which was not sustainable from both the environment and climate change perspectives. A paradigm shift towards cross-sectoral water management regime is yet to be achieved (Islam *et al*., 2020), where additional knowledge about the influence of climate variables would play a key role.

Drought of Bangladesh, especially in the northern part, has already attracted numerous researchers. Many studies over the last decades have projected that the northern part of Bangladesh will be more vulnerable to droughts (Shahid, 2011; Shahid and Behrawan, 2008). Although there is an agreement about greater agricultural losses from drought (Ahammed *et al*., 2020; Alauddin and Sarker, 2014; World Bank, 2013; Alam *et al*., 2012), various contributions show different opinions about recent droughts in the region (Miyan, 2015; Nury and Hasan, 2016), which creates a room for further investigation.

Investigations have been conducted to assess drought severity, vulnerability, historical trend and also to predict using for instance Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index, and analytical hierarchical process (Alamgir *et al*., 2020; Uddin *et al*., 2020; Hoque *et al*., 2020; Ahammed *et al*.,

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2020; Miah *et al*., 2017), However, use of statistical tools is hardly found in the existing literature, particularly focusing Bangladesh.

SPI, designed by McKee *et al*. (1993), it is relatively simple, can describe drought through water supply condition, and is based on rainfall data alone. It has the strength to be employed for a variety of timescales. SPI is capable to monitor short term water supplies to observe soil moisture, important for both agricultural production and longer term water resources to observe groundwater supplies, streamflow, lake and so on (Hayes *et al*., 1999). Many countries including USA, Turkey, Argentina, Canada, Spain, Korea, Hungary, China and India, are using this index to monitor droughts (Nury *et al*., 2016; Quiring and Papakryiakou, 2003; Hayes *et al*., 1999; Wilhite *et al*., 1985). While substantial number of researches utilized SPI, most of the studies have not considered the whole water cycle, instead considered groundwater extraction for irrigation (Rahaman *et al*., 2016). The amount of water required has rarely been addressed in water management.

In this backdrop, this research, in addition to rainfall, the primary factor in governing drought phenomena (Edossa *et al*., 2014), intends to investigate the shortage of water supply in the northern Bangladesh. Since rainfall is one of the basic natural water resources of the study area, this work likes to reinvestigate recent droughts, trends and shortage of water from rainfall with the estimation of drought indices, using statistical tool.

Figure 1. Location map of the study area Rangpur division in northwestern Bangladesh.

Table 1. Drought category according to SPI (McKee et al., 1993).

SPI	Drought category
0 to - 0.99	Mild drought
- 1.00 to -1.49	Moderately drought
- 1.50 to -1.99	Severely drought
- 2.00 to less	Extremely drought

2. Materials and Methods

2.1. Study Area

The study area is Rangpur division, which is located in the northwestern part of Bangladesh (Figure 1). The area of Rangpur division is approximately 16320.26 sq km, spanning 25°20′ to 26°37′N latitudes and 88°50′ to 89°53′ E longitudes and is mostly of alluvial plain. The land is famous for agricultural productions such as rice, jute, oilseeds, tobacco etc. It is bounded by West Bengal of India on the north and west, Meghalaya of India on the east, and Rajshahi division on the south. Atrai, Brahmaputra, Dharla, Mahananda, Tangon, Teesta are the main

rivers in this region. The biggest irrigation project of the country, Tista Barrage Project of length 615 m is located at Doani of Hatibandha upazila, Lalmonirhat, Rangpur division.

2.2. Materials

Daily rainfall data for 30 years from 1988 to 2017 recorded in three meteorological stations in the region namely Rangpur, Dinajpur, and Syedpur (Figure 1) by the Bangladesh Meteorological Department (BMD) have been used for the analysis.

2.3. Methods

2.3.1. Standardized Precipitation Index

Standardized precipitation index or simply SPI is a scale of deviated rainfall from a typical rainfall probability distribution function with zero mean and unit standard deviation. A gamma probability density function is used to calculate the gamma distribution. The SPI obtained from the gamma distribution is a standard normal Z-value with zero mean and unit variance. The SPI takes the form is as given below.

$$SPI = -\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right);\ 0 < H(x) \leq 0.5 \quad (1)$$

$$SPI = +\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right);\ 0.5 < H(x) \leq 1 \quad (2)$$

and,

$$t = \sqrt{ln(\frac{1}{H(x)^2})} \quad ;\ 0 < H(x) \leq 0.5 \quad (3)$$

$$t = \sqrt{ln(\frac{1}{(1.0-H(x))^2})} \quad ;0.5 < H(x) \leq 1 \quad (4)$$

where, $H(x)$ is the cumulative probability, and$c_0 = 2.515517;\ c_1 = 0.802583;\ c_2 = 0.010328$; $d_1 = 1.432788;\ d_2 = 0.189269$ and$d_3 = 0.001308$ (Abramowitz and Stegun, 1965).

With the estimated Z-values as said SPI values using Eqn. 1 and 2 above, the drought can be classified as shown in Table 1.

2.3.2. Mann-Kendall Test

The Mann-Kendall (MK) test is a rank-based test for evaluating monotonic patterns and to see whether a series of pairs of values are related (Helsel and Hirsch, 2002). At various levels of importance, the significance of the observed patterns can be determined. The World Meteorological Organization, WMO has recommended that climate and hydrologic data time series be examined for statistically relevant patterns. The following formula is used to measure the MK test statistic and the sign function:

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sign(x_j - x_i) \quad (5)$$

$$sign(x_j - x_i) = \begin{cases} +1 & x_j > x_i \\ 0 & x_j = x_i \\ -1 & x_j < x_i \end{cases} \quad (6)$$

where, *n* is the total number of data, x_i or x_j is the data point at times *i*or j(j >i). The variance of S can be obtained as written below.

$$var(S) = [n(n-1)(2n+5) - \sum_{i=1}^{m} t_i i(i-1)(2i+5)]/18 \quad (7)$$

where, t_i is the number of ties of extent i, and m is the number of tied groups. For, $n > 10\ or\ more$, the standard test statistic Z is same as the MK test statistic as written below.

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}} & if \ \ S > 0 \\ 0 & if \ \ S = 0 \\ \frac{S+1}{\sqrt{var(S)}} & if \ \ S < 0 \end{cases} \quad (8)$$

The Z value is used to determine whether a significant statistical pattern exists. Z values that are positive indicate upward trends, while negative values indicate downward trends.

2.3.3. Spearman's Rho Test

The Spearman's Rho (SR) is a rank-based non-parametric statistical test similar to MK that can be used to detect monotonic trend in a time series (Yue *et al*., 2002; Yenigun*et al*., 2008). It's a simple test to see if there's some overlap between two classifications of the same set of data. The SR test statistic can be explained as follows (Sneyers, 1990).

$$r_s = 1 - \frac{6\left[\sum_{i=1}^{n}(R(x_i)-i)^2\right]}{(n^3-n)} \quad (9)$$

$$Z_{SR} = r_S\sqrt{\frac{n-2}{1-r_S{}^2}} \quad (10)$$

where, $R(X_i)$ is the rank of the i^{th} observation X_i in the time series, and n is the length of the time series. Positive values of Z_{SR} indicate increasing trend, while negative Z_{SR} indicates decreasing trends in the time series.

3. Results and Discussions

SPI is an estimate of rainfall at a given location that can be calculated using rainfall records over a variety of timescales, ranging from 1 to 48 months. In the present estimations, the time scales 3M and 6M are used because these are widely accepted to be the best options for addressing basic drought and agricultural impacts from drought when studying a region (WMO and GWP, 2016; Mamun *et al*., 2021). This is the extended work for Rangpur division in northwest Bangladesh as shown by Mamun *et al*. (2021) for Rajshahi division.

SPIs have been estimated for all the stations of Rangpur, Dinajpur and Syedpur respectively for all the months from 1988 to 2017. Figure 2 shows only for the month of July.Assessing the entire estimations, results show that Rangpur region has suffered from drought in the years 1994, 1995, 2000, 2006 and 2014. In 1994 and 1995, the SPI index value falls below -1.5 successive four months as drought months and other months are normal. The indices in most of the months in 1994 and 1995 have obtained a value as less than -1.5 indicating that the year 1994 and 1995 experienced moderate to severe drought. The value of indices has even gone below -1.5 in the year 2014, which indicate that the area suffered from moderate to severe drought.

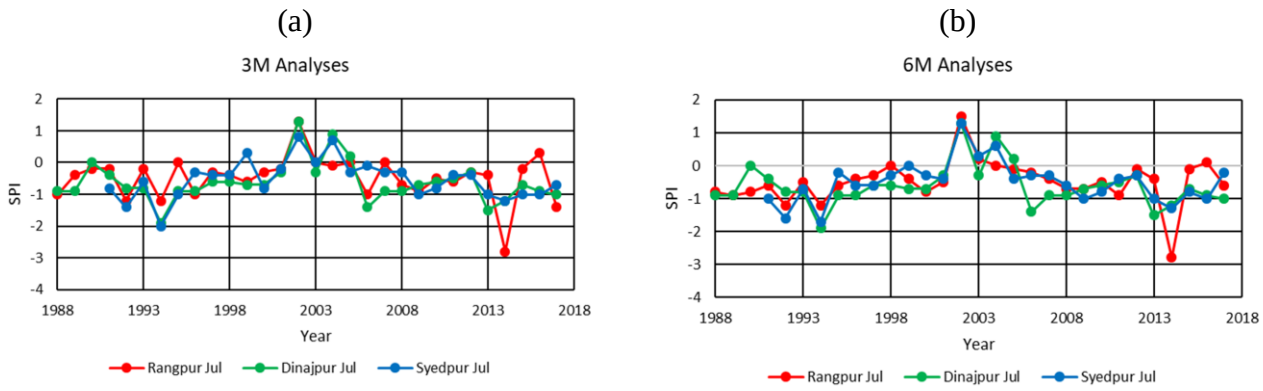

Figure 2. Estimated SPI in Rangpur Division of Bangladesh for the month of July from 1988 to 2017, using a) 3M and b) 6M analyses.

Similarly, Dinajpur was under moderate to severe drought in the year 1994, 1995, 2000, 2006 & 2014. On other hand, few months of the estimated SPIs in Syedpur are greater or close to -1.5 as estimated. However, the years 1994 and 2000 experienced moderate to severe drought.

This study finds that the study area has experienced moderate to severe drought in 1994, 1995, 2000, 2006 and 2014respectively, which resembles the similar findings byNury and Hasan (2016) and Islam *et al*., (2014).Where extremely dry events were shown in 1994, 1995, 2000 and 2011 along with the droughts in 1994, 2000 and 2006 in Rangpur.

This study has estimated the trends using Mann-Kendall and Spearman's Rho test as shown in Table 2 over the estimated SPIs. The months January, March, April, August, October, November and December in Rangpur; February, July, August, October, November and December in Dinajpur; and February, March, July, September to December in Syedpur are showing negative trends (Table 2). The months June, July and August are the rainy or monsoon season in all over Bangladesh, while the months March to May and the months September to November are pre and post monsoon seasons (Syed and Amin, 2016). Trend analyses show that trends for the months from July to December are negative in the estimated indices. Though there is a positive trend positive, this work has discussed for the month June as one of monsoon months experiencing shortage of water in the later section.

The yearly maximum and minimum indices along with linear trends are shown in Figures 3-4. In the yearly maximum in both 3M and 6M analyses linear trends are found to be negative for the whole study area with a significant slope of -0.04 in 3M analyses. On other hand, in the yearly minimum in 3M analyses the study area Rangpur and Dinajpur are showing negative trend with a slope of -0.02, except Syedpur station having a tiny positive trend. while 6M analyses the whole study area are showing tiny positive trend. Results are indicating that Rangpur division is likely to suffer mild in the coming years than those of the past from drought.

Table 2. Trend estimations using Mann-Kendall and Spearman's Rho tests in SPIs estimated for Rangpur, Dinajpur and Syedpur.

Month	Rangpur							Dinajpur							Syedpur						
	Using 3M Time Scale SPI			Using 6M Time Scale SPI			Remarks	Using 3M Time Scale SPI			Using 6M Time Scale SPI			Remarks	Using 3M Time Scale SPI			Using 6M Time Scale SPI			Remarks
	MK test	SR test	TR	MK test	SR test	TR		MK test	SR test	TR	MK test	SR test	TR		MK test	SR test	TR	MK test	SR test	TR	
January	-1.5	-1.1	-	-0.8	-0.8	-	Both -	-1.6	-1.5	-	0.9	0.9	+		-2.2	-2.7	-	0	0.1	+	
February	-2	-2	-	0.9	0.9	+		-1	-0.9	-	-0.8	-0.9	-	Both -	-1.5	-1.4	-	-0.4	-0.3	-	Both -
March	-0.4	-0.5	-	-0.3	-0.5	-	Both -	-0.2	0.1	-/+	0.8	0.8	+		-1.1	-1	-	-0.1	-0.1	-	Both -
April	-0.4	-0.3	-	-0.4	-0.2	-	Both -	0.2	0.7	+	0.4	0.7	+		1.5	1.7	+	0.8	0.9	+	
May	-0.2	-0.3	-	0.3	0.2	+		0.9	0.8	+	1	1	+		-0.4	-0.4	+	0.3	0.3	+	
June	1	1	+	0.5	0.5	+		0.7	0.7	+	0.3	0.4	+		0.3	0.5	+	0.3	0.5	+	
July	0.1	-0.1	+/-	1.6	1.6	+		-1.2	-1.3	-	-0.4	-0.6	-	Both -	-0.5	-0.3	-	-0.1	-0.1	-	Both -
August	-1.1	-1.2	-	-0.6	-0.4	-	Both -	-0.3	-0.5	-	-0.9	-1	-	Both -	0.3	0.4	+	0.3	0.4	+	
September	0.7	0.6	+	-1.1	-1.2	-		0.2	0.2	+	-1.1	-1	-		-1.2	-1	-	-1	-0.9	-	Both - and stronger
October	-0.4	-0.5	-	-0.5	-0.6	-	Both -	-1.9	-2.2	-	-0.6	-0.7	-	Both -	-1	-1	-	-0.3	-0.1	-	Both -
November	-1.1	-1	-	-0.6	-0.7	-	Both -	-1.1	-1.3	-	-0.7	-0.9	-	Both -	-0.9	-1.1	-	-0.4	-0.3	-	Both -
December	-1.4	-1.4	-	0.4	0.3	-	Both -	-1.2	-1.2	-	-0.9	-1	-	Both - and stronger	-0.5	-0.5	-	-0.9	-0.9	-	Both -

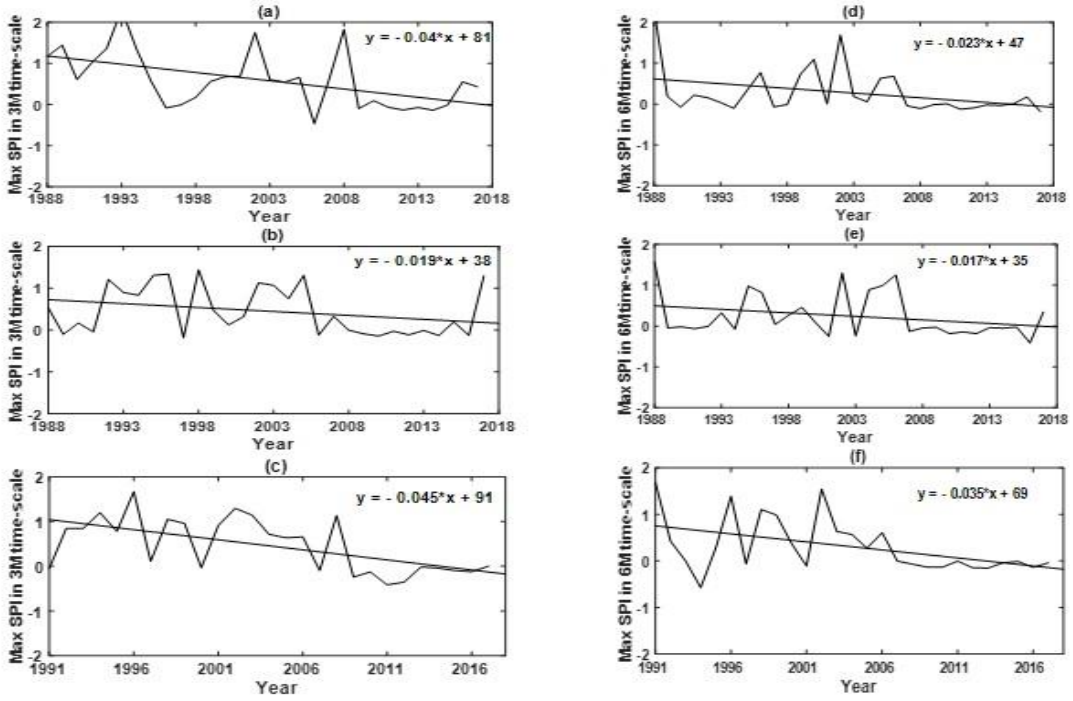

Figure 3. Maximum SPI index trend from 1988 to 2017, in 3M time-scale analyses at a) Rangpur, b) Dinajpur and c) Saidpur; in 6M time-scale analyses at d) Rangpur, e) Dinajpur and f) Syedpur.

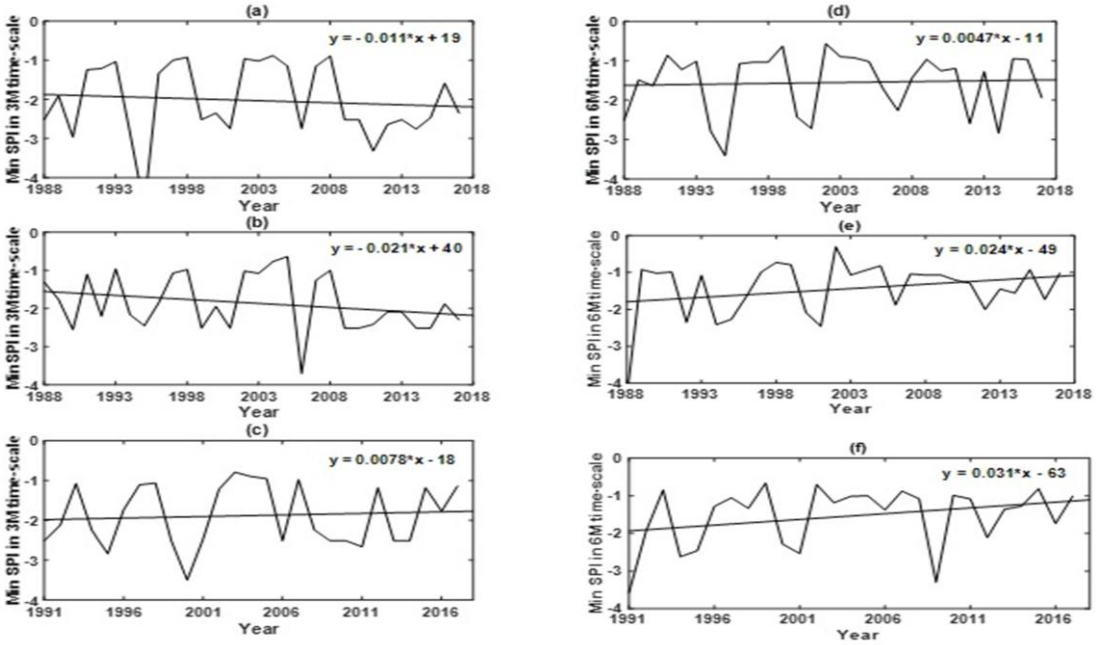

Figure 4. Minimum SPI index trend from 1988 to 2017, in 3M time-scale analyses at a) Rangpur, b) Dinajpur and c) Saidpur; in 6M time-scale analyses at d) Rangpur, e) Dinajpur and f) Syedpur.

MK and SR tests (Table 2), along with maximum indices (Figure 3) have attributed that the months June is showing tiny positive trend while July and August are showing negative trends. On the other hand, a little slope yearly minimum indices (Figure 4) are shown the tiny positive trends. As the months June, July and August belongs to monsoon season and are showing negative trends in the estimated drought indices, the following section is brought here to show detailed rainfall along with estimated SPIs for the monsoon season. Monthly rainfall, cumulative rainfall through which the indices are estimated, and indices estimated using 6M time scale are shown in Figures 5-7 for the rainfall recorded at Rangpur, Dinajpur and Syedpur for the months June, July and August. Here, 6M time scale is applied since the scale is suggested for investigating agricultural impacts from drought.

Monthly rainfall in monsoon season in Rangpur region shows positive trends for June and July respectively and negative trends for August with the slopes 0.0001, -0.0006 and -0.0002 (Figure 4). The month of August shows that the difference between monthly rainfall and cumulative rainfall is maximum, and this maximum difference indicates that the months June and July are evidencing much rain water than that of the month August.

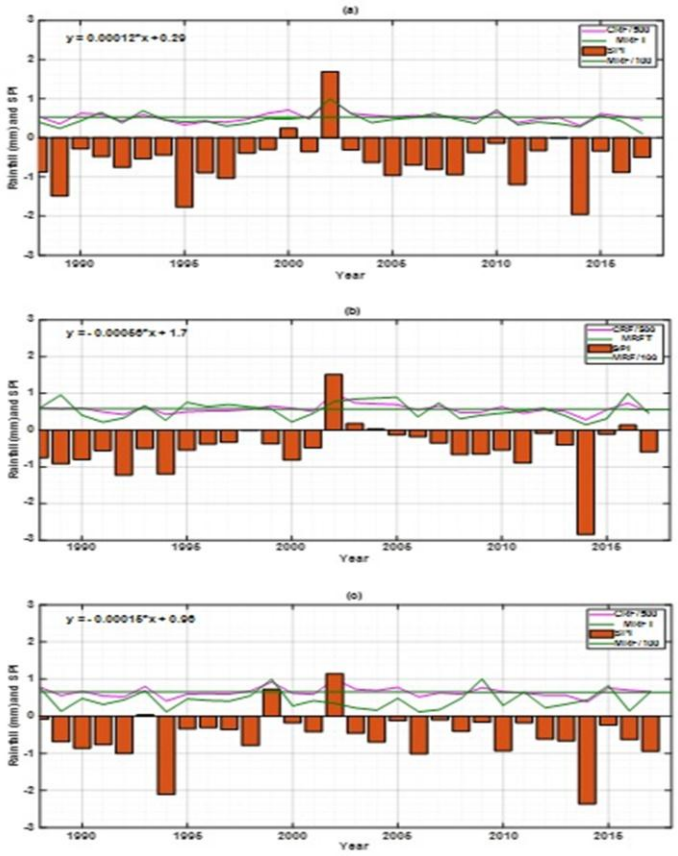

Figure 5. Monthly rainfall (MRF), cumulative rainfall (CRF) and SPIs with 6M time-scale along with monthly rainfall trend (MRFT) for the months a) June, b) July and c) August at Rangpur.

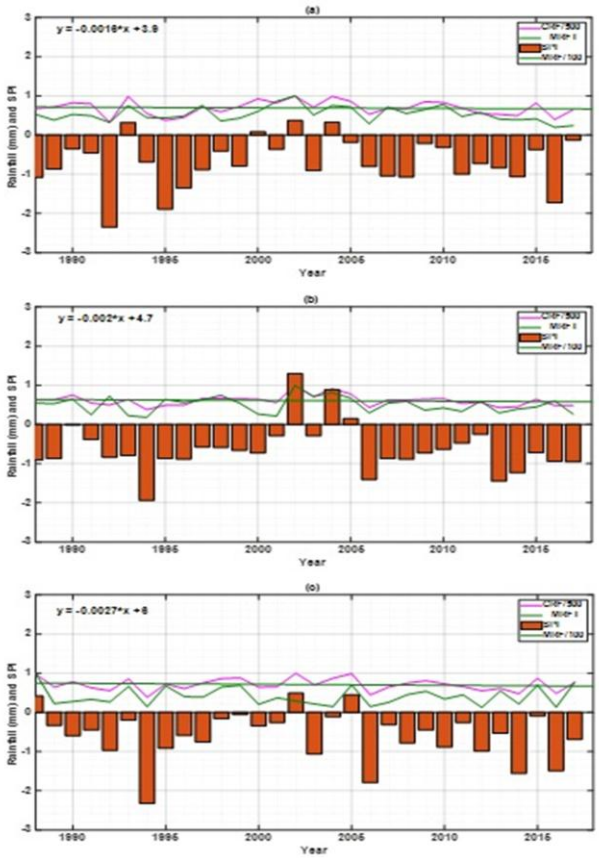

Figure 6. Monthly rainfall (MRF), cumulative rainfall (CRF) and SPIs with 6M time-scale along with monthly rainfall trend (MRFT) for the months a) June, b) July and c) August at Dinajpur.

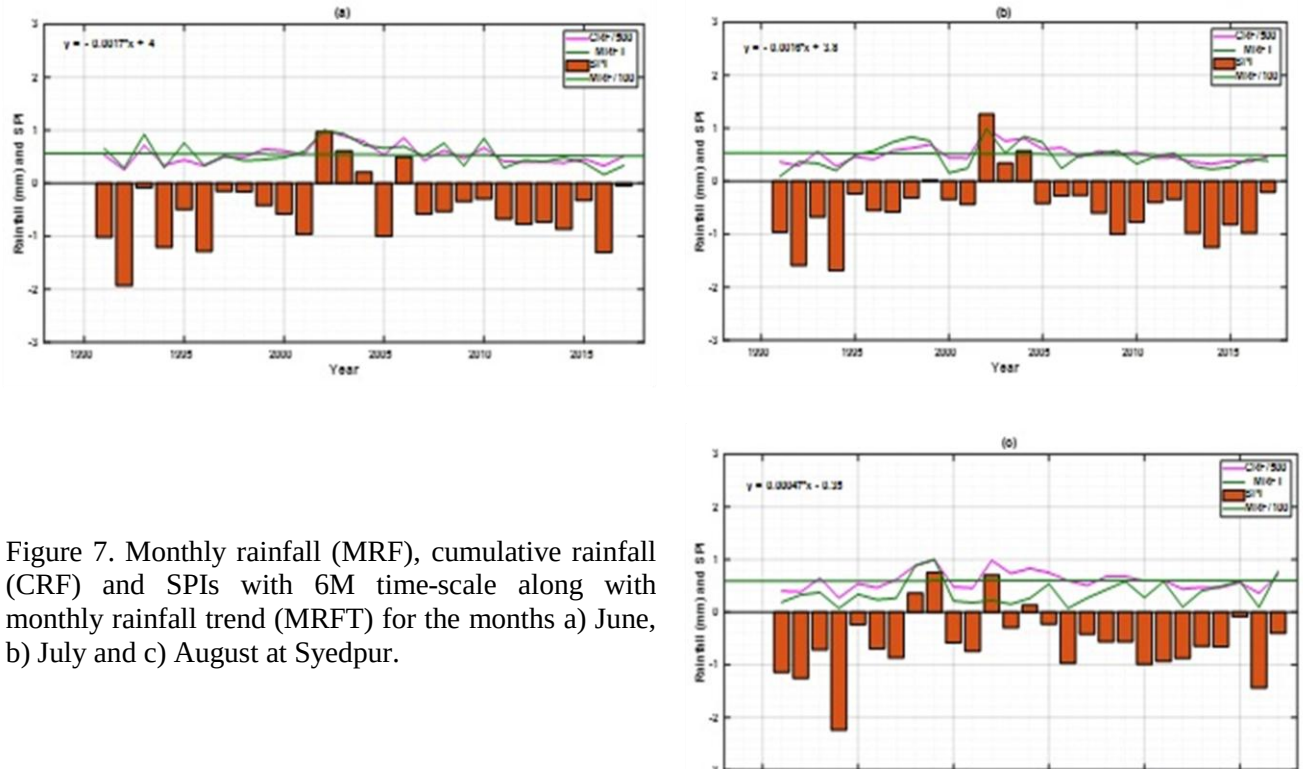

Figure 7. Monthly rainfall (MRF), cumulative rainfall (CRF) and SPIs with 6M time-scale along with monthly rainfall trend (MRFT) for the months a) June, b) July and c) August at Syedpur.

Similarly, the monthly rainfall in monsoon season in Dinajpur region shows negative trends with the slopes -0.002, -0.002 and -0.003 for June, July and August respectively (Figure 5). Estimations once again indicate that the months of June is much rain water than the months of July and August.

Monthly rainfall in monsoon season in Syedpur shows negative trend with the slopes -0.002 and -0.002 for June and July, respectively (Figure 6). The month August showing tiny positive trends with the slope 0.0005 indicates similar pattern that the months June and July lack rain water compared to that during the month August. However, the negatively trended rainfall in August in all regions do not show better indices (Tables 2-3), since one of the slopes are found to be 0.0005 and others are close to be -1.0 or less.

Above findings interpret that during the monsoon season the whole study area lacks rain water, whereas rain water is the most important agent for keeping better agricultural production. If the amount of rain water becomes scarce the area is likely to face shortage of agricultural productivity. Initially groundwater may be used for agriculture to replenish the productivity gap, but the overall climate of the region would deteriorate. An overall water deficiency in percentage is estimated using rainfall data during monsoon. This is done from the differences of converted monthly rainfall and cumulative rainfall to a unique scale for Rangpur division (Figure 7). Results show that Syedpur experiences the least water deficit in the region, while Dinajpur experiences the most. Overall water deficit ranges from 2% to 26% in different years, and average water deficit is found to be 13% for the whole study area. Hence, initiatives for Rangpur division to increase supply of water, at least 13% more than the rainwater, for agriculture require a special attention.

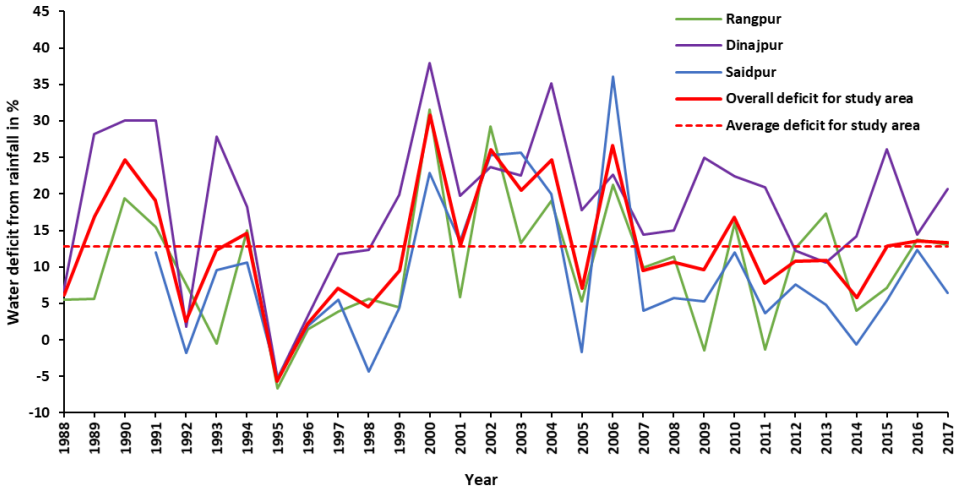

Figure 8. Overall water deficit from rainfall in monsoon for the months June, July and August in Rangpur division of northwest Bangladesh.

4. Conclusions

Drought is not a sudden event rather a creeping climatic phenomenon, and is difficult to predict its occurrence, magnitude, intensity, and return period. Analysis of drought is the highest important in the dry parts of northern Bangladesh for planning of water and rational utilization of irrigated water as agriculture is the main economic activity and highly depends on rainfall.

This research has reinvestigated recent drought status of Rangpur division with the estimation of SPI using rainfall data from 1988 to 2017, and has found discrepancies in past drought years. This work has identified that the years 1994, 1995, 2000 2006 and 2014 have experienced moderate to severe drought. Drought trends have figured out shortage of water in the study area using the estimated standardized precipitation indices. Most of the estimated yearly maximum and minimum indices have attributed negative trends with a diverse slope from -0.02 to -0.05 except Rangpur, Dinajpur and Syedpur having small positive trend with a slope 0.005 to 0.03 in minimum indices with 6M analysis. Mann-Kendall and Spearman's Rho test have identified negative trends for monsoon season, i.e. the months of June, July and August. Findings have interpreted that the study area is experiencing roughly 13% of shortage in rainwater during monsoon season. It has been observed that the cumulative monthly rainfall is always higher than the monthly rainfall. As a result, most of the estimated indices have found below zero. Water mostly from rainfall replenish water bodies on the surface and to recharge the groundwater, and shortage of water may further obstruct sustainability and overall irrigation. The outcomes of the present study suggest that strategies of water resources management should be according to the changing patterns in drought in the northern Bangladesh.

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Seasonal Boundaries in Harmonic Analysis of Temperature and Rainfall Time Series for Studying the Climatic Patterns in Central Part of Northern Bangladesh

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Abstract

Temperature and rainfall are the two most significant variables through which the climate of an area can be learned. This work has studied the seasonal boundaries in Chandpur, Dhaka, Tangail and Mymensingh of central part of northern Bangladesh in a year using the daily records of temperature and rainfall from 1985 to 2017 for 33 years with the harmonic analysis. All analyses have assessed four seasonal boundaries. The analyses of minimum and maximum temperatures time series have indicated that the first, second, third and fourth boundaries are respectively at 48 to 54th day, 137 to 146th day, 239 to 244th day and 326 to 336th day in each year. While the analyses of rainfall time series have assessed that the four seasonal boundaries start at respectively from 54 to 65th day, 146 to 156th day, 237 to 247th day and 327 to 337th day. The seasons as well as the seasonal boundaries projected in the study area have appeared that the seasons in southern part start 2 or 3 days earlier than those of the northern part. Spatial variation in the boundaries of the seasons within the studied area is found small and varying from 6 to 10 days in temperature and 10 days in rainfall. Estimated mean four seasonal boundaries are at 20th February, 19th May, 28th August, and 25th Novemberin minimum temperature; 22nd February, 23rd May, 29th August, and 29th November in maximum temperature; and 26th February, 30th May, 29th August and 27th November respectively. Thus, the seasons and seasonal durations estimated in this study may assist concerned authorities in taking measures to optimize the risks may a result from changing climate difficulties for smooth agricultural production.

Keywords: Climate, harmonic analysis, temperature, rainfall, season, Bangladesh.

1. Introduction

Climate of an area is described through the average of temperature, precipitation, humidity, wind, cloud, pressure and so on of a region for a long period, and it varies with time and space. Global and local climate changes are now visible issues and given priorities for sustainable development in all over the world. In this context, Bangladesh is already underlined as one of the most vulnerable countries to climate change (World Bank, 2009; Harmeling and Eckstein, 2012; Kreft and Eckstein, 2014; Maple-croft, 2013; Kreft *et al*., 2016; Karim and Mimura, 2008; Penning-Rowsell *et al*., 2014). This work intends to study the variability of seasons using the analysis of climate records of temperature and rainfall in northern Bangladesh.

The climate of the northern region is slightly different from other regions in Bangladesh and dominated by tropical monsoons. It is categorized by high temperature, modest rainfall with often disproportionate humidity and equally marked seasonal variations (Rashid, 1991). The most striking feature of this climate is the reversal of the wind circulation between winter and rainy season, which is an integral part of the circulation system of the Indian subcontinent. From the climatic point of view four distinct seasons are recognized in Bangladesh: the winter from mid-December to February, the pre-monsoon summer from March to May, the rainy monsoon from June to mid-October and the autumn season from mid-October to mid-December (Ahmed, 1997). However, the real-life observations speculate that the seasons or the seasonal lengths in the year are varying. The area is largely dependent on rain-fed agriculture, whereas the rainfall patterns are found to be variable in this region along with other regions of the country (Khan *et al*., 2019; Shahid *et al*., 2012; Shahid *et al*., 2010). Therefore, it is essential

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to inspect the seasons or the break point of changes in rainfall patterns along with other climatic patterns with time and space.

On other hand, Rashid (1991) has described Rajshahi as an area of extreme weather and showed in summer, the highest maximum temperature to be well above 40°C, whereas in winter the lowest minimum temperature to be below 5°C. Asaduzzaman (1995) has analyzed the climate of Barind region using rainfall, temperature and pressure, and reported that the mean annual rainfall of this region is lower less than 2000 mm. Reid and Sims (2007) have observed that the temperatures have increased about 1°C in May and 0.5°C in November between 1985 and 1998. It is found that maximum temperature has been increased dramatically over the last 40 years period, while the highest temperature of 44°C was recorded at Bogra and Ishurdi in April 1956 and May 1970 respectively, and the lowest temperature of 3.2°C was recorded at Rajshahi in January 2003 (Asib and Jakir, 2017). The variabilities in temperature and rainfall of the country are already been highlighted in various contributions. This work likes to find the break events in the climate time series of temperature and rainfall as shown in the contribution by Rahman *et al*. (2020) using harmonic analysis of minimum and maximum temperatures.

Justino *et al*. (2011) have demonstrated the usefulness of harmonic analysis in the context of seasonal variation. Harmonic analysis can decompose a time-dependent periodic function into a sequence of oscillatory components and then reconstruct the function using the oscillatory components with different amplitude and phase values (Aslan *et al*., 1997). The proportion of variance in the original time series data set accounted for by each term of the harmonics can also be calculated. The geographic setting in Bangladesh, climatic patterns of the study area and the estimation of seasons in a year in the analysis of climate records are described in the following sections.

2. Geographic Location and Climatic Patterns

Bangladesh extends from 20°34'N to 26°38'N latitude and from 88°01'E to 92°41'E longitude. Except the hilly southeast, most of the country is a low-lying plainland. It is surrounded by the Assam Hills in the east, the Meghalaya Plateau in the north, the lofty Himalayas lying farther to the north. To its south lies the Bay of Bengal, and to the west lie the plainland of west Bengal and the vast tract of the Gangetic Plain. The climate of Bangladesh is subtropical in the center-north and tropical in the south, with a pleasantly warm and sunny winter from November to February, a short hot spring between March and May, and a long rainy season from June to October due to the summer monsoon. Bangladesh being in the tropical monsoon region it experiences high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations.

Since the geographical position of Bangladesh is in the subtropical zone, so the most climatic phenomena are very closely related to its temperature. Mainly the variation of temperature in different times causes atmospheric unrest through the country. The presence of great Himalaya is also a major driving force in determining the temperature and other related climatic phenomena in Bangladesh. Many studies have been conducted to investigate the variability of climate in Bangladesh (Rahman *et al*., 1997; Jones, 1995; Singh, 2001; Shahid, 2008; Shahid, 2010a; Shahid, 2010b; Shahid, 2011).

