Flash Flood Management Approach for Flood Risk Areas Using Numerical Climate Modeling Data Analysis

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Research

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Flash flood management approach for flood risk areas using numerical climate modeling data analysis

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Abstract

The present study measures management of flash flood to avoid the devastating impacts on boro rice production at Sunamganj district. This study interacts for meteorological parameter assessment with global climate data. Three major climatic parameters (precipitation, temperature and cloud fraction) have been considered for this study. These three climatic data were analyzed using numerical software EdGCM for the period 1920 to 2020 and then downscaled by Transform software. Flash floods have been classified as general flash floods and devastating flash flood. Flash floods have been reported to be severe in March and April. A trend was evaluated for the detection of flash flooding occurrences. The study concludes that when temperature is high, a small amount of rainfall can cause a slight cloud fraction to cause flooding. Flash flooding occurs when temperature is above 76°F(24.44^{o}C), rainfall is at least 3 mm and cloud fraction is at most 46%. Furthermore, for validation Mann-Kendall trend analysis have been done. The test result discovered increasing trend for rainfall and decreasing trend for temperature and cloud fraction. Finally, an algorithm was developed in C++ program as a flash flood precaution tool which helped to prepare strategy as well as to adapt with the flash flood.

Keywords: Flash flood, Boro rice, Numerical Climate Modeling, Risk analysis, Mann-Kendall test, Strategy development.

Introduction

Flash floods arise from intense storms dropping large amounts of rain within a short duration with little or no warning. The occurrence of flash flooding is of concern in hydrologic and natural hazards science due to the top ranking of such events among natural disasters in terms of both the number of people affected globally and the proportion of individual fatalities (Borga, 2011). A flash flood or a rapid onset flood refers to short duration flooding with a comparatively high peak discharge of water in a particular place. Flash flood occurs within a few hours of heavy rainfall, rapid snowmelt or after a sudden glacier lake outburst or embankment failure or very rapid break up of an ice block which is due to rapid increase in temperature. Flash flood stimulates shortly after sever rainfalls reaching up to 100 mm within 6 hours and extreme flow of high water and normally occur in small dry valleys. In the flash flood events unexpected increase in water close in streams and rivers and very high flow speed bring large amount of debris, boulders, uprooted trees, obliteration of infrastructures and constructed buildings stand in its path. (Hill,2010). The frequency of natural disasters has been increasing over the years, resulting in loss of life, damage to property and destruction of the environment (Living with Risk, 2000).

Agriculture is a risky business in Bangladesh. Crop production of farmers is badly affected by a diverse range of risks (Swanson, 2008). Flood is part and parcel of living for a large number of people in Asia and the Pacific. It is a regular phenomenon particularly in such countries as Bangladesh, Myanmar, Thailand, India, Vietnam and Cambodia, where the loss of human lives, natural resources, crops and livestock have at times destroyed the financial backbone of farmers. There are about 31 million hectares of flood-prone areas in South and South East Asia, of which 13 million are used for agriculture, mainly for the planting of some form of deep-water rice

(Singh, et. al. 2001). In the haor areas of North-Eastern region, flood caused wide ranging damage of Boro crop, during the August flood, some areas were newly inundated after a long period and the two floods in spite of their distinctive features, have caused significant damage to affected areas. Damage was incurred in the form of: Loss of lives, dwelling houses and livelihood, crop damage and physical infrastructure damage. CPD has estimated the loss of Boro rice production to be to the tune to 15.8 lac MT. The loss is equivalent to 8.3% of national average of Boro production. This is about 52.2% of total Boro rice production of the concerned six districts. (CPD,2007). Haors with their unique hydro-ecological characteristics are large bowl-shaped floodplain depressions located in the north-eastern region of Bangladesh in Sunamganj, Sylhet, Moulvibazar, Kishoreganj, Habiganj, Brahmanbaria, and Netrokona districts (CEGIS, 2012). Almost 80% of the haor area is covered by boro rice which is the main crop and is frequently affected by the flash floods in the pre-monsoon months of April and May (Khan et al., 2012). The concept of risk assessment needs to be changed to include such measures as adaptation strategies and to recognize not only the role of geography, or location, but to also recognize socially constructed vulnerability (Chang CH,2011). Along with risk assessment there is also the issue of risk reduction, which is often limited in terms of funding and resources, but it is important to achieve it through awareness, education, dissemination, and community preparedness and to keep it in mind during health system planning (Few R, 2004). Adaptation is the principal way to deal with the unavoidable impacts of climate change. It is a mechanism to manage risks, adjust economic activity to reduce vulnerability and to improve business certainty (Governments, C. 2007). The framework for the formulation of a realistic strategy for adaptation to future floods was outlined and can be implemented in five, universally applicable, steps. These are: Flood risk assessment, building the scenarios of adaptation, scenario choice, analysis of legislative instruments and implementation. There are many gaps in the research that has been conducted on flash flood, including gaps in crop production, as well as the gaps in understanding how we can reduce the implications of climate change, which plays a significant role in the presence of natural disasters, especially floods. In terms of Boro production during floods, further research needs to be conducted to determine the appropriate variety of Boro Crop. Little research has been done to examine long–term health implications, even in high–income countries. This research would be important in order to learn how to provide counseling and continued care long after a flood has occurred. Mortality risks and risks of infectious disease also require research, as there is hardly any quantifiable research in this area.

