J. Asiat. Soc. Bangladesh, Sci. **44**(2): 211-224, December 2018

ASSESSMENT OF FLOOD RISK IN THE EASTERN PART OF JAMUNA FLOODPLAIN

MARUF BILLAH[1]* AND MEHEDI AHMED ANSARY[2]
[1]*Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*
[2]*Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*

Abstract

Risk assessment provides the scope to understand the vulnerability situation of any area based on different hazard context. The study has been conducted in the eastern part of Jamuna floodplain area to examine its flood vulnerability. To perform the analysis, the whole study area has been surveyed and examined applying Geographic Information System. The entire hazard, vulnerability as well as the capacity factors are assessed and have been classified into different categories from very low to very high. Individual factor analysis has been considered to realize the specific condition of different factors. Finally, flood hazard map has been prepared to examine the vulnerability of the proposed area. This type of work helps the planners and disaster managers to identify the most risk zone which should receive immediate hazard mitigation measures as well as help to take a decision in an emergency situation when a flood may occur in the study area.

Key words: Flood hazard, Vulnerability, Capacity, Geographic information system

Introduction

Risk assessment is becoming popular in the management and policies of all the major countries especially in disaster management sector like a flood (Meyer *et al.* 2009). In the context of Bangladesh, risk assessment is even more important as she faces different natural calamities on a regular basis and flood is one of them. It noticeably damage humanlives, properties, environments and contributed about 39.26% of worldwide natural disasters and caused about US$ 397.3 billion worth damage between 2000 and 2014 (Em-dat 2010). As Bangladesh is part of the world's most dynamic hydrological and the biggest active delta system, the landscape, position, and outfall of the three major rivers shape the annual hydrological cycle of the land. Too much rain in rainy season and too little water in the dry season is the annual phenomenon in a hydrological cycle. Here regular monsoon event, 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

*Author for correspondence: E-mail: marufbillah413@gmail.com

economy of the country. Extreme events of flood adversely affect the development, economy, poverty and almost every sector. The quick advancement of satellite-based innovations and the remarkable advancements in spatial data examination and demonstration have empowered various improvements in exact flood risk evaluation and also rational flood management.

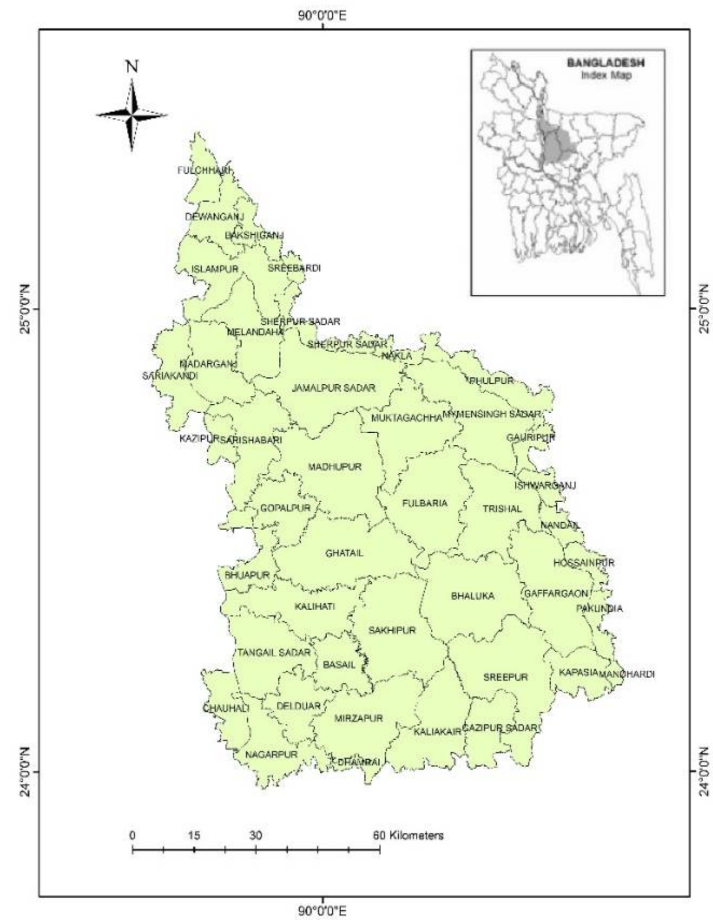

Fig. 1. Study area (Karzakram 2011).

