GIS Based Flood Risk Assessment: A Case Study on Three Wards of Dhaka City

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Introduction

The purpose of risk assessment is to define the nature of the risk problem. The risk assessment provides a systematic process to answer question about the frequency and severity of potential hazards and national and / or community vulnerabilities. Asking question helps establish the scope of the risk assessment. Modern technology has advanced hazard mapping and prediction of future events considerably through technique such as geological mapping and satellite imagery, production of high resolution maps and computer modeling. New geographic information system (GIS) mapping techniques in particular, are revolutionizing the potential capacity to analyze hazards, risks and vulnerability (EC, 2000: world bank, 1997).

A network of rivers surrounds Dhaka city. After 1988 flood, the western part of Dhaka City is protected from river flooding. But, floods in 1998 and 2004 affect both the protected western part and unprotected eastern part of the city. All these protective measures were taken without considering the behavior of uncertainty and risk. As a result this step has been taken flood risk assessment for a small community. Here an attempt has been taken to establish a flood risk assessment for Ward no 25, 27, 28 in Dhaka city. So in this research it is try to find out a way to develop a risk assessment procedure to estimate the flood risk of the study area that is understandable to everyone.

Objectives

The objectives of the study are to investigate the flood hazard that occurred in the study area and to assess vulnerability, damage and risk of the study area.

Methodology

Sample Size and Sampling Procedure

In the study area total structure or population size is 11960. Sample size 600 is taken 5% of the total 11960 structures. This sample is taken to gather information which helps categorizing the structure, a wide range of information on the different contents of different structures, present market value of that contents and 1998 flood water depth in that specific location. Stratified random sampling technique is adopted for the survey purpose. 11960 structures are categorized in 38 categories of structure. These 38 categories of structure are being considered as the 38 stratum and from every stratum 5% sample size is taken for the survey.

Data Sources

The purpose of various data collection, types of data and sources of data are summarized in Table 1.

Table 1: Data and its sources

Sl	Data Required	Purpose	Data Type	Data Source
1.	Rainfall Data(50 years)	To Identify the Flood Return Period	Excel Format	Bangladesh Meteorological Department.
2.	Spot Height Data	To formulate Digital Elevation Model (DEM) of the study area	Secondary (GIS point shape file)	Detailed Area Plan, Dhaka
3.	Geomorphologic map of Dhaka City	To identify the geomorphology of the study area	Secondary (GIS polyline shape file)	GSB, Bangladesh
4.	Floor of the Buildings	To identify vulnerability potentials	Secondary (GIS polygon shape file)	Detailed Area Plan, Dhaka
5.	Building Distribution of Dhaka City	To identify vulnerability potentials and estimate buildings' content damage	Secondary (GIS polygon shape file)	Detailed Area Plan, Dhaka
6.	Building use	To identify vulnerability potentials	Excel Format	Detailed Area Plan, Dhaka
7.	Flood Water Depth (1998)	To formulate Scenario Flood Depth	Primary(GIS point shape file)	Field Survey
8.	Material types for Buildings and Roads	To identify vulnerability potentials	Secondary (GIS Polyline shape file)	Detailed Area Plan, Dhaka
9.	Damaged property	To identify damage	Excel Format	Field Survey
10.	Road Network, Specific Structure Location	To estimate infrastructure damage	Secondary (GIS Polyline shape file)	Detailed Area Plan, Dhaka
11.	Market value of that Property	To identify the cost of contents of the study area	Excel Format & GIS Attribute table	Field Survey

Working Procedure

- Flood frequency analysis is done with 50 years rainfall data of Dhaka station.
- Digital Elevation Model (DEM) generation with the help of spot height data from mean sea level.
- Geomorphological analysis is done by the characterization of the geomorphological features found in the study area.
- Historical flood scenario or 1998 flood depth map is created by using the flood water depth data, which is collected by field survey.
- Map of hazard zonation will be made based on flood depth map, digital elevation model and geomorphological map by performing a weighted overlay operation in ArcGIS 9.2.
- The next step is to make a cadastral database or building inventory information of the element at risk in the study area.
- Vulnerability function for the different element at risk will be formulated based on 1998 flood water depth map.
- Cost value will be assigned to the different categories of element at risk, with the information obtain from the field survey.
- By multiplying the cost and vulnerability function of each structure, it become possible to get damage value for that structure.
- Finally this 'damage value' is multiplying with the 'probability of flood occurrence' which is found through the flood return period analysis in previous steps. In this way the

risk value of each structure is being calculated. Sum of every element's risk value is the total risk of the study area.