2.1. Temperature

January is the coldest month in Bangladesh. However, the cold winter air that moves into the country from the northwestern part of India loses much of its intensity by the time it reaches the northwestern corner of the country. Average temperatures in January vary from about 17^0C in the northwestern and northeastern parts to 20^0-21^0C in the coastal areas. In late December and early January, minimum temperature in the extreme northwestern and northeastern parts of the country reaches within 4 to 7 degrees of freezing point. As the winter season progresses into the pre-monsoon hot season, temperature rises, reaching the maximum in April, which is the middle of the pre-monsoon hot season. Average temperatures in April vary from about 27°C in the northeast to 30°C in the extreme west central part of the country. In some places of Rajshahi and Rangpur divisions the maximum temperature in summer season rises to 40°C or above. After April, temperature decreases slightly during the summer months, which coincides with the rainy season. Widespread cloud covers causes dampening of temperature during the latter part of the pre-monsoon season. Average temperatures in July vary from about 27°C in the southeast to 29°C in the northwestern part of the country. Previous studies on the variations of temperature in Bangladesh indicated that the increasing trend of annual maximum temperature from 1961-1990 is

0.029°C per year which is statistically significant at 1% level (Singh and Khan, 2000). Contributions have shown that mean maximum temperature would be increased to 0.40°C and 0.73°C by 2050 and 2100 respectively. Mean annual minimum temperature would be increased to 0.04°C and 0.08°C by 2050 and 2100 respectively. It is also predicted that the average temperature in Bangladesh would be increased to 0.22°C and 0.41°C by 2050 and 2100 respectively (Karmakar *et al*., 2000).

2.2. Rainfall

The single most dominant element of the climate of Bangladesh is the rainfall. Because of the country's location in the tropical monsoon region, the amount of rainfall is very high. However, there is a distinct seasonal pattern in the annual cycle of rainfall, which is much more pronounced than the annual cycle of temperature. The winter season is very dry, and accounts for only 2%-4% of the total annual rainfall. Rainfall during this season varies from less than 2 cm in the west and south to slightly over 4 cm in the northeast. The amount is slightly enhanced in the northeastern part due to the additional uplifting of moist air provided by the Meghalaya Plateau. As the winter season progresses into the pre-monsoon hot season, rainfall increases due to intense surface heat and the influx of moisture from the Bay of Bengal. Rainfall during this season accounts for 10%-25% of the total annual rainfall which is caused by the thunderstorms or nor ’wester (locally called Kalbaixakhi [Kalbaishakhi]).

The amount of rainfall in this season varies from about 20 cm in the west central part to slightly over 80 cm in the northeast. The additional uplifting (by the Meghalaya Plateau) of the moist air causes higher amount of rainfall in the northeast. Rainfall during the rainy season is caused by the tropical depressions that enter the country from the Bay of Bengal. These account for 70% of the annual total in the eastern part, 80% in the southwest, and slightly over 85% in the northwestern part of Bangladesh. The amount of rainfall in this season varies from 100 cm in the west central part to over 200 cm in the south and northeast. Average rainy days during the season vary from 60 in the west-central part to 95 days in the southeastern and over 100 days in the northeastern part. Geographic distribution of annual rainfall shows a variation from 150 cm in the west-central part of the country to more than 400 cm in the northeastern and southeastern parts. The maximum amount of rainfall has been recorded in the northern part of Sylhet district and in the southeastern part of the country (Cox's Bazar and Bandarban districts).

3. Materials and Methods

3.1. Study Area

The study area is in the central Northern part of Bangladesh that ranges from $23^{o}14'$ to $24^{o}44'$ N latitude and from $89^{o}56'$ to $90^{o}42'$ E longitude with an area of about 10,945 km^2 under Dhaka and Mymensingh divisions along with a small area of Chattogram division as shown in Figure 1. Most of the study area is low-lying plain land, downwards sloppy toward south and east. Overall elevation from mean sea level varies from 13 m to 3 m respectively from northwest to southeast or to east. Locations of four meteorological stations namely Chandpur, Dhaka, Tangail and Mymensingh are shown in Figure 1.

3.2. Data

This research has analyzed minimum temperature, maximum temperature and rainfall time series for 33 years from 1985 to 2017 obtained from Bangladesh Meteorological Department. Daily time series data were recorded at four stations in the study area. Data obtained are seemed to be healthier because of homogeneity in nature and very minimal rate of missing records even less than 0.8%. The cubic spline interpolation technique has used to estimate such missing records.

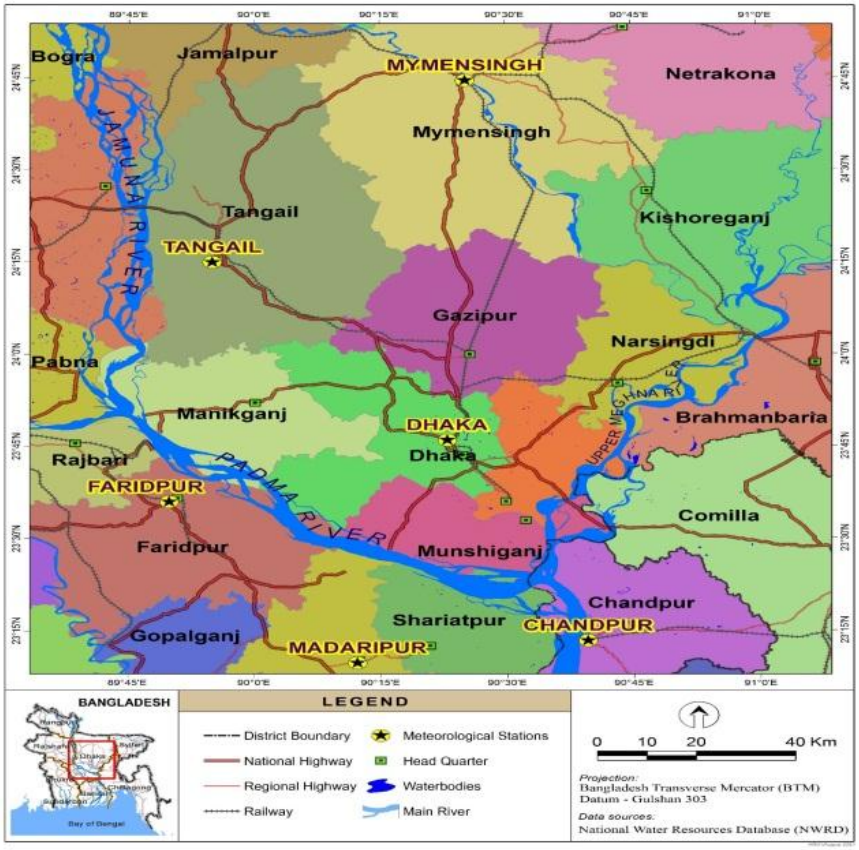

Figure 1. Location map of the study area, middle part of the Northern Bangladesh

3.3. Harmonic Analysis

Harmonic analysis decomposes a signal into an infinite sequence of harmonic elements, which are initially composed of a sine wave and a cosine wave of equal frequency. These two waves are then combined to form a single cosine wave with a fixed amplitude and phase angle. A complex curve can be expressed using harmonic analysis as the sum of a Fourier series of cosine waves and the complex curve is created by adding successive harmonic terms, and each part curve or term accounts for a percentage of the total variance in the original time-series data set (Davis, 1986). Fourier series for a continuous function, $y(t)$for the interval $[0, m]$can be written as shown by Rahman *et al*. (2020) and Jakubauskas *et al*. (2001):

$$y(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left(a_n \cos \frac{2n\pi t}{m} + b_n \sin \frac{2n\pi t}{m} \right) \quad (1)$$

The Eqn. 1 can be further written as:

$$y(t) = c_0 + \sum_{n=1}^{\infty} c_n \cos \left(\frac{2\pi n t}{m} - \emptyset_n \right) \quad (2)$$

assuming the i^{th} harmonic to the i^{th} term in the Fourier series for the series of length l and $i \geq 1$, the i^{th} harmonic can be converted to a single cosine term as:

$$a_i \cos \frac{2\pi i t}{m} + b_i \sin \frac{2\pi i t}{m} = c_i \cos \left(\frac{2\pi i t}{m} - \emptyset_i \right)$$

where, $c_i = \sqrt{a_i^2 + b_i^2}$ is the amplitude and $\varphi_i = tan^{-1}\frac{b_i}{a_i}$ is the angle between the vector $\langle a_i, b_i \rangle$. The Fourier coefficients, c_0, a_0, a_n and b_n can be written as:

$$c_o = \frac{1}{2}a_o$$

$$a_0 = \frac{2}{m}\int_0^m y(t)dt$$

$$a_n = \frac{2}{m}\int_0^m y(t)\cos\frac{2\pi nt}{m}dt \qquad for\ n \geq 0$$

$$b_n = \frac{2}{m}\int_0^m y(t)\sin\frac{2\pi nt}{m}dt \qquad for\ n \geq 0$$

Eqn. 2 represents nth harmonic of the time series, where, c_n is the amplitude, and ϕ_n as the phase angle of the nth harmonic. Using single value of *n* the n^{th} harmonic term and using the values from 1 to *n*, the successive n^{th} harmonic can be determined. Detail harmonic analysis and seasonal boundaries in daily temperature time series can be obtained in the contribution made by Rahman *et al*. (2020).

4. Results and Discussions

Harmonic analysis can reconstruct the climate time series integrating harmonics derived from the recorded climate time series. The number of harmonics applied to reconstruct a time series determine the degree of accuracy. This work has tested for the climate time series that the harmonics having frequency more than 85 days is adequate to define the seasonal boundaries over time series. Such four harmonics having frequencies nearly 86, 97, 97 and 85 days respectively and successive progress as resultant time series are estimated. The four seasonal boundaries are determined in the harmonic estimations taking the time when amplitudes come to equal or very nearly equal height and the seasonal boundaries are shown in Figures 2-6 respectively for one-year daily climate time series of i) minimum temperature ii) maximum temperature and iii) rainfall for the four stations respectively as Chandpur, Dhaka, Tangail and Mymensingh from 1985 to 2017.

Seasonal boundaries have estimated for each year from 1985 to 2017 for all the stations of the study area. Estimated yearly boundaries are labeled as B1, B2, B3 and B4 in minimum temperature, maximum temperature and rainfall with harmonic analysis and are summarized. Four seasonal boundaries are obtained in the analyses of each year.

For Tangail station first, second, third and fourth boundaries are obtained respectively at 52, 139, 241 and 329th day in minimum temperature; 53, 143, 243 and 335th day in maximum temperature; and 65, 156, 247 and 337th day in rainfall as shown in Table 1-3.

For Chandpur station first, second, third and fourth boundaries are estimated at 54, 143, 243 and 333rdday in minimum temperature; 53, 146, 240 and 334th day in maximum temperature; and 54, 146, 237 and 327thday respectively in rainfall analyses as shown in Table 1-3. Estimated boundaries in different harmonic analyses of temperature and rainfall are found to be closer.

For Mymensingh station first, second, third and fourth boundaries are respectively at 48, 137, 239 and 326th day in minimum temperature; 54, 145, 244 and 336th day in maximum temperature; and 61, 154, 245 and 335th day in rainfall as shown in Table 1-3.

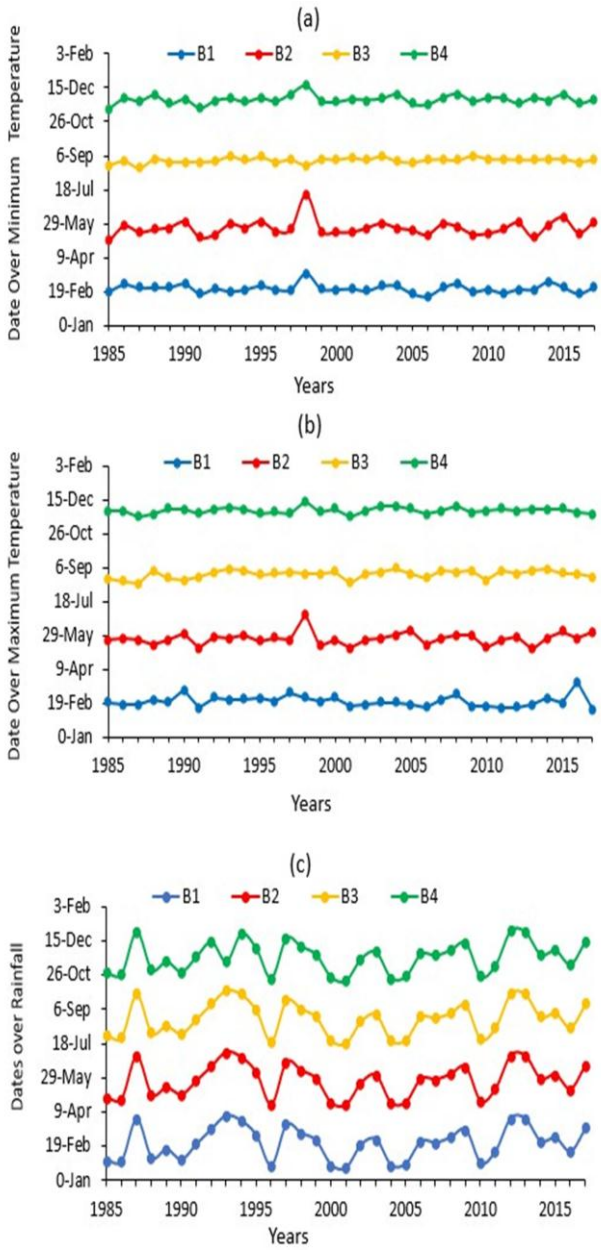

Figure 2. Estimated seasonal boundaries in calendar date as shown as day in Table 1-3, B- over harmonic analyses of a) minimum temperature b) maximum temperature and c) rainfall for Chandpur station.

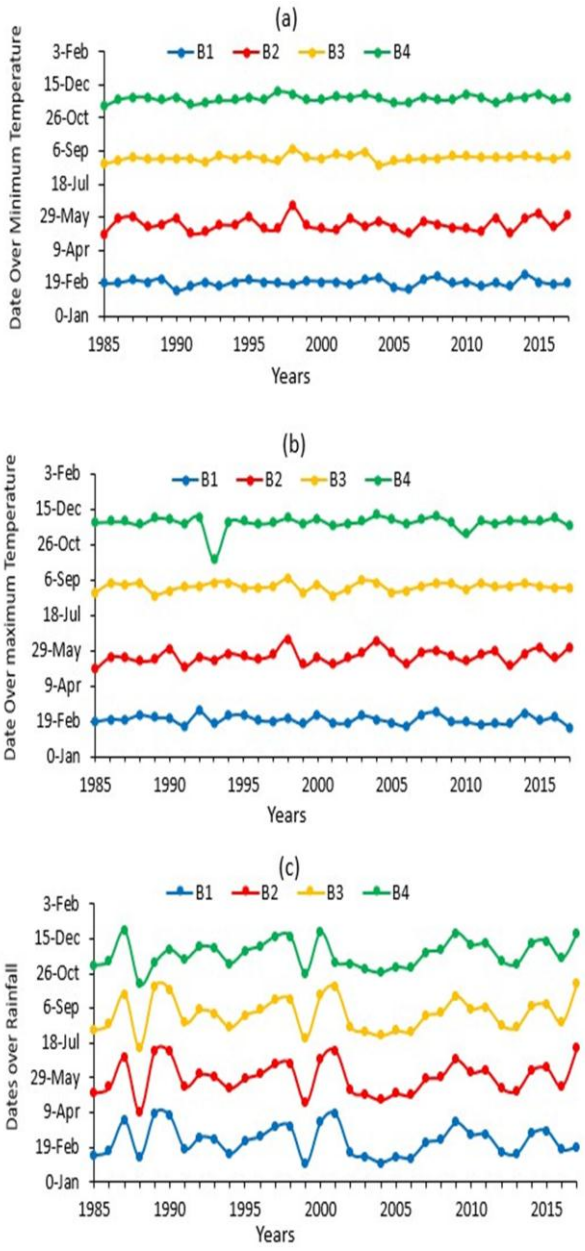

Figure 3. Estimated seasonal boundaries in calendar date as shown as day in Table 1-3, B- over harmonic analyses of a) minimum temperature b) maximum temperature and c) rainfall for Dhaka station.

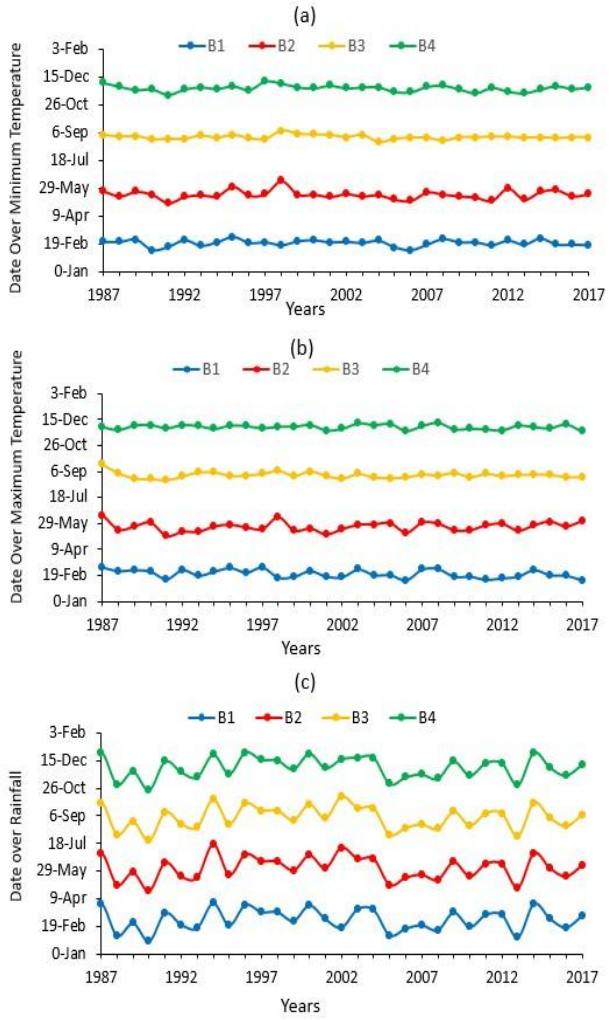

Figure 4. Estimated seasonal boundaries in calendar date as shown as day in Table 1-3, B- over harmonic analyses of a) minimum temperature b) maximum temperature and c) rainfall for Tangail station.

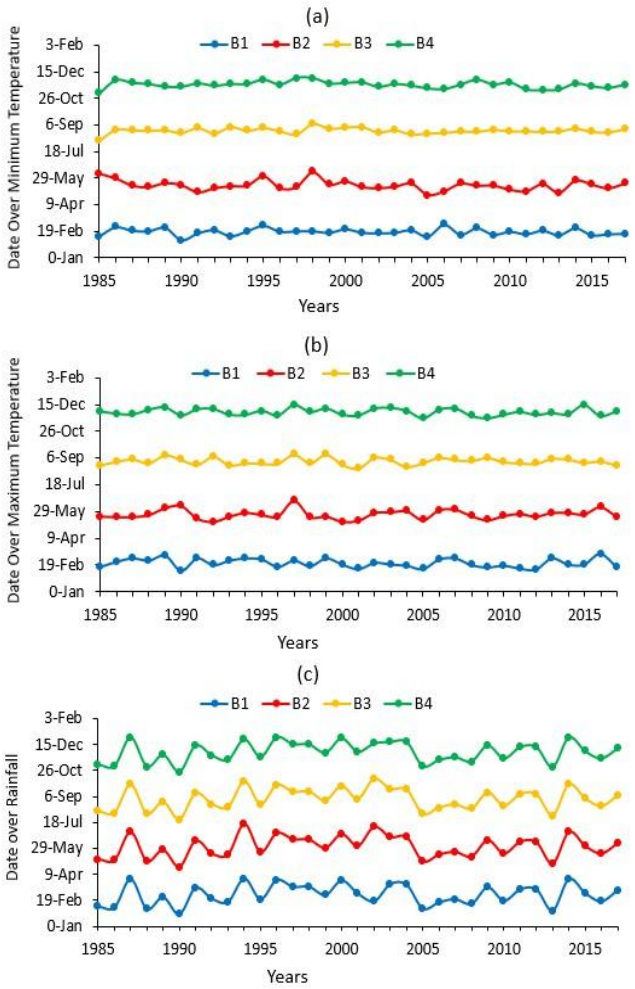

Figure 5. Estimated seasonal boundaries in calendar date as shown as day in Table 1-3, B- over harmonic analyses of a) minimum temperature b) maximum temperature and c) rainfall for Mymensingh station.

For Dhaka station first, second, third and fourth boundaries are obtained respectively at 50, 139, 240 and 330th in minimum temperature; 52, 142, 241 and 332nd day in maximum temperature and 58, 151, 242 and 328th day in rainfall as shown in Table 1-3.

Seasonal boundaries in the daily minimum temperature, maximum temperature and rainfall time series have found that first, second, third and fourth boundaries are varying respectively from 48 to 54th day, 137 to 146th day, 239 to 244th day and 326 to 336th day in all the analyses of the study area. Estimated boundaries within a year have the variations and are appeared to be small mostly less than 10 days. However, the boundaries with the year show a little trend.

This work has further averaged the estimated seasonal boundaries in each station for each time series of minimum temperature, maximum temperature and rainfall for 33 years. Besides the estimated average seasonal boundary, seasonal boundaries have converted the calendar day as shown in Figures 2-6 and Table 1-3. Determined seasons at four stations over 33 years are appeared to be almost unvaried. Thus, this research work concludes that the whole study area is belonging to the same climate and has four distinct seasons in the year.

Overall boundaries estimated in calendar date from minimum temperature, maximum temperature and rainfall in different stations (Figure 2-6) also show that the boundaries projected for different stations are appeared to start 2 or 3 days earlier in the southern stations than that of the northern stations. Spatial variation in the boundaries of the seasons within the studied area is found to be small and varying from 6 to 10 days for temperature and 10 days for rainfall.

Table 1. Station wise seasonal boundary for minimum temperature.

Stations	Seasonal boundary: Starting day							
	First Season		Second Season		Third Season		Fourth Season	
	N. Day	C. Day	N. Day	C. Day	N. Day	C. Day	N. Day	C. Day
Chandpur	54	23-Feb	143	22-May	243	30-Aug	333	28-Nov
Dhaka	50	19-Feb	139	18-May	240	27-Aug	330	25-Nov
Tangail	52	21-Feb	139	18-May	241	28-Aug	329	24-Nov
Mymensingh	48	17-Feb	137	16-May	239	26-Aug	326	21-Nov

N-number, C-calendar

Table 2. Station wise seasonal boundary for maximum temperature.

Stations	Seasonal boundary: Starting day							
	First Season		Second Season		Third Season		Fourth Season	
	N. Day	C. Day	N. Day	C. Day	N. Day	C. Day	N. Day	C. Day
Chandpur	53	22-Feb	146	25-May	240	27-Aug	334	29-Nov
Dhaka	52	21-Feb	142	21-May	241	28-Aug	332	27-Nov
Tangail	53	22-Feb	143	22-May	243	30-Aug	335	30-Nov
Mymensingh	54	23-Feb	145	24-May	244	31-Aug	336	1-Dec

N-number, C-calendar

Table 3. Station wise seasonal boundary for rainfall.

Stations	Seasonal boundary: Starting day							
	First Season		Second Season		Third Season		Fourth Season	
	N. Day	C. Day	N. Day	C. Day	N. Day	C. Day	N. Day	C. Day
Chandpur	54	23-Feb	146	25-May	237	24-Aug	327	22-Nov
Dhaka	58	27-Feb	151	30-May	242	29-Aug	328	23-Nov
Tangail	65	5-Mar	156	4-Jun	247	3-Sep	337	2-Dec
Mymensingh	61	1-Mar	154	2-Jun	245	1-Sep	335	30-Nov

N-number, C-calendar

The estimated four seasons are March-May, June-August, September-November, and December-February, and the results are consistent with Shahid (2010) and Syed and Amin's (2016)seasons. There is no scientific evidence for identifying seasons in the study area. Anomalies in defining seasons have also been found as the seasonality isn't always easy to describe. However, this work has determined four seasons in a year for the study area and visualized with an average seasonal length of 90 days from 85 to 95 days. Seasonal lengths, on the other hand, are not observed to be consistent. The fourth season looks to be 88 days long, while the second season is 97 days long, and the remaining seasons are 90 to 100 days long.

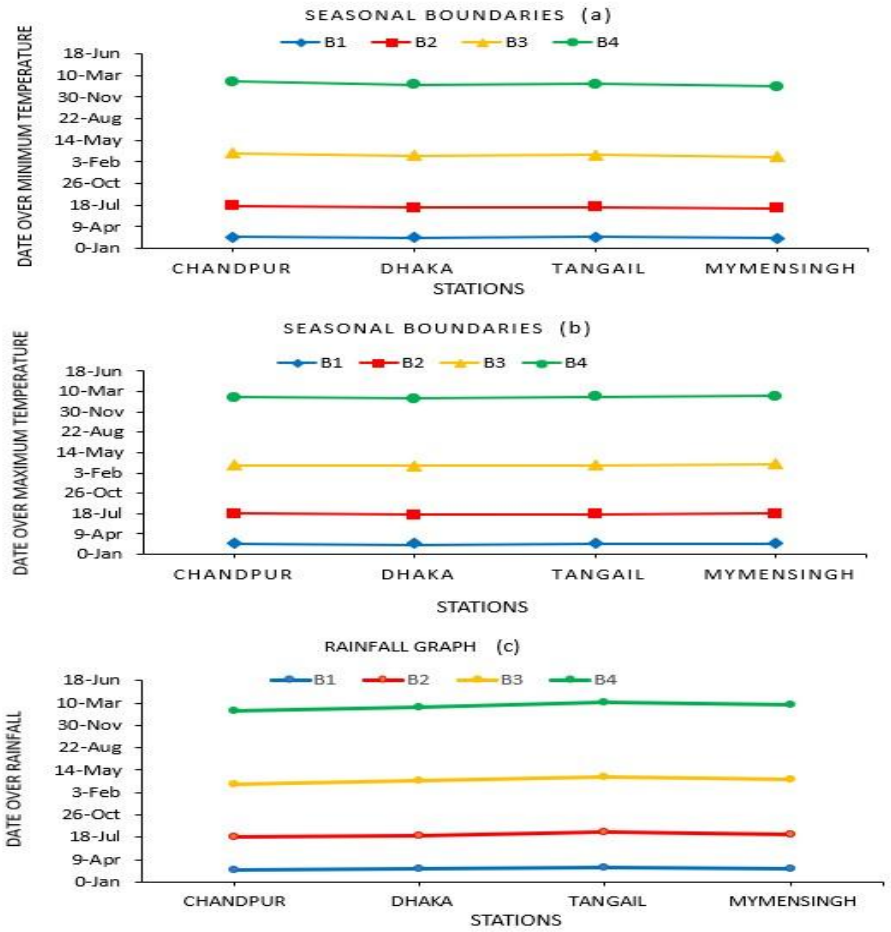

Figure 6. Seasonal boundaries in calendar date with stations a) minimum temperature b) maximum temperature and c) rainfall.

Changes in local climate and weather are suggested by a slightly earlier start to the season and a variance in seasonal length in the research area. The seasons or seasonal boundaries are may not exact, but well agreed with the traditional six seasons in Bangladesh.

5. Conclusions

In this study, four seasonal boundaries have estimated for each year from 1985 to 2017 and realized the first, second, third, and fourth seasonal boundaries respectively from 17-23rd February, 16-22nd May, 26-30th August, and 21-28th November in minimum temperature; 21-23rd February, 21-25th May, 27-31th August, and 27th November to 1st December in maximum temperature; and 23rd February to 1st March, 25th May to 4th June, 24th August to 3rd September and 22nd November to 2nd December in rainfall respectively. Therefore, the apparent seasons determined are March to May, June to August, September to November, and December to February. The results of the 33-years data analyses have revealed that the seasonal boundaries throughout the year vary from 6 to 10 days in temperature and 10 days in rainfall. The addition of further climate data to the current analysis may narrower the seasonal boundary down to a single day.

Although the climate data utilized in this study are homogenous, the analysis has not looked at the pattern of harmonics for inhomogeneity data. Harmonic analysis may or may not be able to determine the seasonal boundaries for inhomogeneous climatic data in practice. There are also a few trends in the year that are close to a slope of 0.05 of the projected borders, but the 33-year duration of the time series is not appeared to be enough to make an error-proof trend over the boundary. Temperature and rainfall are only two climate variables that may

not be sufficient to get a stronger conclusion. Nonetheless, in the absence of data for a longer time period, this study is likely to serve as the foundation for a local climate calendar for government-provided agricultural extension services, and the estimation of realistic seasons may thus aid in increasing agricultural productivity.

Acknowledgements

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Identification of Potential Sources of Groundwater Salinity Based on Hydrochemistry in the South-West Coastal Area of Bangladesh

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Abstract

Potential sources of groundwater salinity in south-west coastal area of Bangladesh were identified based on specific hydrochemical parameters (Na, Ca, Mg, Cl^-, HCO_3^{2-}, SO_4^{2-}, NO_3^-) of the 55 groundwater samples. To fulfill the research objectives various recommended methods have been considered in the study. The study shows that salinity of 10 samples were originated from halite dissolution, seawater intrusion and brine or evaporates, where chloride and total anion ratios (Cl-/Σanions) are greater than 0.8. The result also shows 30 samples derived from halite dissolution where $Na^+/(Na^+ + Cl^-)$ ratio of approximately equal to 0.5. From the results, there are only 5 samples were found as common values within the ratios of Cl^-/Σanions and $Na^+/(Na^+ + Cl^-)$. So the result indicates that halide dissolution was not the principal sources of salinity in most of the groundwater samples (50). Similar result also observed in most of the groundwater samples, however salinity sources were not from the dissolution of halite (NaCl) and result shows 10 samples fall on the molar Na/Cl ratios line, 13 samples are above the line and 32 samples show below the line. The Na/Cl values range from 0.1681 to 0.8668, which suggest 2 samples show as fresh water, 32 samples show as fresh water with saline contaminated and 21 samples show as seawater nature. The Piper Trilinear diagram result also indicates Na-Cl type of water which is the most proximal to the coast and its composition almost similar to that of the seawater. Finally, the study concludes that groundwater salinity in most of the area principally originate from seawater sources and in few areas from the dissolution of halite or other sources.

Keywords: Salinity, Potential sources, Groundwater, Coastal area, Bangladesh..

1. Introduction

Groundwater salinity has become a great concern in the study area, where freshwater resources are unavailable in most of the area. This occurs due to the salinization from different sources. Salinization is the most widespread phenomenon of groundwater contamination (Barker *et al.*, 1998; Bear *et al.*, 1999; Cruz and Silva, 2000; Giménez and Morell, 1997). However a major phenomenon is possibly sea water intrusion. Intrusion of saline waters in coastal regions occurs naturally, and can be exacerbated due to exploitation of coastal aquifers as water sources (Ozler, 2003; Martinez and Bocanegra, 2002; Petalas and Diamantis 1999; Barker *et al.*, 1998; Calvache and Pulido-Bosch 1997). But sea water intrusion is not only the phenomena for the salinization, other sources may be the active for groundwater salinity. Potential salinization sources in deep groundwater are diverse, including natural saline groundwater, halite dissolution, presence of paleo-brackish water, seawater intrusion, oil and gas-field brine, domestic, agricultural and industrial effluents (Zahid *et al.*, 2007). So, in the present study, to understand the potential sources of groundwater salinity, several methods and techniques have been used based on major specific hydrochemical parameters. Each of the potential salinity sources have a distinguished chemical fingerprint that can be delineated by studying the ratios of the dissolved constituents of the salinized groundwater (Marie *et al.*, 2001). In general, salinization process is common for all over the season. So, pre-monsoon sampling hydrochemical parameters and their calculated values have been used in the study to find out the potential sources of salinity in groundwater of the area.

2. Materials and Methods

The study was scheduled to conduct in south west coastal region, which includes Kalaroa, Satkhira sadar, Debhata, Kaligonj and Shyamnagar Upazilla of Satkhira district of Bangladesh (Figure 1). The analyzed hydrochemical parameters of Na, Ca, Mg, Cl^-, HCO_3^{2-}, SO_4^{2-}, NO_3^- of the 55 groundwater samples were collected during pre-monsoon period of March to July (Shafiuzzaman and Haque, 2016). The analyzed data have been formulated and calculated by using the recommended methods to fulfill the research objectives (Table 1). To

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identify the potential sources of groundwater salinity, various recommended methods have been considered in the study. Groundwater derived from halite dissolution would have $Na^+/(Na^+ + Cl^-)$ ratio of approximately equal to 0.5 (Hounslow, 1995). Kortatsi (2006) observed, if the chloride and total anion ratios ($Cl^-/\Sigma anions$) are greater than 0.8 which suggesting that groundwater possibly originates from halite dissolution, seawater intrusion and brine or evaporates. The Na/Cl relationship has often been used to identify the mechanism for salinity distribution and saline intrusions (Sami, 1992; Panteleit *et al.*, 2001). As average, the weight ratio of Na^+ (mg/l)/Cl^-(mg/l) in sea water has 0.556 or less, fresh water has 0.8 to1.1 or more and fresh water contaminated with sea water has the ratios of 0.5 to 0.78 (Handa, 1972). Major hydrochemical constituents were plotted in the piper trilinear diagram to evaluate the sources of groundwater salinity in the study. The Na-Cl type of water, which indicates saline water contamination occur due to sea water intrusion to the aquifer of the area. Such type of water composition is the most similar to that of the seawater, which strongly indicates groundwater were evidently affected by the very saline water (Pulido-Leboeuf, 2004).

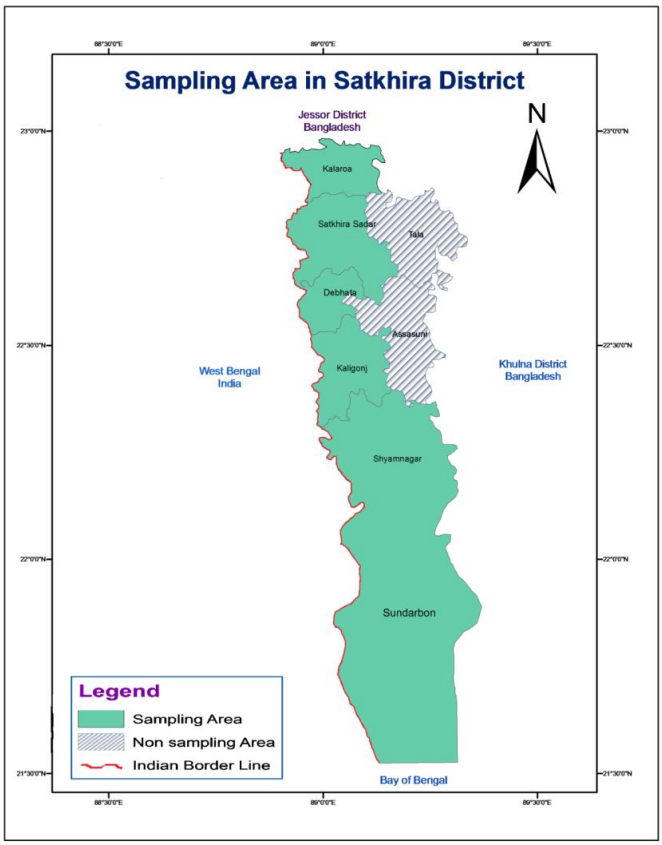

Figure 1. Groundwater sampling locations in the study area.

3. Result and Discussion

Kortatsi (2006) observed, if the chloride and total anion ratios (Cl-/Σanions) are greater than 0.8 which suggests that groundwater possibly originates from halite dissolution, seawater intrusion and brine or evaporates. The study result shows that only ten samples (S-12, S-33, S-34, S-37, S-39, S-46, S-47, S-51, S-53 and S-55) have such possibility in the area (Figure 2). Groundwater derived from halite dissolution would have $Na^+/(Na^+ + Cl^-)$ ratio of approximately equal to 0.5 (Hounslow, 1995). It also means that $Na^+ \approx Cl^-$. Such type of results were found for 30 samples (S-3, S-4, S-5, S-7, S-8, S-9, S-13, S-17, S-19,S-20, S-21, S-23, S-24, S-29, S-32, S-35, S-36,S-38, S-40, S-42, S-44, S-45, S-46, S-47, S-48, S-50,S-51, S-52, S-53 and S-55) of the area (Figure 3). However, there was only 5 samples (S-46, S-47, S-51, S-53 and S-55) are common within $Cl^-/\Sigma anions$ and $Na^+/(Na^+ + Cl^-)$ ratios. Since common groundwater samples are comparatively very few (only 5 out of 55 samples). So this result concluded that there was no possible source of halite dissolution in most of the well locations in the area.

Table 1. The analyzed hydrochemical and calculated parameters of groundwater in the area.