Materials and Methods

The concept of risk: A risk is observed as the likelihood of occurrence or the gradation of loss of a specified element expected from a specific hazard (Schneiderbauer and Ehrlich 2004). While risk measurement varies according to discipline. In hazard research, a risk is equal to the product of two or three factors (Crichton 2002, Wisner *et al.* 2004), though dissimilar views exist (Chakraborty *et al.* 2005) . For example, (Crichton 2002) summaries chance with a three-way relationship in which risk, presentation, and helplessness contribute freely. On the other hand, Asian Disaster Reduction Center (Shaluf 2007) defines hazard as the coverage areas of three factors - hazard, exposure, and vulnerability - that act simultaneously to generate the risk of natural hazards, which can be expressed as:

$$\text{Risk} = \text{Hazard} \times \text{vulnerability} \qquad \text{(Eq. 1)}$$

$$\text{Risk} = \text{Hazard} \times \text{exposure} \times \text{vulnerability} \qquad \text{(Eq. 2)}$$

While hazards are a probable threat to inhabitants and the surroundings, a risk is an interplay between hazard and vulnerability. Elements at risk, a commonly used term in hazard research, allows the assessment of economic losses from a life-threatening event (Meyer *et al.* 2009). But it is usually not included in the risk equation; it is considered as a part of the vulnerability and exposure analysis.

However, according to the United Nations Disaster Relief Coordinator Office (Peduzzi *et al.* 2009), a risk is the function of elements at risk (e.g., population), hazards, and vulnerability. It varies from the concept of others, who describe risk as a production of hazard and vulnerability (Wisner *et al*. 2004). The risk to a specific community varies over time and time and depends on their socio-economic, traditional, and other characteristics (Cannon 2000, Wisner *et al.* 2004). Moreover the risk of the natural hazards relay on both the hazard and the capability of the community to withstand shocks from disaster.

Risk assessment: Risk assessment refers to the evaluation of the capacity of estimated risks based on the local society's suitability criteria. Processed data and information have been used in the developed model and finally a risk map has been prepared using the following speculation:

$$\text{Risk} = \frac{\text{Hazard} \times \text{vulnerability}}{\text{Coping capacity}} \qquad \text{(Eq. 3)}$$

Concept of flood risk assessment: Flood risk assessment is an interdisciplinary task. It combines various types of source, information and models. Some assessment attempts to estimate many possible hazard factors like flood extent and inundation depth, how probable they are and what may be the consequence (de Moel *et al.* 2015).

Integrated risk assessment model: Risk is the product of hazard, exposure, vulnerability, and coping capacity. Using these measures, hazard (the probability or severity of flood, elevation from sea level), exposure characterizes (structure, population, population density, distance from river), and capacity (awareness, relief system, economic strength, use of indigenous knowledge, education system), it is possible to determine community's risk to hazards and can take the necessary actions to lessen the risk of disaster. The proposed model was mainly developed to assess the flood risk of the Jamuna Floodplain. Hence, all these above-mentioned components are applicable to single hazard investigation. The model is based on three important principles.

First, a single hazard perspective is used rather than a multi-hazard.

Second, it is only applicable for hazards that have spatial relevance, such as the flood. Spatially non-relevant hazards such as disaster earthquake or cyclone cannot be used.

Third, the model may be useful to determine community risk by integrating hazard and vulnerability. However, it is unable to recognize individuals' risk. An important pitfall of this model is that it requires plentiful data to operationalize the concept.

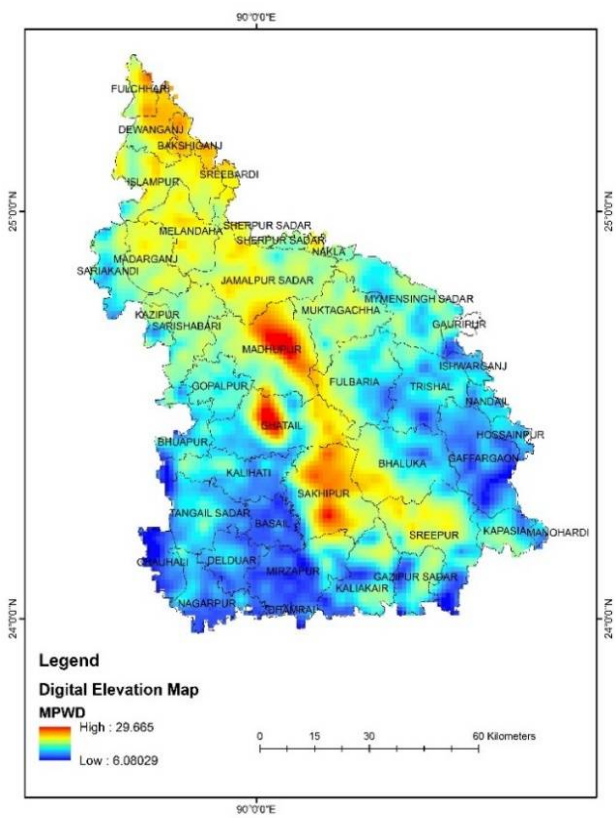

Fig. 2. Elevation map.