Detail working procedure of the data processing of the research is shown in Figure 1.

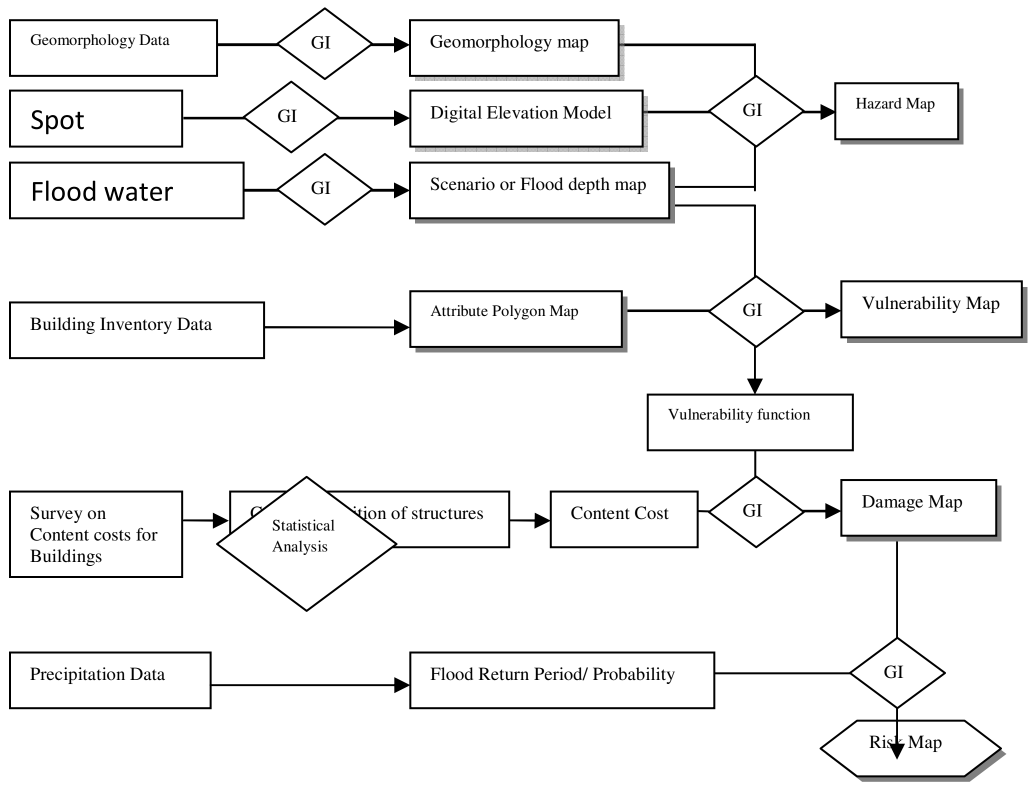


Fig. 1: Data processing framework of the study

Study Area

Dhaka, the capital city of Bangladesh was founded about 400 years ago by the side of the river Buriganga. Dhaka extending over an area of about 1.5 sq. km. nears the junction of the Dholai Khal and Buriganga River (Banglapedia volume 2). The area and population of Dhaka mega city or Dhaka statistical metropolitan area (DSMA) were 1600 sq. km. and 6.83 million respectively. Area under Dhaka city corporation (DCC) was 360 sq. km., with a population of 3.39 million. The present population of DSMA in is about 10.5 million (BBS,2001). The city is bounded by the rivers Buriganga to the south, Turag to the west and Balu to the east and Tungi Khal to the north. In fact it is observed that some 60% of the Greater Dhaka East area regularly goes under water every year between June and October due to lack of flood protection in that area. In 1991, JICA and ADB conducted feasibility study on this area. And in 2006, Halcrow Group Limited, UK, have done a study for updating/upgrading the Feasibility Study of Dhaka Integrated Flood Control Embankment. They divided the whole eastern part of Dhaka into three compartments. They proposed some structural measures which includes construction of embankment, flood wall, pump station and buildup of some pond area. But non-structural measures like preparation of Flood hazard map has not included.