Study area	Sample ID	Na^+ (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl^- (mg/l)	HCO_3^{2-} (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	Na^+/Cl^- (mg/l)	$Cl^-/\Sigma anions$ (meq/l)	$Na^+/(Na^+ + Cl^-)$ (meq/l)	Na/Cl (mmol/l)
Kalaroa Upazila	S1	171.29	124.36	101.25	480.32	280	25.21	0.28	0.3566	0.72	0.35	0.55
	S2	700.12	118.38	92.68	1800.28	580	169.35	0.39	0.3889	0.79	0.37	0.6
	S3	49.48	98.1	75.28	72.19	430	10.25	0.08	0.6854	0.49	**0.51**	1.057
	S4	52.78	99.59	78.24	82.32	452	14.25	0.05	0.6412	0.23	**0.50**	0.989
	S5	50.38	98.49	76.29	78.83	448	13.27	0.05	0.6391	0.30	**0.49**	0.986
	S6	481.23	103.75	92.48	1378.15	554	28.2	0.29	0.3492	0.80	0.35	0.538
	S7	49.32	97.23	89.29	77.32	422	9.25	0.09	0.6379	0.23	**0.49**	0.984
	S8	50.92	101.09	91.27	78.98	413	10.24	0.01	0.6447	0.24	**0.50**	0.994
	S9	53.76	38.07	22.16	83.04	446	12.30	0.02	0.6474	0.24	**0.50**	0.998
	S10	489.14	106.12	97.41	1389.64	576	37.84	0.20	0.352	0.79	0.35	0.543
	S11	51.12	98.85	89.75	134.32	425	13.68	0.06	0.3806	0.34	0.37	0.587
	S12	503.35	121	99.07	1597.48	579	41.21	0.10	0.3151	**0.81**	0.33	0.486
	S13	50.68	96.75	87.42	58.47	397	14.07	0.07	0.8668	0.19	**0.57**	1.337
Satkhira Sadar Upazila	S14	38.02	91.15	81.54	79.24	403	9.83	0.19	0.4798	0.25	0.42	0.74
	S15	302.57	118.29	95.67	855.25	410	24.59	0.09	0.3538	0.77	0.35	0.546
	S16	18.05	89.59	76.18	36.78	312	8.24	0.13	0.4908	0.16	0.43	0.757
	S17	36.89	56.71	43.27	48.85	296	7.46	0.13	0.7552	0.21	**0.54**	1.165
	S18	19.43	39.49	29.45	42.59	322	10.25	0.18	0.4562	0.18	0.41	0.704
	S19	17.62	87.13	69.48	28.48	304	8.62	0.16	0.6187	0.13	**0.49**	0.954
	S20	23.49	59.24	45.14	31.41	306	9.57	0.09	0.7479	0.14	**0.53**	1.153
	S21	26.4	52.36	46.31	40.72	320	5.63	0.17	0.6483	0.18	**0.50**	1.0
	S22	39.24	86.74	73.41	81.07	391	9.61	0.17	0.484	0.26	0.43	0.746
	S23	41.57	74.93	66.41	61.86	369	13.17	0.09	0.672	0.22	**0.51**	1.036
Debhata Upazila	S24	17.53	39.21	24.58	31.41	334	16.28	0.17	0.5581	0.13	**0.46**	0.861
	S25	32.91	83.14	52.16	81.24	403	21.06	0.08	0.4051	0.24	0.38	0.625
	S26	19.45	51.29	41.28	36.67	342	5.48	0.14	0.5304	0.15	0.45	0.818
	S27	18.62	41.02	37.89	41.21	283	4.27	0.25	0.4518	0.20	0.41	0.697
	S28	23.14	58.62	42.15	46.57	387	9.74	0.12	0.4969	0.17	0.43	0.766
	S29	21.54	40.31	33.57	39.57	336	17.12	0.18	0.5444	0.16	**0.46**	0.839
	S30	28.30	76.41	48.63	75.23	387	19.47	0.10	0.3762	0.24	0.37	0.58
	S31	31.47	79.48	51.07	79.13	389	20.07	0.09	0.3977	0.25	0.38	0.613
	S32	16.34	51.07	46.27	29.47	327	8.24	0.16	0.5545	0.13	**0.46**	0.855
Kaligonj Upazila	S33	803.23	89.99	74.18	2012.68	296	56.28	0.25	0.3991	**0.90**	0.38	0.615
	S34	794.14	58.04	49.07	1905.21	396	3.41	0.45	0.4168	**0.89**	0.39	0.643
	S35	51.74	79.68	59.86	73.69	302	34.98	0.30	0.6994	0.27	**0.52**	1.083
	S36	185.75	32.92	22.19	285.14	613	18.26	0.18	0.6514	0.43	**0.50**	1.005
	S37	792.48	108.32	86.57	1892.19	418	34.26	0.27	0.4188	**0.87**	0.39	0.646
	S38	208.71	30.83	24.87	289.37	608	20.15	0.28	0.72	0.44	**0.53**	1.112
	S39	743.69	87.42	76.58	1534.72	299	49.52	0.27	0.4846	**0.88**	0.43	0.747
	S40	48.62	53.08	46.75	67.19	398	3.25	0.18	0.7236	0.22	**0.53**	1.116
	S41	48.63	41.79	47.40	289.27	397	3.23	0.16	0.1681	0.55	0.20	0.259
	S42	32.58	68.44	59.25	49.63	432	5.26	0.19	0.6565	0.16	**0.50**	1.012
	S43	702.41	81.06	63.27	612.76	301	39.45	0.35	1.1463	0.75	0.64	1.768
Shyamnagar Upazila	S44	92.71	48.31	30.47	138.44	368	2.16	0.07	0.6697	0.39	**0.51**	1.033
	S45	967.53	56.14	52.07	1704.86	857	46.37	0.12	0.5675	0.76	**0.47**	0.875
	S46	1642.18	32.38	58.92	2306.98	865	62.38	0.15	0.7118	**0.81**	**0.52**	1.098
	S47	1592.7	60.14	53.15	2290.45	860	69.35	0.10	0.6954	**0.81**	**0.52**	1.072
	S48	1593.25	67.26	54.89	2197.13	864	66.41	0.05	0.7252	0.80	**0.53**	1.118
	S49	883.47	57.06	51.47	1679.04	852	42.35	0.14	0.5262	0.68	0.45	0.811
	S50	848.41	51.89	46.27	1363.60	608	33.26	0.09	0.6222	0.78	**0.49**	0.959
	S51	1735.92	68.48	59.39	2845.83	928	98.26	0.05	0.61	**0.82**	**0.48**	0.941
	S52	1563.47	65.74	58.51	2214.34	917	67.58	0.06	0.7061	0.79	**0.52**	1.089
	S53	1768.15	43.67	32.45	2864.74	376	102.41	0.10	0.6172	**0.91**	**0.49**	0.952
	S54	94.08	53.75	51.75	179.85	441	5.87	0.10	0.5231	0.41	0.45	0.807
	S55	1614.54	69.58	57.36	2292.30	763	70.31	0.04	0.7043	**0.82**	**0.52**	1.086

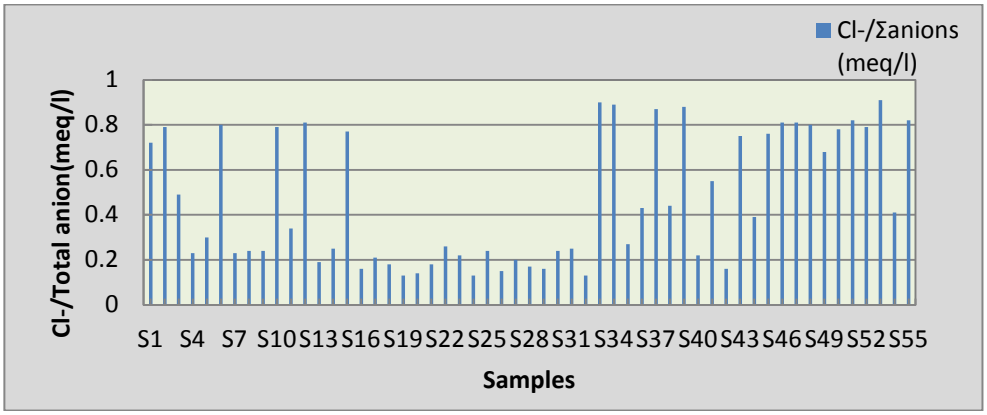

Figure 2. The chloride and total anion ratios of groundwater samples in the area.

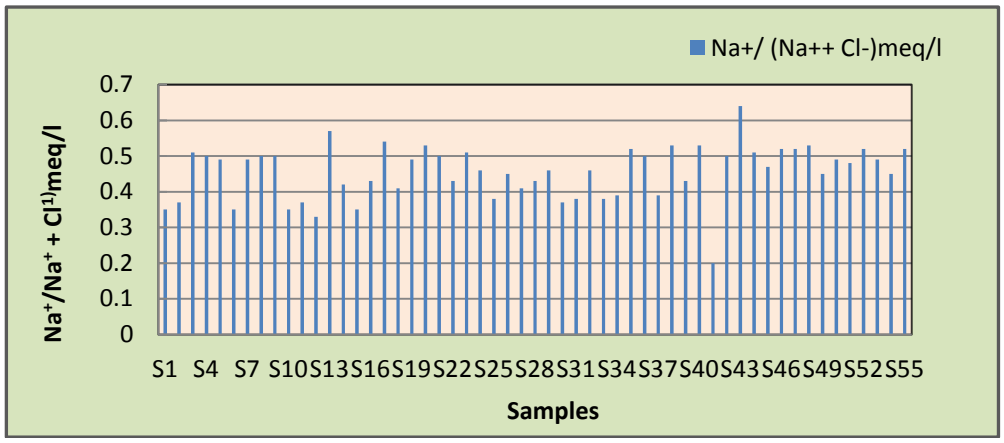

Figure 3. $Na^+/(Na^+ + Cl^-)$ ratio of groundwater samples in the study area.

The molar ratio of Na/Cl has also used to determine the possible sources of salinity in groundwater from halite dissolution in the area. Halite contains Na and Cl in equal concentrations. So, dissolution of halite (NaCl) will add Na and Cl to solution in a one to one fashion. Therefore, groundwater affected by halite dissolution should typically contain molar Na/Cl ratios equal to 1 (one) unless the ratio is affected by cation exchange reactions (Richter *et al.*, 1991). According to this suggestion, there are 10 of the total groundwater samples were molar Na/Cl ratios close to 1 (one) or equal to 1 (one) which suggests additional mixing of water derived from dissolution of Halite and associated evaporates, and rest of 45 groundwater samples which Na/Cl ratios are not close to 1 (one) that is varied from 1 (one) (Figure 4). The result indicates that only 10 samples fall on the molar Na/Cl ratios line, while 13 samples are above and 32 samples show below the line. So the results concluded that salinity sources in most of the groundwater samples were not from the dissolution of halite (NaCl) rather than may be affected by cation exchange reactions and from other sources in the area. The study also observed that the spatial distribution of molar Na/Cl ratios of groundwater samples which have equal to 1 (one) mainly located in the well locations of Kalaroa (S1 to S13), few in Satkhira (S14 to S23) and in Kaligonj upazila ((S33 to S43) of the area (Table 1).

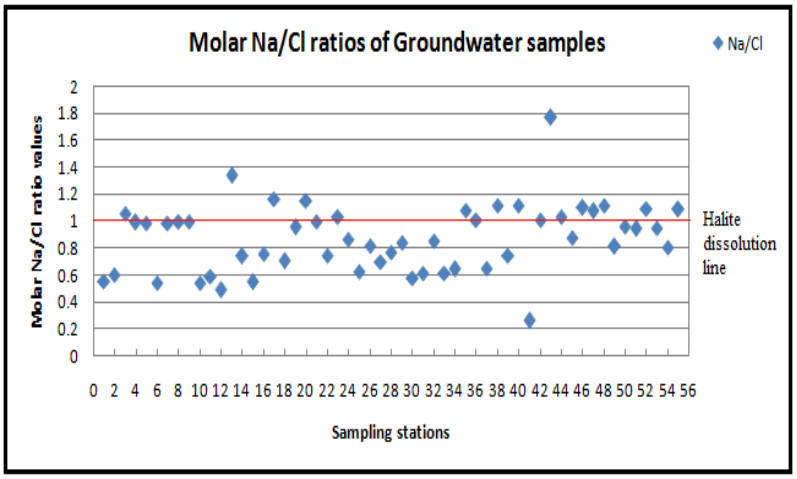

Figure 4. Molar Na/Cl ratios of groundwater samples in the study area.

The Na/Cl relationship has often been used to identify the mechanism for salinity distribution and saline intrusions (Sami, 1992 & Panteleit *et al.*, 2001). As average, the weight ratio of Na^+ (mg/l) /Cl^-(mg/l) for salinity in sea water has 0.556 or less, fresh water has 0.8 to1.1 or more and fresh water contaminated with sea water has the ratios of 0.5 to 0.78 (Handa, 1972). So the result of ratios Na/Cl values of groundwater samples of the area varied from 0.1681to 0.8668 and classify the water in three categories (Figure 5). The result observed that 2 samples (S13 and S43) are fresh, 32 samples are as fresh water with sea water contaminated and rest of 21 samples are seawater nature.

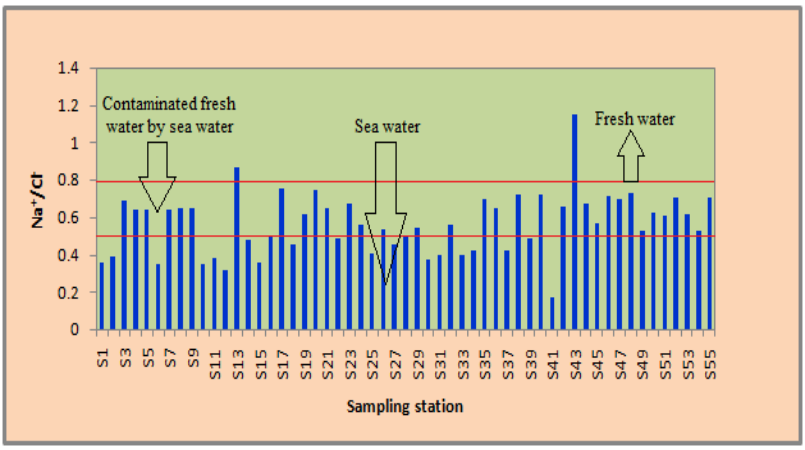

Figure 5: Sources of salinity determination based on Na^+ /Cl^- ratio of groundwater samples in the area.

The result of major chemical constituents of groundwater samples which have plotted in the Piper Trilinear diagram (Figure 6). The figure mentioned that Ca-HCO_3 and Na-Cl types of groundwater were found in the area. The Na-Cl type of water indicates that saline water containing well locations is the most proximal to the coast in the area. The result shows that 14 groundwater samples are saline water dominated among the 55 collected samples. Such type of water composition almost similar to that of the seawater, which strongly indicates the ground waters were evidently affected by the saline water (Pulido-Leboeuf, 2004) that occurs due to sea water intrusion to the groundwater aquifers of the study area.

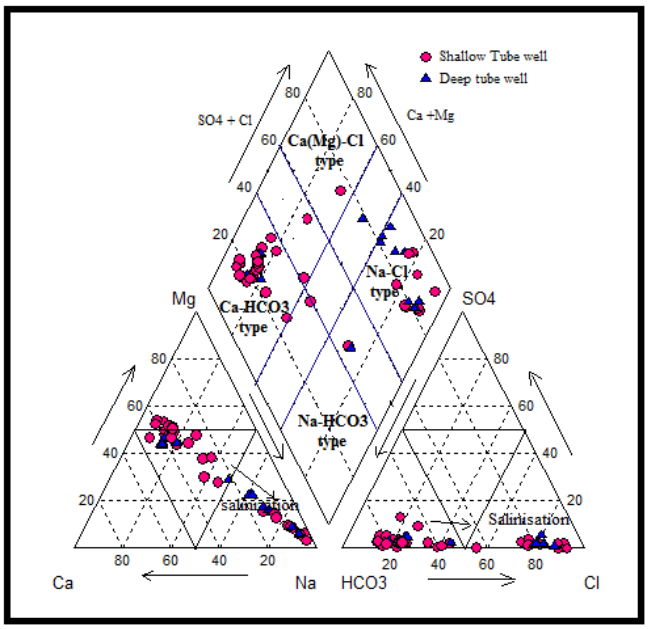

Figure 6. Piper diagram of major chemical compositions of groundwater in the area.

4. Conclusions

The potential salinity sources in the study carried out based on the hydrochemistry (Na, Ca, Mg, Cl^-, HCO_3^{2-}, SO_4^{2-} and $NO3^-$) of the 55 groundwater samples by using recommended methods. The result shows ten samples which chloride and total anion ratios (Cl-/Σanions) are greater than 0.8 indicates salinity possibly originated from halite dissolution, seawater intrusion and brine or evaporates. There are 30 samples derived from halite dissolution which $Na^+/(Na^+ + Cl^-)$ ratio of approximately equal to 0.5. However only 5 samples are common within the Cl^-/Σanions and $Na^+/(Na^+ + Cl^-)$ ratios. It indicates most of the samples (50) were not from the halide dissolution. However only 10 samples fall on the molar Na/Cl ratios line, while 13 samples are above and 32 samples show below the line. So the results concluded that salinity sources in most of the groundwater samples were not from the dissolution of halite (NaCl). In addition the ratios of Na/Cl values were varied from 0.1681to 0.8668 and classified the water as fresh for 2 samples, fresh water with saline contaminated for 32 samples and seawater nature for 21 samples. The Piper Trilinear diagram also observed that the principal types of Ca-HCO_3 and Na-Cl groundwater were found in the area. However Na-Cl type of water denoted saline containing water which is the most proximal to the coast and water composition almost similar to that of the seawater. So groundwater salinity in most of the area mainly contaminated due to seawater intrusion and also contaminated in some areas from the dissolution of halite or other sources.

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Land Conversion to Fish farming Pond and it's Impact on Ecosystem of Rajshahi, Bangladesh

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Abstract

It was observed that in the study area land conversion is an emerging crisis because conversion of agricultural land and wet land to fish farming increasing sharply. Globally, a precedent increase in land use change has led to increase the impact of agricultural land use change. Fish farming activities has been shown to contribute immensely to land use change as it enhancing income generated. In fact, conversion of fish farming pond source is believed to be accounted for quick profit. It was noted that, the agricultural land especially low land conversion to fish farming 150 hector. Which is increased by 35.65% during the last 25 years and at a rate of 1.46% per year due to water logging in the area. From the survey it was found that farmers were engaging to fish farming due to its high productivity and draw quick profit, which invites adverse negative impact on ecosystem and along its services. Most of the respondents opined that farmers were willing to convert their low-lying crop land to fish farming pond because of farmer can earn double to triple profit than normal crops cultivation. Consequently, the results show that natural ecosystem pond especially bio- diversity are very vulnerable in the study area.

Keywords: Land conversion, Fish farming pond, Impact, Ecosystem.

1. Introduction

Conversion is considered as one of the oldest problems in the study area. A few decades ago, as a Bangladesh was rich in agrarian region, but rapid land conversion into different commercial which activities have led to a sharply degradation of agriculture land and also its production. Moreover, Bangladesh has always been an agrarian country, it is generally claimed that every year about 1% of farm land in the country is being converted to non-agricultural uses (Quasem, 2011 and Halim *et al.*, 2013). On the other hand, the country is losing 1% arable land due to the population growth and its infrastructure development in every year (Islam and Hasan, 2011).

Land being one of the basic natural resource has always been the subject matter of debate regarding its effective use (Bardhan, 2010). When the country's population and its per capita income rise agricultural land is usually transferred to non-agricultural land as the demand for non-farm products and services (Quasem, 2011). The growing demand for fish farming cultivation uses and the farmer perceived for meeting these demands gradually resulted in more and more agricultural land converted to fish farming.

The conversion of agricultural land into fish farming pond enhanced sharply for economic profitability. It's also has quickly gained momentum as an innovative and economic mechanism for generating employment and increasing household income. Due to essay to basic amenities in fish farming pond like better profit, easy cultivation, economic, social well-being and social development which are very low in agricultural sector as compared to the fish farming cultivation.

As a results farmer encourages to fish farming pond. A study carried out by of Bangladesh revealed that agricultural land has converted to water body more which rate of conversion was at about 9.12% (Halim *et al.*, 2013).

Due to economic growth and living expectation, many respondents convert their land to fish farming pond. In the study area, most of respondents have their water body. Some of them have lease in types of water bodies and some have lease out types of pond and other types. It is also observed that orchard cultivation is most common phenomenon in the area. As per opinion of the respondent increasing demand for income facilities and expenditure facilities farmers decide to involve digging pond and then cultivation to fish farming. Due to fulfill the food demand farmers cultivate their pond intensively and use chemical fertilizer, pesticide and other poisoned

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elements. This is why, natural pond elements are decreasing and ecosystem services are being loss and polluted day by day.

Ecosystem services, defined as the benefits that human obtain from ecosystem (EHW, 2016).Agricultural ecosystem are primarily managed to optimize the provisioning ecosystem service of food, fiber and fuel. In the process, they depend upon a wide variety of supporting and regulating services, such as soil fertility and pollination (MA, 2005; NRC, 2005). Agriculture also receives an array of ecosystem dis-services that reduce productivity or increase production costs (e.g., herb ivory and competition for water). In Bangladesh, few studies so far have been conducted land conversion to fish farming pond. Few of them focused on land use changing pattern in the context of ecosystem. The main objectives are identify the causes and consequences of fish farming pond conversion in the study area and to find out how impact fish farming pond on ecosystem.

2. Materials and Methods

The study was conducted from January 2019 to 2020in three phases. In the first phase, details information about the areas were collected. In the second phase, population, consultation and data collection were done. In the last phase validation, data management, data analysis and final report were made. The study areas were selected in Charghat Upazilla comprise to Yusufpur, Salua, Nimpara, Sardah, Charghat, Bhayalakshmipur union and Charghat Pauroshava (Municipalities). Total 30 participants (3 respondents under different age category and occupations group from each union) were selected for interview regarding land conversion to fish farming and impacts in ecosystem. All respondents were under all union. Male and female were also considered in the study. The respondents were selected from farmers, job holders and land lords. Primary data were collected through guided semi-structured questionnaire regarding reason for land conversion to fish farming and impacts on ecosystem. Both primary and secondary data were collected from local offices, books and journals. Collected data were justified for reliability and validation. To fulfil the research objectives data were analyzed using MS-Excel and presented in tabular and graphical form for ease perception.

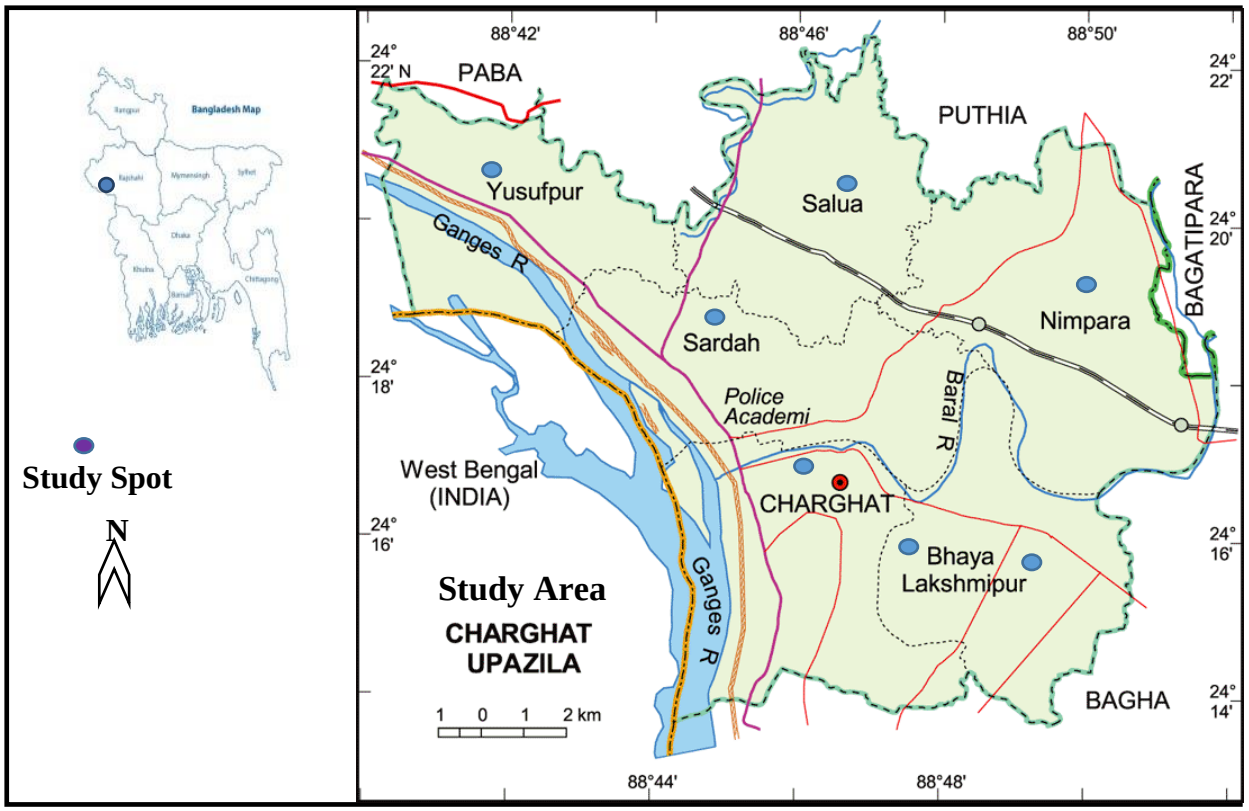

Figure 1. Map of the study area.

3. Results and Discussion

Land use change occurs, it may lead to either positive and negative impacts, depending on the values and goals of those affected by change. Both positive and negative impacts were identified for most types of land use change. Land conversion has led to increase agricultural land use change. Almost all land are ecosystem service are affected partly or fully by land conversion.

3.1 Land use Pattern in the Area

The major land use pattern of Charghat Upazila of Rajshahi district has been categorized into agricultural land, orchard, infrastructural land, water bodies, fallow land, and char land and river area. Total land area of Charghat Upazila 16458hec. Of which agricultural land is 7718hec, Orchard land 4610hec, Infrastructure 2711hec, water bodies 524.64hec, Char land 430 hec and river area 340.48hec.

3.2 Conversion of Agricultural land to Fish Farming Pond

The land under agriculture was more in 2000 than 2020 because most of the respondents of that time were engaged in agricultural occupation and land under orchard land and fish farming were less than 2020.Whereas agricultural land has been converted to fish farming more and more and others conversion orchard are the common phenomenon. Water bodies increased than previous especially the number of fish farming in pond have increased due to more profit and economic profitability. There is a trend towards agriculture land decreased gradually on the contrary, fish farming pond increased sharply. The Figure 2 shows that every year the number of ponds increased frequently in the study area. On the other hand,agricultural land reduces gradually (Figure-3) due to low profit and low production. Consequently the results show thatdemand of increasing fish farming in pond increased year by year.

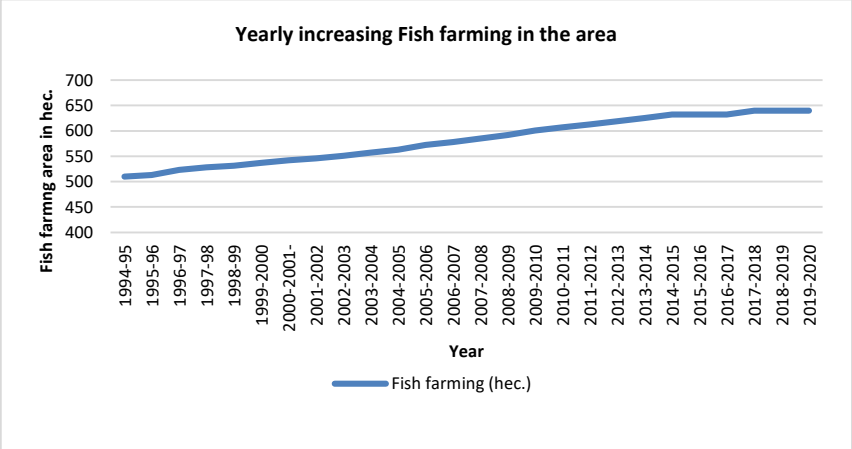

Figure 2: Yearly changing land use pattern due to increasing fish farming in Charghat Upazila.

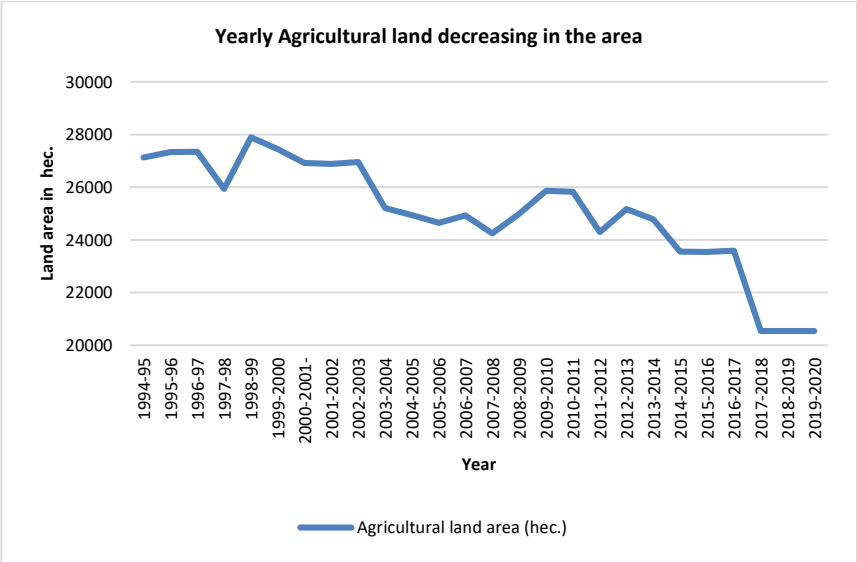

Figure 3: Yearly changing land use pattern due to agricultural land decreasing in Charghat Upazila.

3.3 Land Use Change

Land use pattern changes in three different time periods have been examined for detecting the land use changes in Charghat Upazila. The results shown that the agricultural land decreased, orchard land, infrastructure area, char land, water bodies, river area increased proportionately (Table 1). The agricultural land of Charghat Upazila in 1994 was 10217 hector (i.e.62% of total land area) and in 2004 it became 9267 hectors (56% of total land area) 2014 was 8253 hector (i.e. 50% of total land area) and 2020 became7718 hector(46% of total land). It has therefore been decreased to 53.5% hector during the last 25 years indicating 2.14% decline per year. The infrastructural land was 1525 hector (9.27%) in1994, 1822 hec. (11.07%) in 2004, 2246 hec. (13.61%) in 2014, 2711hec. (16.47%) in 2020, suggesting that it has increased 12.6% during the period; which is 0.05% increased per year. Likewise, the area under orchard was 3507 hector (21.3%) in 1995, 4182 hector (25.4%) in 2004, 4671 hector (28.4%) in 2014 and 4610 hector (28.01) in 2020. The area under water bodies was 375 hectors (2.28%) in 1995, 420 hectors (2.55%) in 2004, 485hector (2.95%) in 2014 and 524.64 hec. (3.19%) in 2020. It suggests that it has increased average. 2.74% during the period. The river area was 315 hectors (1.91%) in 1995 and 340.48 hector (2.07%) in 2020. So, the river area has been raised average. 1.9% during the past 25 years indicating a 0.08% increased per year. Likewise, the char land has been amplified because its area was 420 hec (2.55%) in 1995 and 430 hec (2.62%) in 2020(Table 1).

Table1 Land use change of Charghat Upazila during (1994-2020)

Land use pattern	Area in (hec) 1994	Area in (hec) 2004	Area in (hec) 2014	Area in (hec) 2020	Converted area (1994- 2004)	Converted in % (1994-2004)	Converted area (2004-2014)	Converted in % (2004-2014)	Converted area (2014-2020)	Converted in% (2014-2020)
Agricultural	10217	9267	8253	7718	950	-9.30	1014	-10.94	535	-6.48
Infrastructure	1525	1822	2240	2711	297	+19.47	418	+22.94	471	+21.02
Orchard	3507	4182	4671	4610	675	+19.24	489	+11.69	61	-1.30
Water bodies	375	420	485	524.64	45	+12.00	65	+15.48	39.64	+8.17
Char land	420	380	405	430	40	-14.00	25	+6.57	25	+6.57
River area	315	285	320	340.48	30	-9.52	35	+12.28	20.48	+6.40

(N.B + = Increasing trend, - = Decreasing trend)

3.4 Challenges for Agricultural Land

In the present finding it is observed that the agricultural land is facing a greater challenge. The agricultural land of the study area has been decreased (26.72%) during the past 25 years and a rate of (1.03%) per year(Table 2).Figure4a,b shows that the area under agricultural land has been decreasing, otherwise orchard land, water bodies, infrastructure have been increased frequently, river area and char land have been increasing steadily over the same period. This trend suggests that the agricultural land is converting into other type of land use, especially applicable for fish farming and the orchard cultivation. Likewise, that every year agricultural land is decreasing by the increasing areas of fish farming and the infrastructure. These findings corroborate to those reported earlier (Islam, 2000; Rahman *et al*., 2005; Rahman and Saha,2009;Islam and Hassan, 2011 and Golap *et al*., 2017).

Table 2 Conversion of agricultural land of Charghat upazila during 1994-2020.

Year	Agricultural land (hec)	Duration (Year)	Decreased (%)	Decreased per year (%)
1994	10217	-	-	
2004	9267	1994-2004	9.30	-0.93
2014	8253	2004-2014	10.94	-1.09
2020	7718	2014-2020	6.48	-1.08
			Total = 26.72	Average = 1.03

(N.B. - = Decreasing trend)

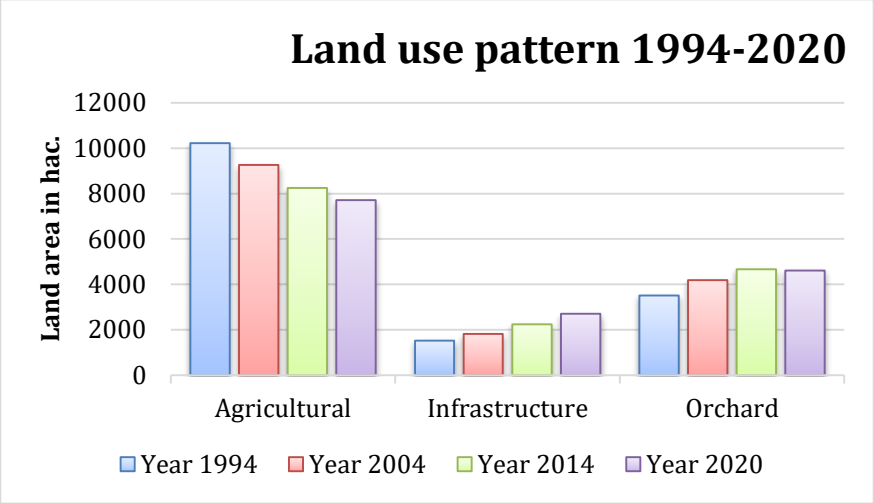

Figure 4a

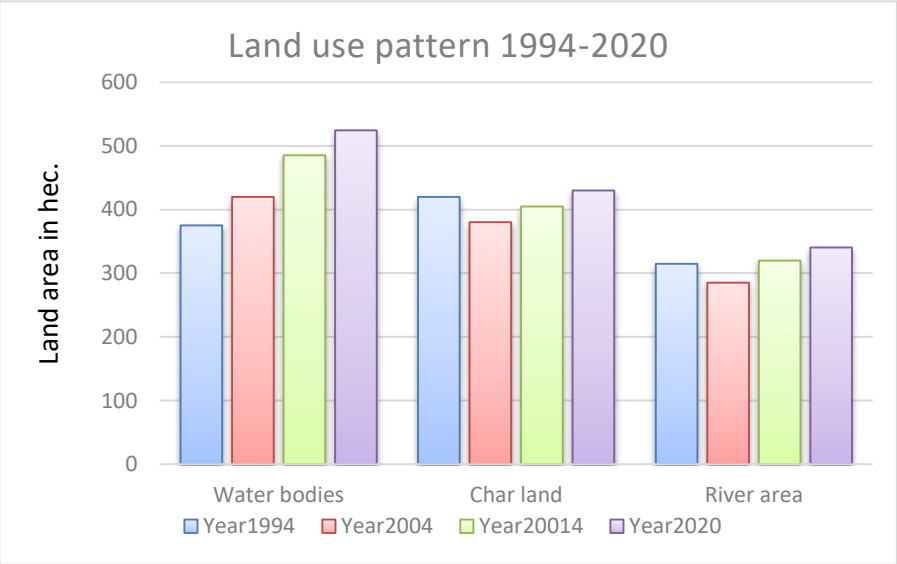

Figure 4b

Figure 4a,b Land use change due to land conversion in the study area (1994-2020)

3.5 Factor Affecting Land Convert to Fish Farming in Ponds

In our present observation, every year a large number of low potential productivity agricultural lands are being converted because of low return financial profitability.Other reason hard industry, high labor cost, uncertain productivity, crises of labor and cost even though their aptitude also main factor for their converting land. Another aspect is the lack of interest of younger generation in agriculture due to low return. There are several studies which show that increasing cost especially labor cost that has reduced net return and thus incentives of farmers to cultivate their land (Prabakar, 2011; Pandey, 2012;Govindaprasad and Manikandan, 2014). Meanwhile, the high profitability fish farming production also expects benefits such as high productivity and draw quick profit, new employment opportunities and the provision of some services for newcomers.

Increasing fish farming also results enhancing support for pond base businesses. These businesses are associated with different processing plans those are experiencing a direct link of agricultural and agricultural land allied cultivation. It may, however, be noted that a direct loss of crop production when agricultural land declines in the study area. Table 3shows that low level water body has been increased by 35.65% during the last 25 years and at a rate of 1.46% per year

Table 3 Fish Farming pond of CharghatUpazila During 1994-2020

Year	Water bodies (inhec)	Duration (Year)	Increased (%)	Increased Per year (%)
1994	375	--	--	--
2004	420	1994-2004	12.00	1.2
2014	485	2004-2014	15.48	1.55
2020	525	2014-2020	8.17	1.63
			Total =35.65	Average=1.46

(N.B.+ = Increased trend)

Due to water logging. Firstly, the reason of fish farming is more profitable than other crop farming. Secondly, seasonal casual labor shortage in crop farming induced converting low lying inland into fish farming. The similar findings are also supported by Sarker *et al.*, 2006 and Golap *et al*., 2017. In present finding, of the study area the economic profitability of fish farming was higher compared to cultivating rice or any other crops. In the study area thus, farmers converted their crop fields specially rice field into pond fish culture. It reveals that the area of agricultural land decreased by 9.30,10. 94 and 6.48 while fish farming increased by12.00, 15.48, and 8.17 in the year to 2004, 2014 and 2020, respectively shown in Table 2, 3. The fish farming in pond increased all union except Yusufpur union Table 4. The highest increased of fish farming in Salua, Nimpara and also Charghat union, respectively.

Table 4 Fish farming increasing in the study area from 1994 to 2020

Union	Change the water body in Charghat Upazila over the time (hec)						
	Year 1994	Year 2004	Pond increased (1994-2004) (%)	Year 2014	Pond increased (2004-2014) (%)	Year 2020	Pond increased (2014-2020) (%)
Yusufpur	30	30	0.0	35	2.25	35	0.0
Salua	65	70	7.69	75	2.25	85	4.50
Nimpara	45	55	4.50	65	4.50	75	4.50
Sardah	45	50	2.25	60	4.50	65	2.25
Charghat	105	125	21.0	150	31.25	160	4.50
Bhayalakshmipur	40	40	0.0	45	2.25	47	0.90
Paurosova	45	50	2.25	55	2.25	58	1.65

3.6 The Millennium Ecosystem Assessment

In our present investigation, ecosystem service does not provide supporting and regulating as well as providing services to human well-being due to rapid land conversion. Agricultural land conversion to orchard land, water body and vegetables land likewise few wetlands and khas land convert to agricultural land and non-agricultural uses. Moreover, the agricultural land conversion at a alarming rate which is1.06% per year. Agricultural lands typically are managed to maximize provisioning services, but demand many supporting and regulating services to do so. In addition, declining agricultural land is the reason for less over all ecosystem services production.