Topographic analysis: For the purpose of using geographical data in the planned model, Upazilla map are constructed from an administrative shapefile provided by the Government of Bangladesh. GPX converter (an online open source) has been used to obtain elevation data for a particular area which was later processed and assembled into a spatial database using GIS and image processing (Fig. 2). According to the elevation of the study area elevation rank has been prepared on a map (Fig. 3).

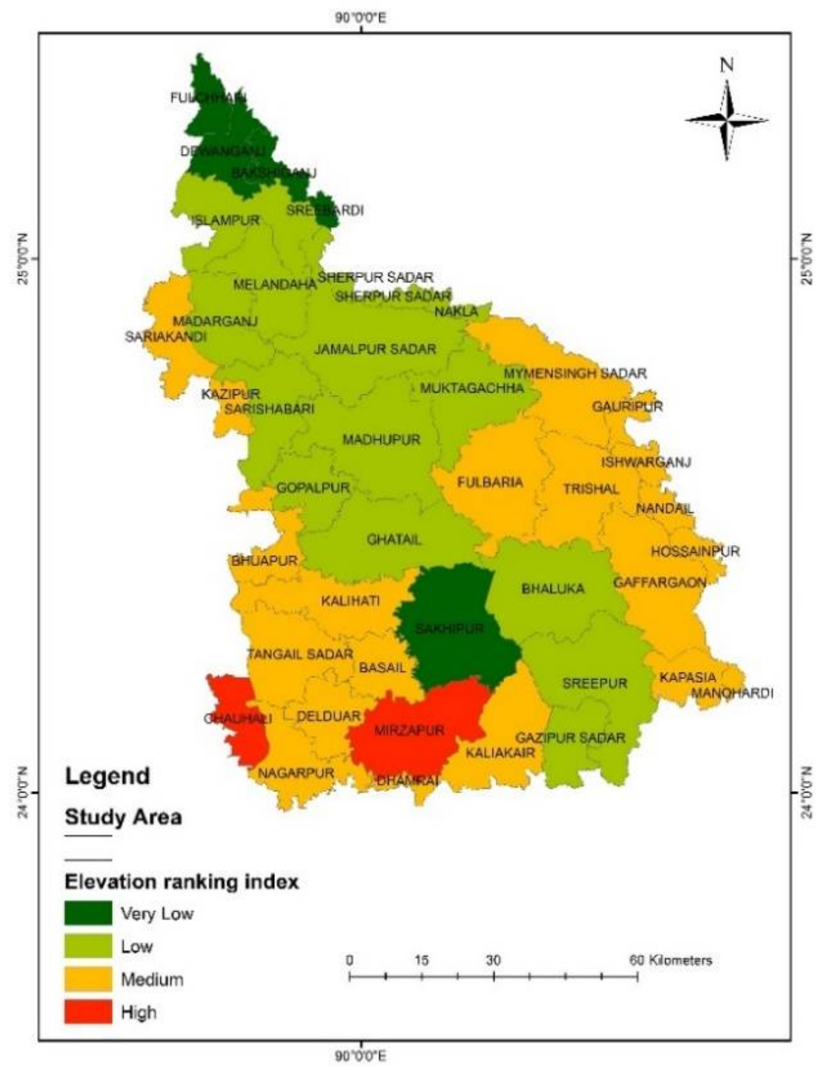

Fig. 3. Elevation ranking.

Analysis of variables of the proposed model

Raster elevation ranked as 20 meters and above height from the sea level is 5 in rank, and 1 is in risk rank while very low in risk index. The estimated values, ranks and risk index are given in the Table 1.

Table 1. Elevation value, rank and index used in the model.

	Values	Rank	Risk index
1 - 5	1	5	Very high
6 - 10	2	4	High
11 - 15	3	3	Medium
16 - 20	4	2	Low
20 +	5	1	Very low

Source: Tingsanchali and Karim 2010.

Table 2. Upazilawise population density in the study area.