Further research is also needed to determine to what extent climatic parameter adds to flash flood risks assessment and to develop a precaution strategy.

Objective of the study was

- To develop a formulation framework and precaution strategy about flash flood.
- To develop a suitable cropping pattern for the study area.

Materials and methods

Study area

This research has been conducted at the haor areas of Sunamganj district in the Sylhet division. Shown in Fig.1.

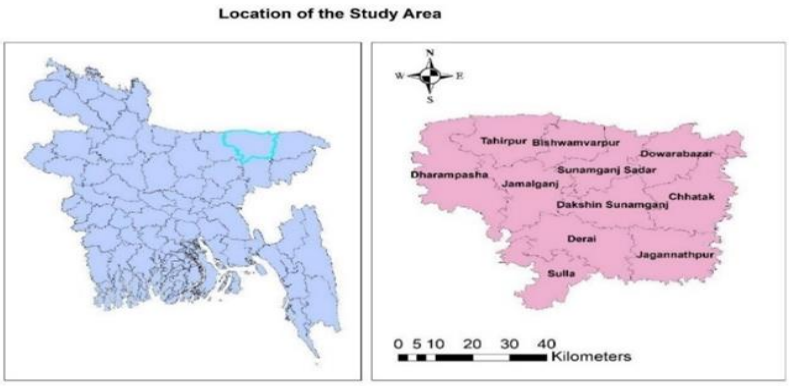


Fig. 1. Study Area

Sunamganj District (sylhet division) area 3,669.58 sq km, located in between 24°34' and 25°12' north latitudes and in between 90°56' and 91°49' east longitudes. It is bounded by Meghalaya state of India on the north, habiganj and kishoreganj districts on the south, sylhet district on the east, netrokona district on the west (Banglapedia)

Data Collection

Rainfall, temperature and cloud fraction data was considered for this study. 100 years' data of temperature, rainfall and cloud fraction was obtained from Educational Global Climate Model (EdGCM) software and then converted these data into regional/local scale by using Transform software.

Extracting data from EdGCM

At first data was generated by using the EdGCM software. EdGCM stands for Educational Global Climate Model. EdGCM, an integrated software suite designed to simplify the process of setting up, running, analyzing and reporting on global climate model simulations. Almost 100 years of data was generated for the parameter of Cloud fraction, Rainfall and Temperature. The data generated from EdGCM is in global format. To convert these data into regional scale Transform software was used. Transform software is a software that is used for statistical downscaling of global data into local data which is then used for climate modeling data analysis. Data extracting procedure was shown in Fig.2.

Fig.2. Data Extracting procedure from EdGCM

Results and Discussion

Risk is completely associated with uncertainty and damage. Symbolically, it can be present as:

Risk = Uncertainty + Damage.

Risk can be defined as the probability of loss; it depends on vulnerability, hazard and exposure. "Risk (i.e. 'total risk') means the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk". Total risk can be measured as:

Risk (total) = Hazard (Elements at Risk) +Vulnerability.

Risk and vulnerability are related to each other. Vulnerability is the plight of a commodity, system or asset that makes it susceptible to damage in the face of a hazard. Hazard on the other hand, is an unavoidable event that brings dangers.

The framework for flood risk management begins with the definition of 'flood risk'. There is no single definition for flood risk but the one that is very useful to start from says that flood risk is unity of hazard, exposure and vulnerability (Kron, 2005).

