Characterization of the Flooding Scenario of Bangladesh Using Flood Intensity Index

M.R. Tithi[1], M.S. Ali[2], R. Sadi[3], S. Tabassum[4]

[1]*Student, Department of Civil Engineering, KUET, Bangladesh (mayida_tithi@yahoo.com)*
[2]*Professor, Department of Civil Engineering, KUET, Bangladesh (msali@ce.kuet.ac.bd)*
[3]*Student, Department of Civil Engineering, AUST, Bangladesh (rafi.sadi.144@gmail.com)*
[4]*Student, Department of Civil Engineering, RUET, Bangladesh (sumayatabassum161@gmail.com)*

Abstract

Flood is the most devastating disaster in Bangladesh as it ranked 1st for the case of the population exposed and 3rd in the case of economic exposure in the world ranking of disaster. Besides, the summary of disaster parameters for time spans 1940-1980 and 1981-2018 showed that the number of disasters, affected people and economic loss due to these disasters increase with time at an alarming rate. In this study, the Flood Intensity Index (FII) was calculated as a function of inundation depth and flooding duration. In addition to that, the floods in different years were classified based on the average Flood Intensity Index (FII). Besides, the vulnerable stations to flood in Brahmaputra, Ganges, and Meghna basins were identified based on the estimated FII. However, this study was mainly concentrated on Flood Intensity Index (FII), the pattern of flood hydrograph of Bangladesh was also studied. Comparing 60 years of data of rainfall anomaly with the flood, it was observed in most of the cases that the flood anomaly of this country is in phase with that of territorial rainfall anomaly. Although it was expected that the huge upstream flow has a high impact on floods in this country, such a scenario was observed in fewer cases. Though the yearly variations in inundation depths for the selected (9 most vulnerable) stations were found to be negligible among high flooding years, the flooding durations showed considerable variations that cause the change in the Flood Intensity Index of Bangladesh.

Keywords: Flood; Flood intensity index; rainfall anomaly

1. Introduction

Bangladesh is the part of world's most dynamic hydrological and the biggest active delta system with an area of about 1,47,570 sq-km. It has 405 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna (BWDB, 2011). Three minor rivers originated from Myanmar. The topography, location, and outfall of the three great rivers shapes the annual hydrological cycle of the land. Too much and too little water in a hydrological cycle is the annual phenomenon. Regular monsoon event is the flood, the depth and duration of inundation are the deciding factors whether it is affecting beneficially or adversely. Monsoon inflow along with rainfall historically shapes the civilization, development, environment, ecology, and the economy of the country.

Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology, and environment (BWDB, 2017). But flood more than that causing direct and indirect damages and considerable inconveniences to the population.

The country is mostly flat with few hills in the southeast and the northeast part. Generally ground slopes of the country extend from the north to the south and the elevation ranging from 60 meters to one meter above Mean Sea Level (MSL) at the Northwest boundary of the country and at the coastal areas in the south. The land in the west of the Brahmaputra is higher than the eastern part. The Ganges, Brahmaputra and Meghna river systems together, drain the huge runoff generated from large area with the highest rainfall areas in the world. Their total catchment area is approximately 1.6 million sq-km of which only about 7.5% lies in Bangladesh and the rest, 92.5% lies outside the territory.

Bangladesh is a disaster-prone country, and the effect of climate change magnifies the governing factors of the disasters. The severity of flood can be explained in terms of economic loss and human casualty, and area of innundation. At present there is no index to quantify the flood intensity. A high peak flood may cause less damage if it sustains for short period of time, on the other hand a low peak flood may cause considerable damage, if the innundation stays longer period of time. Considering above facts, Flood Intensity Index (FII) is introduced to characterize a flood, which is considered as product of inundation depth and flooding duration. Flood Intensity Index (FII) is a measurable index to characterize a flood accounting all the impacts of climatic change, this index can be used in expressing the change in flooding scenario due to climate change.

Previously, the affected area was used to measure the intensity of the floods (Miah, 1988; World Bank, 1989). Following that the author (Miah, 1988) stated the return period for normal floods is 2.25 years, for moderate to severe floods is 4 years, for severe floods is 7 years, and for catastrophic floods is 33 to 50 years. Besides, the (World Bank, 1989) shows return periods of floods of different intensities concerning the area covered (Table 1). It suggested, a similar flood of 1988 would occur once in about 100 years and that of 1987 in about 20 years. However, as a result of flood accentuating consequences of climate change and sea-level rise, the interval between major (catastrophic) floods has been declining in recent times and likely to do so even more in the future. Note that floods inundating at least one-third of the country occurred on five occasions during the past half-century: in 1955, 1974, 1987, 1988, and 1998, the interval has been 19 years, 13 years, and 10 years successively.