Maximum (70.15%) respondent said that before fish farming in pond the low land provides them food, fiber and fuel. Few respondent (50.12%) said that land also provides them soil fertility and pollination and productivity. Most of respondent(90.12%) said that after conversion it results less production of crop with less productive soil, top soil erosion, soil nutrient depletion reduced food, fiber, and fuel and also less pollinators.

Diagram-1 shows that The Millennium Ecosystem Assessment (Reid *et al*., 2005)classified ecosystem service in to four categories; 1)regulating services which control our climate disease vectors, crop pests and pollination 2) provisioning services that provide potable water, food, fiber and medicine 3) cultural service that influences our beliefs tradition's and provides our enjoyment opportunities and 4) supporting services that is under pin life on earth through the cycling of nutrients' soil formation and photosynthesis (MA 2005). This was achieved mainly due to improved agricultural ecosystem services.

It is observed that The Millennium Ecosystem Assessment in the area does not provide sustainable ecosystem services due to rapid land conversion. The consequences of conversion results are insufficient benefits to human provided by natural ecosystem.

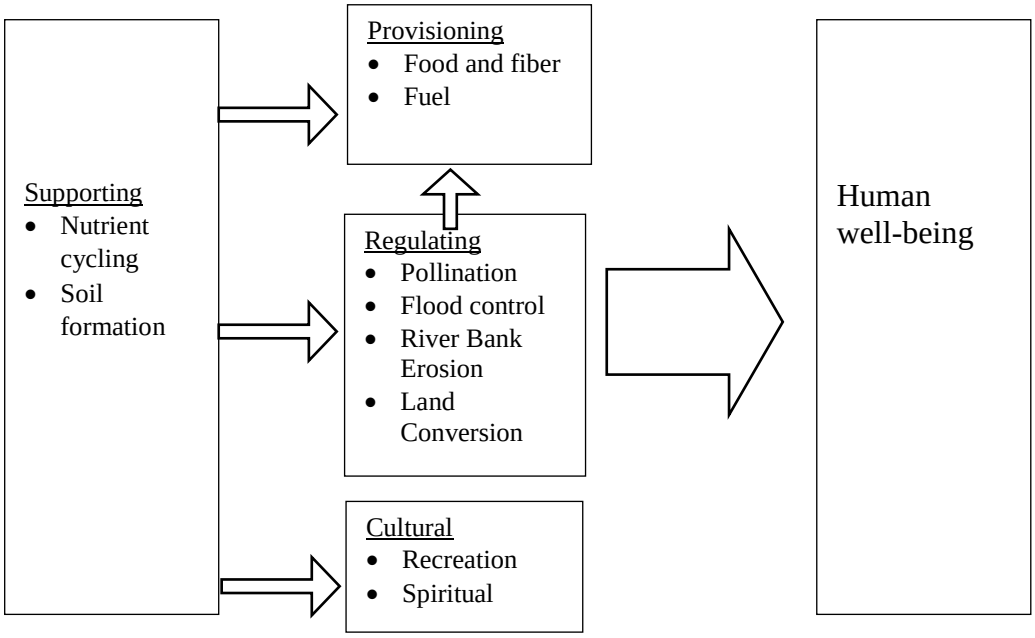

Diagram-1 The Millennium Ecosystem Assessment (Adapted and simplified by the Authors from Alcamo *et al.,* 2003).

3.7 Land Conversion under Millennium Ecosystem Assessment (MEA)

In our present investigation, land conversion processes increase frequently. Agricultural land was converted to water body35.65% as well as orchard land 29.63%.Agricultural practices in orchards have a strong impact on several ecosystem functions and consequently, on ecosystem service relationships (Dementias *et al*.,2017).On the other hand, agricultural practices in fish farming ponds have a negative impact on ecosystem service. Consequently, changes in the land that affect provisioning ecosystem services potable water, food fiber that can increase or decrease land productivity. Vegetation provides a vital regulating service by preventing soil erosion but land use change usually leads to loss of vegetation cover. All the respondents (100%) mentioned agricultural land conversion is the main consequences of production loss (95%), crop damages (94%) and pest damage (93%). Food and fiber and fuel insecurity is another important consequence that(91%)respondents mentioned. 85% respondents pointed out that disservice ecosystem brings nutrient runoff and habitat loss and 8% respondent told about pesticide poisoning of no target species. They also mention that agriculture ecosystem provides them supporting, provisioning, regulating and also cultural service. The majority of the respondent 79% ecosystem service for human well-being about (69%) respondents noticed that fish farming in pond negatively services include supporting and regulating services. 55% of the total respondents marks non-market services system.

Whereas 45% mentioned dis-services of ecosystem. Only 21% people respondent told that it also provides their provision services like crop production. Diagram 2 shows that natural ecosystem converted to fish farming in pond influences adverse negative impact ecosystem services on human wellbeing. The Millennium Ecosystem Assessment (MA 2005) proposed a conceptual framework, which has become widely used and adopted, that describes the services that ecosystems provide and how they contribute to human well-being. The diagram-1 shows that linkage between categories of ecosystem service and components of human well-being. Moreover, agricultural lands typically are managed to maximize provisioning services, but demand many supporting and regulating services to do so.

Land use change has influenced overall ecosystem service and also decline natural ecosystem. Provision of ecosystem services in farmlands is directly determined by their design and management (Zhang *et al.*, 2007) and strongly influenced by the function and diversity of the surrounding landscape (Kremen *et al.*, 2005)

3.8 Ecosystem Service in Fish Farming Pond

In our present investigation that ecosystem service are vulnerable due to agricultural land conversion to fish farming in pond. Ecosystem services, defined as the benefits that human obtains from ecosystem (EHW, 2016) are classed into four categories: supporting services, provisioning service, regulating service, and cultural service. Supporting service and regulating service provide soil fertility and pollination, provisions services that provide potable water, food, fiber and medicine and cultural service that influence our beliefs tradition's and provide our enjoyment opportunities such as recreational park, education. However, supporting services mean to human ends and not ends themselves (Wallace, 2007). As per opinion, of respondent the increased area under fish farming in pond replacing former food crop area can have direct consequence, including reduced productivity, soil fertility, crop damage which may be considered dis-services of ecosystem. Diagram 2 expresses that fish farming in pond service are negatively managed optimize the provisioning ecosystem service of food, fiber and fuel. On the way, supporting service and regulating service do not provide soil fertility and pollination. Only non-market services regards to management of fish farming ecosystem in pond. The diagram-2 relies on a how fish farming ecosystem are mismanaged on the diversity, composition, and functioning of the area.

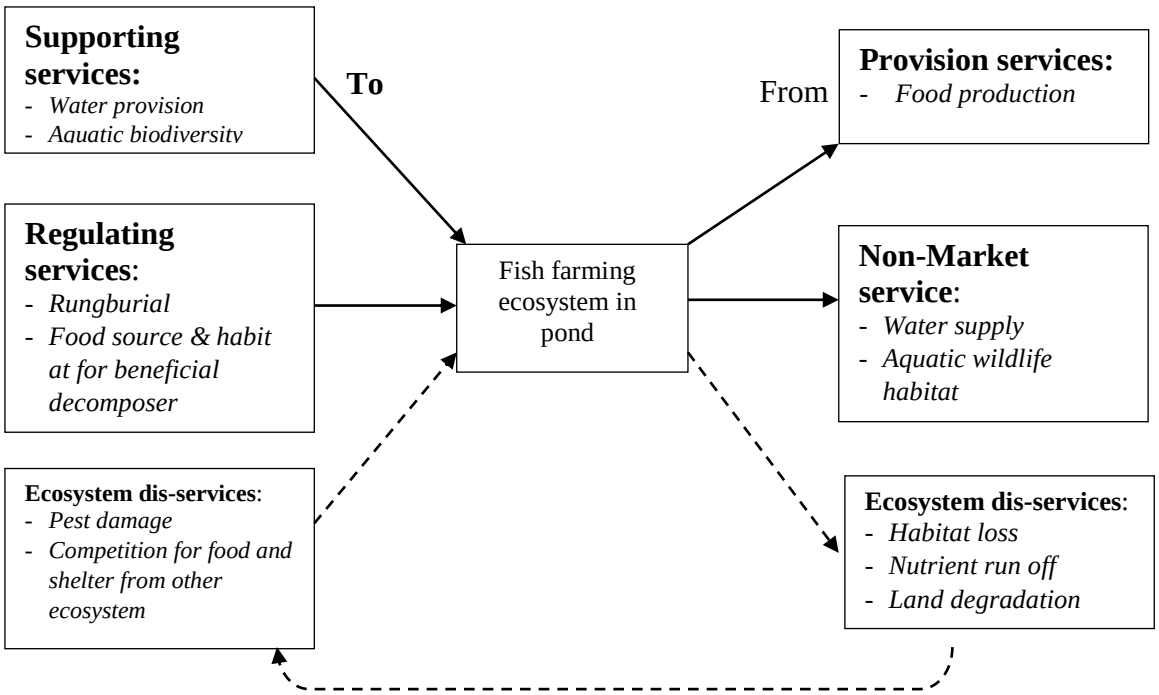

Diagram 2: Ecosystem services and dis-service due to fish farming pond (Adapted by the Authors from Zhang *et al.*, 2007)

Maximum respondents (78%) mentioned that fish farming production can be considered to disservices including pest damage, fiber competition for water, and competition for pollination. Few respondents (45%) said that it also affects flows of natural ecosystem services and dis-services from production land to surrounding areas. In addition, dis-services from fish farming also include land degradation or loss of habitat, soil, water quality, and other offsite, negative impacts and strongly influenced by the functional ecosystem services. Reversible results is shown in agricultural ecosystem service (Garbach *et al.,* 2014 and Kremen *et al.*,2005).

3.9 Ecosystem Services of Charghat Upazila

The land in Charghat Upazila is vital for the social and economic well-being of local people as well as a significant source of income generating opportunity such as education. In the past, Charghat has enjoyed consistent growth in the agricultural sector specially khair *(Acacia catechu),* jute *(Corchorus capsularis)* culture increase in the number of agricultural commodities and production for export. This was achieved mainly due to improved agricultural practices. At present finding of Charghat Upazila, a substantial increase of areas under fish farming and orchard cultivation continued due to financial profitability. Furthermore, Charghat Upazila ecosystem services are highly vulnerable to a number of impacts due to the complex effects of human use of natural resources and subsequent land use change. Every change in land has not only short term but also long term consequences of ecosystem service. Moreover, orchard ecosystem provided provisioning services (food, fiber and fuel) not provide our supporting service and regulating and cultural services. Whereas fish farming in pond showed negative services in the same time. Most of the respondent (97%) stated that land conversion hampers the ecosystem services. About (78%) of the total respondent said that fish farming in pond affected the natural ecosystem services. The rest of the respondents replied that they do not have clear idea about ecosystem services.

It is observed that increasing orchard cultivation and fish farming in pond resulting in reduced agricultural ecosystem service. Agricultural ecosystem service is primarily managed to optimize the provisioning ecosystem service of food, fiber and fuel(Zhang *et al*., 2007).In the process, they depend upon a wide variety of supporting and regulating services, such as soil fertility and pollination (MA,2005);NRC,2005), that determine the underlying biophysical capacity of agriculture ecosystems (Wood *etal*.,2000). Agriculture also receives an array of ecosystem dis-services (EDS) that reduce productivity or increase production costs (*e.g*., herb ivory and competition for water).

4. Impacts of Land Conversion due to Fish Farming in Pond

Fish farming in pond, being an essential sector of integrated farming system, play an important role in the economy of Charghat Upazila. Survey data indicates that from 1995-2020 among agriculture to fish farming the change rate of low land cropped area to fish farming has been increased 29.21%, medium land to fish farming has been increased 4.79%, and other by 1.65% (Table 3). It could be noted that, agricultural area has been decreased by 26.72% (Table 2). The consequences in land conversion are of many fish farming in ponds one of them. For economic profitability most of the lands are getting fish farming and the land for agricultural crop production is reduced day by day, due to this the crops and trees are getting damaged. Similar results were found (Islam, 2016).On the other hand, land convert to fish farming led to water logging or submerged as well as hampered water flow in the rainy season in the area. Most of the respondent (90.65%) said that before conversion natural pond existing animal diversity likely kaloguishap *(Varanus Bengalensis)*, Sonaliguishap *(Varanus flavescens)*, Bara-kasim *(Trionyx gangeticus),* Matiashap *(Enhydris enhydris),* Dora shap *(Xenochrophis piscator),* Darasshap *(Ptyasmucosus),* Gokrashap *(Naja naja),* Boro-kakra *(Scylla serrata),* Choto-kakra *(Gelasimusannulipes),* Boro-shamuk *(Pila globosa),* Choto-shamuk *(Lymnaea spp.),* Lamba-shamuk *(Melania tuberculata),* Zinuk *(Lamellidens marginalis)* and Bang *(Bufo melanotictus)* are common conversion the fish farmer uses of chemical fertilizer, insecticide and also pesticide at the alarming rate as a results those species decline gradually which contribute food chain as well as food web. Some of the respondents pointed that land conversion to fish farming in pond decreases soil fertility, decreased vegetable production and decreases grain production. Few respondents (15.12%) opinedstated that habitat loss is one of the important impacts which reduced local species richness, crop damage, soil erosion, air and water quality.

4.1 Impacts of Biodiversity in the study area

In our present investigation, due to land conversion to fish farming it results many traditional flora and fauna are vulnerable or endanger in the area. Maximum respondent (75%) said that in other to increase their production they use excess chemical fertilizer, pesticides and insecticides both cultivation which is a cause of extinct some environmental friendly fauna diversity as like as well as flora diversity. Furthermore, they said that before conversion available faunal diversity likely kaloguishap *(Varanus bengalensis)*, Sonaliguishap *(Varanus flavescens)*, Bara-kasim *(Trionyx gangeticus)*, and reptilesBang *(Bufo melanotictus)*. Mollusca's Choto-shamuk *(Lymnaea spp.)* Lamba-shamuk *(Melania tuberculata)* and Zinuk *(Lamellidens marginalis)* at present in the natural waterbody. After fish farming in pond those faunal species has gone in the area. Only (20%) respondent said that previous day fisheries diversity especially indigenists fishes available in different water body to the area are ruhi (*Labeo rohita*), Mrigel (*Chirrhinus mrigala*), Catla (*Catla catla*), Calibaush (*Labeo calbasu*), Magur (*Clarias batrachus*), Shing (*Hetropenusha fossils*), Shoil (*Channa storiatus*), Boal (*Wallago attu*), Sharputi (*Puntus sarana*), Phalli (*Notoptenus notopterus*), and Tangra (*Mystus vittatus*). At present findingextotic fishes are available like grass carp (*Cteopharyngodon idela*), Silver carp (*Hypoholmichthys molitux*), Telapa (*Oreochromis mossumbicus*), Nilotica (*Oreochromis niloticus*) etc. have also been introduced for commercial pisciculture in ponds and tanks. Some respondent focusing on bird's diversity specially the migratory is decreasing day by day due to habitat depletion. On average (65%) respondents stated that feed activities and naturally decline the biodiversity in the area. Fish farming in pond plays an important role in these processes and is responsible for biodiversity decline. Over the past 25 years, ecosystems have changed more rapidly than at any other period in the study area. Most of the respondent (98%) opinions stated that land use changes have been shown to be one of the leading causes of biodiversity loss in terrestrial ecosystem (The Millennium Ecosystem Assessment, MEA2005), they also mentioned that biodiversity including wild animals, birds, fish, insects and pollinators are important to support the ecosystem activity in a functioning ecosystem service therefore the exclusion of any component creates imbalance in the ecosystems service.

Land use, specifically in agricultural land conversion to fish farming, has great impact on biodiversity. Another aspect contributing to biodiversity decline is that humans today depend for survival on tiny fraction of wild species that has been domesticated. All long term historical land use changes responsible for natural ecosystems conversion to semi natural ecosystems or artificial systems contributed to the extensive changes in biodiversity composition and ecological processes. Land use changes have been shown to be one of the leading causes of biodiversity loss in terrestrial ecosystems (Daily *et al.,* 2009 and Reidsma *et al*., 2006).

4.2 Impact of Environmental Degradation in Charghat Upazila

According to respondents it is observed that forestation is decreasing due to rapid land conversion. The trees have been cut down randomly with the increase digging pond in fish farming. On the other hand, due to decreasing agricultural land, to fulfill demand of the farmer not only cultivate their land but also cultivate pond culture intensively. They use chemical fertilizer, pesticide, herbicides and also poisoned element both cultivations. Otherwise they also supply feed to growth carp fish frequently. Pesticide use has negative consequences on the quality of water (Loewy *et al*., 2003) or on biodiversity (Floch *et al*., 2009). Pesticides may disturb food webs since they are not only lethal to crop pests but also to beneficiary insects as well as pollinators (Biddingr *et al*., 2013; Geiger *et al*., 2011; Thompson, 2003). Herbicides may also disturb natural nutrient decomposition by killing beneficiary earthworms, fungi and bacteria in soil (Oliveira and Merwin, 2001; Andersen *et al.,* 2013).So, the nature is getting imbalanced as a result the disasters like waterlogging, flood, and drought are appearing. Most of the respondents (90.50%) reported that land convert to fish farming pond is also responsible for environmental degradation in the study area and other consequences of environment. Maximum respondents (45.50%) noticed that land conversion to fish farming in pond increase soil erosion. Few respondents (15.50%) mention the reducing rate of tree of floral diversity respectively. Some of respondent (13.33%) mention that air pollution and only (26.67%) respondents said that water pollutions shown in figure 5.

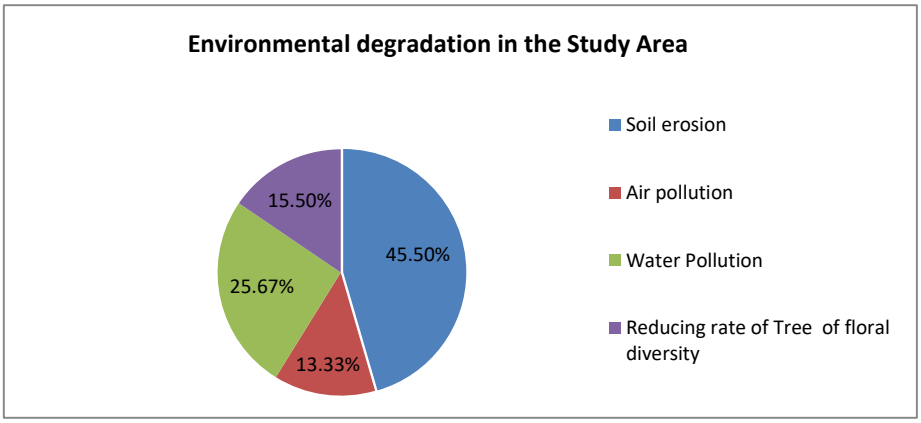

Figure 5: Impact of environmental degradation due to land conversion to fish farming pond in Charghat Upazila.

4.3 Contribution and Socio-Economic Impact in the study area

Land use change occurs, it may lead to either positive and negative impacts, depending on the values and goals of those affected by change and their individual circumstances. Both positive and negative socio-economic impacts were identified for most types of land use change. It is observed that land conversion has positives socio-economic impacts by expansion of fish farming in pond they have increased livelihood, enhanced social status and also house hold income. Few respondent's attitudes were negative in this case. Some respondents (45%) said that land conversion can give instant profit. Maximum respondents said that fish farming in pond reduce the poverty by generating employment and income. Few respondents (15%) mention that in the long run fish farming in pond cultivation decrease food grain pulse's, oil seeds and vegetable production which may threats the food security as well as ecosystem services in the area. Average (90%) respondents mention that by product of fish farming contaminate natural ecosystem in surrounding area and it causes unfavorable condition for ecosystem service.

5. Conclusions

From the finding of the study it is concluded that land conversion has impact on ecosystem. Changes in land use patterns brought both positive and negative impacts on ecosystem services. Negative impacts were observed in fish farming in ponds ecosystem. It was found that agricultural land of the study area is converted by 1.03% per year. On the other hand, fish farming in pond increased by 1.46% per year. If this trend continues, agricultural land will be not available in future. The major causes of agricultural land conversion are low return and profitability, casual labor shortage and also water logging. On the other hand, fish farming in pond cultivation farmer gain quick and high profit, more economic and also develop their social status, which is adverse negative effect of Millennium Ecosystem Assessment (namely provisioning services supporting, regulating and also cultural services) also many environmental friendly flora and faunal species have gone endanger or vulnerable. Otherwise, decreasing agricultural land, to fulfill demand the farmer both cultivate land intensively. They use chemical fertilizer, pesticide and also poisoned element both cultivations as a result, environmental degradation such as soil erosion, water pollution and air pollution has been occurred respectively. It is observed that natural fish farming production is decreasing day by day and land fertility is being reduced due to fish farming in pond. Overall fish farming pond is gaining popularity day by day. Therefore, every year agricultural land has been decreasing in alarming rate which is adverse harm full negative effect of agricultural land and also its production. Moreover, the study area converted land is impacting sustainable development immediately. If the perceived problems could be solved by raising awareness among the people, go for vertical uses of land, motivate farmer to crop cultivation, adopting appropriate policy for agricultural and land use planning. So, Government should take necessary policy in this regard particularly to stop the conversion of land. Especially the conversion of farm land to fish farming in pond will continue to be perhaps the greatest threat to the long-term viability of the agricultural sector and healthy ecosystem services.

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Effect of Botanicals on the Growth of Chili Plant, Yield and Control of Leaf Curl Disease in Experimental Field

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Abstract

Chili *(Capsicum annuum L.)* is a common spice of Bangladesh. It is used every day to prepare different kind of recipes. Chili plant is usually infested by whitefly *(Bemisia tabasi* Gen*)*, which severely damages the production of chili. This study was carried out to evaluate the efficacy of aqueous extracts (10%) of twelve botanicals: Bottle gourd (*Lagenaria siceraria*) leaves, Lemon (*Citrus limon*) peels, Pomelo *(Citrus maxima)* peels, Turmeric (*Curcuma longa)* leaves, Lemon (*Citrus limon*) leaves, Custard apple *(Annona reticulata)* leaves, Juckfruit (*Artocarpus heterophyllus*) leaves, Drum stick *(Moringa oleifera)* leaves, fresh Turmeric (*Curcuma longa)* rhizome, Black plum (*Syzygium cumini)* leaves, Holy basil *(Ocimum tenuiflorum)* leaves and Garden croton (*Codiaeum variegatum)* leaves to observe the plant growth, yield and control of whiteflies (*Bemisia tabasi* Gen) in experimental chili (local variety - magura) field during 15th September, 2020 – 14th February, 2021. The Garden croton leaves treatment showed best performance on the number of chili fruits per plant whereas lowest number of fruits was found in Jackfruit (*Artocarpus heterophyllus*) leaves treatment. Turmeric (*C. longa)* leaf treatment showed best performance on size of chili (cm) while the smallest size of chili was found in Custard apple *(Annona reticulate)* leaf treatment. Four extracts (Turmeric rhizome, Lemon peel, Pomelo peel and Black plum leaves) showed the best performances against Leaf Curl disease of chili and gave a moderate to good yield. Although yield was found better in the Garden croton leaf treatment but efficacy was very poor against the Leaf Curl disease. Turmeric rhizome, Lemon peel, Pomelo peel and Black plum leaf extracts can be used as bio-pesticide for the control of whiteflies in chili field.

Keywords: Chili, Botanicals, Whiteflies and Leaf Curl

1. Introduction

Chili *(Capsicum annuum L.)* is a spice plant belongs to genus Capsicum under the family, Solanaceae. The species encompasses a wide variety of shapes and sizes of peppers, both mild and hot, such as bell peppers, jalapenos, New Mexico chili and cayenne peppers (Francis, 2003). *Capsicum* fruits have been a part of human diets since about 7,500 BC, and are one of the oldest cultivated crops in the Americas (Bosland, 1998), as origins of cultivating chili peppers are traced to East-Central Mexico some 6,000 years ago (Kraft *et al.*, 2014). They were one of the first self-pollinating crops cultivated in Mexico, Central America, and parts of South America. The distribution of chili peppers to Asia occurred through its introduction by Portuguese traders, who were aware of its trade value and resemblance to the spiciness of black pepper promoted its commerce in the Asian spice trade routes (Bosland and Voatava, 2000). It was introduced in India by the Portuguese towards the end of the 15th century. In 21st Century Asian Cuisine, chili peppers are commonly used across diverse regions (Robinson, 2007).

Chili fruits contain large amounts of vitamin C while other species contain significant amounts of provitamin A beta-carotene *(*Rodríguez-Burruezo, 2010). In addition, peppers are a rich source of vitamin B_6. Chilis are widely used in many cuisines as a spice to add pungent 'heat' to dishes. Capsaicin and related compounds known as capsaicinoids are the substances giving chili peppers their intensity when ingested or applied topically. Hot peppers are used in traditional medicine as well as in food (Grubben *et al.*, 2004). Some cultivars grown specifically for their aesthetic value include the U.S. National Arboretum's 'Black Pearl' and the 'Bolivian Rainbow'.

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Major constraints of chili cultivation are whiteflies, who damage chili from seedling to final growth stage. Whiteflies are Hemipterans that typically feed on the undersides of plant leaves. They comprise the family Aleyrodidae, the only family in the super family Aleyrodoidea. In warm or tropical climates and especially in greenhouses, whiteflies produce major problems in crop protection. Worldwide economic losses due to whitefly infestation are estimated at hundreds of millions of dollars annually (Capinera, 2008). Whiteflies feed by tapping into the phloem of plants, introducing toxic saliva and decreasing the plants' overall turgor pressure. Since whiteflies congregate in large numbers, susceptible plants can be quickly overwhelmed. Further harm is done by mold growth encouraged by the honeydew whiteflies secrete.

It is widely recognized that chemical pesticides are very harmful to our environment as well as for living beings. But bio-pesticides are plant extracts, which are less hazardous to environment. On the other hand, one kind of botanical may be effective against only one kind of insect or pest, combination of two or more botanicals may help to control all kinds of insects in the crop field. Bio-pesticide from plant extract is cheaper in comparison to chemical pesticides and even farmers may be able to make it at their home. Botanicals are easily prepared and their use in controlling chili whiteflies from local plants is sustainable (Azad *et al.*, 2012).

Therefore, the present study was conducted to assess the efficacy of some botanicals on plant growth, yield and Leaf Curl disease control in experimental chili field at University of Rajshahi, Bangladesh.

2. Materials and Methods

2.1. Experimental Plot Preparation for Chili Cultivation

This experiment was conducted in Rabi season (September 15, 2020 to February 14, 2021) at Botanical Pesticides Research Field of the Institute of Environmental Science of University of Rajshahi. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and twelve botanicals as treatments. The plot size was 14 m x 5 m with the space between two plots and between two replicates was 1.0 m. The experimental land was first opened with a country plough. Ploughed soil was then brought into desirable final tilth condition by five operations of pouching followed by laddering. The stubbles of the crops and uprooted weeds were removed from the field and the land was properly leveled for plantation of chili. To support the growth of plant, different fertilizers viz. cow-dung, Triple Super Phosphate (TSP), Murate of Potash (MP) and Urea fertilizers were applied. The whole amount of fertilizers was used as the basal dose during pit preparation. Then, 15-days old seedlings were planted in the experimental plots (Table 1). The plots were irrigated with tap-water when necessary.

Table 1. Information about chili cultivation

Information	**Chili variety and Cultivation Period**
Name of crop	Chili
Chili variety	Magura
Scientific name	(*Capsicum annuum* L.)
Seedlings age	15 Days
Collection of seedlings	Katakhali Hat, Rajshahi
Date of transplanting	15th September, 2020
Date of harvesting	14th February, 2021
No of spray	14 times
Spray date (start)	15-12-2019
Spray date (end)	13-02-2020

2.2. Preparation of Aqueous Botanical Extracts for Spray

Leaves of Bottle gourd (*Lagenaria siceraria*), Lemon (*Citrus limon*) Peels, Pomelo *(Citrus maxima)* peels, Turmeric (*Curcuma longa)* leaves, Lemon (*Citrus limon*) leaves, Custard apple *(Annona reticulata)* leaves, Jackfruit (*Artocarpus heterophyllus*) leaves, Drum stick *(Moringa oleifera)* leaves, Fresh turmeric (*Curcuma longa)* roots, Black plum (*Syzygium cumini)* leaves, Holy basil *(Ocimum tenuiflorum)* leaves and Garden croton (*Codiaeum variegatum)* leaves were collected from the campus of University of Rajshahi, Bangladesh. After collection, the plant materials were washed in running tap water. About 100 g of ground of chopped leaves, peel of fruits and roots were dissolved in one liter of water and boiled for 30 minutes. Then after cooling down, the solutions were filtered with plastic filter and the concentration was made 10% and preserved in plastic bottles at room temperature.

2.3. Spraying Method

Botanicals extracts were sprayed on experimental chili field twice a week with the help of sprayer. One control treatment in chili field (without botanical pesticide) was maintained in this experiment where only water was sprayed.

2.4. Whiteflies and Leaf Curl Disease Monitoring

Abundance of whiteflies on chili leaves and Leaf Curl were monitored regularly in the experimental field. The pest infestation and the amount of damages were recorded every week.

2.5. Statistical Analysis of Data

The observed data were analyzed by statistically program. Mean values were adjusted by one way ANOVA and the levels of significance were tested by Duncan's Multiple Range Test (Duncan, 1951) ($P < 0.05$) using standard software.

3. Results and Discussion

The experiment was conducted to evaluate the effects of some botanical extracts, which may act as effective insecticides against chili whiteflies. Therefore, the effectiveness of twelve plant extracts was evaluated in chili field and the results have been presented along with possible interpretations.

Figure 1 shows the effect of botanicals on plant height (cm) of chili. The treatment of Garden croton leaf showed the best performance on increasing height of chili plant (67.00±5.00a). The extract of Black plum leaf treatment showed moderate growth of chili plant (63.33±7.26ab), whereas the lowest height of chili plant (32.33±5.49e) was found in the treatment of Bottle gourd leaves. The treatment with the extracts of Garden croton leaves showed about 1.72 times better performance than that of control treatment (Figure 1). Other botanical extracts also showed significant effect on the increase of plant height of chili.

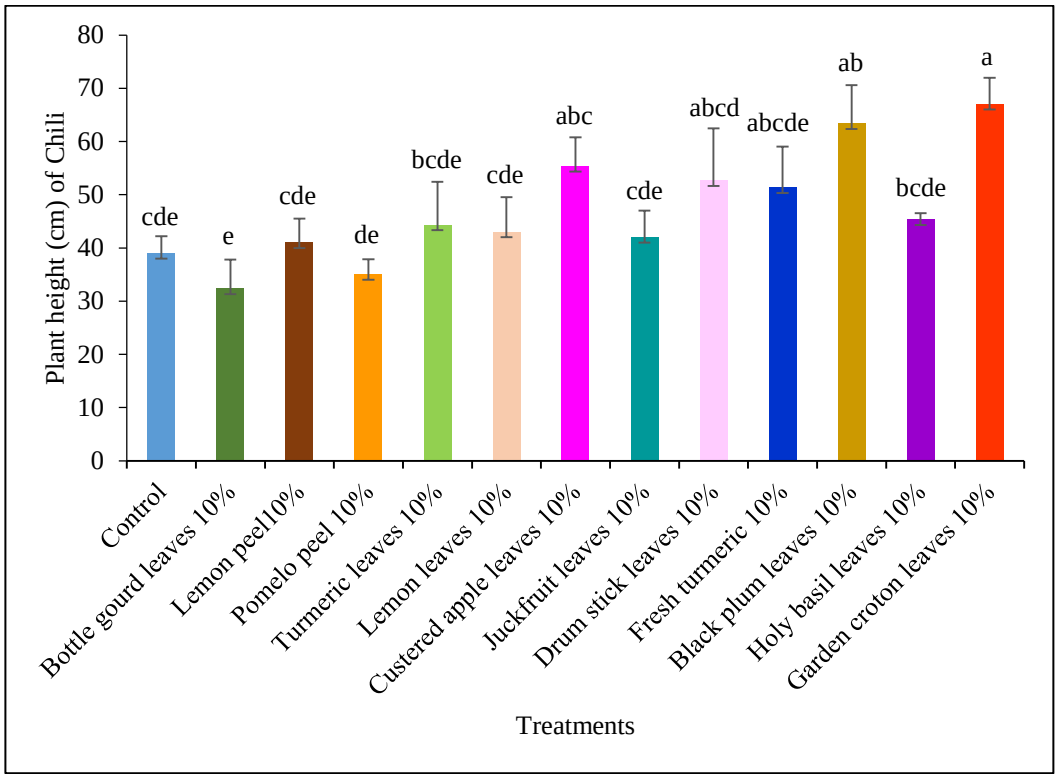

Figure 1. Effect of Botanical Extracts on Plant height (cm) of Chili

Figure 2 shows the effect of botanicals on the growth of primary branches of chili. The Garden croton leaves treatment showed the best performance on primary branches (4.00±0.58a) of plant of chili. The extract of Pomelo peel, Custard apple leaves and Holy basil leaves treatment showed lowest primary branches (2.33±0.33a) of chili. The Garden croton leaves treatment kept about 1.50 times better performance than that of control treatment (Figure 2).

On the other hand, Figure 3 also shows the effect of botanicals on secondary branches of plant of chili. The Garden croton leaves treatment showed the best performance on secondary branches (7.33±0.67a) of chili. The extract of Jackfruit leaves treatment showed the lowest number of secondary branches (3.33±0.67c) of chili. The Garden croton leaves treatment kept about 1.38 times better performance than that of the control treatment (Figure 3)

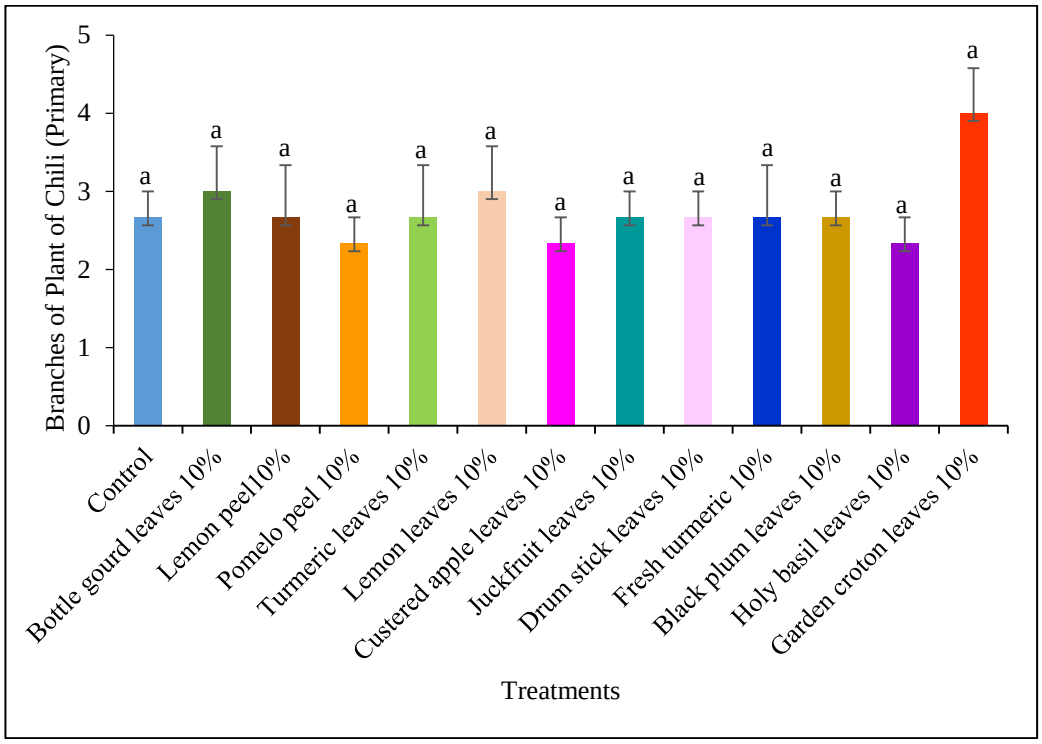

Figure 2. Effect of Botanical Extracts on Primary Branches of Plant of Green Chili

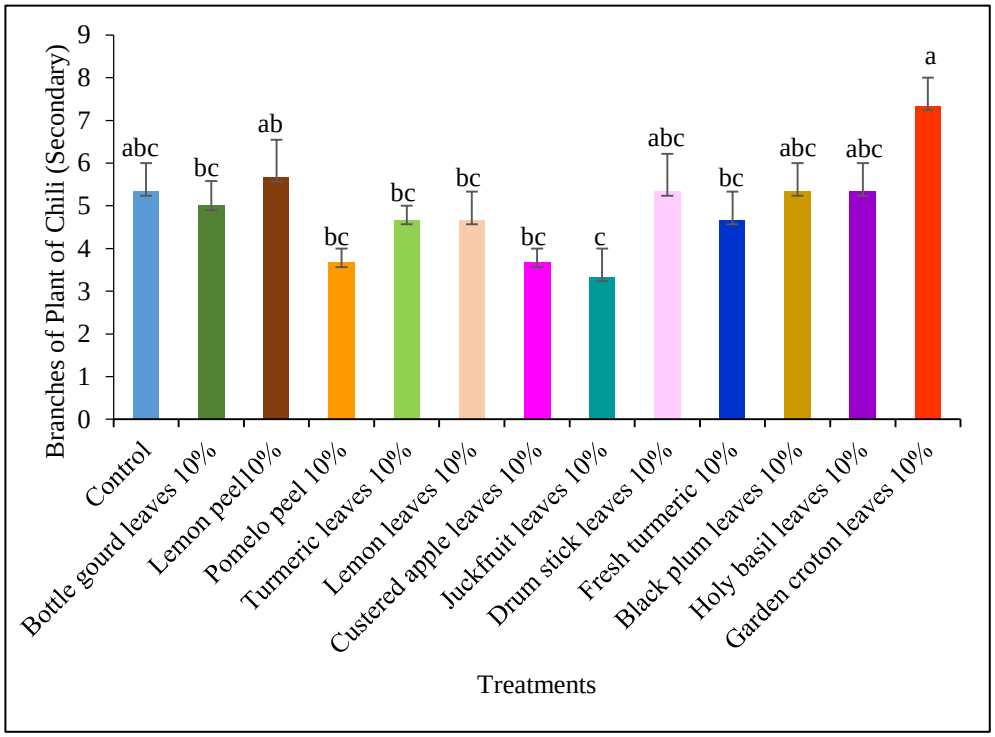

Figure 3. Effect of Botanical Extracts on Secondary Branches of Plant of Chili

Figure 4 shows the effect of botanicals on total leaves of chili. The Black plum leaves 10% treatment showed the best performance on total leaves (113.33±24.83a) of chili. The extract of Garden croton leaves showed moderate number of total leaves (112.67±4.37a) of chili. Whereas the lowest total leaves (43.00±20.42c) of chili plant was found in Bottle gourd leaves treatment. The Black plum leaves treatment kept about 2.21 times better performance than that of the control treatment (Figure 4).