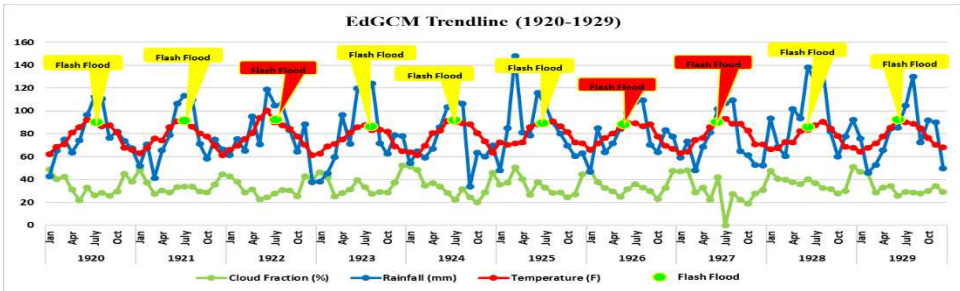
EdGCM trend analysis

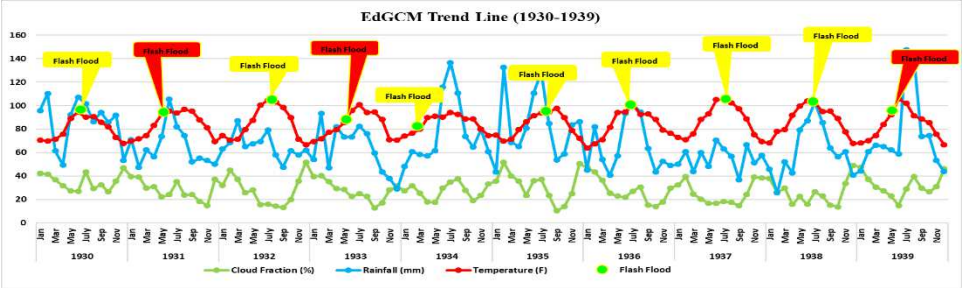
The trend is made using temperature, precipitation, and cloud fraction data. EdGCM and Transform software were used to generate global and downscaled data for Sunamganj district. Generally, normal flash floods occur in Sunamganj all year long, but in July to October, a high percentage of flash floods occur. According to data analyzed between 1920 and 2018, it was found that when the floods occurred in March and April, they became destructive in nature and in that time the flood situation, temperature, rainfall and cloud fraction were noted in-temperature minimum 76°F ($\geq$76^{o}F), rainfall minimum 3 mm ($\geq$ 3 mm) and cloud fraction maximum 46 % ($\leq$ 46 %).

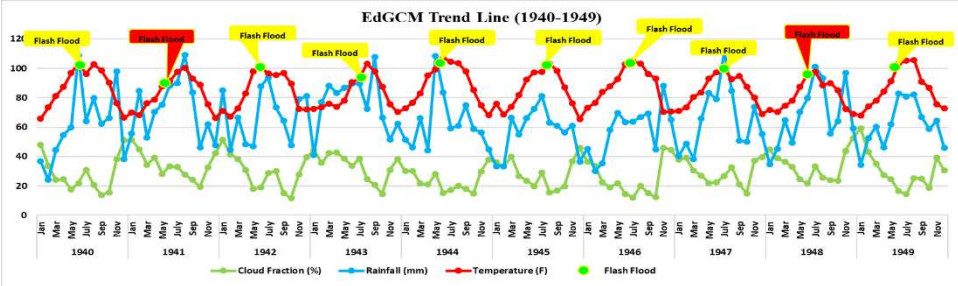
Trend analysis of Sunamganj district

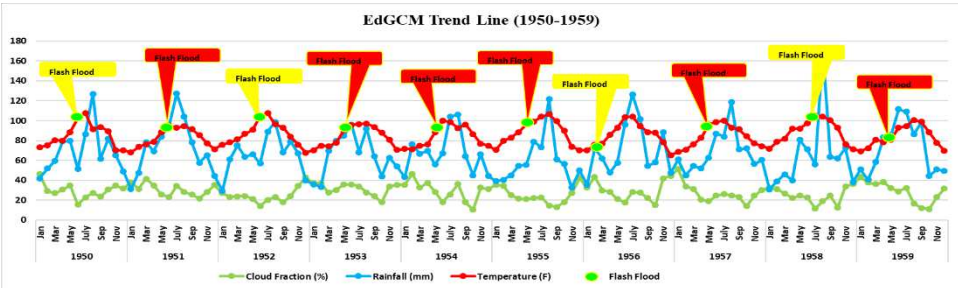
Covering all three parameters in the graph helps to have a clearer picture of the interdependence of these parameters. The green, blue, and red lines indicate the fraction of clouds, rainfall, and temperature, respectively.