Hydrologic Condition of Dhaka City

The eastern part of Dhaka is bounded by the Balu river which is also hydrologically connected with Tongi Khal. In terms of flood protection works, Dhaka city can be divided into two parts: Dhaka west and Dhaka east. The area of Dhaka west is 243 km^2 and is surrounded by embankment and embankment cum road, where as the area of Dhaka east is 119 km^2 and consists of unprotected lowlands within the floodplain of the Balu river (JICA, 1987). The most of the areas of Greater Dhaka city are urban areas including residential areas, large commercial complex, offices, schools, hospitals and small garments & other industries. The population of Greater Dhaka city was 4.47 million in 1990, which is projected to increase to 8.59 million in 2010 (JICA, 1991). Dhaka is not only the nation's capital but also has potential to become a mega city by 2010. Condition of Dhaka city during flood period always draws special attention due to its strategic importance.

Unprotected Eastern Part of Dhaka City

Unfortunately, the eastern part of Dhaka city has suffered from flooding in all the major floods. There has always been a concern about this flood situation of this part of the nation's capital. Right after flood in 1998, there have been many concerns and discussions to construct embankment in the eastern part of the city. Government has been considering to construct embank or embankment cum bypass road in the east side of the city. But, before construction of such embankment, the drainage of the Dhaka East should be well planned. City dwellers have bad experience of water logging and drainage congestion in the western part due to the embankment. Lessons should be learned from the drainage situation of the western part of the city. To avoid similar situation in eastern part of the city, details drainage plan such as routes of canals, retention ponds, location of pump stations and regulators, etc. should be done. Otherwise, the eastern part will also suffer from water logging even from a small rainfall.

Geomorphology of Dhaka and the Study Area

The major geomorphic units of the city are: the high land or the Dhaka terrace, the low lands or floodplains, depressions and abandoned channels. Low lying swamps and marshes located in and around the city are other major topographic features.

The study area (Ward no 25, 27, 28) in the eastern part is around 5 kilometer away from the nearest river Balu. Thus the effect of flood is less than the nearer area of the river Balu. The study area contains a large amount of commercial activity and residential buildings. Towards the river Balu from the study area, agricultural lands are increasing and the commercial and residential landuse are reducing. Thus the damage of the flood is more in the study area than the neare area of the Balu river. Most of the urban poor live in a very congested and the structure where they live is very soft and vulnerable against flood. Flood causes a huge damage of property, infrastructure and loss of lives.

- Dhaka city is surrounded by a network of rivers.
- After 1988 flood, the western part of Dhaka City is protected from river flooding.
- But, floods in 1998 and 2004 affect both the protected western part and unprotected eastern part of the city.
- All these protective measures were taken without considering the behavior of uncertainty and risk. (Gain Animesh, 2008)

For this reason, Ward no. 25, 27 and 28 of western part of Dhaka city have been selected as the study area for this research. The area has a mixture of high land, high and low land, low land, depression, abandoned channel, narrow water, natural levee, sand bar etc.

Flood Hazard Assessment

Floods in Dhaka have always been studied from a hydrological or meteorological point of view, while geomorphology has played little or no role in most of them. In addition, floods have been related almost only to the magnitude of the peak discharges or the amount of rainfall. But large-scale features like detailed topography of the city, structure of the city with respect to spacing of houses and streets, distribution of the water inside the city and location of the most affected neighborhoods, have been hardly taken into account. For this reason, the present assessment will be done using a geomorphological approach (badilla coto), considering Digital Elevation Model and the flood scenario of 1998 flood event basing the hazard zonation on a combination of secondary data and field observations. The construction of flood scenarios will be mainly based on field survey. Hopefully, this approach to study an old problem will provide fresh ideas to the authorities involved in hazard mitigation and prevention in the study area and the rest part of Dhaka city.

Data Management and Processing

There are 11960 structures found in the study area and they are linked with the attribute like, road no. locality, road name, structure name, structure type, floor, structure name, building use etc. Among them for this study only structure type, floor, building use is needed. But in building use attribute 109 types' uses are found which are classified in 38 categories. Geomorphology features of the greater Dhaka are extracted by the boundary of the study area. After running this operation in GIS, geomorphological feature like mixed with high and low land, low land, depression; abandoned channel and narrow water are found for the study area, that are used for the further hazard analysis. Spot height is GIS point shape file that is extracted by the boundary of the study area. After running this operation in GIS, 74 spot height points are collected and consider for the digital elevation analysis of the study area. Taking interview of the local people collects the information about highest water level during 1998 flood. As it was a historical flood event people could easily remind and some place some marks are found that are done by the local people. This indicates the highest level of floodwater during 1998 flood. 103 spot depths are taken for the three wards 25, 27, 28.