SL. no.	Name of the Upazila	Area (sq. km)	Total population	Density/ sq. km	Density rank (*)
1	Basail	157.78	148555	941	2
2	Bhaluka	444.05	264991	596	2
3	Delduar	184.54	175684	952	2
4	Fulbari	402.41	345283	858	2
5	Gafargaon	401.16	379803	946	2
6	Ghatail	451.30	341376	756	2
7	Gopalpur	193.37	252747	1307	3
8	Jamalpur Sadar	489.56	501924	1025	3
9	Kaliakair	414.14	232915	741	2
10	Kalihati	301.22	354959	1178	3
11	Madargonj	225.38	24306	107	1
12	Madhupur	500.67	375295	749	2
13	Melandaha	239.65	262478	1095	3
14	Mirzapur	373.89	337496	902	2
15	Muktagacha	314.71	321759	1022	3
16	Sakhipur	429.63	220281	512	2
17	Sharishabari	263.48	289106	1097	3
18	Tangail Sadar	334.26	680518	2035	5
19	Trisal	338.98	336797	993	2

* Population density index, 100 – 500 = 1, 501 – 1000 = 2, 1001 – 1500 = 3, 1501 – 2000 = 4, 2000+ =5

Source: Bangladesh Bureau of Statistics 2011.

Analysis of population density of human settlement: The population density of the study area provided further evidence of the problems especially in the case of losses of life due to flooding. To assess the flood risk on population settlement, Upazila wise population density statistics has been usedand shown in Table 2. A population density index map has been developed for better visualization (Fig. 4).

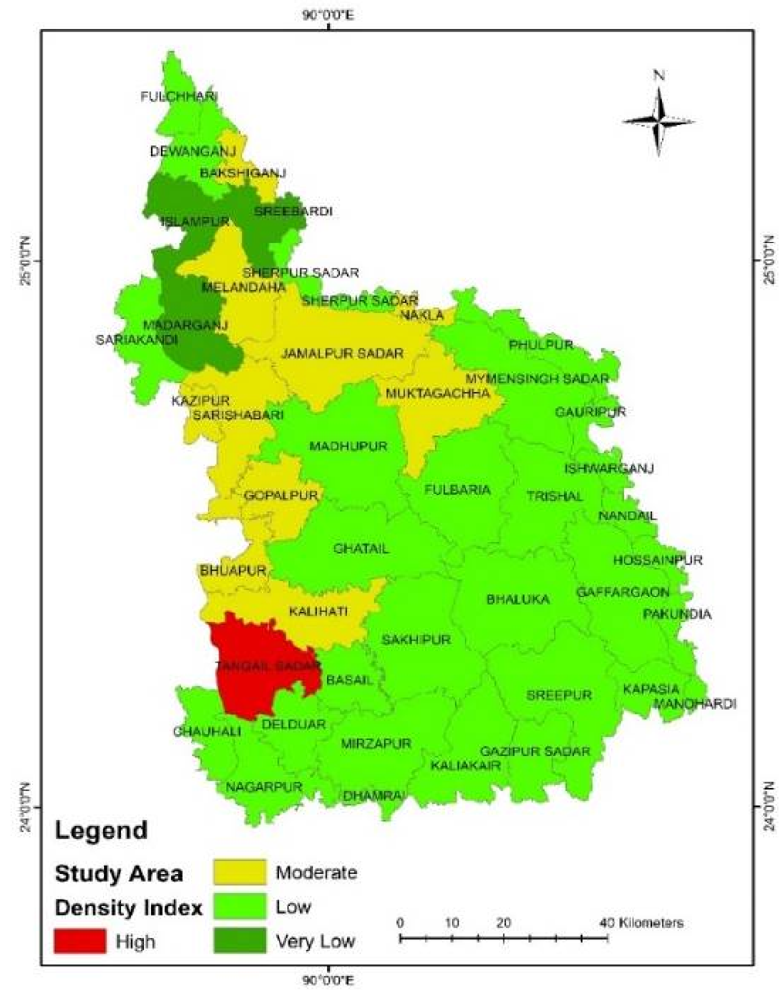

Fig. 4. Population density index.

Hydrological analysis: The vulnerability of flood in any catchment or basin area or floodplain depends on the hydrological characteristics of its own. To determine the actual scenario of hydrological risk, distance from the river of each unit of land (Upazila) calculated and in this case the river Jamuna has been taken into consideration as a river. Upazila wise distance rank has been prepared on the basis of a distance from the river. The distance has been calculated using proximity toolset in Arcgis 10.1 version. Fig. 5 represents the distant ranking.

Table 3. Hydrological data used in the model.