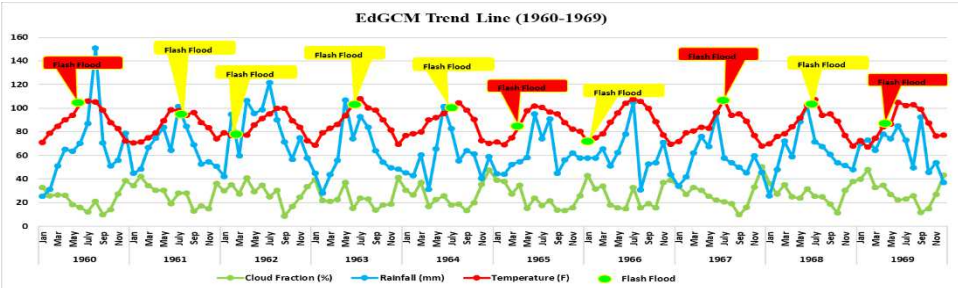
The green dots in the red line indicate flash floods. In fact, most of the temperatures are on the higher side during flash floods as the green dots coincide with the crest of the temperature line. Trend analysis of Sunamganj district step by step (1920-2020) was shown in Fig.3.











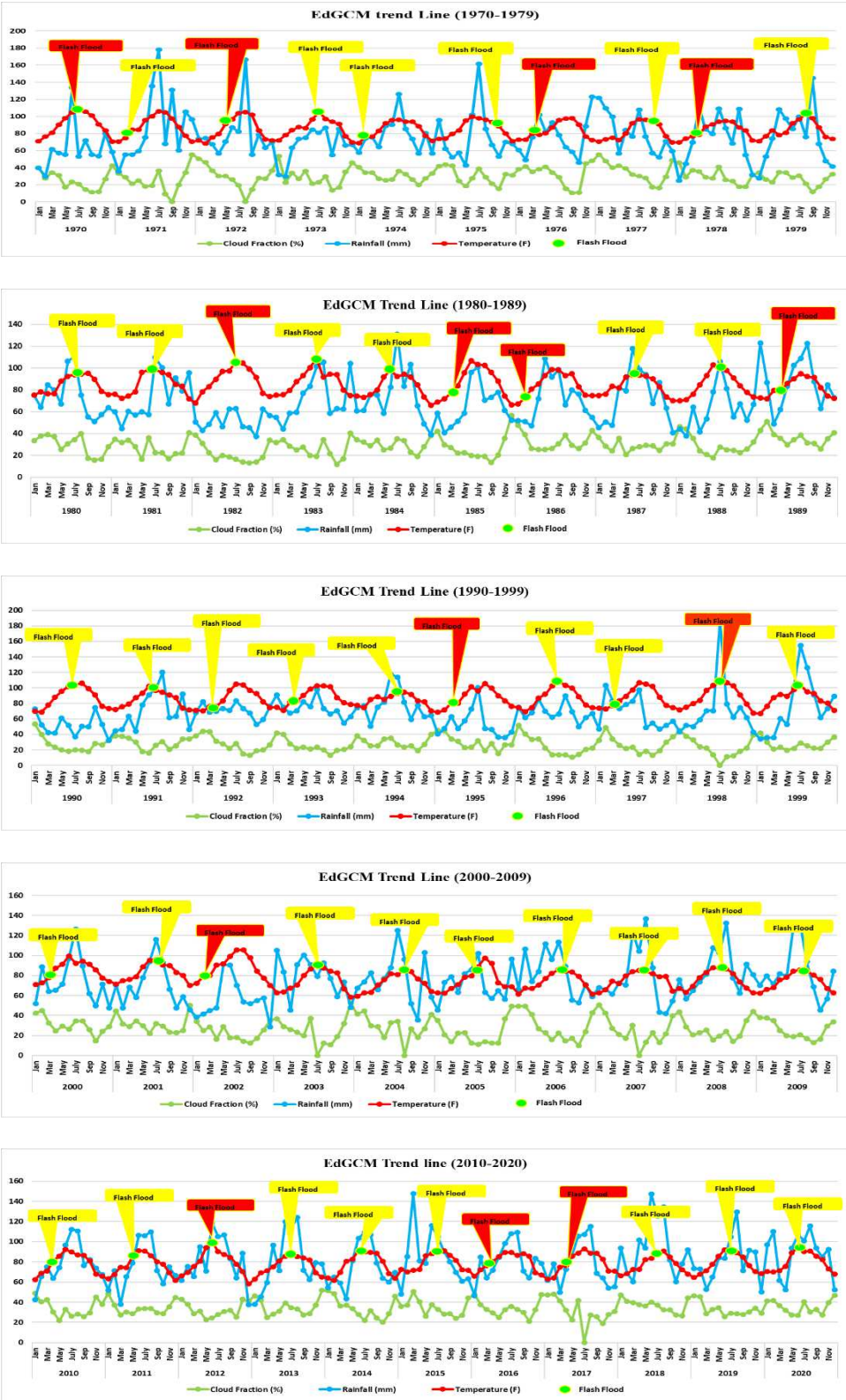


Fig. 3. Flash flood trend of Sunamganj district from 1920-2020

The devastating and non-devastating flash flooding year in the study area was shown in Table 1.

Table 1. Devastating and Non-devastating flash flood

Name of flash flood	Year
Devastating	1922,1926,1927,1931,1933,1939,1941,1948,1951,1953,1954, 1955,1957,1959,1960,1965,1969,1970,1972,1976,1978,1982, 1985,1986,1989,1995,1998,2002,2012,2016,2017.
Non-devastating	1920,1921,1923-1925,1928,1929,1930,1932,1934-1938,1940, 1942-1947,1949,1950,1952,1956,1958,1961-1964, 1966-1968, 1971,1973-1975,1977,1979-1981,1983,1984,1987,1988,1990-1994,1996,1997,1999-2001,2003-2011,2013-2015,2018-2020.

Mann-Kendall Z test for climatic parameters