Resulting Flood Hazard Map

Hazard zonation maps were done based on the above three analysis, Geomorphological map, Digital Elevation Model and Flood Depth Map of the Study area as it was explained in previous Stage. Then a weighted Overlay operation is run with the help of GIS tools.

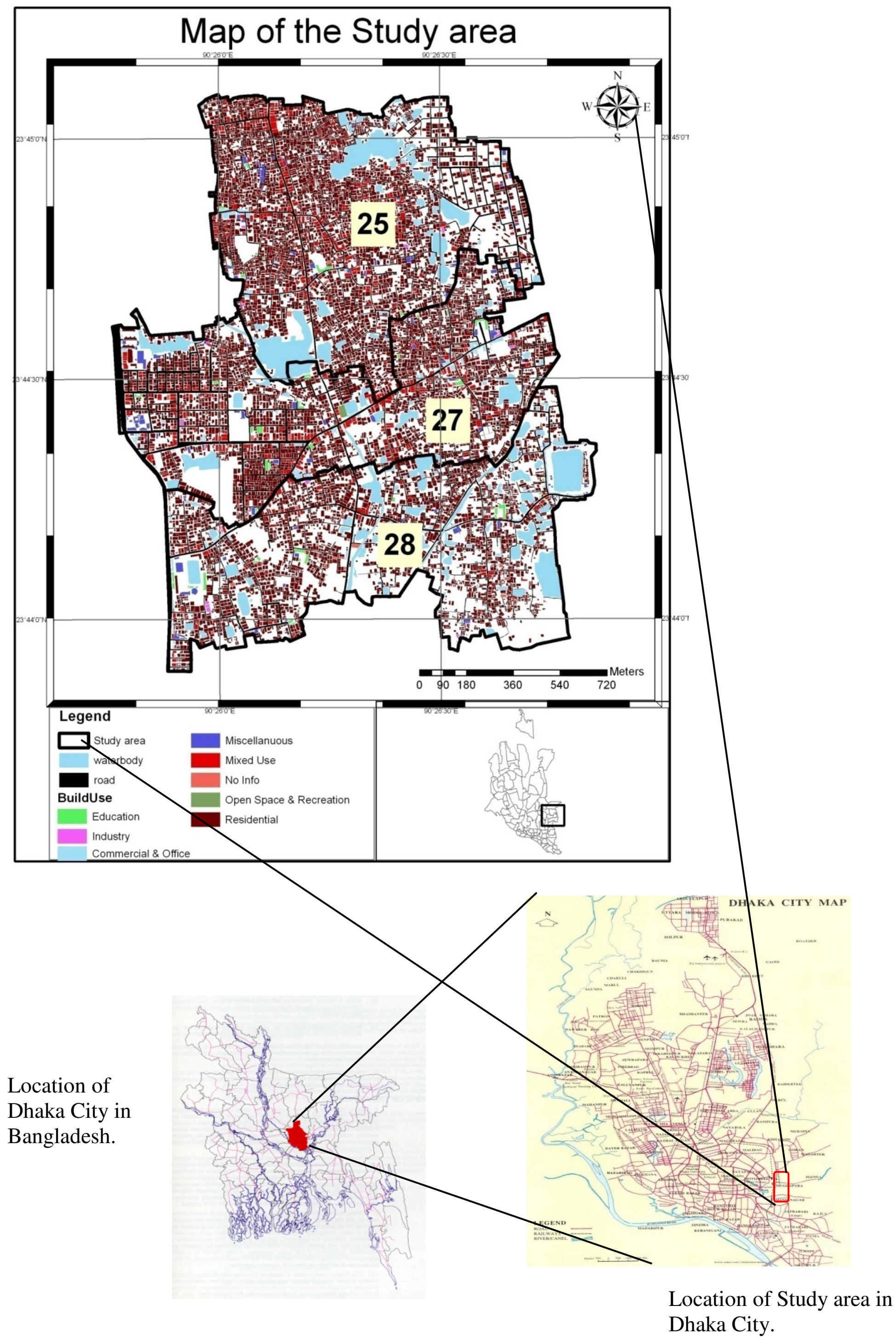
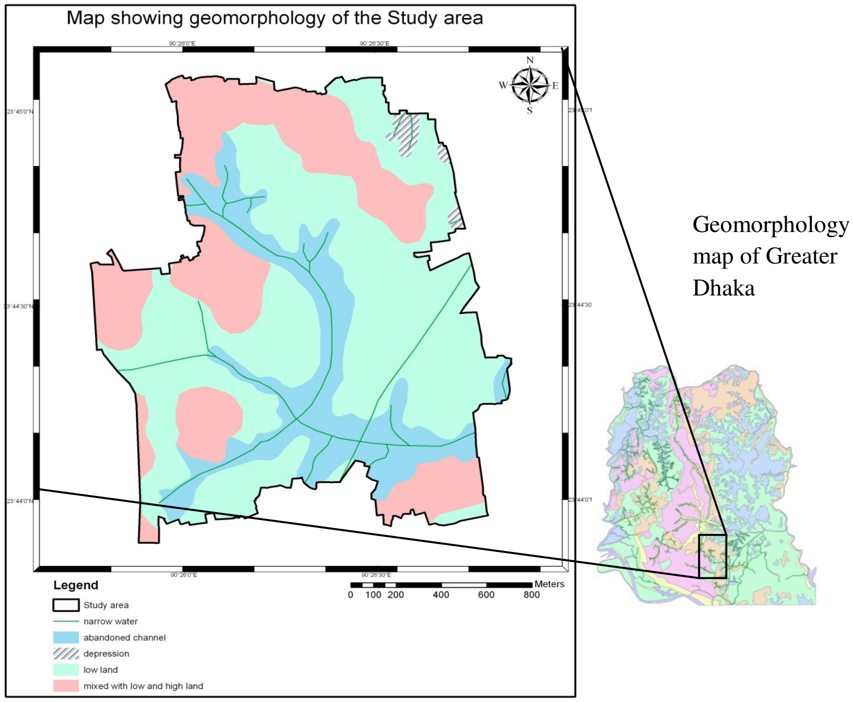