Table 1. Return period of flood characterized in relation to area covered (World Bank, 1989)

Return period (Years)	**Affected area (% of the country)**	**Return period (Years)**	**Affected area (% of the country)**
2	20	50	52
5	30	100	60
10	37	500	70
20	43		

By the framework provided in Table 1, floods of 1988 and 1998 both inundating about 60 percent of the country, would be similarly categorized and would both be assigned a return period of about 100 years. But in reality, the 1998 flood event was far more destructive than the 1988 flood, as its duration (65 days) was several times more than that of the 1988 (15-20 days) flood. Now, the destructive capacity of a flood is used to characterize its intensity. In addition to that, a longer flood period has a greater impact.

The flood intensity index was introduced by (Ahmed and Ahmed, 2003). If a flood is above the flood danger level for an area, the authors computed the FII by multiplying the duration (number of days) of that flood in that area by the depth of the flood. Based on the calculations, they reported that the 1998 flood was far worse than that of 1988. Further, (Ali et al., 2012) has analyzed the FII of two megafloods and compared it with a normal flooding year 2008, and explained the possible effect of sea-level rise on floods in Bangladesh. In this study, in addition to calculating the FII for 18 flooding years, 18 years of flood hydrographs have been studied for six stations, namely Bahadurabad, Bhagyakul, Serajgonj, Rajshahi, Goalundo, and Hardinge bridge to characterize the flooding scenario of Bangladesh**.**

This study categorized past floods based on FII. Besides, most vulnerable and highly flood affected stations were found out.

2. Methodology

The annual flood report for the flooding year 1988 to 2017 is collected from Flood Forecasting and Warning Centre, Bangladesh Water Developement Board, Dhaka. From the report the danger level (m) , the peak of the flood level (m) and other necessary information are studied. The disaster related data were collected from OFDA/CRFD International Disaster Database (http://www.em-dat.net), University Catholique de Louvain, Brussels, Belgium.
The flood report contains danger level of flood (m), peak of the water level(m) and days of inundation above danger level. The calculation procedure is given bellow:

Flood Intensity Index (FII)	= Maximum innundation depth for a particular year x the flooding duration.
Maximum innundation depth	= height of the water level above the danger level (m).
	= the peak of the flood level (m) -the danger level (m).

Here, the flooding duration is the number of days for which the flooding water depth was above danger level. Firstly, the Flood Intensity Index (FII) for different flooding years are determined. Secondly, based on the average Flood Intensity Index (FII), the flood in different years and different stations are characterized. Floods are categorized as normal or low flood, moderate and severe or high flood based on this average FII.
In this study, the moderate flood events were defined as the average flood intensity index of a period ± 3%. Here, average of 18 years flood intensity index was taken, the value of which was 12.87. Therefore, for moderate flood, the Flood Intensity Index is in between 10 to 16. For high flood or severe flood FII > 16 and for normal or low flood FII < 10.

3. Results and Discussions

Figure 1 shows the comparison of Monsoon rainfall anomaly with that of flooding area. The anomaly is defined as the percent deviation of a parameter from its temporal mean value. It is observed that for more than 85% cases, the flood anomaly is in phase with that of territorial rainfall in Bangladesh. Although it is expected that the huge upstream flow has a high impact on floods of Bangladesh, such scenario is observed only for 15% cases. In the figure the 1998 flood shows such a case.