Sl. No.	Name of the Upazila	Area (Sq. km)	Average distance from the river (Km)	Distance rank *
1	Basail	157.78	38.62	3
2	Bhaluka	444.05	51.49	4
3	Delduar	184.54	24.14	1
4	Fulbari	402.41	54.71	4
5	Gafargaon	401.16	86.90	5
6	Ghatail	451.30	32.18	1
7	Gopalpur	193.37	8.04	1
8	Jamalpur Sadar	489.56	40.23	3
9	Kaliakair	414.14	65.98	5
10	Kalihati	301.22	6.43	1
11	Madargonj	225.38	9.65	1
12	Madhupur	500.67	37.01	2
13	Melandaha	239.65	25.74	2
14	Mirzapur	373.89	41.84	3
15	Muktagacha	314.71	59.54	4
16	Sakhipur	429.63	45.06	3
17	Sharishabari	263.48	14.48	1
18	Tangail Sadar	334.26	17.70	1
19	Trisal	338.98	67.59	5

*Distance index, 0 - 16 = 1, 17 - 32 = 2, 33 - 48 = 3, 49 - 64 = 4, 65+ = 5

Average vulnerability index: To calculate the average vulnerability of the selected area, population density and the distance from the river has been considered because the flood will affect more if it sticks in a densely populated area rather than an area which has less density. On the other hand distance from the river is another parameter as in our country maximum flood occurs when the river cannot contain the excessive water flow coming down from the upward in monsoon period. A vulnerability index map (Fig. 6) has been developed using the average score of the distance from the river and population density.

Coping capacities or coping strategies: Coping capacities or coping strategies are highly complementary since greater resilience is achieved. People of the study area adapted various strategies to cope with the flood of their own and also with the help of different organizations. Focus group discussion (FGD), key informant interview (KII) have been conducted in every Upazilla. Coping strategies of the local people used in the developed model as furnished in the table below: (Table 4) and the map (Fig. 7) symbolize the overall capacity scenario of that specific area.

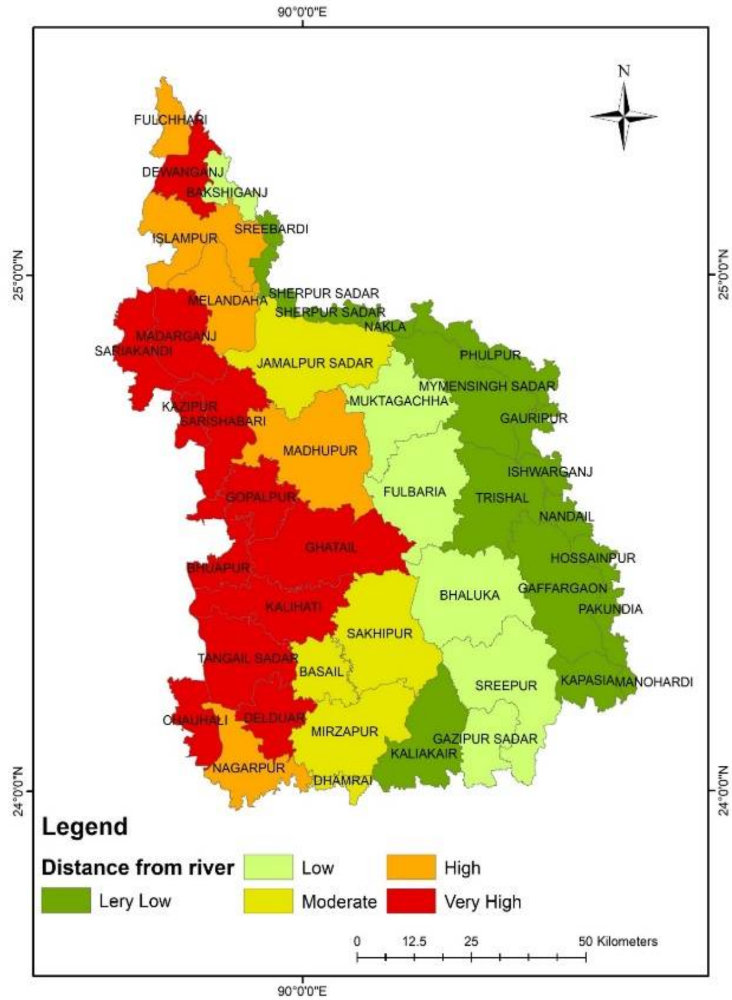

Fig. 5. Distant rank from the river.