Mann–Kendall trend test (Mann,1945) and (Kendall, 1976) which is one of the widely used (Basistha A et, al.2009, Oguntunde PG, et, al 2012) non-parametric tests to detect significant trends in time series is used in the present study. The Mann-Kendall trend test, being a function of the ranks of the observations rather than their actual values, is not affected by the actual distribution of the data and is less sensitive to outliers.

The results of Mann-Kendall Z test for 100 years were shown in Table 2.

Table 2. Results of Mann-Kendall Z test for 100 years (1921-2020) annual trend.

	TEMPERATURE	**RAINFALL**	**CLOUD FRACTION**
Time series	Annual	Annual	Annual
First year	1920	1920	1920
Last year	2020	2020	2020
No. of observations	100	100	100
Test Z	-0.71	2.60	-0.68
Trend	Decreasing (declining)	Increasing (inclining)	Decreasing (declining)
Significance	+	**	+
Sen's slope (Q)	-0.012	0.006	-0.010

Sen's slope estimator for climatic parameters

Trend of climatic parameters over the study period of 100 years were shown in Table 3.

Table 3. Trends of climatic parameters over the study period (1921-2020).

	TEMPERATURE	**RAINFALL**	**CLOUD FRACTION**
Sen's slope (Q)	-0.012	0.006	-0.010

Three different trends of temperature, rainfall and cloud fraction for 100 years was shown in Fig.4.

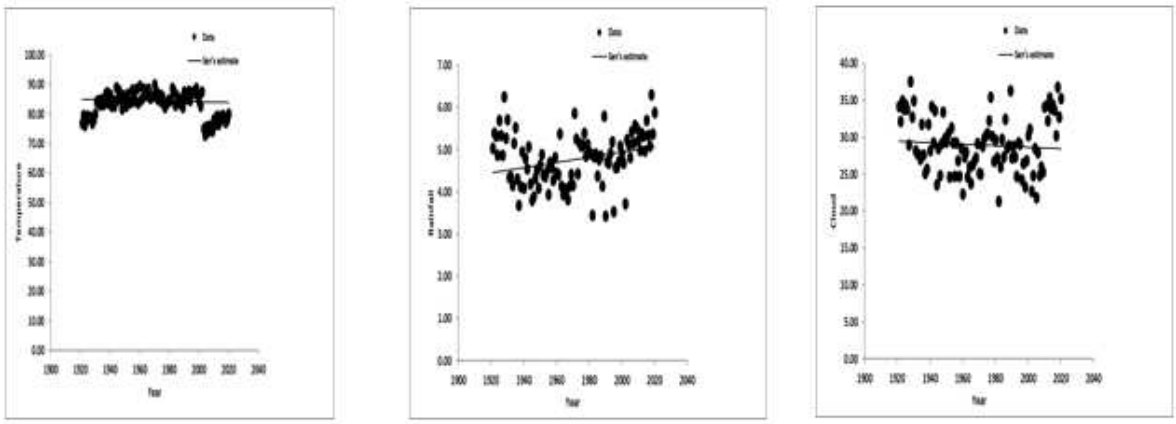


Fig.4. Trend of climatic parameters (temperature, precipitation and cloud fraction) for 100 years