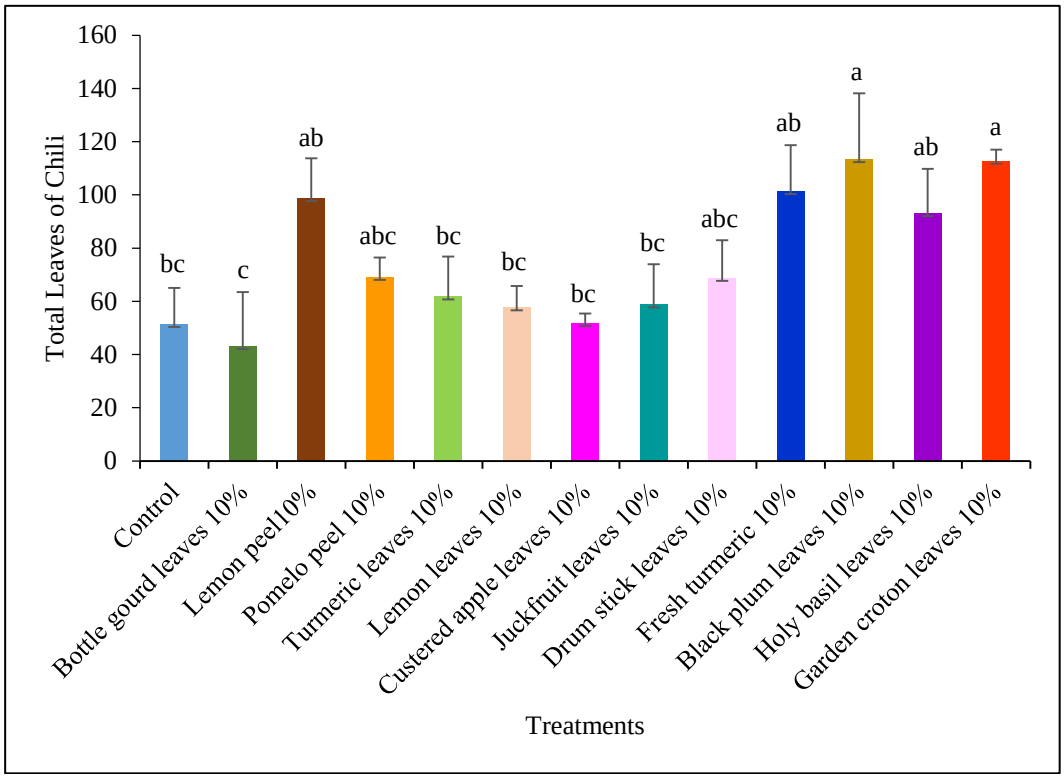

Figure 4. Effects of Botanical Extracts on Total Leaves of Plant of Chili

Figure 5 shows the effect of botanicals on average size of chili fruit (cm). The Turmeric leaves treatment showed the best performance on average fruit size (7.17±0.17a) of chili. The Fresh turmeric treatment showed medium size of chili fruit (7.00±0.29ab), whereas the lowest size of (5.50±1.00b) was found in Custard apple leaves. The Turmeric leaves showed 1.13 times better performance than that of the control treatment.

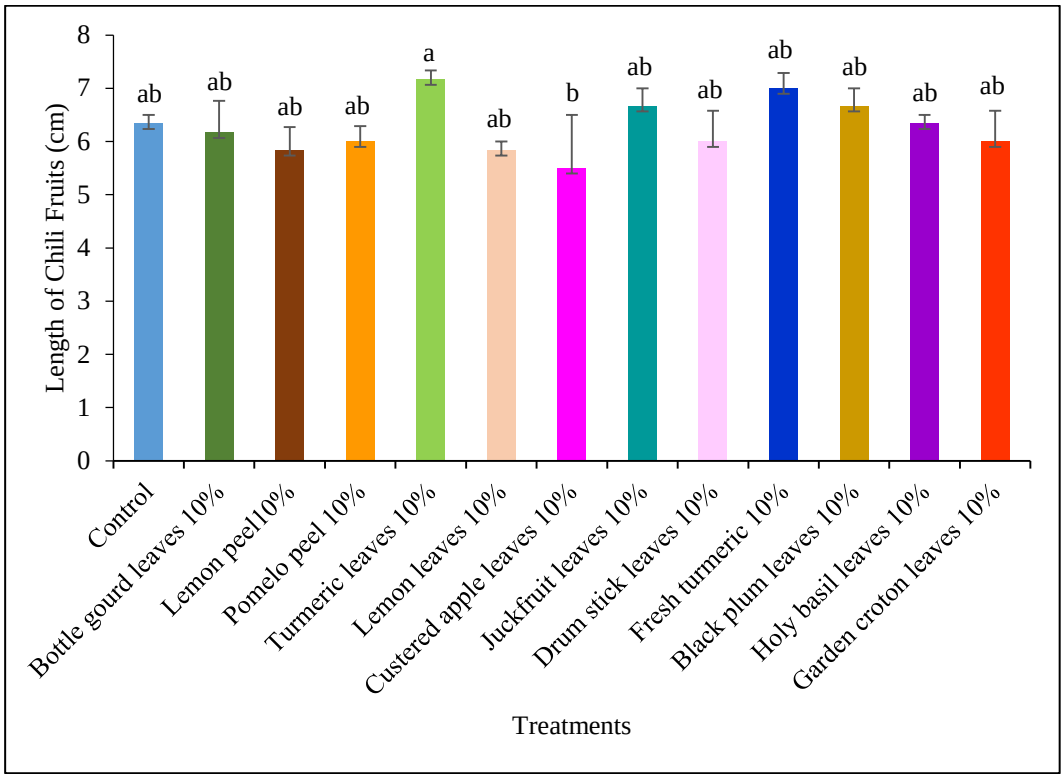

Figure 5. Effect of Botanical Extracts on Fruit Size of Chili

Figure 6 shows the effect of botanicals on number of fruits per plant of chili. The Garden croton leaves treatment showed the best performance on number of fruits per plant, Black plum leaves gave moderate number of fruits per plant (26.67±1.45a) and lowest number of fruits (5.67±1.45c) was found in Jackfruit leaves treatment. The Garden croton leaves treatment showed 2.52 times better performance than that of control (Figure 6). Other treatments also have significant effect on the number of fruits of per plant of chili.

Figure 7 shows the effect of botanicals on yield of chili (gm).The best yield (13.83±6.29af) of chili was found in Garden croton leaves treatment. The Black plum leaves treatment showed moderate yield of chili (13.33±0.73a) and the lowest yield (2.83±0.73c) was found in Jackfruit leaves treatment. The Garden croton leaves treatment gave 2.44 times better performance than that of control treatment (Figure 7).

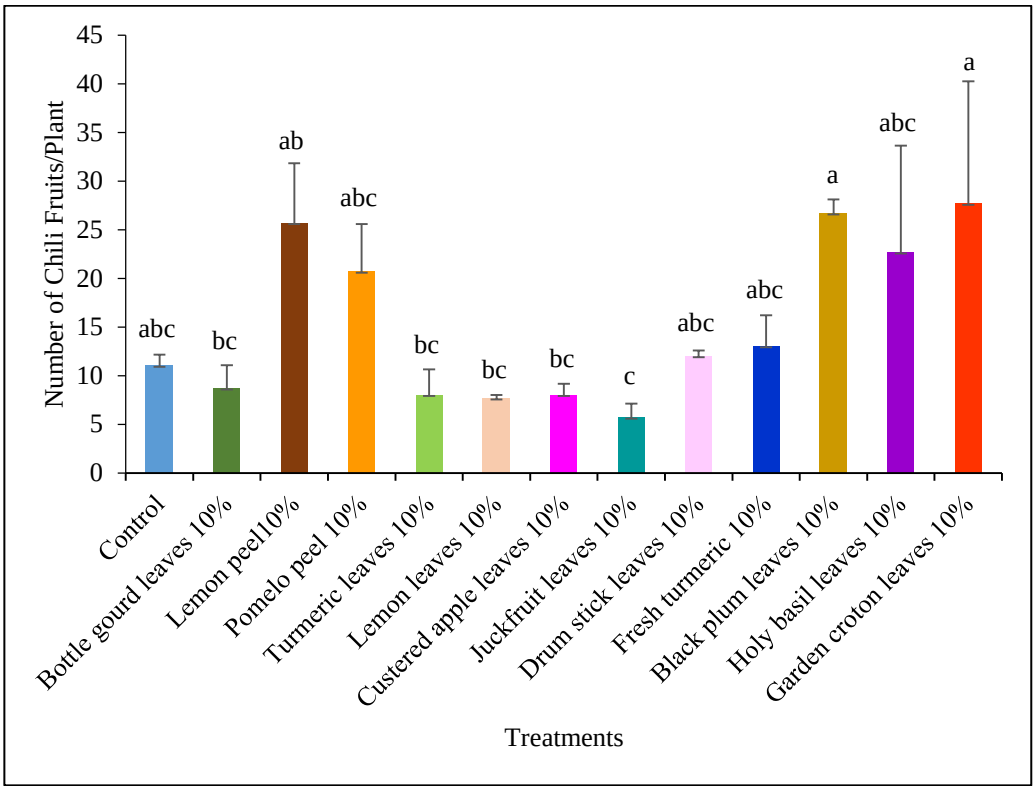

Figure 6. Effect of Botanical Extracts on Fruit Numbers of Chili

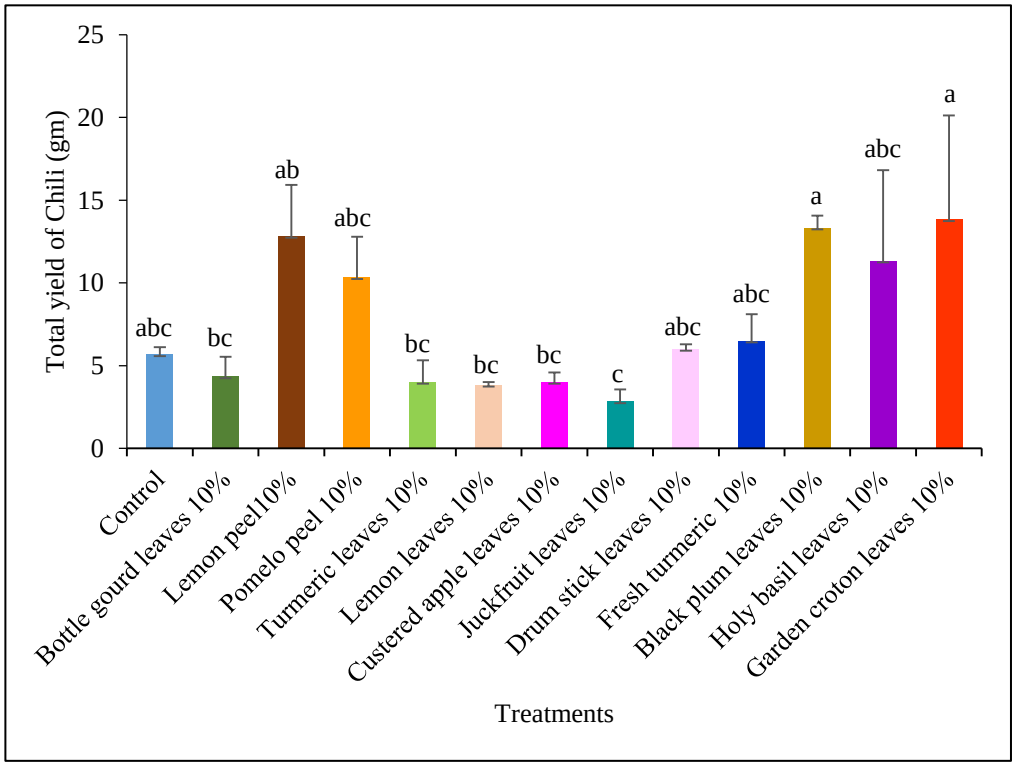

Figure 7. Effect of Botanical Extracts on Total Yield of Green Chili (gm)

The effect of botanical extracts on leaf curl disease of chili is shown in Table 2. Out of 12 botanicals, extracts of Turmeric rhizome, Lemon peel, Pomelo peel and Black plum leaves showed best performances against leaf curl disease of chili, whereas 100% infestation of leaf curl was observed in Control, Bottle gourd leaves, Custard apple leaves and Garden croton leaves treatments. Although yield is better in Garden croton leaves treatment but efficacy is very poor against the leaf curl disease. Neem extract minimize the ripe fruit rot of chili. Garlic extract could effectively control chili anthracnose (Harbant *et al.*, 1999).

Table 2. Effect on Botanical Extracts on the Control of Leaf Curl Disease of Chili

Sl. No.	Treatments	Leaf Curl affected Plants	% of Plants affected by Leaf Curl
1	Control	3	100%
2	Bottle gourd leaves 10%	3	100%
3	Lemon peel10%	0	0%
4	Pomelo peel 10%	0	0%
5	Turmeric leaves 10%	1	33.33%
6	Lemon leaves 10%	2	66.66%
7	Custard apple leaves 10%	3	100%
8	Jackfruit leaves 10%	0	0%
9	Drum stick leaves 10%	1	33.33%
10	Fresh turmeric 10%	0	0%
11	Black plum leaves 10%	0	0%
12	Holy basil leaves 10%	2	66.66%
13	Garden croton leaves 10%	3	100%

Botanicals are traditional and non-synthetic protectants derived from plants. Traditionally, different types of plant parts are used for the protection of agricultural produce; these plants are available in many developing countries and contain several active ingredients and act in different ways under different circumstances (Isman, 2006). Botanicals break down rapidly to harmless metabolites and appear less likely to build up genetic resistance to targeted species. They are also less harmful to mammals and other beneficial organisms (Rahman, 2009).

4. Conclusions

Garden croton (*Codiaeum variegatum)* leaves treatment showed better performance for plant growth and yield of chili but efficacy is very poor against the leaf curl disease. However, extracts of Turmeric rhizome, Lemon peel, Pomelo peel and Black plum leaves showed good performances against the Leaf Curl disease of chili as well as yield of chili. Therefore, Turmeric rhizome, Lemon peel, Pomelo peel and Black plum leaves extracts can be used as bio-pesticide for the control treatment of whiteflies in chili field in eco-friendly way.

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Pesticidal Action of *Petunia integrifolia* (Hook.) Schinz & Thell. Extracts against Three Stored Product Pests

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Abstract

Petroleum ether (Pet. ether), Chloroform ($CHCl_3$) and Methanol (CH_3OH) extracts of the whole plant of *Petunia integrifolia* (Hook.) Schinz & Thell. were subjected to dose-mortality and repellent activity tests against three economically important stored product pests *Tribolium castaneum* (Hbst.), *Sitophilus oryzae* (L.) and *Callosobruchus chinensis* (L.) adults. The Pet. ether extract gave LD_{50} values 774.211, 482.944, 362.967, 290.312, 267.072, 250.437, 232.646 and 210.590 µg/cm^2 against *T. castaneum*; 622.589, 488.302, 326.090, 261.275, 226.743, 200.496, 190.368 and 179.741 µg/cm^2 against *S. oryzae* and 223.226, 139.425, 94.990, 60.167, 49.126, 37.729, 32.584 and 26.798 µg/cm^2 against *C. chinensis*; the $CHCl_3$ extract gave LD_{50} values 1346.655, 994.006, 690.838, 617.103, 499.323, 465.245, 417.610 and 377.448 µg/cm^2 against *T. castaneum*; 1072.029, 945.599, 700.804, 609.574, 557.205, 531.474, 428.500 and 422.962 µg/cm^2 against *S. oryzae* and 2231.894, 540.441, 283.154, 103.783, 66.703, 53.207, 37.959 and 30.396 µg/cm^2 against *C. chinensis* adults; and the CH_3OH extract gave LD_{50} values 1618.731, 1160.860, 844.502, 633.850, 579.368, 305.023, 226.975 and 220.973 µg/cm^2 against *T. castaneum* and 1601.432, 1313.371, 768.993, 573.965, 474.193, 399.749, 337.305 and 335.388 µg/cm^2 against *C. chinensis* all after 6, 12, 18, 24, 30, 36, 42 and 48 h of exposure respectively.

Keywords: *Petunia integrifolia*, Extracts, *Tribolium castaneum*, *Sitophilus oryzae*, *Callosobruchus chinensis*.

1. Introduction

Petunia integrifolia (Hook.) Schinz & Thell. (Solanaceae) is an annual herbaceous plant of South American origin and very close relative to tobacco or tomato plants. The attribute of very less pest infestation triggers to subject this plant for investigation of pest control potentials against three stored product pests. The test insect *Tribolium castaneum* (Hbst.) (Coleoptera: Tenebrionidae) is one of the most serious pests of stored products (Metcalf and Flint, 1962). It is commonly known as the 'red flour beetle' that occurs worldwide and attacks stored products, particularly in grains and seeds. The adult and larvae are considered secondary pest which feeds on previously damaged grains or seeds. They are adapted to feed on cracked-shell nut and almond in storage conditions (Pires *et al.*, 2017). They also damage many stored commodities, for instance- rice, wheat, whole-wheat flour and semolina, etc. (Qasim *et al.*, 2013). *Sitophilus oryzae* (L.) is also a serious pest of cereal crops, including wheat, rice and maize in storage. It is commonly known as 'rice weevil' (Koehler, 2018). Another test insect *Callosobruchus chinensis* (L.) is commonly known as the adzuki bean weevil, is not a true weevil, belonging instead to the leaf beetle family, Chrysomelidae. Due to their generalized legume diets and wide distribution, this insect is one of the most destructive crop pests to the stored legume industry (Yanagi *et al.*, 2013). For many years synthetic insecticides have been used for the control of all forms of agricultural pests, including both field and storage pests and have occupied as an essential commercial item in the market (Oberemok *et al.*, 2015). Plants have been used as the source of medicinal and pesticidal properties from the remotest antiquity (Thenmozhi and Sivaraj, 2011). Over 50% of all modern clinical drugs are also of natural product in origin (Stuffness and Douros, 1982) and play an important role in the pharmaceutical industry (Baker *et al.*, 1995). *Petunia* sp. has effective medicinal properties (Lay, 2015), as well as it is known for its toxic nature (Chortyk *et al.*, 1997). The leaf extracts have promising antibacterial properties to many human pathogenic bacteria and have great significance in therapeutics (Kumar, 2015). This plant also shows significant biological activity against sweet potato whiteflies (Chortyk *et al.*, 1997; Kays *et al.*, 1994). However, no similar work was

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found in the literature survey. Moreover, information on pest control potentials of *P. integrifolia* is still scanty. Thus this step has been attempted for a thorough screening of the test plant to detect its bioactive potentials against three selected stored product pests.

2. Materials and Methods

2.1. Collection and Preparation of Test Materials

The whole plant of *P. integrifolia* was collected during February 2019 from the Rajshahi University campus; and the herbarium keeper identified it by the voucher specimens kept in the herbarium in the Department of Botany, University of Rajshahi, Bangladesh. The collected plants were brushed for removing soil and chopped into small pieces, dried under shade and powdered together with the help of an electric grinder, weighed and placed into a conical flask to add solvents. The solvents Pet. ether, $CHCl_3$ and CH_3OH were used (100 g × 300 ml × 2 times) successively each of which was kept for 48 h on a shaker. For each of the extracts, filtration was done by Whatman No. 40 filter paper at 24 h of interval in the same flask followed by the evaporation until the extract was left as a scum. The extracts were then removed to glass vials and preserved at 4ºC with proper labelling.

2.2. Collection and Culture of Test Insects

The test insects *T. castaneum*, *S. oryzae* and *C. chinensis* adults were collected from the mass cultures of the Crop Protection and Toxicology Laboratory, Department of Zoology, University of Rajshahi, Bangladesh. Sub-cultures of the test insects were maintained for the instant supply of test beetles during experimentation.

2.3. Dose-mortality Tests on *T. castaneum* Adults

Here, the *Ad Hoc* experiments were set to find out the final concentrations for the selection of doses. For the insecticidal activity test, the extract was dissolved in its solvent of extraction at different concentrations to go through *Ad Hoc* experiments to set considerable mortality and those concentrations were considered as doses. The final concentrations used in this experiment were 707, 531, 354 and 177 µg/cm^2 for the Pet. ether; 1061, 884, 707 and 531 µg/cm^2 for the $CHCl_3$ and 1061, 884 and 707 µg/cm^2 for the CH_3OH extracts. For each replication, 1 ml of the doses was dropped on a Petri dish (60 mm) in such a way that it made a uniform film over the Petri dish. Then the Petri dish was air-dried, leaving the extract on it. The actual extract present in 1ml mixture was calculated by dividing the value by the area of the Petri dish and thus the dose per square centimeter was calculated. After drying 10 beetles (1-2 days old) were released in each of the Petri dishes in 3 replicates. After preparing the Petri dish by applying and evaporating the solvent, a control batch was also maintained with the same number of insects. The treated insects were placed in an incubator at the same temperature as reared in stock cultures and the mortality of the insects was counted after 6 h and more 7 times with 6 hours interval up to 48 h of exposure.

2.4. Dose-mortality Tests on *S. oryzae* and *C. chinensis* Adults

The methods of experiment for insecticidal test on *S. oryzae* or *C. chinensis* were not the same as done on *T. castaneum*, but on *S. oryzae* or *C. chinensis* were the same for their feeding habit. Here, the *Ad Hoc* experiments were set to find out the final concentrations for the selection of doses. The concentrations of the Pet. ether extract of *P. integrifolia* used against *S. oryzae* were 707, 531, 354 and 177 µg/cm^2 and for the $CHCl_3$ extract 849, 707 and 566 µg/cm^2. Against *C. chinensis* the concentrations of the Pet. ether extract were 141, 106, 71 and 35 µg/cm^2; for the $CHCl_3$ extract 469, 354, 248, 141 and 35 µg/cm^2 and the CH_3OH extract were 707, 566, 424 and 354 µg/cm^2. However, the CH_3OH extract of *P. integrifolia* did not show any lethality against *S. oryzae* adults. For each replication, 1 ml of each of the prepared doses were mixed with the grains and being volatile the solvent was evaporated out shortly. The actual extract present in 1 ml mixture was calculated by dividing the value by the area of the Petri dish. After drying well, 10 insects of the same age were released on the food grains in 3 replicates. A control batch was also maintained with the same number of insects after preparing the food grains by applying and evaporating the solvent only. The treated beetles were then placed in the incubator at the same temperature as reared in the stock cultures and the mortality was counted as done in the case of *T. castaneum*.

2.5. Statistical Analysis

The mortality data were corrected by the Abbott's formula (Abbott, 1925): $P_r = (P_o - P_c / 100 - Pc) \times 100$, Where, P_r = Corrected mortality (%), P_o = Observed mortality (%) and P_c = Control mortality (%). The data were subjected to Probit analysis according to Finney (1947) and Busvine (1971). The lethality relationship was expressed as median lethal dose (LD_{50}) for the test agents.

2.6. Repellent Activity

The repellency test was adopted from the method of McDonald *et al*. (1970) with some modifications. A general concentration for each of the extracts (Pet. ether, $CHCl_3$ and CH_3OH) was selected as stock dose for repellency applied against the adults of *T. castaneum* to make other successive doses by serial dilution to give 0.1571, 0.0785, 0.0392, 0.0196 and 0.0098 mg/cm^2 and for *S. oryzae* and *C. chinensis* the doses were established as same as the previous one. For the application of the extracts of *P. integrifolia* on *T. castaneum*, half filter paper discs (Whatman No. 40, 9 cm diam.) were prepared and selected doses of all the extracts separately applied to each of the half-disc and allowed to dry out as exposed in the air for 20 minutes. Each treated half-disc was then attached lengthwise, edge-to-edge, to a control half-disc with adhesive tape and placed in a Petri dish (9 cm in diam.). For each of the test samples, three replicates were maintained. Being volatile, the solvent was evaporated out within a few minutes. Then ten insects were released in the middle of each filter paper circle. Whereas, in the case of *S. oryzae* and *C. chinensis*, Petri dish (of 9 cm in diam.) was divided into three parts and marked with two narrow sticks through adhesive tape. Then both sides filled with food where on one side treated food and the other side with non-treated food followed by the concentration except the middle one. Then ten adult insects were released into the middle of the Petri dish. Repellency was observed for one-hour interval and up to five successive hours of exposure for all three insect species populations. In the case of *T. castaneum*, just by counting the number of insects from the non-treated part of the filter paper spread on the floor of the 9 cm Petri dish. While for *S. oryzae* and *C. chinensis*, just by counting the number of insects from the non-treated part and the middle part of the 9 cm Petri dish floor. The values in the recorded data were calculated for percent repulsion, which was again developed by arcsine transformation for the analysis of variance (ANOVA). The average of the counts was converted to per cent repellency (PR) using the formula of Talukder and Howse (1993, 1995): $PR = (N_c\text{-}5) \times 20$; where, N_c is the average hourly observation of insects on the nontreated half of the disc.

3. Results

3.1. Dose-mortality Effects on *T. castaneum*, *S. oryzae* and *C. chinensis* Adults

The results of the dose-mortality assay of the Pet. ether, $CHCl_3$ and CH_3OH extracts of *P. integrifolia* against the test beetles *T. castaneum*, *S. oryzae* and *C. chinensis* are represented in Table 1. The lethal activity of the Pet. ether extract of *P. integrifolia* against *T. castaneum* gave LD_{50} values ranged from 774.211 to 210.590 µg/cm^2; for the $CHCl_3$ extract the LD_{50} values ranged from 1346.655 to 377.448 µg/cm^2 and for the CH_3OH extract the LD_{50} values ranged from 1618.731 to 220.973 µg/cm^2; against *S. oryzae* the Pet. ether extract gave LD_{50} values ranged from 622.589 to 179.741 µg/cm^2 and for the $CHCl_3$ extract the LD_{50} values ranged from 1072.029 to 422.962 µg/cm^2; and against *C. chinensis* the Pet. ether extract gave LD_{50} values ranged from 223.226 to 26.798 µg/cm^2; for the $CHCl_3$ extract the LD_{50} values ranged from 2231.894 to 30.396 µg/cm^2 and for the CH_3OH extract the LD_{50} values ranged from 1601.432 to 335.388 µg/cm^2 all after 6, 12, 18, 24, 30, 36, 42 and 48 h of exposure respectively.

Table 1. LD_{50} values of the leaf extracts of *P. integrifolia* against *T. castaneum, S. oryzae* and *C. chinensis* adults.

Name of the test agent	Chemical extract	LD_{50} (µg/cm^2)							
		6 h	12 h	18 h	24 h	30 h	36 h	42 h	48 h
T. castaneum	Pet. ether	774.211	482.944	362.967	290.312	267.072	250.437	232.646	210.590
	$CHCl_3$	1346.655	994.006	690.838	617.103	499.323	465.245	417.610	377.448
	CH_3OH	1618.731	1160.860	844.502	633.850	579.368	305.023	226.975	220.973
S. oryzae	Pet. ether	622.589	488.302	326.090	261.275	226.743	200.496	190.368	179.741
	$CHCl_3$	1072.029	945.599	700.804	609.574	557.205	531.474	428.500	422.962
	CH_3OH	-							
C. chinensis	Pet. ether	223.226	139.425	94.990	60.167	49.126	37.729	32.584	26.798
	$CHCl_3$	2231.894	540.441	283.154	103.783	66.703	53.207	37.959	30.396
	CH_3OH	1601.432	1313.371	768.993	573.965	474.193	399.749	337.305	335.388

However, the CH_3OH extract of *P. integrifolia* did not show any lethality to the test beetle *S. oryzae* adults.

3.2. Repellency Effects on *T. castaneum, S. oryzae* and *C. chinensis* Adults

The repellency test of the extracts of *P. integrifolia* in Pet. ether, $CHCl_3$ and CH_3OH were conducted on the beetles of *T. castaneum, S. oryzae* and *C. chinensis*. However, after determining the value(s) of the analysis of variance(s) (ANOVA), the 'F' values indicated that none of the extracts possesses repellent potentials against the selected pest insects (Table 2). To be sure about the repellent potential of the extracts high throughput of extracts was maintained, while in comparison to the doses used in the dose-mortality tests in this investigation, it was very high.

Table 2. ANOVA results of the repellent activity test against *T. castaneum*, *S. oryzae* and *C. chinensis* adults by the Pet. ether, $CHCl_3$ and CH_3OH extracts of *P. integrifolia*.

Plant	Name of the test agent	Solvent of Extraction	Source of Variation	SS	df	MS	F	P-value
P. integrifolia	*T. castaneum*	Pet. ether	Between doses	5583.163	4	1395.791	4.132	0.0174
			Between time interval	1226.662	4	306.666	0.908	0.483
		$CHCl_3$	Between doses	1643.73	4	410.933	1.188	0.354
			Between time interval	3034.016	4	758.504	2.192	0.116
		CH_3OH	Between doses	4395.913	4	1098.978	1.715	0.196
			Between time interval	1417.936	4	354.484	0.553	0.700
	S. oryzae	Pet. ether	Between doses	304.472	4	76.118	3.142	0.044
			Between time interval	299.652	4	74.913	3.092	0.046
		$CHCl_3$	Between doses	1304.069	4	326.017	3.528	0.030
			Between time interval	824.739	4	206.185	2.231	0.111
		CH_3OH	Between doses	3613.470	4	903.367	3.745	0.025
			Between time interval	2929.958	4	732.490	3.036	0.049
	C. chinensis	Pet. ether	Between doses	307.315	4	76.829	2.615	0.074
			Between time interval	171.738	4	42.935	1.461	0.260
		$CHCl_3$	Between doses	330.690	4	82.672	1.584	0.227
			Between time interval	128.624	4	32.156	0.616	0.657
		CH_3OH	Between doses	327.026	4	81.756	2.257	0.108
			Between time interval	248.974	4	62.243	1.718	0.195

If, $F \geq 8.63$; Significant at 5% level ($P<0.05$).

4. Discussion

The insecticidal potentials depicted through this investigation triggers a possibility of use of this plant in the field of pest management, however most of the previous researchers found anti-microbial activities. The intensity of activity clarified that the Pet. ether extract is stronger than the $CHCl_3$ extract, followed by the less potent CH_3OH extract, and the test agent *C. chinensis* is comparatively susceptible than *S. oryzae* and more susceptible than *T. castaneum* beetles; and the CH_3OH extract was inactive to the test beetle *S. oryzae*. This plant possesses no repellent action against any of the test beetles. A thorough survey of the literature shows that *P. intergifolia* has effective medicinal properties (Kumar, 2015) and toxic potentials as well (Chortyk *et al.*, 1997). The leaf extract of this plant has promising antibacterial properties to many human pathogenic bacteria and has great significance in therapeutics (Kumar, 2015). According to the findings of Rahman *et al.* (2008), *Petunia* has mild-active medicine possessing anti-microbial properties against a wide variety of bacterial strains and shows the mildest anti-oxidation activity (Kays *et al.*, 1994). Lay *et al.* (2003) described the flowers of the Solanaceous ornamental plant *P. hybrida* produce high levels of defensins during the early stages of their development (Rahman *et al.*, 2008). Antifungal proteins of the defensives structures of this plant have been determined (Janssen *et al.*, 2003; Lay *et al.*, 2003). Another species of *Petunia* (*P. violacea*) has a strong property to inhibit the human plasma AChE (Voogelbreinder, 2009). This plant species secretes acyl sugars which create a sticky exudate that covers

the aerial surfaces of the plant is implicated indirect defence against herbivores, tri-trophic interactions and possesses anti-microbial activity (Goffreda *et al.*, 1989; Chortyk *et al.*, 1993; Hare, 2005; Weinhold and Baldwin, 2011; Luu *et al.*, 2017). *Petunia* spp. also show significant biological activity against sweet potato whiteflies (Chortyk *et al.*, 1997; Kays *et al.*, 1994). Elliger and Waiss (1991) described that *Petunia* spp. contain an array of more than three dozen steroidal materials are involved in the resistance to certain lepidopteran larvae. However, several species of *Petunia* are ornamentals grown in the garden for their large, showy and multicoloured flowers (Thenmozhi and Sivaraj, 2011).

5. Conclusions

The findings of the present study indicate a strong lethal potentiality of the extracts of *P. integrifolia* against the stored product pests *T. castaneum*, *S. oryzae* and *C. chinensis* adults. So, attention should be paid to the plant to find out its pesticidal leads. Being natural in origin, the plant extracts could be biodegradable and thus safe and sustainable for the environment.

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Potentiation of *Heritiera littoralis* (Aiton), *Madhuca longifolia* (König) Macbr., *Nerium indicum* (Mill.) and *Sapium indicum* (Willd.) Leaf Extracts against the Insect Vector *Culex quinquefasciatus* (Say) Larvae

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Abstract

Pet. (Petroleum) ether, $CHCl_3$ (Chloroform) and CH_3OH (Methanol) extracts of *Heritiera littoralis* (Aiton), *Madhuca longifolia* (König) Macbr., *Nerium indicum* (Mill.) and *Sapium indicum* (Willd.) leaves have been tested against the significant insect vector *Culex quinquefasciatus* (Say) larvae through dose-mortality assay. The *H. littoralis* gave LC_{50} values 412.31, 146.92, 66.46, 44.31 and 33.91 ppm for the Pet. ether extract and 152.10, 97.12, 72.27, 45.00 and 28.96 ppm for the $CHCl_3$ extract both after 18, 24, 30, 36 and 42 h of exposure; and 625.87, 231.46, 86.10, 15.26 and 2.15 ppm for the CH_3OH extract after 12, 18, 24, 30 and 36 h of exposure respectively. The *M. longifolia* gave LC_{50} values 183.87, 87.56, 65.70, 33.27 and 18.02 ppm for the $CHCl_3$ extract and 213.84, 127.05, 89.07, 54.32 and 31.51 ppm for the CH_3OH extract both after 18, 24, 30, 36 and 42 h of exposure; however, the Pet. ether extract did not show any lethal effect against the test agent. The *N. indicum* gave LC_{50} values 420.46, 367.12, 65.35, 31.16, 19.28 and 15.89 ppm for the Pet. ether extract after 12, 18, 24, 30, 36 and 42 h of exposure respectively; while the $CHCl_3$ and CH_3OH extracts did not offer any mortality to the test larvae. The *S. indicum* gave LC_{50} values 383.43, 54.16, 16.48, 4.41 and 3.78 ppm for the Pet. ether extract after 12, 18, 24, 30 and 36 h of exposure and 414.11, 84.89 and 28.64 ppm for the CH_3OH extract after 12, 18 and 24 h of exposure respectively; however, the $CHCl_3$ extract did not show lethal effect against the test agent. The intensity of activity of the extracts could be arranged in the following descending order: *H. littoralis* (CH_3OH extract) > *S. indicum* (Pet. ether extract) > *N. indicum* (Pet. ether extract) > *M. longifolia* ($CHCl_3$ extract).

Keywords: *Heritiera littoralis*, *Madhuca longifolia*, *Nerium indicum*, *Sapium indicum*, Extracts, *Culex quinquefasciatus*.

1. Introduction

To control mosquitoes, using synthetic insecticides cause various hazards in the environment and other forms of life and may even be responsible for making insecticide-resistant mosquitoes themselves. Many researchers have reported on the effectiveness of plant extracts against different types of mosquito larvae (Rahuman *et al*., 2008a; Rahuman *et al*., 2008b). In recent ages, plants have been widely used instead of synthetic insecticides that are the real storehouse of thousands of phytochemicals (Dhang, 2014). This study aimed at the evaluation of the larvicidal potentials of *Heritiera littoralis* (Aiton), *Madhuca longifolia* (König) Macbr., *Nerium indicum* (Mill.) and *Sapium indicum* (Willd.) leaf extracts against the vector mosquito *Culex quinquefasciatus* (Say) larvae. The test plant, *H. littoralis* (Malvaceae) has been used to treat diarrhoea and dysentery. Different parts of this plant have antifungal, insecticidal, antimycobacterial and antioxidant properties (Kokpol *et al*., 1990; Christopher *et al*., 2014; Miles *et al*., 1991). The sap of this plant contains poisonous action affecting fish in aquatic media (Tewtrakul *et al*., 2010; Miles *et al*., 1987). *M. longifolia* (Sapotaceae) has various medicinal and traditional uses. Different parts of this plant are helpful to treat many diseases. Leaves of this plant control bleeding, bark in ulcers, fruit oil in skin diseases and latex is used to treat cracked feet (Amirthalingam, 2000). This plant also has anti-diabetic, antioxidant properties and traditional therapeutic uses (Sen and Chakraborty, 2020; Gaikwad *et al*., 2009) and has poisonous solid properties on fish (Sharma, 1997). The flowers of *M. longifolia* have been used to standardize Ayurvedic formulation (Rao *et al*., 1997). *N. indicum* (Apocynaceae) plant parts are used as curative agents for various ailments. The bark and leaves are useful as a heart tonic, diuretic, expectorant, diaphoretic and an emetic (Patel *et al*., 2010). Leaf juice of this plant is given in snake and other venomous bites; young leaves

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are effective in ophthalmic with lacrimation. The root is helpful in haemorrhoids in various kinds of cancer like leprosy and ulceration (Vinayagam and Sudha, 2011; Ahmed, 2006; Chauhan *et al*., 2013). This plant species has been reported for antibacterial, antifungal and anti-influenza viral concerns (Khatik *et al*., 2016). *N. indicum* is also used in Ayurveda for the treatment of various human diseases (Chetwani *et al*., 2017). The plant *S. indicum* (Euphorbiaceae) has significant uses in multiple medical aspects, including toothache, fever, gonorrhoea etc. (Burkill, 2011; Purwaningsih, 1991). It exhibits wound healing properties (Azis *et al*., 2015) and is used for insanity and hydrophobic medication (Burkill, 2011; Gautam *et al*., 2017). This plant has poisonous latex and acts as a fish toxicant for the presence of aesculetin in fruits (Gautam *et al*., 2017).