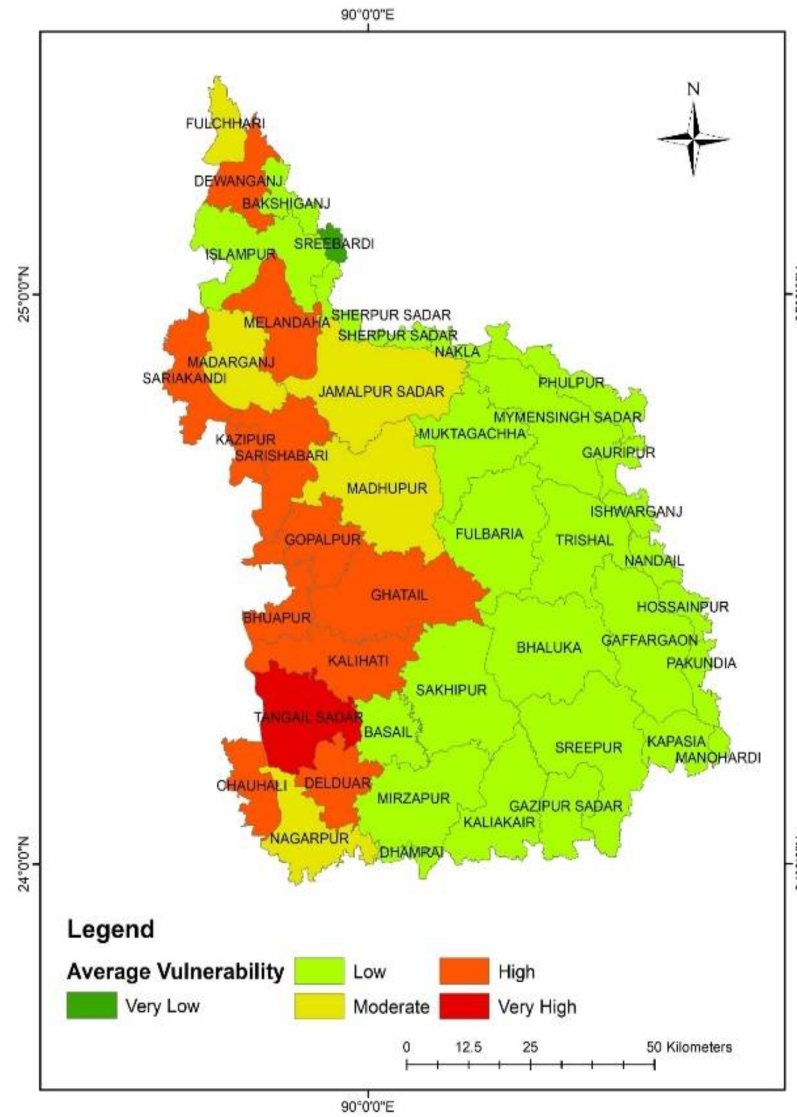

Fig. 6. Average vulnerability index.

Flood risk ranking map: Based on the assessment final risk has been calculated through the equation (Eq. 3). The developed model has run using Arc GIS and final flood risk map have been developed. In the case of the final output of the flood risk map, three major variables like hazard, vulnerability and capacity have been considered. Similarly, in scheming hazard, vulnerability and capacity both ordinal and nominal values were calculated through the model. Fig. 8 is the final yield of flood rink valuation of the study area.

Table 4. Coping capacity, variables and index (Upazila-wise).

Sl. No.	Name of the Upazila	Variables of measuring coping capacity				
		Awareness	Relief system	Economic strength	Use of indigenous knowledge	Education level
		Index	Index	Index	Index	Index
		Very high = 5 High = 4 Medium = 3 Low = 2	Very good = 5 Good = 4 Satisfactory = 3 Not good = 2 Bad = 1	High = 3 Medium = 2 Low = 1	High = 3 Medium = 2 Low = 1	Very high = 5 High = 4 Medium = 3 Low = 2 Very low = 1
1	Basail	4	4	1	2	2
2	Bhaluka	4	5	2	2	2
3	Delduar	4	4	2	2	2
4	Fulbari	3	3	3	3	3
5	Gafargaon	4	2	2	2	2
6	Ghatail	4	4	2	1	2
7	Gopalpur	3	4	1	1	2
8	Jamalpur Sadar	3	3	3	1	3
9	Kaliakair	4	5	3	2	4
10	Kalihati	4	4	1	2	2
11	Madargonj	4	4	2	1	2
12	Madhupur	5	4	2	3	2
13	Melandaha	4	5	1	1	2
14	Mirzapur	5	3	2	3	2
15	Muktagacha	3	3	2	3	2
16	Sakhipur	4	3	2	2	2
17	Sharishabari	4	4	2	3	2
18	Tangail Sadar	4	2	3	1	2
19	Trisal	3	3	2	2	2

Index of economic based on monthly income taka 15000+ = 3, 10000 - 15000 = 2, 0 - 10000 = 1
Index of education (%), 0 - 20 = 1, 21 - 40 = 2, 41 - 60=3, 61 - 80 = 4, 80+ = 5.