Fig. 2: Map of the Study Area



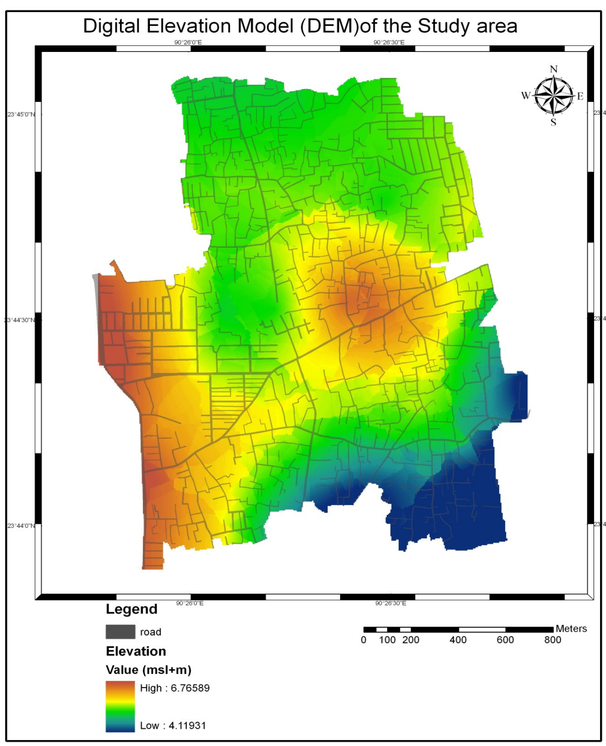


Fig. 4: Digital Elevation Model (DEM) of the Study area.