Adaptation Framework

Flash Flood precaution tool was developed using C++ programme. The algorithm was developed to detect early or late flash flood.

```
#include<bits/stdc++.h>
using namespace std;
int main ()
{
string month [12] = {"JAN", "FEB", "MAR", "APR", "MAY", "JUN", "JUL", "AUG", "SEP", "OCT", "NOV",
"DEC"};
double temperature [12] = {64.904,68.414,71.6,77.63,85.55,91.904,90.212,89.042,85.01,75.92,69.89,69.206};
double rainfall [12] = {4.9,4.86,3.52,4.32,5.58,5.56,6.96,8.62,4.74,6.1,6,3.34};
double cloud [12] = {40.7,40.2,36.93,49.02,43.75,40,44.97,44.02,38.51,52.37,41.1,39.56};
int i = 0;
bool devastating = false;
bool early = false;
bool late = false;
bool flashFlood = false;
for (i = 0; i<12; ++i)
{
if (temperature[i] >= 74.0 && rainfall[i] >= 3.0 && cloud[i] <= 46.0)
{
flashFlood = true;
if (i == 2 || i ==3)
{
devastating = true;
}
if (i == 2)
{
early = true;
}
if (i >= 3 && i <= 8)
{
```

```
            late = true;
        }
    }
  }
  if (flashFlood == true && early == true)
  {
    printf("Early Flash flood\n");
    printf("You can plant BR28, BR29 variety\n");
  }
  if (flashFlood == true && late == true)
  {
    printf("Late Flash flood\n");
    printf("You can plant _______\n");
  }
  printf("-----------End-------------------------------\n\n");
  return 0;
}
#include<bits/stdc++.h>
using namespace std;
int main ()
{
  string month[12] = {"JAN", "FEB", "MAR", "APR", "MAY", "JUN", "JUL", "AUG", "SEP", "OCT",
"NOV", "DEC"};
  double temperature;
  double rainfall;
  double cloud;
  int i = 0;
  int j = 0;
  printf("Enter month name\n");
  for (j = 0; j < 12; ++j)
```

```
{
        cout << "If month = " << month[j] << " then press " << j << "\n";
    }
    while(scanf("%d", &i))
    {
        printf("Enter temperature\n");
        scanf("%lf", &temperature);
        printf("Enter rainfall\n");
        scanf("%lf", &rainfall);
        printf("Enter cloud\n");
        scanf("%lf", &cloud);

        bool devastating = false;
        bool early = false;
        bool late = false;
        bool flashFlood = false;

        if (temperature >= 74.0 && rainfall >= 3.0 && cloud <= 46.0)
        {
            flashFlood = true;
            if (i == 2 || i ==3)
            {
                devastating = true;
            }
            if (i == 2)
            {
                early = true;
            }
            if (i >= 3 && i <= 8)
            {
                late = true;
            }
        }
```

```
if (flashFlood == true && early == true)
        {
            printf("Early Flash flood\n");
            printf("You can plant BR28, BR29 variety\n");
        }
        if (flashFlood == true && late == true)
        {
            printf("Late Flash flood\n");
            printf("You can plant _______\n");
        }
        printf("-----------End-------------------------------\n\n");
        printf("Enter month name\n");
        for (j = 0; j < 12; ++j)
        {
            cout << "If month = " << month[j] << " then press " << j << "\n";
        }
    }

    return 0;
}

/*
75 >
5 >
45 <
2 early or
3 to 8 late
*/
```

```
D:\Algo_Lab\SAU_Input.exe
Enter month name
If month = JAN then press 0
If month = FEB then press 1
If month = MAR then press 2
If month = APR then press 3
If month = MAY then press 4
If month = JUN then press 5
If month = JUL then press 6
If month = AUG then press 7
If month = SEP then press 8
If month = OCT then press 9
If month = NOV then press 10
If month = DEC then press 11
2
Enter temperature
75
Enter rainfall
5
Enter cloud
40
Early Flash flood
You can plant BR28, BR29 variety
-----------End--------------------------------
```

```
Enter month name
If month = JAN then press 0
If month = FEB then press 1
If month = MAR then press 2
If month = APR then press 3
If month = MAY then press 4
If month = JUN then press 5
If month = JUL then press 6
If month = AUG then press 7
If month = SEP then press 8
If month = OCT then press 9
If month = NOV then press 10
If month = DEC then press 11
3
Enter temperature
75
Enter rainfall
7
Enter cloud
5
Late Flash flood
You can plant _______
-----------End--------------------------------

Enter month name
If month = JAN then press 0
If month = FEB then press 1
If month = MAR then press 2
If month = APR then press 3
```