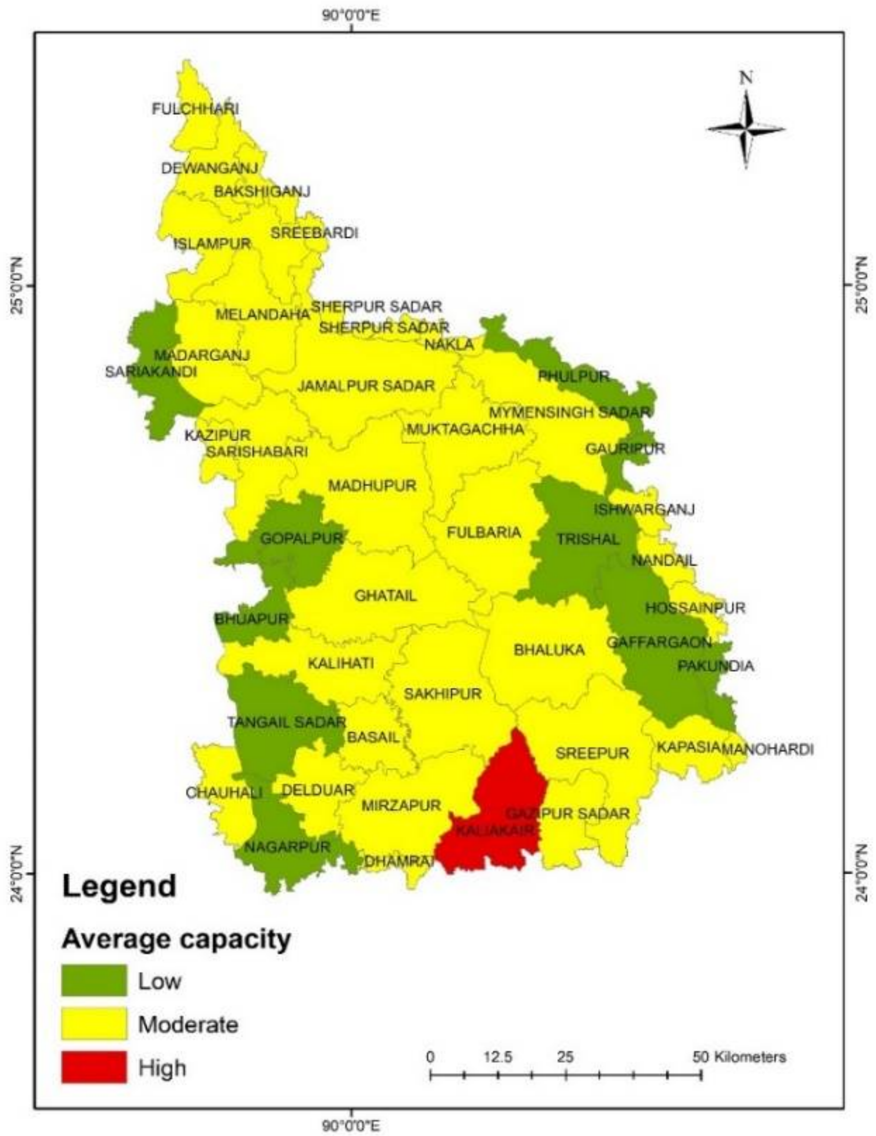

Fig. 7. Average capacity ranking.