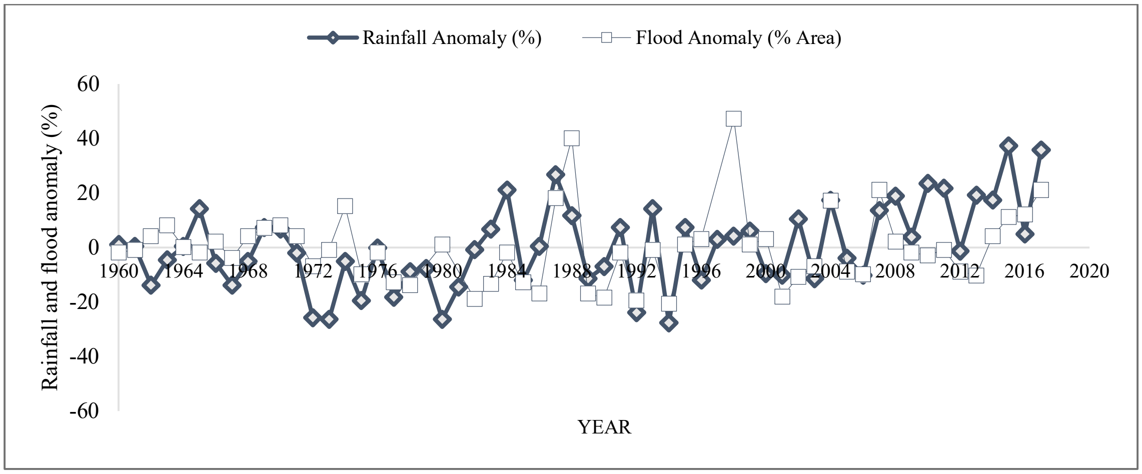

Figure 1. Correlation between Rainfall and Flood in the country

Figure 2. shows the basin wise average FII for different years. It is observed that in 1999, 2008 and 2013 the floods were dominated by Ganges basin. The floods in 1988 and 1998 were also dominated by Brahmaputra basin. The flood in 2000 were equally dominated by Ganges and Meghna basins. Since flash flood has a big contribution for flooding in Meghna basin, it has high Flood Intensity Index (FII) for most of the years, especially floods in 1988, 1993, 2004, 2007, 2010 and 2017.

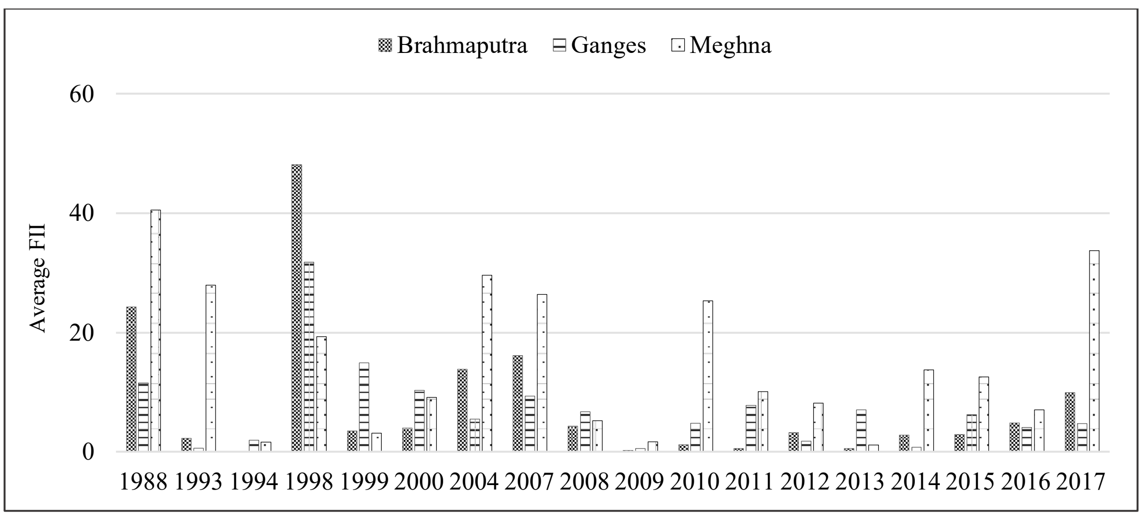

Figure 2. Average Flood Intensity Index (FII) of different basins

Figure 3. shows the categories of floods in different years based on average FII. It is observed that the floods in 1988, 1998, 2004, 2007 and 2017 can be categorized as high flood or severe flood and that of 1993, and 2010 as moderate flood to severe flood and 2000 as normal to moderate flood.