2. Materials and Methods

2.1. Collection and Preparation of Test Materials: The leaves of the selected plants *H. littoralis*, *M. longifolia*, *N. indicum* and *S. indicum* were collected from different places of Bangladesh. *H. littoralis* were collected from Dakop, Khulna District; *S. indicum* from Rampal, Bagerhat District; *M. longifolia* and *N. indicum* were collected from the campus of the University of Rajshahi. The collected leaves of the test plants were cut into small pieces and spread out in wooden trays and kept in a well-ventilated room to dry them under shade at room temperature. Well dried leaves were ground to powder with a blender, weighed, kept in separate conical flasks and then extracted successively with sufficient amounts of solvents (Petroleum ether, $CHCl_3$ and CH_3OH) (100 g × 300 ml × 2 times) for 48 h. Filtration was done by Whatman No. 40 filter paper and after evaporation, the extracts were collected in glass vials and kept in a cool place at 4^{o}C with proper labelling.

2.2. Collection and Culture of the Test Insect: Mosquito egg rafts were collected from the University of Rajshahi campus and reared under laboratory conditions in the Crop Protection and Toxicology Laboratory of the Department of Zoology, University of Rajshahi. This collection and rearing were maintained throughout the experimental period for a continuous supply of larvae of the same age for the tests.

2.3. Larvicidal Activity Test: One-day aged mosquito larvae were used to test the leaf extracts of the test plants. The doses were selected through *Ad Hoc* experiments. Test samples at different concentrations were prepared in test-tubes by the addition of a calculated amount of DMSO (dimethyl sulfoxide) to make them hydrophilic before adding water in each of the test-tubes. Then water was added to fill the pre-marked (up to 10 ml) test-tubes with the help of a pipette. Ten freshly emerged (1 day aged) larvae were added to each of the test tubes containing different selected doses along with a control batch (of only water and DMSO). The counting of dead larvae was made after 6 h of application and it was continued up to 42 h with an interval of 6 h through visual inspection.

The selected doses for *H. littoralis* leaf extract in Petroleum ether were 97, 66, 49, 33 and 21 ppm; in $CHCl_3$ were 95, 69, 48, 32 and 21 ppm and in CH_3OH were 200, 150, 100, 50 and 25 ppm respectively. For *M. longifolia* leaf extract in $CHCl_3$ were 81, 40.50, 20.25, 10.13 and 5.06 ppm and in CH_3OH were 200, 150, 100, 50 and 25 ppm respectively. For *N. indicum* leaf extract in Petroleum ether were 200, 90.50, 45.25, 22.62 and 11.31 ppm and in $CHCl_3$ were176, 88, 44, 22 and 11 ppm respectively. The doses for *S. indicum* leaf extract in Petroleum ether were 100, 50, 25, 12.50 and 6.25 ppm and in CH_3OH were 200, 150, 100, 50 and 25 ppm respectively.

2.4. Statistical Analysis: The lethality data of the extracts on mosquito larvae were corrected by the Abbott's formula (Abbott, 1925): $P_r = (P_o - P_c / 100 - Pc) \times 100$, Where, P_r = Corrected mortality (%), P_o = Observed mortality (%) and P_c = Control mortality (%). The data were subjected to Probit analysis according to Finney (1947) and Busvine (1971). The lethality relationship was expressed as median lethal concentration (LC_{50}) for the test agent.

3. Results

3.1. Larvicidal Effects: The lethality records of the test plants are represented in Table 1. All the three extracts for *H. littoralis* leaves in different solvents showed promising lethality against mosquito larvae while the highest activity was observed in the case of CH_3OH (LC_{50} = 2.15 ppm after 36 h); however, in the case of $CHCl_3$ extract the activity was the lowest and after the same exposure time (the LC_{50} was 45 ppm) [Fig. 1 (a-o)]. Chloroform extract of *M. longifolia* leaves showed higher activity (LC_{50} = 33.27 ppm after 36 h) in comparison to the CH_3OH extract (LC_{50} = 54.32 ppm after 36 h) [Fig. 2 (a-j)]; and Petroleum ether extract of this plant did not offer any activity. In the case of *N. indicum*, only the Petroleum ether extract showed lethality, giving LC_{50} = 19.28 ppm after 36 h of exposure; while the $CHCl_3$ and the CH_3OH extracts of this plant did not show any activity [Fig. 3 (a-

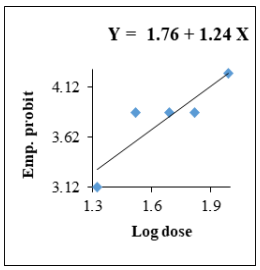
f)]. However, the Petroleum ether extract of *S. indicum* showed better activity (LC_{50} = 3.78 ppm after 36 h) and the CH_3OH extract of the same showed comparatively sharp but obscure lethal action [Fig. 4 (a-h)].

Methanol extract of *H. littoralis*, Petroleum ether extract of *N. indicum*, Petroleum ether and CH_3OH extracts of *S. indicum* appeared to offer mortality of the larvae after 12 h of exposure; and the CH_3OH extract of *H. littoralis*, Petroleum ether and CH_3OH extracts of *S. indicum* offered 100% mortality of the test larvae after 42 h of exposure. According to the intensity of activity, the extracts of the test plants could be arranged in the following descending order: *S. indicum* (Petroleum ether extract) > *H. littoralis* (CH_3OH extract) > *N. indicum* (Petroleum ether extract) > *M. longifolia* ($CHCl_3$ / CH_3OH extract).

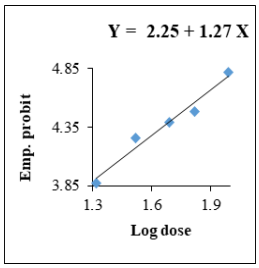
Table 1: LC_{50} values of the leaf extracts of *H. littoralis*, *M. longifolia*, *N. indicum* and *S. indicum* against *C. quinquefasciatus* larvae.

Plant name	**Plant part**	**Solvent**	**LC_{50} (ppm) at different exposure**					
			12 h	**18 h**	**24 h**	**30 h**	**36 h**	**42 h**
H. littoralis	Leaves	Pet. ether	-	412.31(a)	146.92(b)	66.46(c)	44.31(d)	33.91(e)
		$CHCl_3$	-	152.10(f)	97.12(g)	72.27(h)	45.00(i)	28.96(j)
		CH_3OH	625.87(k)	231.46(l)	86.10(m)	15.26(n)	2.15(o)	*
M. longifolia	Leaves	Pet. ether	-	-	-	-	-	-
		$CHCl_3$	-	183.87(a)	87.56(b)	65.70(c)	33.27(d)	18.02(e)
		CH_3OH	-	213.84(f)	127.05(g)	89.07(h)	54.32(i)	31.51(j)
N. indicum	Leaves	Pet. ether	420.46(a)	367.12(b)	65.35(c)	31.16(d)	19.28(e)	15.89(f)
		$CHCl_3$	-	-	-	-	-	-
		CH_3OH	-	-	-	-	-	-
S. indicum	Leaves	Pet. ether	383.43(a)	54.16(b)	16.48(c)	4.41(d)	3.78(e)	*
		$CHCl_3$	-	-	-	-	-	-
		CH_3OH	414.11(f)	84.89(g)	28.64(h)	*	*	*

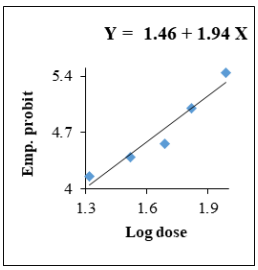
* = All dead.



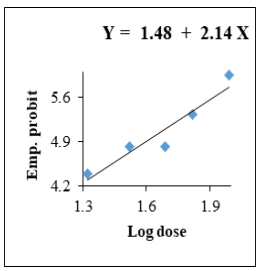
a) Pet. ether extract after 18 h of exposure.



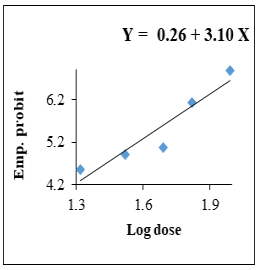
b) Pet. ether extract after 24 h of exposure.



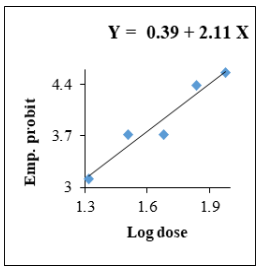
c) Pet. ether extract after 30 h of exposure.



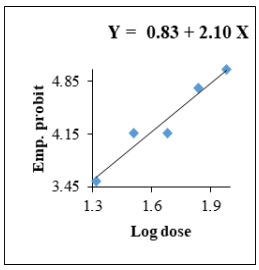
d) Pet. ether extract after 36 h of exposure.



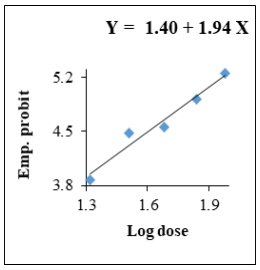
e) Pet. ether extract after 42 h of exposure.



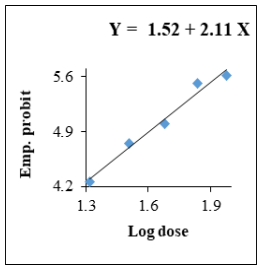
f) $CHCl_3$ extract after 18 h of exposure.



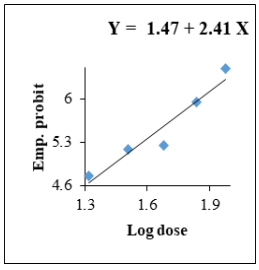
g) $CHCl_3$ extract after 24 h of exposure.



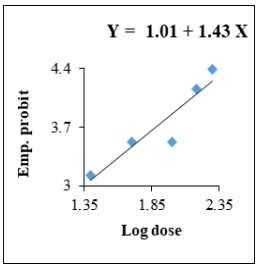
h) $CHCl_3$ extract after 30 h of exposure.



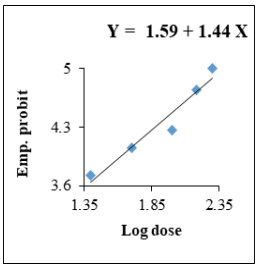
i) $CHCl_3$ extract after 36 h of exposure.



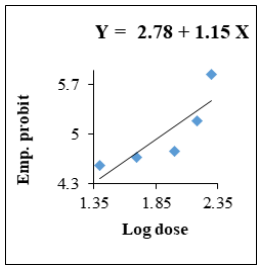
j) $CHCl_3$ extract after 42 h of exposure.



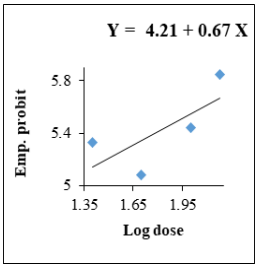
k) CH_3OH extract after 12 h of exposure.



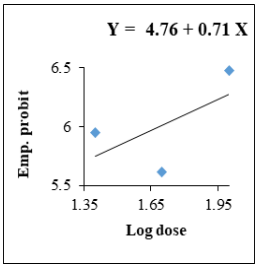
l) CH_3OH extract after 18 h of exposure.



m) CH_3OH extract after 24 h of exposure.

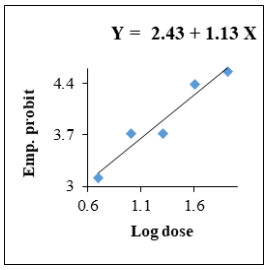


n) CH_3OH extract after 30 h of exposure.

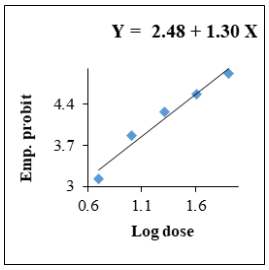


o) CH_3OH extract after 36 h of exposure.

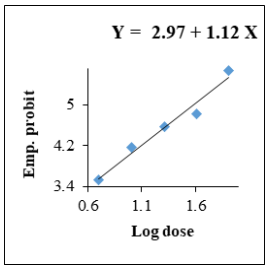
Fig. 1 (a-o): Regression lines of *H. littoralis* leaf extracts against *C. quinquefasciatus* larvae at different hours of exposure.



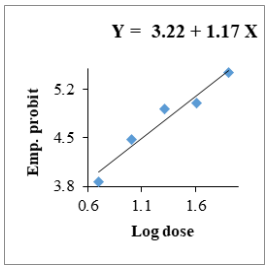
a) $CHCl_3$ extract after 18 h of exposure.



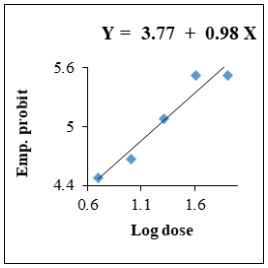
b) $CHCl_3$ extract after 24 h of exposure.



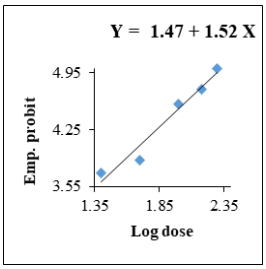
c) $CHCl_3$ extract after 30 h of exposure.



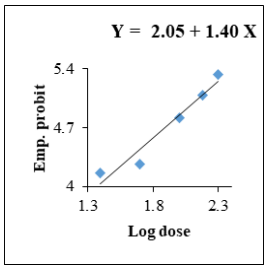
d) $CHCl_3$ extract after 36 h of exposure.



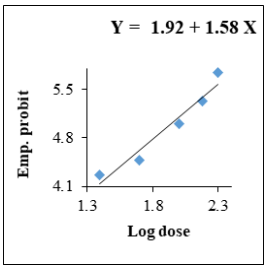
e) $CHCl_3$ extract after 42 h of exposure.



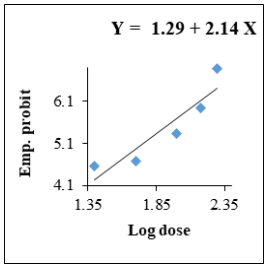
f) CH_3OH extract after 18 h of exposure.



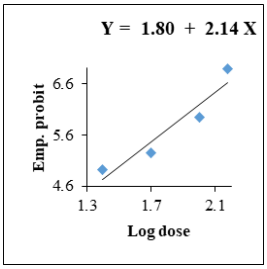
g) CH_3OH extract after 24 h of exposure.



h) CH_3OH extract after 30 h of exposure.

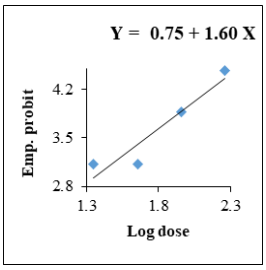


i) CH_3OH extract after 36 h of exposure.

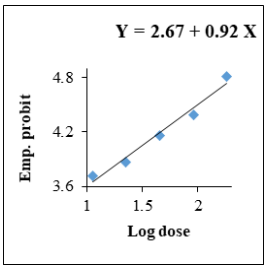


j) CH_3OH extract after 42 h of exposure.

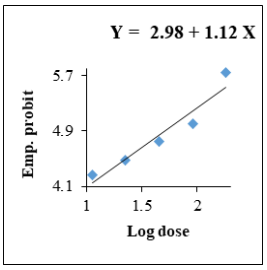
Fig. 2 (a-j): Regression lines of *M. longifolia* leaf extracts against *C. quinquefasciatus* larvae at different hours of exposure.



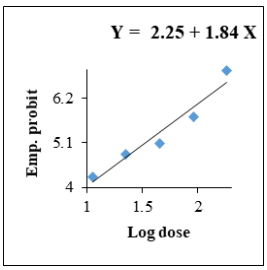
a) Pet. ether extract after 12 h of exposure.



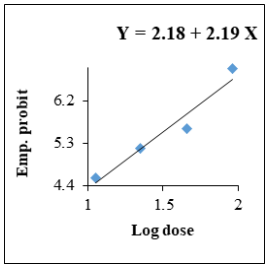
b) Pet. ether extract after 18 h of exposure.

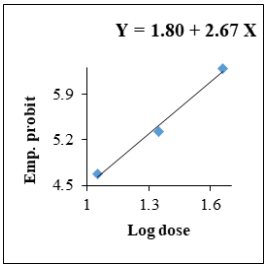


c) Pet. ether extract after 24 h of exposure.



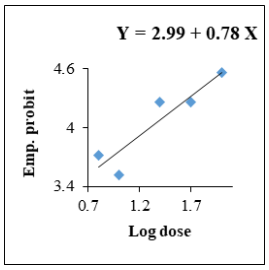
d) Pet. ether extract after 30 h of exposure.



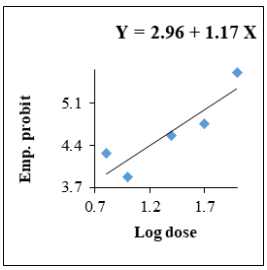


f) Pet. ether extract after 42 h of exposure.

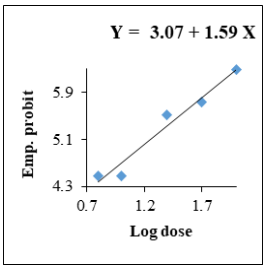
Fig. 3 (a-f): Regression lines of *N. indicum* leaf extracts against *C. quinquefasciatus* larvae at different hours of exposure.



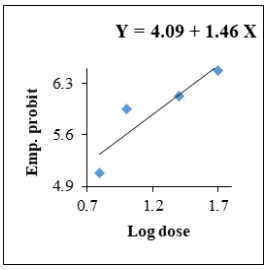
a) Pet. ether extract after 12 h of exposure.



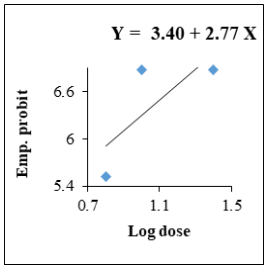
b) Pet. ether extract after 18 h of exposure.



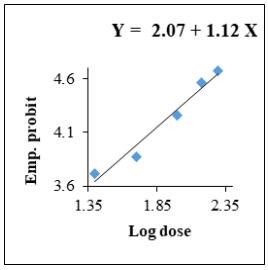
c) Pet. ether extract after 24 h of exposure.



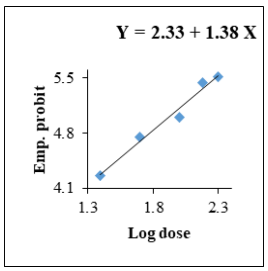
d) Pet. ether extract after 30 h of exposure.



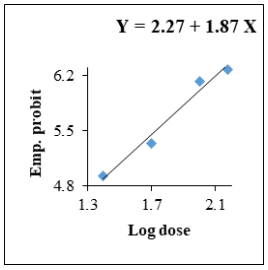
e) Pet. ether extract after 36 h of exposure.



f) CH_3OH extract after 12 h of exposure.



g) CH_3OH extract after 18 h of exposure.



h) CH_3OH extract after 24 h of exposure.

Fig. 4 (a-h): Regression lines of *S. indicum* leaf extracts against *C. quinquefasciatus* larvae at different hours of exposure.

The findings of this investigation received support from the works of previous researchers. The crude extract of *H. littoralis* (twig) showed remarkably potent antibacterial activity against *Staphylococcus aureus* at 5 mg/ml

(Soonthornchareonnon *et al*., 2012). Aqueous extract of *H. littoralis* acts like metabolic poison rotenone on juvenile Nile tilapia (Gomez *et al*., 1986). Chemicals isolated from *H. littoralis* demonstrated ichthyotoxicity and antifungal activities (Bandaranayake *et al*., 1998). Many researchers found insecticidal, antimycobacterial, antioxidant and antifungal properties of this plant (Kokpol *et al*., 1990; Christopher *et al.*, 2014; Miles *et al*., 1991). Another species of the same genera, *H. fomes* possesses a wide range of pharmacological activities such as anti-diabetic, antimicrobial, antioxidant, antinociceptive, and anticancer potentials (Mahmud *et al*., 2014); and this plant also has several biological prospects, such as spermicidal, molluscicidal, antimicrobial, anti-inflammatory and cytotoxic activities (Setty *et al*., 1976; Marston and Hostettmann, 1985; Mahato *et al*., 1988a; Mahato *et al*., 1988b). *M. longifolia* possesses antimicrobial activity against the bacterial spp. *Escherichia coli* and *Staphylococcus aureus* (Purnima and Swarnalatha, 2018). Chakma (2011) mentioned that this plant has antimicrobial activity against many pathogenic bacteria. This author found this plant's acetone and aqueous extracts to show an antibiotic effect on both the Gram-positive and Gram-negative bacteria. Khare *et al.* (2018) described the various pharmacological uses of its leaves, flowers and bark, and added that this plant is used in the treatment of eczema, wound healing, anti-burn, bone fracture, anthelminthic, emollient, skin disease, rheumatism, headache, chronic bronchitis and diabetes mellitus, etc. Sakthivadivel and Daniel (2008) found the mortality of *Anopheles stephensi* and *Aedes aegypti* larvae by applying the seed extracts of *M. longifolia*. *Madhuca* cake possesses a significant insecticidal and pesticidal activity against phytonematode (Pandey *et al*., 2003). Mani *et al.* (2003) also reported on the pesticidal activity of this plant against *Tetranychus urticae*. Prashanth *et al.* (2010) mentioned its paste could be used as an antidote for scorpion sting and in treating ulcer and tonsillitis. Chauhan *et al*. (2013) investigated the inhibitory effect of *N. indicum* against some bacterial spp. and concluded that it was found effective (19 mm inhibition zone) to inhibit the growth of the bacterial strains. Parastoo *et al.* (2012) showed the antibacterial activity of *N. indicum* extracts against the bacterial spp. *Bacillus* sp., *E. coli*, *Yersinia* sp. and *Staphylococcus* sp. Masih *et al.* (2014) found that the aqueous extract of *N. indicum* leaves possesses a broad-spectrum antimicrobial activity against the various clinical fungi. They proved that this plant has antifungal potentials against *Aspergillus fumigatus* (20 mm) and *Alternaria solani* (22 mm). Many researchers reported that the root powder of *N. indicum* contains anti-hemorrhoidal compounds and is used to treat ulcers around the genitals. This plant's leaves and bark also have potentiality against insects, rats, and parasites (MHAP, 2019). Pieces of evidence established by previous researchers on the potentiality of *S. indicum* confirm this investigation's findings (Rahman *et al*., 1999). Bandaranayake (1998) mentioned it as an Indian poisonous plant containing piscicidal agent(s). This researcher also noted the unripe fruits of this plant contain irritant metabolites. Khanam *et al.* (2008) described that the extracts of *S. indicum* seed showed toxicity against mature larvae and adult beetles of *Tribolium castaneum* and *T. confusum*. They also mentioned the extracts of *S. indicum* affect the growth and development of many insects spp. especially to the weight of larvae, pupae and adults; on the developmental period and have an excellent insecticidal value to suppress the population of the insect pests. Chumkaew *et al.* (2003) mentioned that this plant exhibits an antimycobacterial solid activity. Thus, the findings from this investigation, as well as from the previous researchers suggest that a thorough investigation of the biological activities of the test plants *H. littoralis*, *M. longifolia*, *N. indicum* and *S. indicum* followed by the elucidation of the bioactive chemical components and their synthesis may offer larvicide(s) of natural origin to curb the global mosquito population.

5. Conclusions

The results on the investigation of larvicidal potentials of *H. littoralis*, *M. longifolia*, *N. indicum* and *S. indicum* leaves extracted in Petroleum ether, $CHCl_3$ and CH_3OH depicted that these plants have larvicidal components, many of which could be promising to control the mosquito vectors. Further studies on isolation and identification of the biologically active compounds from the leaves of these plants could be very much to be solicited.

Acknowledgements

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Evaluation of IC_{50} and MUPE Value of Four Different Fruit Seed Oils and Its Significance

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Abstract

Free radical scavenging IC_{50} value of a substance is the measure of antioxidant capacity, and Molar Unit Pi Bond Equivalent (MUPE) value is the measure of unsaturation. In the present investigation IC_{50} value of the Chal kumra (*Benincasa hispida*), Boroi (*Ziziphus mauritiana*), Malta (*Citrus sinensis L*), and Jolpai (*Elaeocarpus serratus*) seed oils were 49.8142 (µg/ml), 292.7694 (µg/ml) 118.07 (µg/ml), and 78.2517 (µg/ml), respectively. And MUPE value of *Benincasa hispida* seed oil (BHSO), *Ziziphus mauritiana* seed oil (ZMSO), *Citrus sinensis* seed oil (CSSO) and *Elaeocarpus serratus* seed oil (ESSO) were 0.3671, 0.3469, 0.2933 and 0.2920, respectively. According to IC_{50} value the order is ZMSO>CSSO>ESSO>BHSO and according to MUPE value the order is BHSO > ZMSO > CSSO > ESSO. The highest MUPE value (0.3671) of BHSO indicates its free radical scavenging capacity is the highest that is its IC_{50} value is the lowest among the four seed oils examined.

Keywords: IC_{50}, MUPE, Unsaturation, PUFA, Oil seeds.

1. Introduction

Different types of seed oils contain fat soluble vitamins and antioxidant components, and the unsaturated bonds of oils also acts as free radical scavenger. Since time immemorial, the following four types of herbaceous plants are famous for their medicinal properties. For example, Malta (*Citrus sinensis L*) of Rutaceae family which exerts effect on the immune system is used in treating pneumonia, blood pressure, intestinal problem and diseases related to Vitamin-C deficiency (Milind and Dev., 2012). *Elaeocarpus serratus* of Elaeocarpaceae family a tropical fruit with nutritive and medicinal values and used traditionally to treat diarrhea (Biswas *et al*., 2012). *Ziziphus mauritiana* of Rhamnaceae family is employed in pulmonary ailments, fevers and for relieving vomiting and abdominal pains in pregnancy (Dahiru *et al.*, 2006). Chal kumra (*Benincasa hispida*) of Cucurbeieceae family is used in various complications such as, gastrointestinal problems, respiratory disease, heart disease, diabetes mellitus and urinary diseases (Aqilah, 2011).

Antioxidants refer to any substances which possess the ability to protect the body from cell damage (Chauhan *et al*., 2016) caused by free radical induced oxidative stress. They exert their activity by inhibiting or delaying the process of lipid oxidation by scavenging the free radicals (Ashraf *et al*., 2015). Although they are present at low concentration in foodstuffs, they are able to prevent oxidation significantly. At this moment there are considerable evidence that free radical induces oxidative damage to biomolecules, causes cancer, aging, neurodegenerative diseases, atherosclerosis, and several other pathological events in living organisms (Halliwell and Gutteridge., 1990). Antioxidants which scavenge free radicals are known to have an important role in preventing these free radical induced-diseases. This is why there is an increasing interest in the antioxidants effects of compounds derived from plants, and their influence in relation to their nutritional incidents and their role in health and diseases is very important. Natural antioxidants constitute a broad range of substance including phenol or nitrogen containing compounds which are polar in nature to carotenoids which are oily in nature due to long chain hydrocarbon in their structure (Shahidi *et al*., 1992).

The objective of this investigation was to find the relationship between the antioxidant capacity of the oil extracted from the aforementioned seeds of the plants and the nature of the chemical component, specially in terms of the amount of unsaturated bonds and antioxidant capacity.

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2. Materials and Methods

2.1. Collection of Materials

Seeds of four plants selected for analyses were Malta (*Citrus sinensis L*), Chal kumra (*Benincasa hispida*), Jolpai (*Elaeocarpus serratus*) and Boroi (*Ziziphus mauritiana*). The seeds were collected from local market in Rajshahi city, Bangladesh. The seeds were taken out from the fruits and outer shells of the seeds were removed manually from kernel. Kernels obtained in this way were grounded in powder by using a grinder. The oils were extracted with pet. Ether (40º-60º) C. In each of the cases; the produced oil was filtered with filter paper (11 µm pore size) to remove any kind of particulate matter from it.

2.2. GC-MS Analysis of Oil: Sample Preparation

Preparation of Fatty acid methyl ester (FAMEs:) The fatty acid content of fixed oils was investigated with GC-MS by analyzing their methyl esters with (GC-MS). Fatty acid methyl esters were prepared by following the procedure stated below. For each of the sample 200 mg (2-3 drop) of sample (Oil) was taken in a 10 mL Pyrex test tube. Then 3.5 mL of 0.5 M Sodium Methoxide was added to the test tube and the test tube was heated using burner before completing the bubbles. Now 1.5 mL petroleum ether was added to the mixture and shaken vigorously. Then around 5 mL deionized water was added to test tube slowly and wait for settling down of the layer. Upper layer was taken into the GC vial and subject to GC-MS analysis. b) Running the sample- The analysis of oil was performed on SHIMADZU GC-2010 Plus equipped with auto-sampler (AOC-20s) and auto-injector (AOC-20i) using SH Rxi 5MS Sill column (30m×0.25mm; 0.25 µm). The carrier gas used was helium at 2.00 mL/min flow pressure; oven temperature was programmed from 60 °C (hold time 0.00 min) and raised at 40 °C/min to a final temperature of 230 °C (hold time 0.00 min). The injector temperature was 250 °C and injection volume was 1.0 µL at 75:1 split ratio (injection mode was Split). Solvent cut time was 3.00 min and total run time was 42.50 min. The detector used was SHIMADZU GCMS-QP-2020 and detector temperature was 255 °C (Sharmin *et al.*, 2021).

2.3. Determination of Free Radical Scavenging Activity

2, 2-diphenylpicrylhydrazyl (DPPH) is widely used to evaluate the free radical scavenging capacity of anti-oxidant (Braca *et al.*, 2001). DPPH free radical is reduced to the corresponding hydrazine when it reacts with hydrogen donors. In this method, free radical scavenging activity was evaluated by measuring the decrease of the absorbance of DPPH solution at 517nm. When the DPPH is scavenged by an anti-oxidant, the color of the solution changed from purple to yellow, and the absorbance of the solution decreases through donation of hydrogen to form a stable DPPH molecule (Fig-3). 500 µL of oil of each kind was added in 3 ml of 0.002% DPPH solution in n-hexane and shaken well. Absorbance was taken at 517 nm for all the sample solutions and the blank (contained only 0.002% DPPH solution in n-hexane) after keeping the reagent mixture in the darkness for thirty minutes.

The scavenging activity against DPPH was calculated using the following equation;

Scavenging activity (%) = [(A-B)/A] x 100 ……Equation (1)

Where A was the absorbance of control (DPPH solution without the sample/ Standard), B was the absorbance of DPPH solution in the presence of the sample (Extracts/ Retinol).

Then, % scavenging activity or % inhibition was plotted against log concentration; from the graph IC_{50} (Inhibitory concentration fifty) value was calculated by linear regression analysis.

2.4. Calculation of Molar Unit Pi Bond Equivalent (MUPE)

To calculate MUPE, molecular weight of fatty acids was calculated; percentage value of each of the fatty acids in the oil composition (Sharmin *et al.*, 2021) was divided by corresponding molecular weight. The obtained value was multiplied by number of pi bonds present in the corresponding fatty acid structure (Equation 2). MUPE of a particular oil composition was calculated by adding all the MUPE of each of the fatty acids of the particular oil composition (Table 3).

$$\text{MUPE} = \frac{\text{\% value of FA in the}}{\text{MW}} \times \text{No. of pi } (\pi) \text{ bonds in the FA} \ldots\ldots \text{Eq. - (2)}$$

FA= Fatty Acid

3. Results and Discussion

Oil contents of *Ziziphus mauritiana* (ZMSO), *Benincasa hispida* (BHSO), *Citrus sinensis L*. (CSSO) and *Elaeocarpus serratus* (ESSO) seed oils were 32.86, 18.5, 33.85 and 30 % respectively (Table 1). The IC_{50} values of DPPH free radical scavenging activity of ZMSO, BHSO, CSSO and ESSO seed oil were 292.7694, 49.8142, 118.07 and 78.2517 µg/ml, respectively which were compared against Vitamin-A (Retinol, IC_{50} : 15.294 µg/ml), (Table 2, Figure 2). In case of antioxidant screening BHSO showed very strong free radical scavenging activity (IC_{50} : 49.8142 µg/ml). CSSO and ESSO showed lower antioxidant activity (IC_{50} : 118.07 and 78.2517 µg/ml, respectively) than BHSO. Radical scavenging activity of ZMSO was found to be the lowest among the four seed oils. Molar Unit Pi Bond Equivalent of BHSO, ZMSO, CSSO and ESSO are 0.3671, 0.3469, 0.2933 and 0.2920, respectively (Table 3). According to MUPE value the order of oils is BHSO > ZMSO > CSSO > ESSO (Figure 2).

Table 1. Oil content of Malta, Jolpai, Boroi and Chal kumra seed

Name	% Oil content
Citrus sinensis L (L.N.-Malta)	33.85 %
Elaeocarpus serratus (L.N.-Jolpai)	30 %
Ziziphus mauritiana (L.N.-Boroi)	32.86 %
Benincasa hispida (L.N.-Chal kumra)	18.5 %

L.N=Local Name

Table 2. DPPH free radical Scavenging activity of *Benincasa hispida* (BHSO), *Ziziphus mauritiana* (ZMSO), *Citrus sinensis L*. (CSSO) and *Elaeocarpus serratus* (ESSO)

Sample Conc.(µg/l)	Log. Con	Absorbance at 517 nm		Percent (%) of scavenging activity		IC_{50}(µg/ml)	
Benincasa hispida							
		BHSO	Vit-A	BHSO	Vit-A	BHSO	Vit-A
Control			0.6321				
6.70	0.8607	0.6113	0.5294	3.2906	16.2475	49.8142	15.295
13.38	1.1264	0.4821	0.3974	23.7304	37.1302		
20.10	1.3032	0.4537	0.3257	28.2239	48.4733		
26.80	1.4281	0.4244	0.0577	32.8587	90.8717		
33.47	1.5185	0.3612	0.0412	42.8571	93.4820		
Ziziphus mauritiana							
Control		ZMSO	Vit-A	ZMSO	Vit-A	ZMSO	Vit-A
6.70	0.8607	0.6051	0.5294	4.2715	16.2475	292.7694	15.295
13.38	1.1264	0.5721	0.3974	9.4922	37.1302		
20.10	1.3032	0.5431	0.3257	14.0801	48.4733		
26.80	1.4281	0.5017	0.0577	20.6296	90.8717		
33.47	1.5185	0.4801	0.0412	24.0468	93.4820		
Citrus sinensis L.							
		ZMSO	Vit-A	ZMSO	Vit-A	CSSO	Vit-A
Control			0.6321			118.07	15.295
6.70	0.8607	0.6254	0.5294	1.0599	16.2475		
13.38	1.1264	0.5538	0.3974	12.3873	37.1302		
20.10	1.3032	0.5142	0.3257	18.6521	48.4733		
26.80	1.4281	0.4824	0.0547	23.6829	90.8717		
33.47	1.5185	0.4486	0.0412	29.0302	93.4820		
Elaeocarpus serratus							
		ESSO	Vit-A	ESSO	Vit-A	ESSO	Vit-A
Control			0.6321			78.2517	15.295
6.70	0.8607	0.5925	0.5294	6.2648	16.2475		
13.38	1.1264	0.5246	0.3974	17.0068	37.1302		
20.10	1.3032	0.5068	0.3257	19.8228	48.4733		
26.80	1.4281	0.4465	0.0547	29.3624	90.8717		
33.47	1.5185	0.3892	0.0412	38.4275	93.4820		

Table 3. Molar Unit Pi Bond Equivalent of BHSO, ZMSO, CSSO and ESSO

	Name of fatty acid	BHSO				
		MW	Symbol	Quantity(%)	No of Pi bond	MUPE*
1	Palmitic acid	256	C16:0	31.21	0	0
2	Stearic acid	284	C18:0	9.76	0	0
3	Oleic acid	282	C18:1	15.13	1	0.0536
4	Linoleic acid	280	C18:2	43.90	2	0.3135
						Total= 0.3671
		ZMSO				
1	Palmitic acid	256	C16:0	19.15	0	0
2	Stearic acid	284	C18:0	11.64	0	0
3	Oleic acid	282	C18:1	40.94	1	0.1451
4	Linoleic acid	280	C18:2	28.27	2	0.2018
						Total= 0.3469
		CSSO				
1	Palmitic acid	256	C 16:0	30.17	0	0
2	Stearic acid	284	C 18:0	14.45	0	0
3	Oleic acid	282	C18:1	28.43	1	0.1008
4	Linoleic acid	280	C18:2	26.95	2	0.1925
						Total= 0.2933
		ESSO				
1	Palmitic acid	256	C16:0	20.08	0	0
2	Stearic acid	284	C18:0	17.79	0	0
3	Oleic acid	282	C18:1	27.82	1	0.0986
4	Linoleic acid	280	C18:2	23.15	2	0.1653
5	Myristic acid	243	C14:0	4.04	0	0
6	Palmitoleic acid	254	C16:1	7.16	1	0.0281
						Total= 0.2920

MUPE*= Molar Unit Pi Bond Equivalent, MW= Molecular Weight

In a different investigation, the GC-MS data of the fatty acid composition of the plant seeds of CSSO, BHSO, ZMSO revealed the presence of palmitic acid, stearic acid, oleic acid and linoleic acid, where as in ESSO oil the presence of previously mentioned four fatty acids plus myristic acid and palmitoleic acid were revealed (Table 4) (Sharmin *et al.*, 2021). BHSO contain the highest amount of linoleic acid (43.90%) which explains the highest MUPE value (0.3671) of it. Molar Unit Pi Bond Equivalent of BHSO, ZMSO, CSSO and ESSO are 0.3671,

0.3469, 0.2933 and 0.2920 respectively. (Table 3). According to Equation 2, Molar Unit Pi Bond Equivalent (MUPE) is directly proportional to the number of pi bond present in the compound. There are two pi bonds in linoleic acid and one pi bond in oleic acid. Rest of the fatty acids in the investigation has no pi bond. According to MUPE value the order of oils is BHSO > ZMSO > CSSO > ESSO (Figure 2).