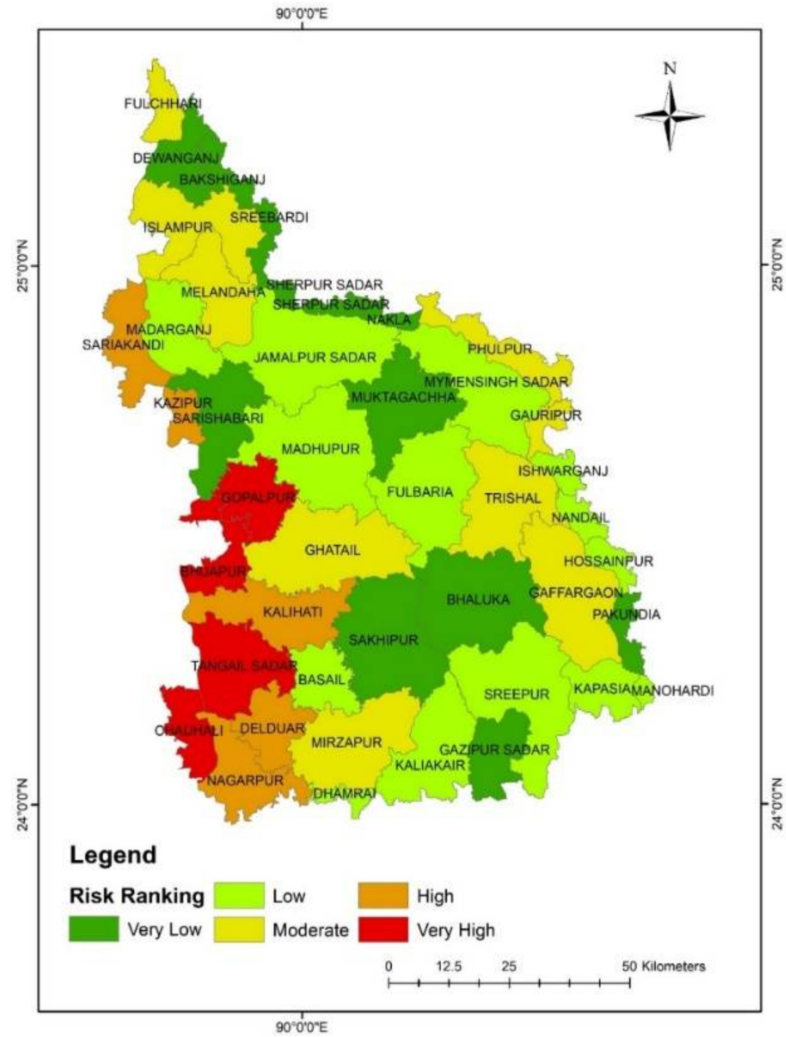

Fig. 8. Flood risk ranking.

Conclusion

After analyzing all variables stated above, final flood risk has been assessed and is shown in the final map (Fig. 8) which shows the index of flood risk of the Jamuna floodplain. The proposed model could also be applicable for the assessment of flood risk for the whole country as both social and topographical factors have been considered here. This assessment has been conducted to identify the priority areas which should give more emphasis for flood mitigation procedures. This type of work is helpful for the planners, disaster management organizations and also for the government to think about the future plan in the considered area.

References

Bangladesh Bureau of Statistics, 2011. Bangladesh Population and Housing Census 2011.

Cannon, T., 2000. Vulnerability analysis and disasters. *Floods* **1**: 45-55.

Chakraborty, J., G.A Tobin and B.E Montz. 2005. Population evacuation: assessing spatial variability in geophysical risk and social vulnerability to natural hazards. *Natural Hazards Review **6***(1): 23-33.

Crichton, D. 2002. UK and global insurance responses to flood hazard. *Water International* **27**(1): 119-131.

de Moel, H., B. Jongman, H. Kreibich, B. Merz, E. Penning-Rowsell and P.J. Ward 2015. Flood risk assessments at different spatial scales. *Mitigation and Adaptation Strategies for Global Change* **20**(6): 865-890.

Em-dat, C.R.E.D., 2010. The OFDA/CRED international disaster database. *Université catholique*.

Meyer, V., D. Haase and S. Scheuer. 2009. Flood risk assessment in European river basins - concept, methods, and challenges exemplified at the Mulde river. *Integrated Environmental Assessment and Management* **5**(1): 17-26.

Peduzzi, P., H. Dao, C. Herold. and F. Mouton. 2009. Assessing global exposure and vulnerability towards natural hazards: The disaster risk index. *Natural Hazards and Earth System Sciences* **9**(4): 1149-1159.

Schneiderbauer, S. and D. Ehrlich. 2004. Risk, hazard and people's vulnerability to natural hazards. *A review of definitions, concepts and data. European Commission Joint Research Centre. EUR*, 21410, 40 p.

Shaluf, Mohamed I. 2007. Disaster types. *Disaster Prevention and Management: An International Journal* **16**(5): 704-717.

Tingsanchali, T. and F. Karim. 2010. Flood-hazard assessment and risk-based zoning of a tropical flood plain: Case study of the Yom River, Thailand. *Hydrological Sciences Journal–Journal des Sciences Hydrologiques* **55**(2): 145-161.

Wisner, B., I. Kelman, T. Monk, J.K. Bothara, D. Alexander, A.M. Dixit, D. Benouar, O.D. Cardona, R. C. Kandel and Petal, M., 2004. School seismic safety: Falling between the cracks? *Earthquakes. London*, 1-56 pp.

(Revised copy received on 18.11.2018)