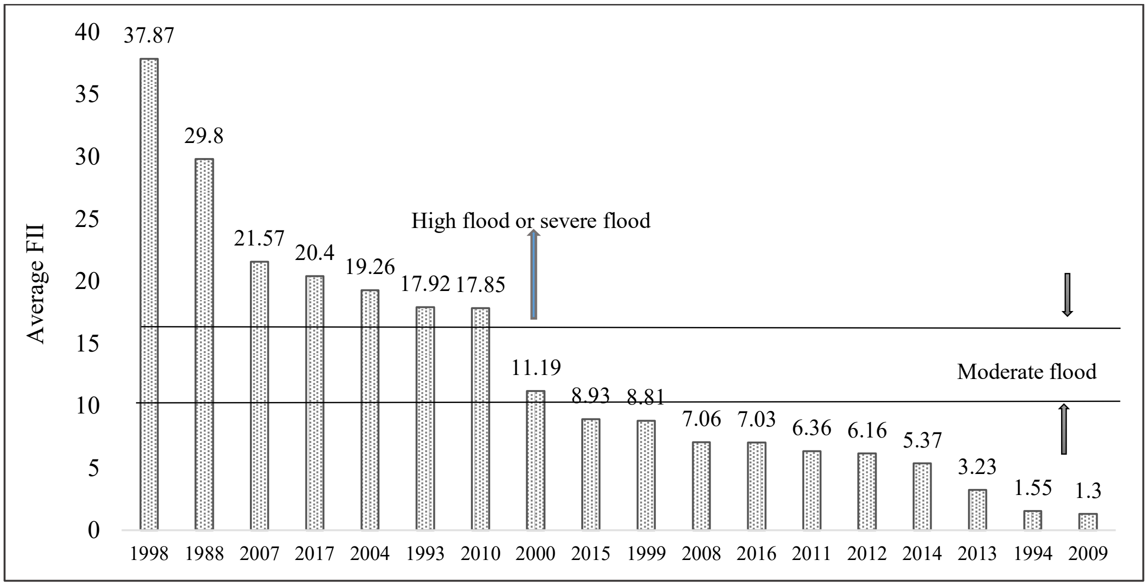

Figure 3. Year wise Average Flood Intensity Index (FII) and classification of floods

Figure 4. shows the FII for the vulnerable stations in three basins in Bangladesh. Considering most of the stations from different basins, it is found that Kanaighat is the most vulnerable station in Bangladesh. Other highly flood affected stations in descending order are Amalshid, Sheola, Bhaghyakul, Goalundo, Taraghat, Sumamganj, Pankha, Manu Railway Bridge, Aricha (Jamuna), Jhikorgacha, Bhairab Bazar, Serajgonj, Narayanganj, Bahadurabad, Habiganj, Mirpur, Durgapur, Comilla and Tongi.

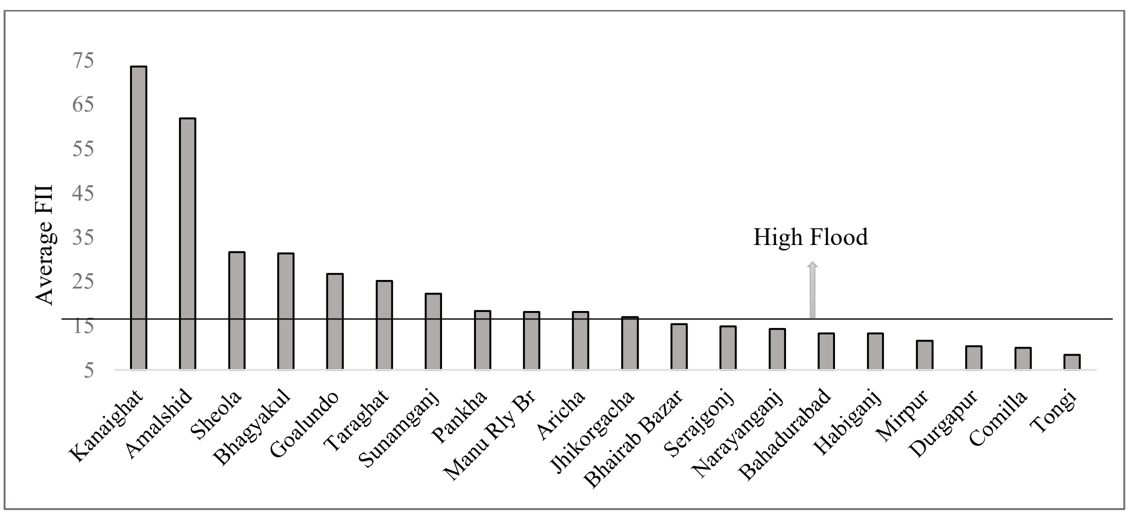

Figure 4. Flood Vulnerable stations with their chronology in Bangladesh

5. Conclusions

Based on the calculated results, following conclusions can be made:

- Bangladesh faced five times of high floods in last 30 years. Based on the average FII, the flood in 1998, 1988, 2004, 2007, and 2017 can be categorized as high flood and that of 1993 and 2010 as moderate to slightly high flood and 2000 as normal to moderate flood. Brahmaputra, Ganges, and Meghna basin are found to be about equally responsible for the floods in Bangladesh.

- Considering all the stations from different basins, it is found that Kanaighat and Amalshid in Meghna, Taraghat in Brahmaputra and Bhagyakul in Ganges basin are the most vulnerable stations to flood in Bangladesh. Other highly flood affected stations in descending order are Goalundo, Sumamganj, Pankha, Manu Railway Bridge, Aricha (Jamuna), Jhikorgacha, Bhairab Bazar, Serajgonj, Narayanganj, Bahadurabad, Habiganj, Mirpur, Durgapur, Comilla and Tongi.
- Although the yearly variation in inundation depth for the selected (9 most vulnerable) stations is found to be negligible among high flooding years 1998, 1988, 2007, and 2004, the flooding durations are found to be changed highly that causes the change in Flood Intensity Index.

Based on the time series of annual flood affected area, the return period of the floods can be calculated and the return period of different types of floods (classified based on FII) can be determined.

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