Formulation of Precautions Strategy

A precaution strategy cycle was shown in Fig.5.

Fig. 5. Precautions Strategy Cycle

Flash Flood Forecast

- Flash flood trend should be developed before Boro season.
- Trend value should be input in develop flash flood precaution tool (in developed algorithm) for variety selection and decision making.

Need to Awareness

- Develop Community based organization.
- DAE and NGO Personnel
- SMS through Smart Phone.

Selection of Rice Variety

- Bangladesh Rice Research Institute (BRRI) developed rice variety.
- Department of Agricultural Extension (DAE) suggested variety
- Bangladesh Agricultural Research Council (BARC) recommended variety.

Flash Flood

- If flash flood occurs, then -

Response

- Rescue efforts
- First aid treatment
- Monitoring of secondary disaster
- Construction of temporary housing
- Establishment of tent villages

Rehabilitation

- Disaster resistant reconstruction
- Appropriate land use planning
- Livelihood support

Conclusion

This study approaches for identifying the meteorological factors that contribute to the occurring flash flood with global climate data and its impacts to local scale data. To attain the objective of the study three climatic parameters were selected. As early flash flood season in Bangladesh has saturated upper soil crust, so the precipitation directly transforms to runoff then converted to flood. So, the other parameters relating so soil do not consider for the study. The analysis of temperature, rainfall and cloud fraction have been done for Sunamganj district to detect flash flood during the period of 1920 to 2020. The data of temperature, rainfall and cloud fraction was generated by using EdGCM and then downscaled into local data by using Transform software. By analyzing it was found that when the temperature is minimum 76^0F, rainfall is minimum 3 mm and the cloud fraction is maximum 46 % then flash flood occurs. There is flash flood all the year around but it was also found that when flash flood hits in the month of March and April then it is more devastating in nature.

Based on the current study some potential recommendation can be made as follows:

1. The study was based on simulated data, further study should be done based on real time data to understand the situation in true manner.
2. The current study considered only three climatic parameters; more climatic parameters should be included to evaluate the trend.
3. A robust forecasting system could be developed to predict future flash flood years to take precautionary measures to reduce production loss.
4. Trend can also be developed for the other flash flood prone areas in Bangladesh.

Abbreviations

EdGCM: Educational global climate modeling

Acknowledgements

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Authors' Contribution

The corresponding author collects and analyzes the data, and wrote the manuscript. All authors read, edit and approved the manuscript.

Authors' information

N/A

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Availability of data and materials

The data will be available at the department of Agricultural Construction and Environmental Engineering, Sylhet Agricultural University, Sylhet-3100, Bangladesh.

Consent for publication

All the co-authors consented for the publication

Competing interests

There is no competing interest.