Free radicals are generally very reactive species with a short life time. These radicals can undergo substitution, addition, rearrangement auto oxidation and single electron transfer (Phaniendra *et al.,* 2015). In this experiment addition mechanism is thought to be involved (Figure 3). Linoleic acid has two pi bonds, so one molecule of linoleic acid can bind with four DPPH free radical; on the other hand, oleic acid has one pi bond, so it can bind with two DPPH free radical. So, the MUPE of any oil depends on fatty acid composition. That's why when a compound contains higher amount of pi bonds, it can scavenge higher amount of free radical. Compounds with smaller value of IC_{50} scavenge higher amount of free radicals. So, the MUPE and IC_{50} values are inversely related.

Table 4. Fatty acid compositions of Malta, Jolpai, Boroi and Chal Kumra seeds oil

	Name of Fatty Acids	***Quantity (%)***				
		CSSO	***ESSO***	***BHSO***	***ZMSO***	***Symbol***
1	***Methyl palmitate (palmitic acid)***	***30.17***	***20.08***	***31.21***	***19.15***	***C16:0***
2	***Methyl octadecenoate (stearic acid)***	***14.45***	***17.79***	***9.76***	***11.64***	***C18:0***
3	***cis-9-oleic acid (oleic acid)***	***28.43***	***27.82***	***15.13***	***40.94***	***C18:1***
4	Methyl linoleate (linoleic acid)	26.95	23.15	43.90	28.27	C18:2
5	Methyl tetradecanoite (myristic acid)	NI	4.04	NI	NI	C14:0
6	Methyl pamitoliate	NI	7.16	NI	NI	C16:1

CSSO =*Citrus sinensis* seed oil, ESSO = *Elaeocarpus serratus* seed oil
BHSO =*Benincasa hispida* seed oil, ZMSO =*Ziziphus mauritina* seed oil and
NI = Not Identified

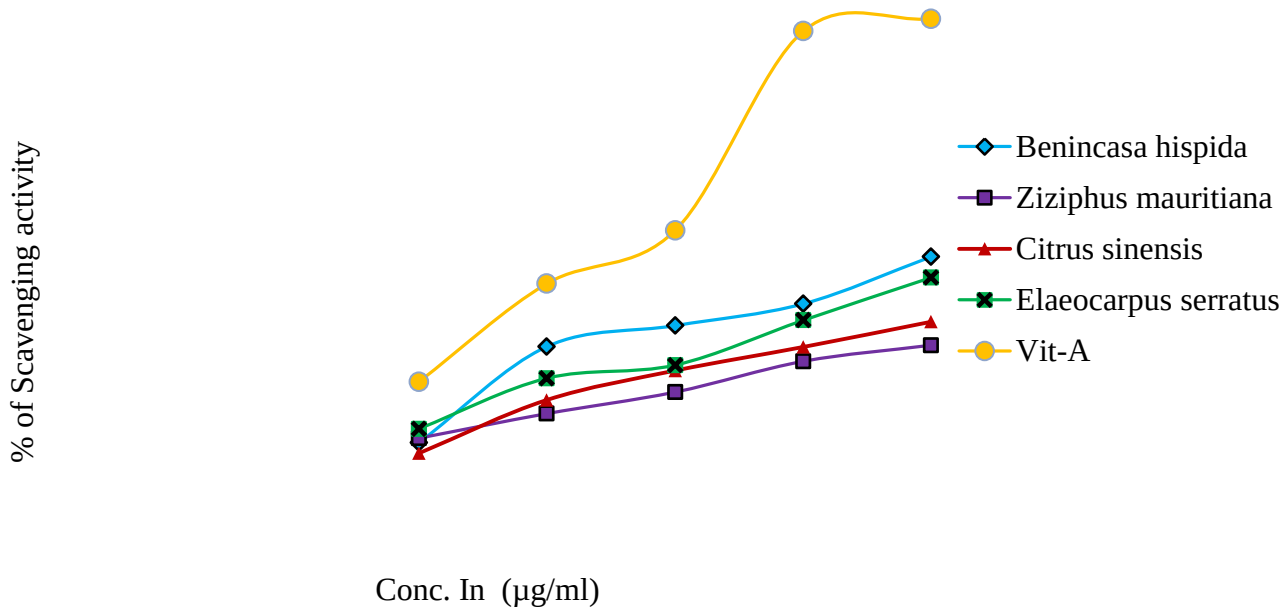

Figure 1. Free radical scavenging activity of four seed oils

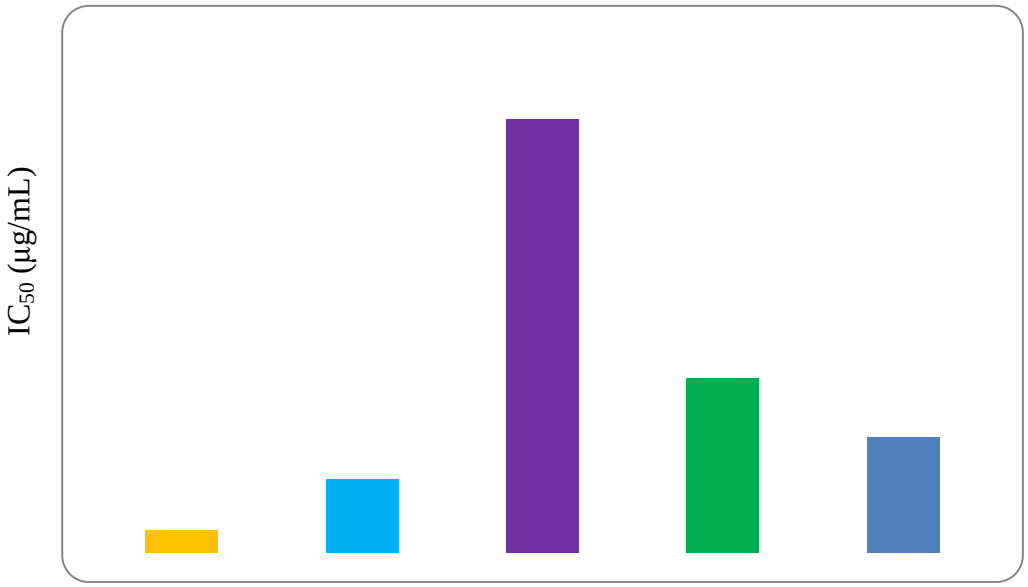

Figure 2. IC_{50} values of four seed oils compared to Retinol

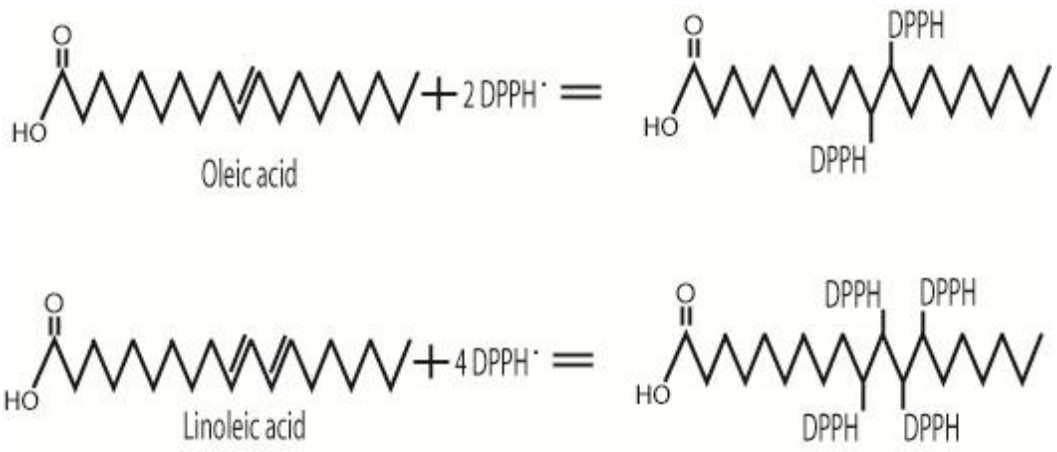

Figure-3. DPPH Free radical addition with pi bond

IC_{50} value of free radical scavenging capacity is the measure of antioxidant effect. The lower the IC_{50} value of a compound the higher is the antioxidant capacity of the compound. As the MUPE of BHSO is the highest its free radical scavenging capacity is higher which can be explained by the observed lowest IC_{50} value 49.8142 of the oil. Interestingly although the MUPE value of ZMSO is higher than that of CSSO and ESSO its IC_{50} value is the highest which indicates that CSSO and ESSO may contain higher amount of different kinds of free radical scavenger other than PUFA.

4. Conclusions

Antioxidant capacity and property of oily substance is very important from biological perspective. It depends both on amount of unsaturated bonds and other properties of the substance like stability of the molecule, bond strength of living group etc. In our investigation we found some deviation in the relation between IC_{50} and MUPE value. So, it is yet to determine what are the substance and reasons behind it.

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Socio-Economic and Environmental Impact of Commercial Poultry Industry in Bangladesh

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Abstract

The poultry industry is growing successfully and becoming a leading industry of Bangladesh. Large numbers of people were engaged in poultry sectors as a freedom business. The study identifies various aspects of the growth, socio-economic status and environmental impact of poultry industry in Bangladesh. This study is an attempt to examine the present situation and future potentiality of Bangladesh poultry industry. In Bangladesh, commercial poultry production has been growing rapidly since the early 1990 by using improved genetics, manufactured feeds and proper farm management techniques. The demand for meat, egg and meat and egg products has been increasing dramatically with income growth, population growth, urbanization and dietary changes. The government and the private sector are working together to solve the problem in poultry industry through various development activities. The government is encouraging private sectors and NGOs to undertake steps for the development of poultry sector by liberalizing its present policy. The major challenges faced by poultry sector are inadequate knowledge of technology of farmer, Capital unavailability, Seasonal fluctuation of demand, limited access to credit, insufficient transportation system and outbreak of diseases like Avian Influenza and New Castle. In addition, there are other problems which hinder the proper development of poultry industry. The paper also presents a series of negative environmental impacts of rapid development of poultry farming like odour pollution, water pollution and disease outbreaks. Additionally, poultry farming is facing management-related difficulties which lead to greater concerns about its sustainability. For sustainable development of poultry sector, some specific recommendations such as proper Government planning and preparation for preventing Avian Influenza and others poultry diseases, Proper training program based on both practical and technological knowledge for poultry farmers, adequate vaccinations services at national or regional level under the official supervision of public veterinary services etc. are made for consideration by the concerned stakeholders of this industry.

Keywords: Poultry Industry, Present Situation, Future Potentiality, Major Challenges, Environmental Impacts, Bangladesh

1. Introduction

Bangladesh is one of the densely populated developing countries of the world. It has a population of 167,265,855 (est. 28 January, 2022) people within the area of 143,000 km. (Worldometer elaboration of the latest United Nations data, 2022). Its economy is very much dependent on agriculture. The agriculture sector of Bangladesh contributes 12.09 percent of GDP to the economy in 2020-21(BBS, 2021). Animal farming is an important sub-sector of agriculture in Bangladesh. About 1.86 percent of GDP came from poultry and livestock farming during the 2020-21 financial years (DLS, 2021). The growth rate of this sub-sector was 7.26 percent in the in financial year 2020-21 (DLS, 2021). In addition to its contribution to the Gross Domestic Product (GDP) and provision of employment opportunities, poultry production is a major source of protein in the country. The contribution of poultry farming is essential to the national economy in case of generating employment opportunity, additional income for households, fulfill the demand for meat and egg and improving the nutritional level of the people. The poultry farming has emerged as a flourishing commercial business in Bangladesh during the recent years. In fact, there has been a silent revolution in the poultry sector during the last decade. As developing country unemployment, inadequate nutrition, poverty and scarcity of agricultural land are the major problems in Bangladesh. About 20.5 percent of the population in Bangladesh lives below the absolute poverty line (BBS, 2020). One-fourth of the country's farmer families are still landless, reveals the preliminary report of Bangladesh Bureau of Statistics (BBS) on Agriculture Census 2019. As poultry requires minimum land, low capital and skill, it can play an important tool to fight against poverty not only for the group of people who

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are landless but also for the distressed women. It has also been acting as an important tool for reducing the migration from rural poor people to the urban areas.

Chicken and egg are the cheapest sources of protein available in developing countries, compared to the more expensive sources like beef and fish. The investment in the sector is approximately $4.16 billion which is expected to double in the next decade. The numbers of poultry farms are increasing at an average of 15 percent annually. The poultry sector contributes around 1.5 percent to the GDP of nearly $250 billion, making it the second-largest sector after ready-made garments (BPICC, 2020). It has already been capable of rising at an annual growth of around 20 percent during last two decades. Small-scale poultry production has developed in a large number of developing countries around the world as an important source of eating for the rural poor. In the last few years, the recognition of small-scale commercial poultry production helped to accelerate the pace of poverty reduction riding in new height in Bangladesh. The poultry sector started during mid seventies and has growth rapidly annual rates of around 20 percent during the last two decades. The main poultry production systems can be broadly classified into: backyard scavenging systems, small-scale commercial systems and large-scale commercial systems.

Between 1960s to the 1980s, commercial firms were established (Kabir, 2005). All the commercial boiler and layer farms were dependent on imported parents stocks before two decades. Beginning with the new millennium, many local and multinational producers started their parent and grandparent stock operation locally to meet the country's demand. Currently, the poultry industry in Bangladesh is proud to have world-renowned broiler and layer strains ranging from grandparents' stock, also known as the GPS. These are purebred, highly valuable eggs with a controlled pedigree. The next stage is parent stock, which produce fertilized eggs. These eggs are sold to farms and poultry businesses. Hatcheries buy these fertilized eggs to produce Day-Old Chicks (DOC). Approximately 525 million broilers DOC and 60 million layers DOC are produced annually (DLS, 2019). These are then sold to commercial producers, who supply directly to the market. The most commonly and available broiler strains in Bangladesh Cobb 500, Ross 308, Indian River Meat, Tiger Sasso, Habbard and Arber acre; whereas the most reared layer strains are Navogen Brown/White, Hyline Brown/White, Shaver 579, ISA Brown, Hi-Sex Brown/White and Bovine White. Government and various non-governmental organizations (NGO's) are promoting poultry development at all levels. Training in disease diagnosis, bio-security of farms, environmental health and disease prevention is provided by those institutions, not only for health personnel, but for the farmers as well. But limited access to institutional services such as extension, training, credit and veterinary services affect country's poultry production.

The poultry Industry has been making progress despite avian Influenza outbreak, rising price of raw materials in the international market, lack of infrastructural support among others. But on the other hand, poultry industry has occurred environmental pollution with a significant amount of manure and sewage being generated simultaneously. Odor emissions, caused by a large number of contributing compounds including ammonia (NH3), volatile organic compounds (VOCs), and hydrogen sulphide (H2S), from poultry farms adversely affect the life of people living nearby these farms.

The poultry industry in Bangladesh is a vital sector to improve agricultural growth and the diet of people. This sector is important particularly as it serves as one of the major sources of daily protein and nutritional supply (Raihan & Mahmud, 2008). Particularly, we have little information about the performance of poultry farms in terms of socio-economic aspect.

Commercial poultry production has been growing rapidly in Bangladesh since early 1990 by using improved genetics, manufactured feeds and management. This improvement is done mainly in the private sector as a device for additional source of income and employment opportunities particularly in rural area (Raha, 2013).

In addition to indigenous chicken, a crossbred of Rhode Island Red male and Fayoumi hen, with phenotypic appearance similar to local chicken called 'Sonali' was introduced in northern part of the country through two projects called Small Holder Livestock Development Project (SLDP) and Participatory Livestock Development Project (PLDP) during 1996-2000. Sonali fowl has proven to be the most profitable and highest-yielding in Bangladeshi conditions. Saleque and Saha (2013) find that Sonali rearing is easier than broiler due to suitable environment of the country. Huque et, al (2011) find that Sonali comprised about 30 percent of the total broiler

and layer production in the country. In 2018, the percentage of Sonali chicken consumption was around 20 percent, but this rose to 45 percent in just a year (DLS, 2019).

Islam (2003) says that the poultry sub-sector is crucially important in the context of agricultural growth and improvement of diets of people in Bangladesh.

Banarjee (2004) observe that in comparison to other livestock, poultry farming require less investment. Persons from low income group may also start the business on a small scale. Particularly women, children or elderly people get full-time or part-time employment opportunities from poultry farming.

Hamid et. al. (2016) observe that the demand for meat, egg and meat and egg products have been expanding dramatically with income growth, population growth, urbanization and dietary changes. Recognizing this fact, the government and the private sector are working together to solve the problem in poultry industry through various development activities.

Raihan and Mahmud (2008) find that access to working capital by smaller stakeholders is also considered as a major hurdle towards the flourish of poultry industries in Bangladesh.

Islam (2005) conduct a research where he showed the demands of poultry products and gap prevailing in this sector. Chakma (2008) mention that Bangladesh experienced Highly Pathogenic Avian Influenza (HPAI) outbreaks during 2007 and 2008. The Bangladeshi poultry sector has been tremendously affected by the disease. Rahman (2008) also mention the economic losses of the farmers for different diseases of poultry farm in his issues and interventions in the poultry sector.

Poultry production adversely affects the environment in numerous ways; such as through poor management of manure and litter, waste streams from processing plants (blood, bones, feathers, etc), birds' carcasses, dust, insects, odour, etc. Furthermore, intensive poultry production is held responsible for the emission of greenhouse gasses, acidification and eutrophication. Steinfeld et al. (2006) observe that the environmental impact of livestock and poultry farming has received increasing attention over the last years, because it is responsible for 18 percent of the global emission of greenhouse gases. Sustainable development of environment friendly commercial poultry industry in Bangladesh seems to have attracted little attention.

The paper explains the production and productivity of poultry industry demand for meet and eggs, poultry diseases, available medicine and production of vaccine in Bangladesh. The paper also address risks associated with the poultry industry including environmental issues and recommended measures to mitigate those risks for the sustainable growth and development of Bangladesh.

2. Materials and Methods

The paper is mainly based on secondary data, published journal, newspaper, magazines, unpublished documents and consultation with some knowledgeable persons in poultry sector. Data were collected from various documents of Bangladesh Bureau of Statistics (BBS), Ministry of Finance, Bangladesh Poultry Industry Association (BPIA), Bangladesh Poultry Industry Central Council (BPICC), Bangladesh Rural Advancement Committee (BRAC) and Department of Livestock Services (DLS).

3. Result and Discussion

3.1 Present Structure of Poultry Industry in Bangladesh

The poultry industry of Bangladesh has gained sufficiency against the current market demand (Raha, 2013), but not against the standard nutritional requirement (DLS, 2016). Starting from the 1990s the industrial poultry sector gained massive momentum towards the industrial phase. After that, it gained a significant annual average growth rate, approximately 15-20 percent annually. Large numbers of farms in different sizes are operating all over the country. The poultry industry was hit by Avian Influenza in 2007, 2009 and 2011and the number of farms reduced to 55,000 in 2013 from 115,000 in 2007 due to outbreak of diseases along with other problems. Now there is an estimated 150,000 poultry farms in Bangladesh (PSAB, 2017).

3.2 Production and Productivity of Commercial Poultry

In recent decades, the demand for livestock products in developing countries including Bangladesh has increased rapidly, propelled by rising levels of income, population and urbanization. Contribution of livestock in Gross Domestic Product (GDP), GDP growth rate of Livestock and share of livestock to Agricultural GDP have slightly decreased in last five years. In 1920-21, 20 percent people are directly and 50 percent people are indirectly employed in Livestock sector. Contribution of livestock and poultry to the National economy 2015-16 to 2020-21 is presented in Table 1.

Table 1: Contribution of Livestock and Poultry to the National Economy of Bangladesh

Variables	Fiscal Years					
	2015-16	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**
1. Contribution of Livestock in Gross Domestic Product (GDP)	1.66%	1.58%	1.54%	1.47%	1.43%	1.44%
2. GDP growth rate of Livestock (Constant Prices)	3.21%	3.35%	3.40%	3.47%	3.04%	3.80%
3.Share of Livestock to Agricultural GDP	14.21%	14.02%	13.62%	13.46%	13.44%	13.10%
4. Employment (Directly)	20%	20%	20%	20%	20%	20%
5. Employment (Indirectly)	20%	40%	46%	50%	50%	50%

Source: Department of Livestock Services (DLS, 2021), Ministry of Livestock and Fisheries, February 2021.

3.3 Poultry Population of Bangladesh

Poultry populations have gradually increased every year in Bangladesh. In 2011-12, the numbers of total chicken was approximately 2428.66 lakh. Last ten years, the numbers of poultry population have increased gradually. In the year of 2020-21, number of total chicken was about 3041.06. The chicken populations have increased 30.70 present in last ten years. The total numbers of duck population have increased from 457.00 lakh to 617.46 lakh from the financial year 2011-12 to 2020-21. The duck populations have increased 40.00 percent in last ten years. Numbers of the total poultry populations in Bangladesh is estimated about 3658.52 lakh in the year of 2020-21. In last ten years the total poultry population has increased 31.62 percent. Changing pattern and growth of poultry production since 2011-12 to 2020-21 is presented in Table 2.

Table 2: Poultry Population of Bangladesh (In Lakh Number) from 2011-12 to 2020-21

Poultry Species	Fiscal Year									
	2011-12	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**
Chicken	2428.66	2490.11	2553.11	2617.70	2683.93	2751.83	2821.45	2892.83	2966.02	3041.06
Duck	457.00	472.54	488.61	505.22	522.40	540.16	558.53	577.52	597.16	617.46
Total Poultry	2885.66	2926.64	3041.72	3122.93	3206.33	3292.00	3379.98	3470.35	3563.18	3658.52

Source: Department of Livestock Services (DLS, 2021), Ministry of Livestock and Fisheries, February 2021.

3.4 Production of DOC in Bangladesh

All over the country, only ten private farms (breeder and hatcheries) produce over 70% broiler day-old chicks and 14 breeder farms and hatcheries produce layer day-old chicks. There is a notable growth of the Day-Old Broilers and Breeders production and it is more than double over last decades. The annual growth trend of DOC is presented in Table 3.

Table 3: Annual Growth Trend of DOC from 2010 to 2019

Types of DOC	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Boiler DOC	320.5	416.0	320.0	450.0	480.0	511.5	557.0	594.5	630.7	700.1
Layer DOC	50.0	55.0	43.0	55.0	57.0	33.7	39.2	45.8	45.9	47.4
Sonali DOC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	300	350

Source: Department of Livestock Services (DLS), Ministry of Livestock and Fisheries, February, 2020.

3.5 Production of Meat and Egg in Bangladesh

Total annual poultry meat and eggs production in the country is reported to increase every year. Most of the advancement in chicken meat production comes from the broiler and Sonali farming in the country. The total annual chicken meat production was 23.30 lakh metric tons in the fiscal year 2011-12. The meat productions have increased dramatically in last ten years. In 2020-21 the country's chicken meat production was about 84.40 lakh metric tons. The meat productions have been increased 509.05 percent in last decade. In 2011-12 the farm egg production from layer DOCs population was about 730.38 crore. Last decade the production of farm eggs have been increased 202.31 percent and in 2020-21 the annual farm egg production was about 2058 crore. Total annual production of meat and egg from fiscal year 2011-12 to 2020-21 is presented in Table 4.

Table 4: Production of Meat and Egg in Bangladesh from Fiscal Year 2011-12 to 2020-21

Product	Unit	Fiscal Year									
		2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Chicken Meat	Lakh Metric Ton	23.30	36.20	45.21	58.60	61.52	71.54	72.06	75.14	76.74	84.40
Egg	Crore Number	730.38	761.74	1016.8	1099.52	1191.24	1493.31	1552	1711	1736	2057.64

Source: Department of Livestock Services (DLS, 2021), Ministry of Livestock and Fisheries, February 2021.

3.6 Demand and Production Availability of Meat and Eggs

Rising population, moderate growth of per capita income and higher income elasticity of demand for poultry products are likely to bring a further increase in the demand of these products in poor and middle class population of our country.

Bangladesh's per capita protein consumption especially meat and egg is about 136.18 gram per day whereas the demand of per capita protein is about 120 gram per day. Bangladesh Bureau of Statistics (BBS) in its latest Household Income and Expenditure Survey (HIES), 2019 report said daily per capita consumption of major meat like chicken, duck and beef as well as fish and egg has increased almost doubled compared to that in 2010, as the local poultry plays a vital role in this regard. According to the statistics, the demand for egg was about 1765.92 crore number whereas the total egg production was about 2057.64 in fiscal year 2020-21. Per head yearly egg demand in Bangladesh is 104 whereas country's yearly per head egg supply is 121.18 (DLS, 2021). Slight availability is found in the per head egg consumption in Bangladesh. Annual demand, production, availability and deficiency of meat and eggs in the fiscal year 2020-21 are presented in Table 5.

Table 5: Demand, production, availability and deficiency of meat and eggs (2020-21)

Products	Demand	Production	Availability/Deficiency
Meat	74.37 Lakh Metric Ton (120 gm/day/head)	84.40 Lakh Metric Ton	136.18 (gm/day/head)
Egg	1765.92 Crore number (104 numbers/year/head)	2057.64 Crore numbers	121.18 (numbers/year/head)
*Estimated population of the country: 16 crore 98 lakh (1st July, 2020)			

Source: Department of Livestock Services (DLS, 2021), ministry of Livestock and Fisheries, February 2021.

3.7. Poultry Diseases and Vaccination

The poultry industry has gained significance all over the world including Bangladesh due to providing economical, healthier food than red meat and other protein sources. But poultry farming system is affected by both environmental and disease stress. Poultry birds are susceptible to several types of infectious and non-infectious diseases (Roberts et. al., 2011). Various viral, bacterial, parasitic and fungal diseases affect the production performance of fast growing broiler birds and laying chickens by affecting respiratory system, reproductive system, immune system, gut system and central nervous system which, in turn, cause loss of appetite, decreasing feed intake, reduction of body weight, drop in egg production, air sac infection, coughing, sneezing, difficulty in breathing, paralysis of neck, wings and legs, bloody diarrhea and higher mortality (Adesiji et. al., 2010). The above mention clinical sign cause huge production losses and enhance the production cost which cause huge economic losses in poultry industry (Abbas, 2014 and Pattison et. al., 2008). Therefore, poultry diseases should be controlled effectively.

In present, poultry vaccines are widely applied to prevent and control contagious poultry diseases. The use of vaccination in poultry industry is aimed to avoid and minimize the emergence of clinical disease at farm level. In the last two decade, the poultry sectors faced enormous financial losses caused by the major epidemic diseases of poultry such as avian influenza and Newcastle disease. Thus, vaccination should be applied in the framework of poultry disease eradication programmes at national or regional levels under the official supervision of Public Veterinary Services.

In 2014-15, production of vaccine was about 177.178 million numbers. Productions of vaccine have increased every year and 289.28 million vaccines have produced in 2018-19 fiscal year. 241.48 million vaccination is used in 2018-19 for the control of poultry infections in Bangladesh. About 91.59 million duck and chicken are attended treatment through the official supervision of Public Veterinary Services in 2018-19. The numbers of treatment have slightly decreased in 2018-19 than previous years. Table 6 represents the amount of production of vaccine, number of vaccination and treatment of poultry in last five years.

Table 6: Production of Vaccine, vaccination and treatment of poultry (million numbers)

Variables	Fiscal Year				
	2014-15	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Production of Vaccine	177.178	228.078	275.18	282.15	289.28
Vaccination	186.632	227.941	229.445	243.385	241.48
Treatment	70.747	80.174	118.95	113.90	91.59

Source: Department of Livestock Services (DLS, 2019), Ministry of Fisheries and Livestock, 2019.

3.8 Major Challenges Facing Poultry Industry

The poultry farmers are severely suffering from security of their farms and investment. Every year thousands of farms are collapsing due to Avian Influenza outbreak and many for their inability to buy high priced poultry ingredients and absorb losses from the fall in market prices. However, the poultry industry of Bangladesh as revealed by literature, currently faces some challenges against its growth potentials. Lack of proper poultry policy principle is a basic constraint to ensure proper implementation of rules and regulations pertaining to run of the poultry sector. Inadequate knowledge of technology of farmers creates a burden to handle the poultry industry properly. Chicken rearing, disease handling, production rate are greatly influenced by inadequate knowledge of technology. Level of education of poultry farmers is very low. They are unconscious and unwilling to introduce new technology. As a result they are unable to forecast the actual demand of poultry meat and eggs that caused great loss to the farm.

Capital unavailability is a major threat for the farmers. Loan system and installment procedure are complicate for small-educated poultry farmers. Moreover, lots of hidden charges and costs are associated to avail loans from the banking sector. Low return flow and high interest rate result low attachment to the poultry farms. Seasonal fluctuation of demand is another major problem of poultry industry. During the seasonal fluctuation, the growth of poultry sector is seriously affected. Transportation system is insufficient in the rural areas. High transportation costs causes problem in the flow of chickens, eggs, medicines among others.

The poultry sector is frequently affected by avian Influenza and other diseases which cause huge losses for the producers but poultry farmers do not get sufficient financial help from government and NGOs to mitigate their losses. Lack of modern and proper management of poultry farms is creating negative environmental impact.

Recent Covid-19 pandemic situation has created an undesirable impact and uncertainty in the poultry sector of Bangladesh. It has seriously affected the entire poultry value chain and one estimation found that it resulted in about 35% drop in commercial day-old chicks (DOC), eggs and meat production in our country (BPICC, 2020). The Covid-19 has awfully disrupted the production system. Chicken meat production rapidly declined from 900000 to 28000 ton per month (Ali, 2020). There had been a 30-45% reduction in day-old chick production, a 35-40% reduction in poultry feed production and a 40-50% reduction in the sale of medicines and other pharmaceutical products. It has created an unwanted mismatch between the demand and supply of poultry products. The selling price of broilers meat and eggs is lower than the production cost. Dhaka Tribune reports that prices of poultry products fell to a 12-year low during the COVID-19 pandemic. Feed output is reported to have fallen by up to 40% and sales of veterinary pharmaceuticals by 50% in June of 2020. BPICC (2020) claimed that the total loss in the poultry sector is about 7000 crores and about 25-30% of the entrepreneurs lost their capital over the last 18 months due to Covid-19.

3.6. Environmental Impact of Poultry Industry

Poultry Production is one of the fastest growing livestock industries in Bangladesh because of its advantages in terms of land use and improvement of protein production. Rapid development of poultry farming brings a series of negative environmental impacts like odour pollution, water pollution, disease outbreaks etc. Additionally, poultry farming is facing management-related difficulties which lead to greater concerns about its sustainability.

Odour associated with poultry operations comes from fresh and decomposing waste products such as manure, carcasses, feathers and litter (Kolominskas et al., 2002; Ferket et al., 2002). Odour from animal feeding operations is the result of a large number of contributing compounds including ammonia (NH3), volatile organic compounds (VOCs), and hydrogen sulphide (H2S) (IEEP, 2005). Of the several manure-based compounds which produce odour, the most commonly reported is ammonia. Ammonia gas has a sharp and pungent odour and can act as an irritant when present in elevated concentrations.

Although generally not causing any public-health concern, odours can represent a strong local problem that is frequently reported by farms' neighbours as the most disturbing environmental impact. The emission of odours mostly depends on the frequency of animal-house cleaning, the temperature and humidity of the manure, the type of manure storage, and air movements.

An additional concern for residents living near poultry facilities are flies. A research conducted by the Ohio Department of Health(ODH) indicates those residences that are located in close proximity to poultry farms (within half a mile) has 83 times the average number of flies. In addition to the nuisance they cause, flies and mosquitoes can transmit diseases, such as cholera, dysentery, typhoid, malaria, filaria and dengue fever. Rats and similar pests are also local nuisance associated with poultry production. As with flies and mosquitoes, they can be a vector for disease transmission. Producer use Pesticides to control pests and predators has been reported to cause pollution when they enter groundwater and surface water. Active molecules or their degradation products enter ecosystems in solution, in emulsion or bound to soil particles and in some instances, may impair the uses of surface waters and groundwater (World Bank, 2007).

In small-scale commercial broiler farms in Bangladesh, antibiotics are more likely to be used without veterinary supervision for therapeutic purpose. Antibiotics are also used in sub-therapeutic doses by adding them to feed and water for prophylaxis, growth promotion and as a risk-management strategy. Use of antibiotic for animal growth promotion is harmful for human body.

Improper disposal of poultry carcasses creates another environmental problem. Disposal of dead birds can contribute to water-quality problems especially in areas prone to flooding or where there is a shallow water table. Methods for the disposal of poultry carcasses include burial, incineration, composting and rendering. In the case of recent highly pathogenic avian influenza (HPAI) outbreaks, the disposal of large numbers of infected birds has presented new and complex problems associated with environmental contamination. Large volumes of carcasses can generate excessive amounts of leachate and other pollutants, increasing the potential for environmental contamination.

4. Conclusion and Recommendations

Poultry Industry can play a vital role in order to ensure the sustainable economic development of Bangladesh. If small scale producers are supported with training and technology and remunerative financial packages for increasing farm production and productivity to help improvement of their food security and livelihood, Poultry industry would facilitate further to double the production of poultry meat and eggs. Arrangement for training through lives stock agencies, NGOs and private agencies are necessary for farmers and labours associated in this sector. Extension service which may include disease management, accommodation and tools and promotional activities are also necessary for increasing production in this sector. Accommodation and organization might be enhanced through arranging suitable farmer guidance to run the farm smoothly. It is the time to step forward for the better accumulation of resources available from this industry and to save the small and medium farmers.

This study revealed some necessary information about the issues and future challenges of poultry sector and set up some effective recommendations to overcome impediments and to uplift the present situation of this sector efficiently. Moreover, this study would help poultry farmers to improve their socio-economic condition as well.

Following Recommendations may be considered for the improvement of existing production of Poultry industry:

- To mitigate food deficit especially protein related food, the poultry sector needs special attention for which public and private collaboration is essential.
- Proper human resource management and staffing as well as extension of the livestock office are required. They should play protective role to sustain the poultry industry.
- Supply chain management should be improved so that the poultry producers can directly supply poultry meat and eggs to the retailer.
- Government needs prior planning and preparation for controlling Avian Influenza and others poultry diseases and should take appropriate steps so that farmers can maintain bio-security and keep healthy environment inside and outside of farms.
- Transportation costs for eggs and chicken and chicken related products should be kept minimal so that consumers can purchase at a reasonable price.
- Proper training program based on both practical and technological knowledge is needed to adapt modern knowledge among the farmers. Training should be given to the farmers in the areas of housing equipment, vaccination system, virus preventive measures, genetic improvement and marketing.

- Vaccination should also be applied in the framework of poultry disease eradication programmes at national or regional levels under the official supervision of public Veterinary Services.
- Farmers must be aware of ways in which their production threatens environment. Only thus, they will be able to find and adopt solutions that will provide both profitability and sustainability of poultry production.

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Coverage of Environmental News in Mainstream Newspapers of Bangladesh

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Abstract

This is a qualitative scrutiny in the field of social science to explore the coverage patterns of environmental news in mainstream newspapers of Bangladesh. *The Daily Ittefaq*, *The Daily Prothom-Alo and The Daily Star* these three newspapers were selected as a sample. By using constructed sampling method from 2004 to 2018 total 540 (*Prothom-Alo* 180, *Daily Star* 180 and *Ittefaq* 180) newspapers were selected. Hence, total copies were analyzed in the study. These 540 newspapers are primary source of this study. Primary data were collected through content analysis from those newspapers. To find out the research objectives both qualitative and quantitative methodology were used. The researcher tries to find out how the environmental issues were covered in the three newspapers. Major content analysis showed that the selected newspapers did cover environmental news, but these issues did not receive proper emphasis. The study also revealed that the top focused issue of those newspapers was disaster (manmade and natural) related. Almost all of the stories were published without deep investigation or in-depth analysis. Researcher concluded that environmental issues were not seen as a prominent topic of those three newspapers. Many straightjacket and event based news were published in these newspapers but there was not produce sufficient analytical news. Researcher suggested that there must be improvement to coverage patterns and some important environmental issues that are relevant to Bangladesh environmental perspectives that needs to be more exposed and covered sufficiently with deep investigation and solution to educate the people.

Keywords: Environmental issues, Mainstream newspapers, News coverage

1. Introduction

Environment is fundamental for all living things. If the environment is not protected, the existence of life on the planet would ultimately be impossible. Moreover, serious environmental degradation has taken place all over the world including Bangladesh. That is why; environmental issues have become very important and sensitive globally. Environmental degradation is a lack of environmental awareness. People need to have a common understanding of the role played by human beings in reducing or worsens environmental degradation. Therefore, environmental awareness building is needed to reduce environmental degradation.

However, now a day‘s tremendous environmental problems and issues are gradually increasing around the world with higher frequency from strong typhoons, hurricanes and cyclones and other extreme events including pollution, floods, landslides, droughts etc. The environment is one of the most crucial decisive factors exerting influence on development‘s possibilities in Bangladesh. The major environmental problems such as deforestation, environment pollution, natural disaster, climate change etc. are related to human activities and development. Significantly, there is an inseparable relationship between environment and development.

Therefore, there is a growing demand from the public for more and more information on environmental issues and a great link between awareness and action. It is shown that environment and environmental news and information have become prominent topic of the public and elites discussion. Hence, mass media plays a significant role in covering news and information on environmental incidences, issues and problems (Pompper, 2004). Media has a big role to play in making people aware of environment issues and taking actions to protect the environment. According to Tengbers (1995), "2600 global media channels operate with the support of about 3000 satellites, reaching nearly 1.5 billion people across the globe. It can be argued that the majority of global citizens learn about environmental issues beyond their immediate surroundings, through the global media".

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Several studies have shown that mass media is a powerful tool that has been and can continue to be used to effect social change. The mass media play a role as a channel and means for the environmental education of people in the world (Hoerisch, 2002).

Media is very effective and it persuades and informs people to think or do something previous research has shown that newspapers about environmental information for people act as a primary source (Wakefied and Elliott, 2003). Many studies have found that news media are the most effective tool about environmental communication. Like that: [Jamilah *et al.* (2015), Kushwaha (2015), Kapoor (2011), Slovic (2000), Yadav and Rani (2011), Boykoff and Boykoff (2007), Kakade *et al. (*2013)] found that on their research articles mass media are the effective tools to create environmental awareness.