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Figures

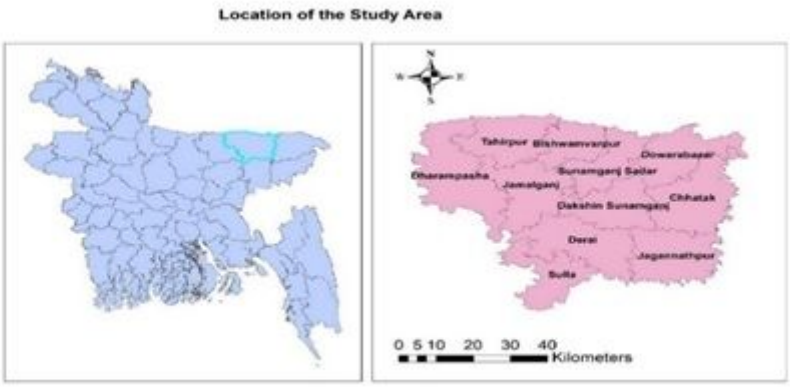

Figure 1

Study Area

Figure 2

Data Extracting procedure from EdGCM

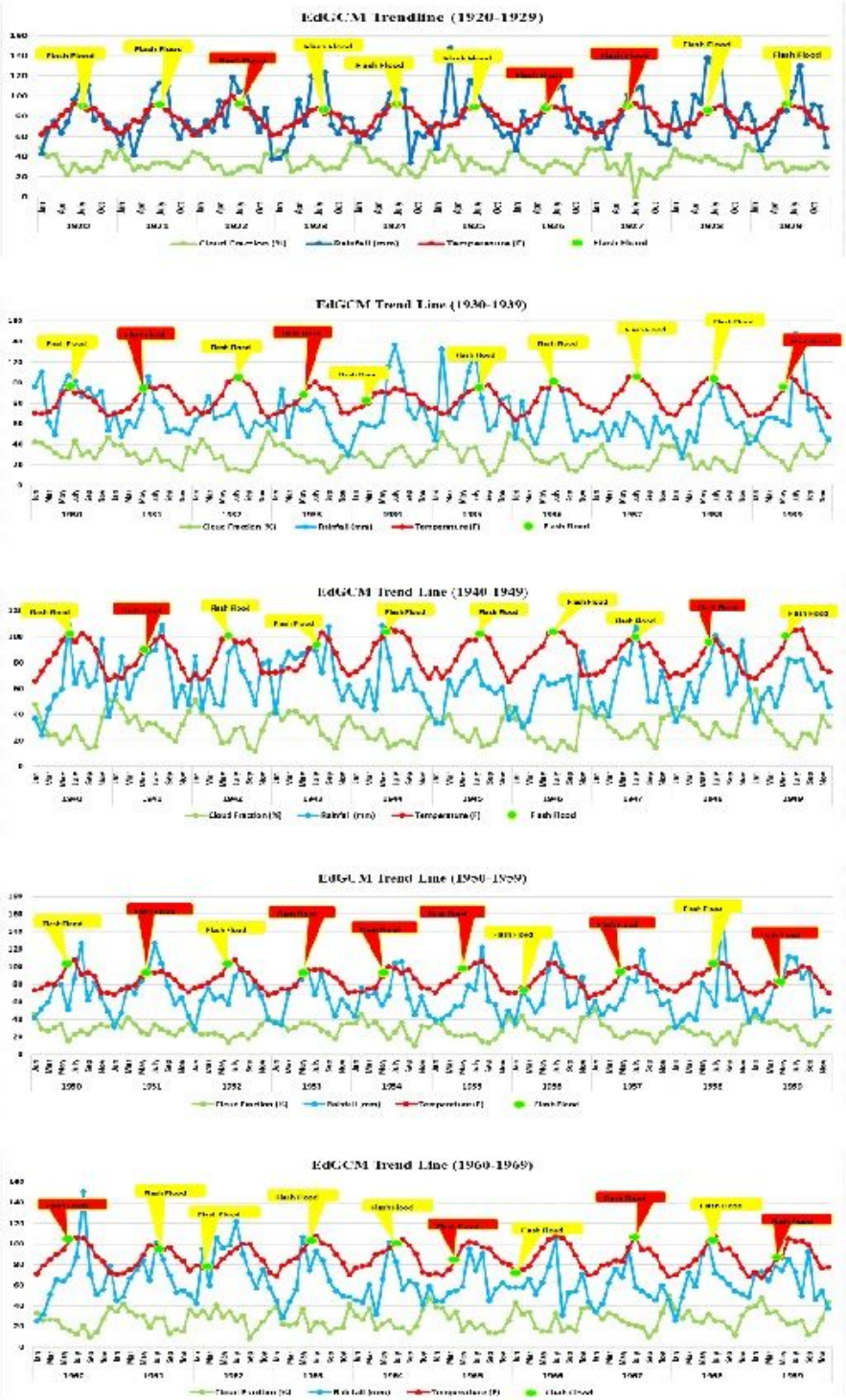

Figure 3

Flash flood trend of Sunamganj district from 1920-2020

Figure 4

Trend of climatic parameters (temperature, precipitation and cloud fraction) for 100 years

Figure 5

Precautions Strategy Cycle