It is said that media is the mirror of society and fourth pillar of the state. In these days media has become the important part of life. However, we know that, mass media is to inform and educate the people. Only media can motivate people easily. Media also set the agenda. The media agenda influences and interacts with the people and the policy agenda. When all of these are connected then the state of the environment would be changed (Lyytimaki, 2012). The dynamics of contemporary socio-ecological systems media representations are very important.

Media coverage of environmental issues helps the readers to understand the concepts that shape their beliefs and perspectives. The mass media play an important role in forming the positive attitudes of the public towards environment.

Among the mass media, the newspaper plays a major role in circulating information, form perceptions, create awareness and thus, catalyze environmental actions. Print media is one of the most popular and efficient forms of mass communication. It plays an important role in transforming and educating the society. With more in depth news and analysis, print media influences and shapes the perception of readers. It has the benefit of creating a longer influence on the minds of the reader, with more in-depth coverage and investigation (Roba, 2012).

Thus, socially responsible media in their reportage can make issues be seen as important at a given time in a given society by placing emphasis on such issues. This could be through frequency of reports, the prominence given to the reports and analysis of the issues at stake. Thus, this study explores the coverage patterns of environmental issues in the mainstream newspapers of Bangladesh, due to its significant impact on human socio economic life. Specially, the existing literature advances that environmental issues and problems are of the lack of attention in newspaper reportage. Considering these the researcher tries to find the how is the coverage patterns of environmental news in Bangladesh newspapers.

Objectives of the Study:

The general objective of the study is to examine the coverage patterns of environmental news in mainstream newspapers of Bangladesh. The main objective of this study is to analyze and explain the practice of presenting environmental news in mainstream newspapers of Bangladesh. To achieve the major objective of the study; following specific objectives have been undertaken:

- To see the coverage patterns of environmental news in mainstream newspapers of Bangladesh
- To find out the environmental issues that are reported on three newspapers
- To find out the level of prominence given to environmental issues in the three dailies
- To assess the role of media in presenting environmental news

2. Methodology

The study is descriptive and qualitative in nature which implementing content analysis. Content analysis is a systematic research method used here to describe the coverage patterns of environmental news in mainstream newspapers of Bangladesh. In here primarily, data were collected through content analysis. As mentioned, the main focus of the study is to analyze the coverage patterns of environmental news in the print media of Bangladesh hence the content analysis is the most suitable research method for this study. Neuendorf (2002) observes that the appropriate approach to analyze the production of media programs is content analysis.

However in order to carry out the research objectives, qualitative and quantitative methodology were employed. Both qualitative and quantitative methods were used to analyze the coverage patterns of environmental news. The study of content materials yielded quantitative data. To represent the quantitative data table were used and for qualitative analysis in here narrative discussions used.

Hence primary data were collected through content analysis. For this study, content analysis was conducted on three mainstream newspapers of Bangladesh namely, *Ittefaq, Prothom Alo and Daily Star*. These three newspapers were selected based on their highest circulation. The fifteen years of study were, from 2004 to 2018 as it was the study aim to observe the coverage patterns of environmental news on those three newspapers in different phases.

A constructed sampling method was used to select the newspapers. This method is used to identify types of cases for in-depth investigation and to represent each day of publication (Krippenforff 2004). For example, for the month of January 2004, Saturdays copies were examined; February's, Sunday's; March's, Monday's and so on. As such, 12 copies of each newspaper were selected for each year. Hence, total 540 (*Prothom-Alo* 180 , *Daily Star* 180 and *Ittefaq* 180) copies of newspapers were analyzed from three identified newspapers for this study. Altogether 933 articles were collected from the three identified newspapers. For qualitative analysis of this study, all of 933 environmental articles of newspapers were analyzed.

3. Result

3.1. Total Coverage of Environmental News Articles

Table 1 and Figure 1 reveal that the Daily Star covered the most environmental news, 333 (including 58 image features), of the three newspapers studied. Prothom-Alo published 320 items (including 33 photo features) and Ittefaq produced 280 stories (including 11 picture features), which is the smallest number of the three daily. The Daily Star published the most picture features, whereas Ittefaq published the least picture features, according to the researchers. Only about 1% of the news in each of the three daily was about the environment. The study demonstrated how much emphasis these three newspapers place on environmental issues in their reporting.

Table 1. Total coverage of environmental news articles

Newspapers	Total News	Total Environmental News with Picture Feature	Picture Feature	Percentage (%)
Daily Ittafaq	24300	280	11	(1.1%)
Daily Prothom-Alo	21600	320	33	(1.4%)
Daily Star	18000	333	58	(1.8%)

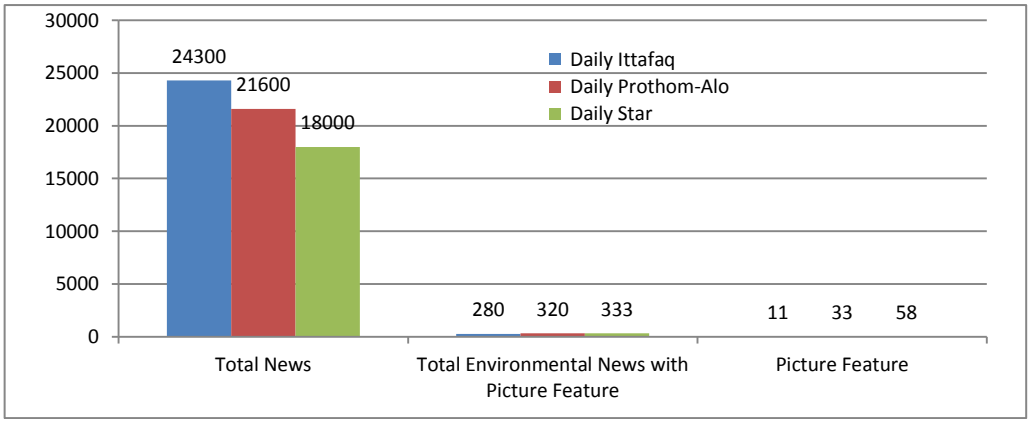

Figure1. Total coverage of environmental news articles

3.2. Placement of Environmental News Articles

Table 2 shows that Ittefaq published 9.2% of environmental news, Prothom-Alo published 11.8 percent, and Daily Star published 10.5 percent of environmental news on the main page. Three dailies on the final page also reported a low amount of environmental news, about 9%. However, it is noteworthy that all of the dailies placed greater emphasis on the inside pages, which covered about 80% of the news. According to the findings, these newspapers do not pay special attention to the front page. As a result, the placement of environmental news shows that the environment is not a major issue of discussion in the country's press.

Table 2. Placement of environmental news articles

Newspapers	First Page	Middle Page	Last Page	Total
Daily Ittafaq	26(9.2%)	230(82.1%)	24(8.5%)	280
Daily Prothom-Alo	38(11.8%)	248(77.5%)	34(10.6%)	320
Daily Star	35(10.5%)	267(80.1%)	31(9.3%)	333

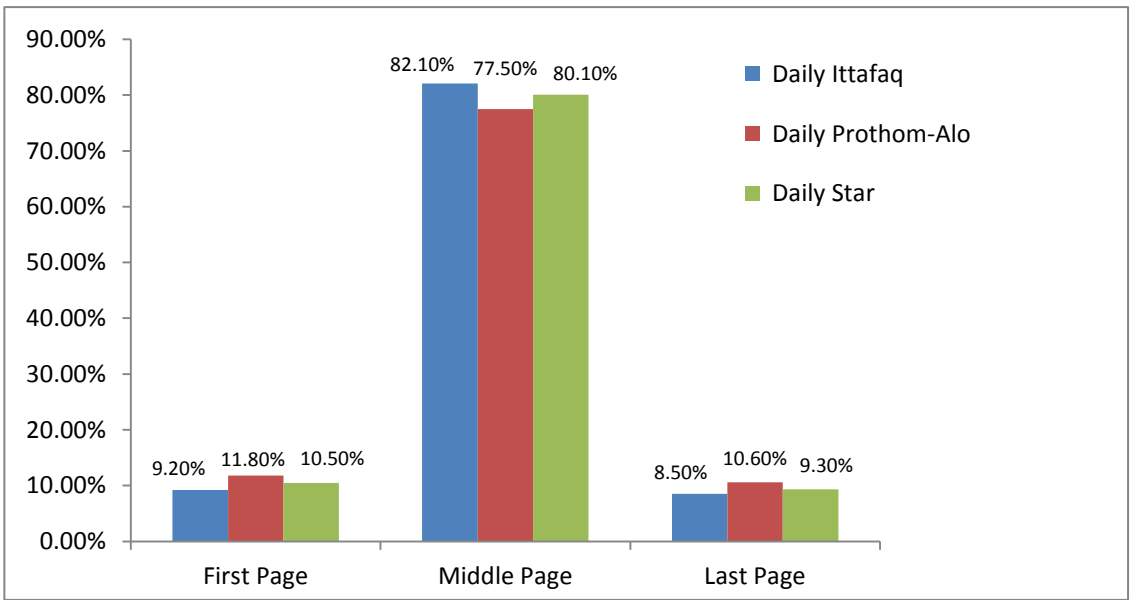

Figure 2. Placement of environmental news articles

3.3. Level of Environmental News (place based)

In here we see that Prothom-Alo reported mostly local news which is 51.2 percent and Daily star reported mostly national issues which is (43.2%). And also the international level Daily Star coverage more stories rather than Prothom-Alo and Ittefaq. Figure showed that all the dailies mostly reported local and national issues than international issues.

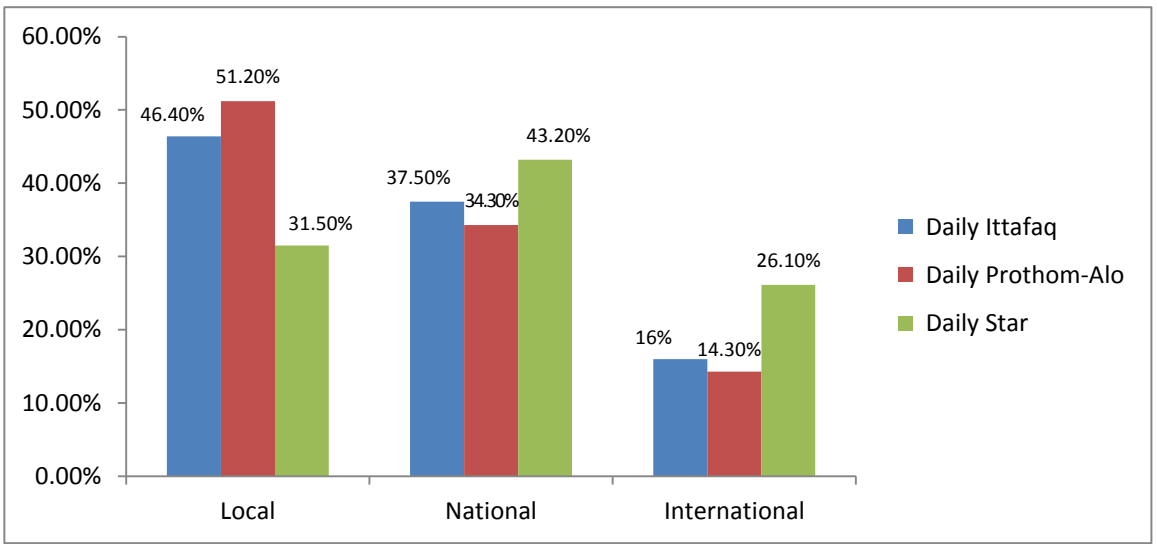

Figure 3. Level of environmental news articles

3.4. Column-Based Coverage of Environmental News

In this study table 4 showed that all the dailies mostly used one, two and three columns news as environmental reporting. The Daily Star covered many stories as four, five and six columns and also covered many eight column news stories. It is significant that there is no any box news. So it is indicated that the newspapers coverage more on straight forward news.

Table 4. Column-based coverage of environmental news

Newspapers	1 Col	2 Col	3 Col	4 Col	5 Col	6 Col	7 Col	8 Col	To tal
Daily Ittafaq	35(12.5%)	85(30%)	98(35%)	49(17.5%)	5(1.7%)	3(1%)	0(0%)	2(0.7%)	280
Daily Prothom-Alo	80(25%)	93(29.0%)	104(32.5%)	35(10.9%)	6(1.8%)	1(0.3%)	0(0%)	1(0.3%)	320
Daily Star	35(10.5%)	63(18.9%)	93(27.9%)	68(20.4%)	28(8.4%)	20(6.0%)	0(0%)	26(7.8%)	333

3.5. Photograph Used in the Environmental News

According to the study, the Daily Star and Ittefaq paid more attention to the picture attachment of environmental news than Prothom-Alo. Daily Ittefaq and Daily Star published over 40% photo features as environmental news stories, while Prothom-Alo published over 29% picture feature as environmental news pieces. It demonstrates that all of the daily image attachments are satisfactory.

Table 5. Photograph used in the environmental news

Newspapers	News with Picture	News without Picture	Only Picture	Total
Daily Ittafaq	124(44.2%)	145(51.7%)	11(3.9%)	280
Daily Prothom-Alo	95(29.6%)	192(60%)	33(10.3%)	320
Daily Star	145(43.5%)	130(39%)	58(17.4%)	333

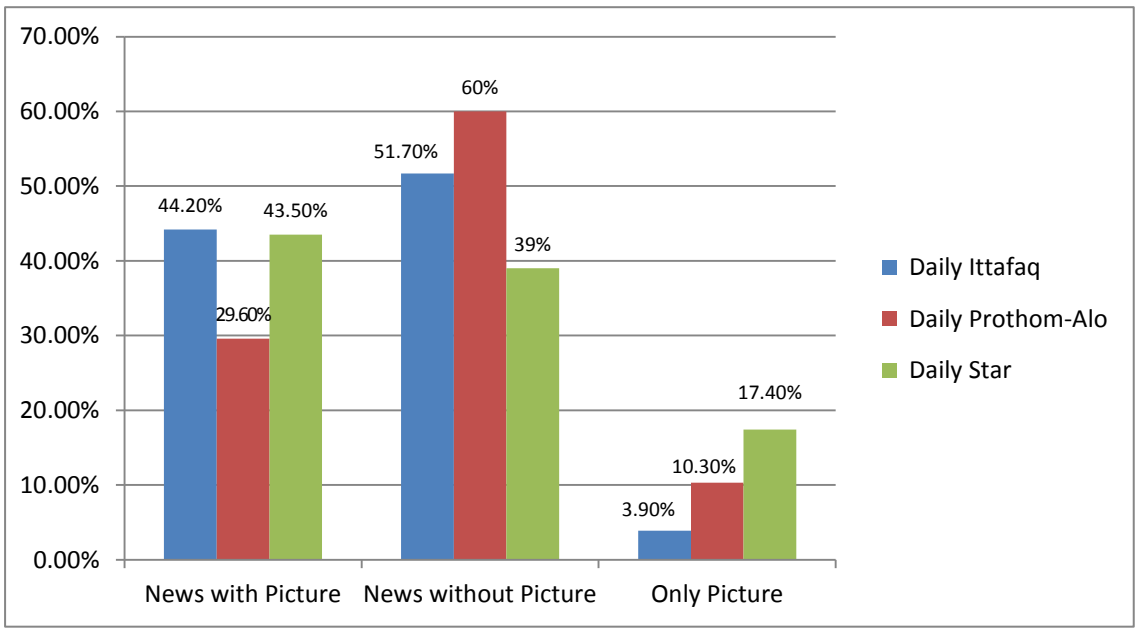

Figure 5. Photograph used in the environmental news

3.6. Number of News in First Page and Opinions in the Editorial page

In terms of journalism, the front page and editorial pages are extremely significant. The first page of environmental news coverage, as well as the editorials page, is particularly essential. In general, highly important issues were reported on these two pages. The researcher discovered that all of the selected daily' first pages and editorial pages are underutilized. It is interesting that the study found that during content analysis, particularly on the initial pages, issues were so trivial that no serious difficulties were recorded.

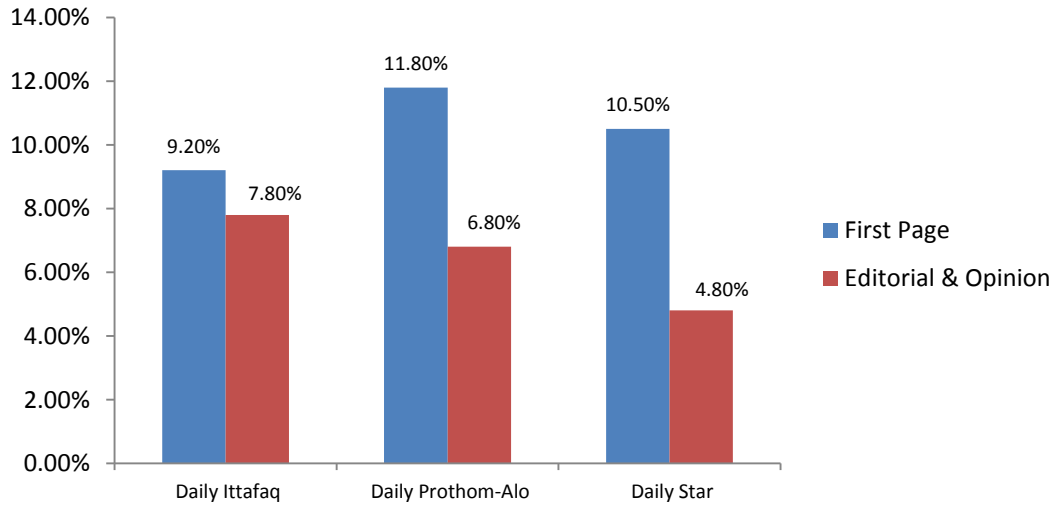

Figure 6. Number of news in first page and opinions in the editorial page

3.7. Sources of Environmental News Articles

When looking at the sources of environmental news, it was discovered that the three daily primarily used correspondents and news agencies as sources of environmental news. The news agency and staff correspondent provide the majority of the information. In three days, no specific reporter was utilized as a source of news, though Prothom-Alo only used 2% of its reporters as a source of environmental news.

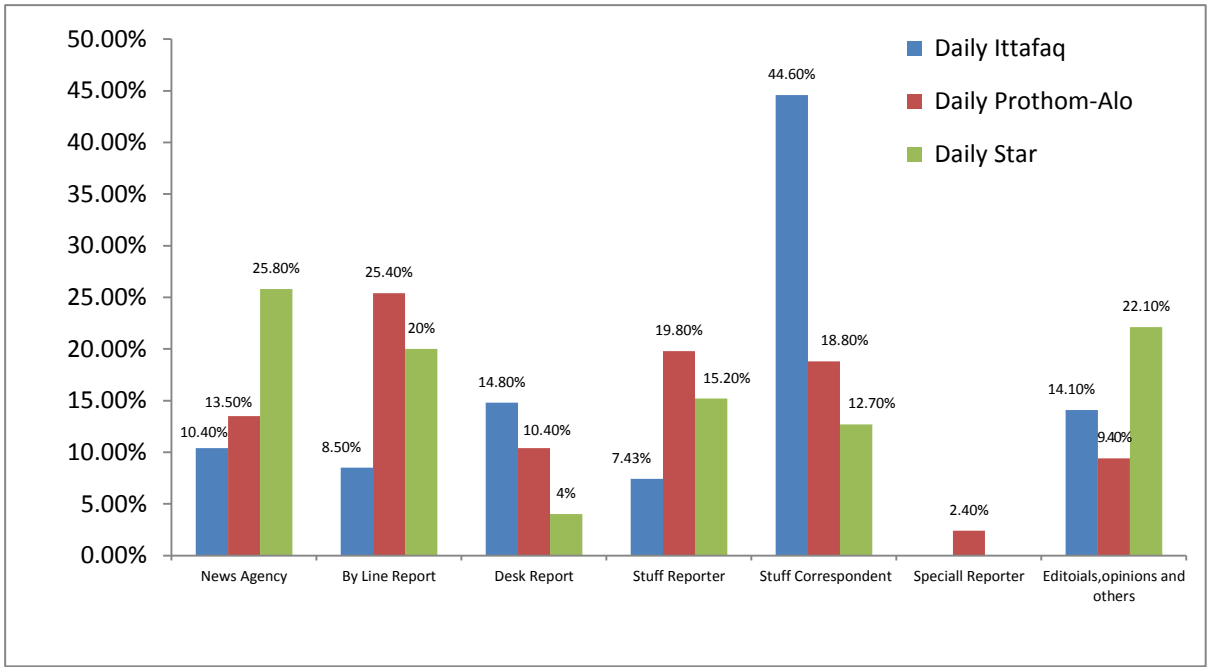

Figure 7. Sources of environmental news articles

3.8. Category of Environmental News Articles

All of the newspapers, according to the table and figure, mostly covered disasters (natural and man-made). Compared to other newspapers, the daily star covers more climate change topics. The three newspapers also covered a wide range of environmental concerns. In addition, the three daily covered far too many seminars and conference-related topics. It is noteworthy that none of the newspapers have covered more issues of forestation, deforestation, biodiversity, garbage disposal, environmental health, and development, all of which are critical to the people's well-being. Because a small number of items have been published on those topics and that's why these environmental issues are categorized in others name.

In this study, the researcher discovered that these three newspapers reported nearly 498 stories out of 831 on disaster-related topics, as well as an excessive amount of seminar and conference-related news that was reported without analysis.

Table 8. Category of environmental news articles

Newspapers	Climate Change	Disaster (Natural and Manmade)	Compensation & International Funding	Environmental Pollution	Seminars & Conference	Others	Total(without picture)
Daily Ittafaq	18(6.6%)	172(63%)	10(3.7%)	29(10.7%)	24(8.9%)	16(5.9%)	269
Daily Prothom-Alo	11(3.8%)	179(62%)	6(2%)	29(10.1%)	36(12.5%)	26(9%)	287
Daily Star	35(12.7%)	147(53%)	10(3.6%)	32(11.6%)	25(9%)	22(8%)	275

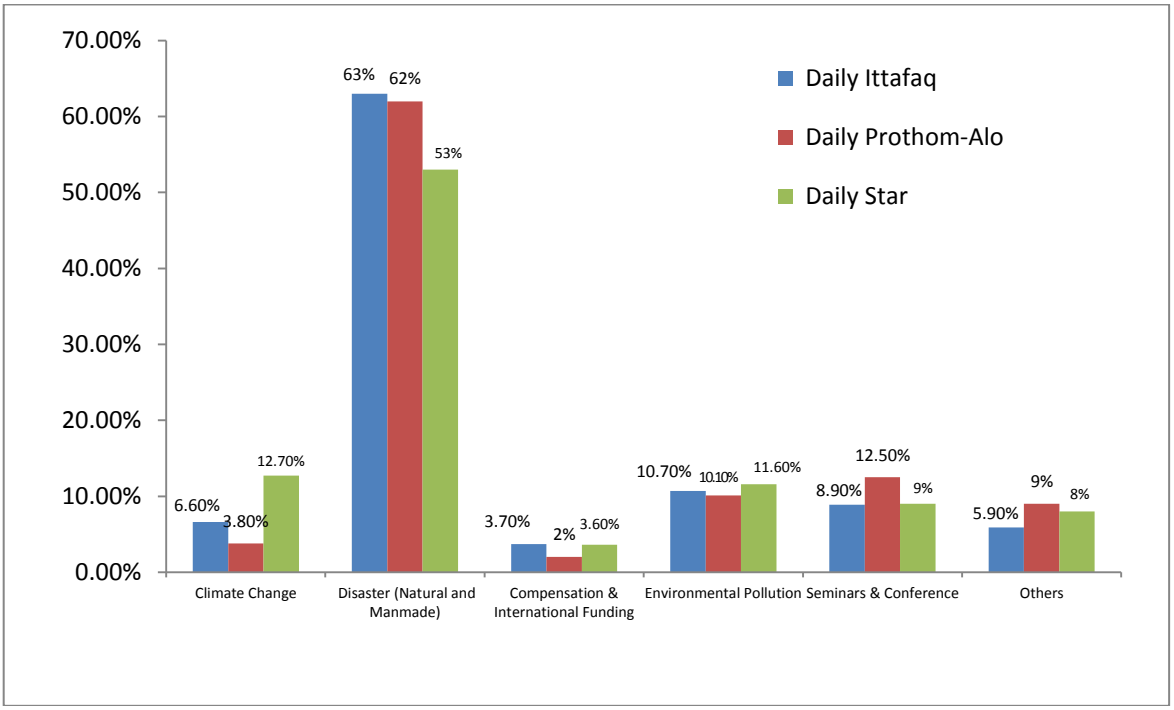

Figure 8. Category of environmental news articles

3.9. Patterns of Environmental News Articles

According to the analysis, all publications reported primarily straight jacket news, with environmental topics accounting for nearly half of all stories. As deep news, the three dailies reported on a small number of subjects. Three dailies' feature and follow-up stories are likewise unsatisfactory. The practice of investigative reporting is unsatisfactory, despite the fact that three dailies publish interpretative news. The number of follow-up and feature stories in newspapers is extremely low.

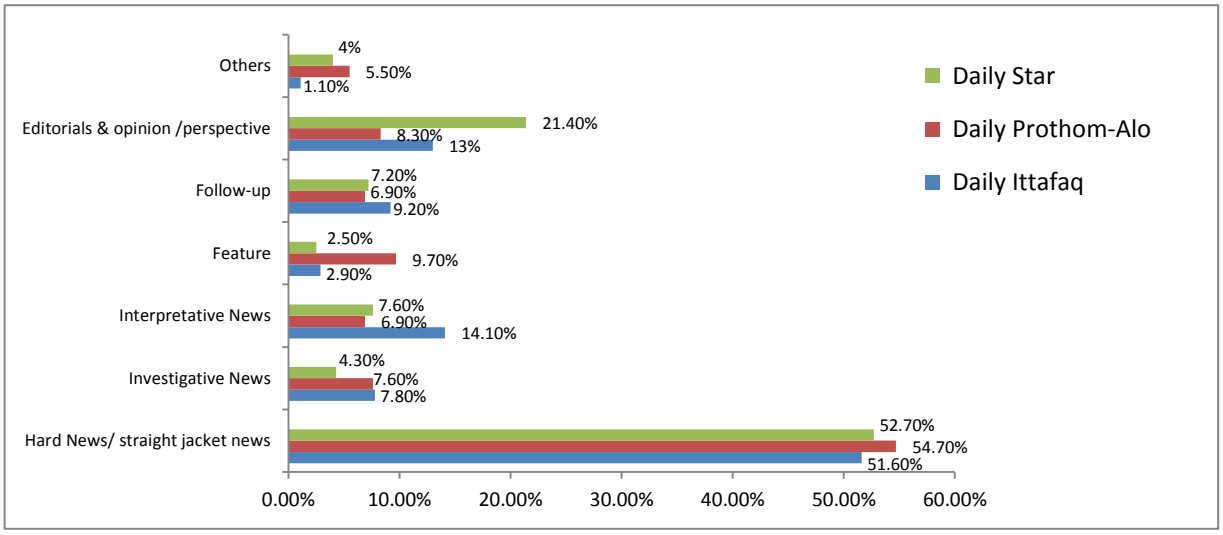

Figure 9. Patterns of environmental news articles

3.10. Nature of the Story of Environmental News Articles

The majority of the reports were determined to be simply reported without any in-depth investigation. Almost half of the issues were reported as just report by Ittefaq, Prothom Alo, and the Daily Star. In this case, the reporter just reported any incident or its aftermath without providing any context for the occurrence. The three newspapers also cover the same topics in terms of public awareness. The daily star reported on solution-based news from more than two newspapers. However, all three dailies covered less than 10% of environmental news from a law and policy standpoint.

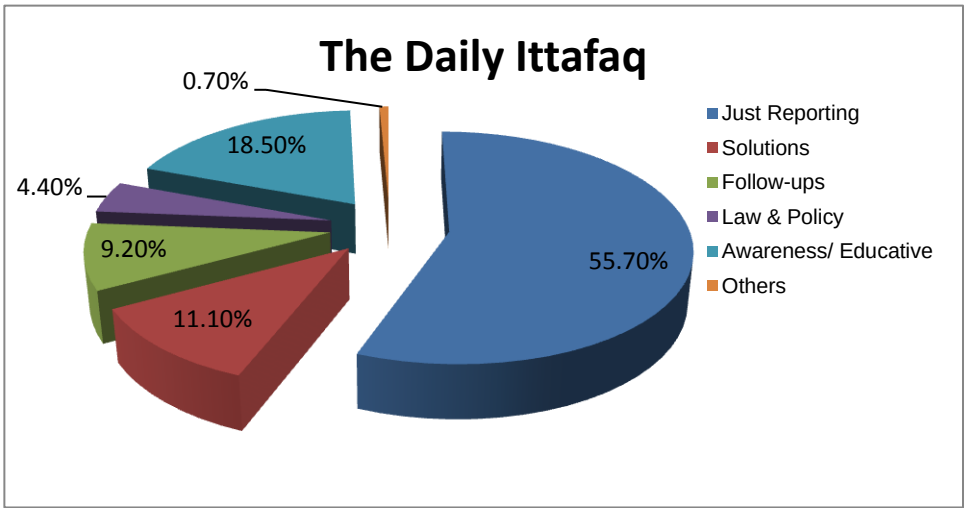

Figure 10. Nature of the story of environmental news articles

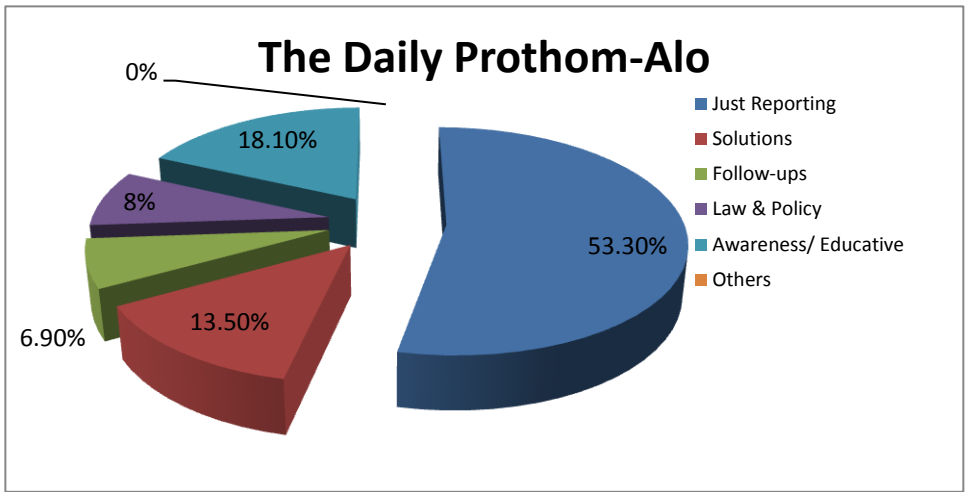

Figure 11. Nature of the story of environmental news articles

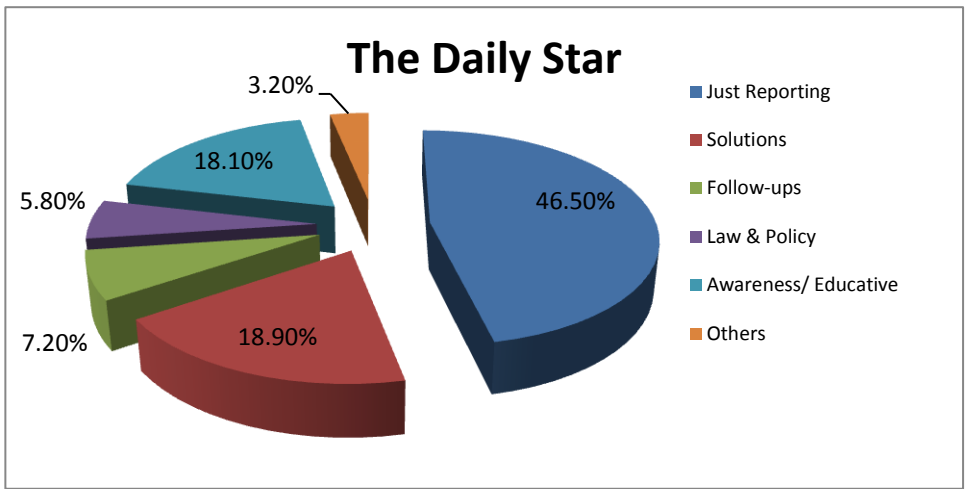

Figure 12. Nature of the story of environmental news articles

4. Qualitative Analysis of environmental news

In this section, we discussed the coverage patterns of environmental news of three selected newspapers that was our study sample. To discuss the coverage pattern of environmental news in here researcher used qualitative approach. So some patterns were showed after qualitative approach. These are following:

In the mainstream newspapers of Bangladesh, environmental news does not represent properly. Environmental issues are not getting optimal space. All the three dailies reported around 1.3% news as environmental news of the total news coverage. Though newspapers always published more political, entertainment and sports news but in environmental news they gave very little space. Moreover, in the newspapers first page and editorials page are very important. In here newspapers published various important issues. But study revealed that in first page and editorials page, environmental topics were not seen as a prominent topic on three dailies. These newspapers did not covered sufficient news in first page and editorial page. Most of the environmental stories were covered in middle page.

We know that a picture speak thousand of words. The press regards that photograph as the best extra information attached to environmental articles. Visual images are important for environmental news representation in order to put some 'soft' element into the stories. Study revealed that Picture attachment is sufficient. Among of three dailies it is seen that Daily star gave more importance to the picture attachment.

In-depth reporting means deep analysis on the issues that answered who which what how, when, where questions. By these types of analysis readers know that more valuable information and can give more priority on the issues. But qualitative analysis found that these dailies maximum stories were just reporting which means when an event occurred newspaper report it, but they did not search reason behind it. The study found that, lack of in-depth reporting are noticed in these newspapers. Qualitative analysis also found that straight jacket news was getting more priority regarding environmental issues in these newspapers. Data analysis also found there are a few articles were covered as a feature follow-up story but there have been no any new suggestion and educative message. These newspapers mostly covered event based stories as an environmental news articles.

After qualitative analysis it also found that, these newspapers have lack of diversification to representing the environmental issues. They gave more priority on particular issues like disaster(manmade and natural), but they did not focus on more important issues like climate change, waste disposal, threat of biodiversity ,environmental development etc. However, there have been no produce any analytical news in these newspapers that also found by the qualitative analysis. These newspapers mostly used news agency, staff correspondent, Staff reporter as a

source of news that's why environmental news were not analytical and most of the stories are only informative not educative.

If we assess the role of those newspapers to coverage the environmental stories study showed that these are not satisfactory. The mainstream newspapers of Bangladesh does not play important role in presenting environmental issues.

5. Discussion

Environment is the most vulnerable topics in the Bangladesh perspective, so these issues how are addressed by the newspapers it is investigated in this study. They present study found that the selected dailies published total 933 environmental stories in the fifteen years (2004 to 2018) of the study period where the *Daily Ittefaq* published 280 stories, *Daily Prothom alo* published 320 stories and the *Daily star* publish 333 environmental stories. To conducted the quantitative and qualitative analysis it was found that among 933 stories 498 stories were covered as a disaster related issues. The three dailies reported mostly straight jacket news and the majority of the stories were published without any investigation or in-depth analysis. Rahmatullah,*et.al* (2021) found that local dailies of Rangpur, given more priority on natural disaster issues without deep investigation or in-depth analysis. Prasad *et al.,* (2009) found that environmental stories on other topic were very few and also shorter in duration and the stories were mostly related to crisis and disaster oriented like landslides and floods. Miah et al. (2011) revealed that the highest (47%) of the issues were natural disaster-related. Saikia (2017) also found that in India media involvement of environmental news is only event-based, environmental issues are not media's prime agenda. Moreover, environmental issues are not get fair and optimal space in India's media

In this study researcher also found that first page and editorials page were not getting priority, among 933 articles most of the stories are reported in middle page, though front page is the most valuable page of the newspapers where the important days news covered by the newspapers. It is indicated that environment topic is not identified as a prominent topic of discussion in the three newspapers. Hasan and Pryanka (2019) study also mentions that the majority of the stories published on the inner page (others page).

Environmental news gets little space in the newspapers. All the three dailies reported around 1.3% news as environmental news of the total news coverage. Roba (2012) found that environmental issues are not getting proper emphasis by the media and these issues were too brief and other issues get priority in coverage. Boyagoda (2017) stated that environmental issues are not only ignored but they were given very small portions in the newspapers.

Very small amount of investigative, interpretative, feature and follow-up stories are covered by the selected newspapers. The study also found that these newspapers published many local environmental issues. News agency, staff correspondent are used as a source of news and local people and government agencies are used as a source in news mostly in these three newspaper. It's indicated that all the three newspaper no produced analytical news. All the three newspapers picture inclusion is satisfactory but jump inclusion is so poor. Most of the stories are covered in one two and three columns though daily star published to much above three columns and also eight columns story. So if we see the role of the selected newspapers to present the environmental issues it is revealed that that overall coverage patterns are not satisfactory though the three dailies do cover environmental stories. So it is concluded that the mainstream newspapers of Bangladesh do cover environmental reporting enough but not get proper emphasis on the issues. Hasan and Pryanka (2019) and Ferdous and Khatun (2020) found the same result from their study. They also found that environmental issues of Bangladesh newspapers do cover, but didn't give more priority on the issues.

6. Conclusions

After examining the coverage patterns of environmental issues researcher concluded that the mainstream newspapers of Bangladesh did cover environmental reporting though the subject matter did not receive much coverage neither got proper emphasize. It is explored that the patterns of environmental news are almost same on the three dailies. In these newspapers, environmental news is not getting optimal space and consideration as a topic of prominent issues. Straight jacket, event based, one sided, regional, official centered issue based such type of patterns was shown in the practice of presentation environmental news. Here picture attachment is satisfactory but jump news inclusion is so poor. The result showed that the newspapers gave more priority on the particular issues. There is no produce too many analytical news, most of the news are reported without detailed

analysis. It is seemed that some important issues that are very important for the people need to be more exposed and covered to educate the public.

The presentational practice in mass media is very important now days. But the present study found that practice of presenting environmental news is quite poor in mass media. Though the people of Bangladesh depend on the media for environmental information heavily, but the coverage of environmental news is rather limited compared to other areas although the nature of environmental reporting is strong in here. Most environmental stories are straight jacket and event based in here; these are not educating the people. So people are not informed about environmental situation by mass media. Though environmental issues are more sensitive in all over the world, but mass media is not communicating properly with the people. As media is the most effective tool for environmental news communications, so it is needed to increase and improve the environmental news coverage in the media.

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