Analysis of the 1998 Flood Event

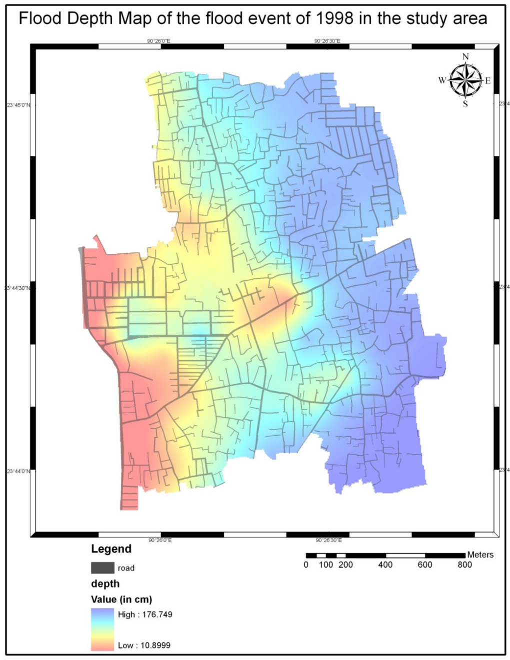


Fig. 5: 1998 Flood Depth Map of the Study area

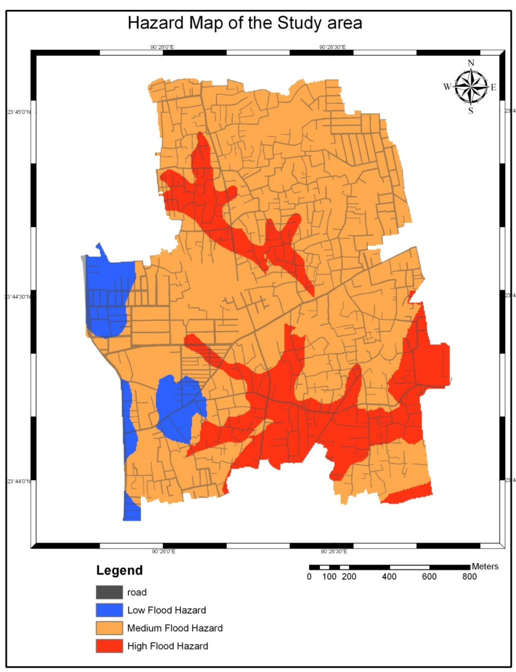


Fig. 6: Flood hazard map of the study area.

Vulnerability Analysis

The method, used in this research for flood vulnerability assessment, can be considered as a GIS-based hybrid between the Actual flood damage and the Existing databases approaches (Badilla coto, 2002). That is because the present vulnerability assessment is based on a detailed database of all the elements at risk within the study area and also on the field collection of information related to the 1998 flood event in the study area.

The Flood Scenario

As it was indicated in hazard assessment chapter, from the information gathered during the field survey, a floodwater depth map of the 1998 flooding in the study area was created. Also a return period of 15 years was calculated for this event using precipitation data.

Because the floodwater depths were mapped in the field as intervals, these scenarios are presented following the same criteria. It was considered that if the continuous depth values obtained from the interpolation of the 1998 flood depth spot were used.

Flood Vulnerability Curves

Known also as stage-damage or depth-damage curves, the vulnerability or loss functions (Badilla Coto, 2002) relate floodwater depth and degree of loss on a specific type of element at risk. So, to exemplify the proposed method, an assessment of damage to contents is carried out; the vulnerability assessment of structures or service offered is not considered, although the same method could be applied in these or other cases.

Some assumptions have to be established before defining the loss functions:

- The flooding is assumed to be passive (floodwater grows gently) with a low sediment load.
- The floodwater flows easily, so no damage to the content due to stagnated water is considered.
- The maximum water depth inside each plot is assumed to be unique and uniformly distributed (only one depth value for each plot).
- When considering flooding to a house, office or building, it is assumed that the content's elements remain in its place; they are not removed by people to a safer position. Actually, this assumption is very logical, considering that people in the study area.
- A complete loss is assumed for floodwater depths larger than 1.5 m, on single floor houses (Badilla coto, 2002).
- For road vulnerability it is assume that the duration of flood water is depend or related on floodwater depth. That means if depth is high duration is more. In this way for road vulnerability, floodwater depth is considered.

Steps in the Application of the Method

- An attribute table is generated by combining the ID map of elements at risk and the floodwater depth map for a specific return period.
- In this table, the predominant depth interval for each plot is determined. This is done because, as explained before, it is assumed that each plot is only affected by a single water level.
- The definition of the content for each structure type will be improved through field observations and interviews with the owners (Detail content definition is given in Annexure). In the same way, more information related to the effect of water on content

items will be gathered, in order to improve the loss functions and obtain more accurate results for the vulnerability assessment.

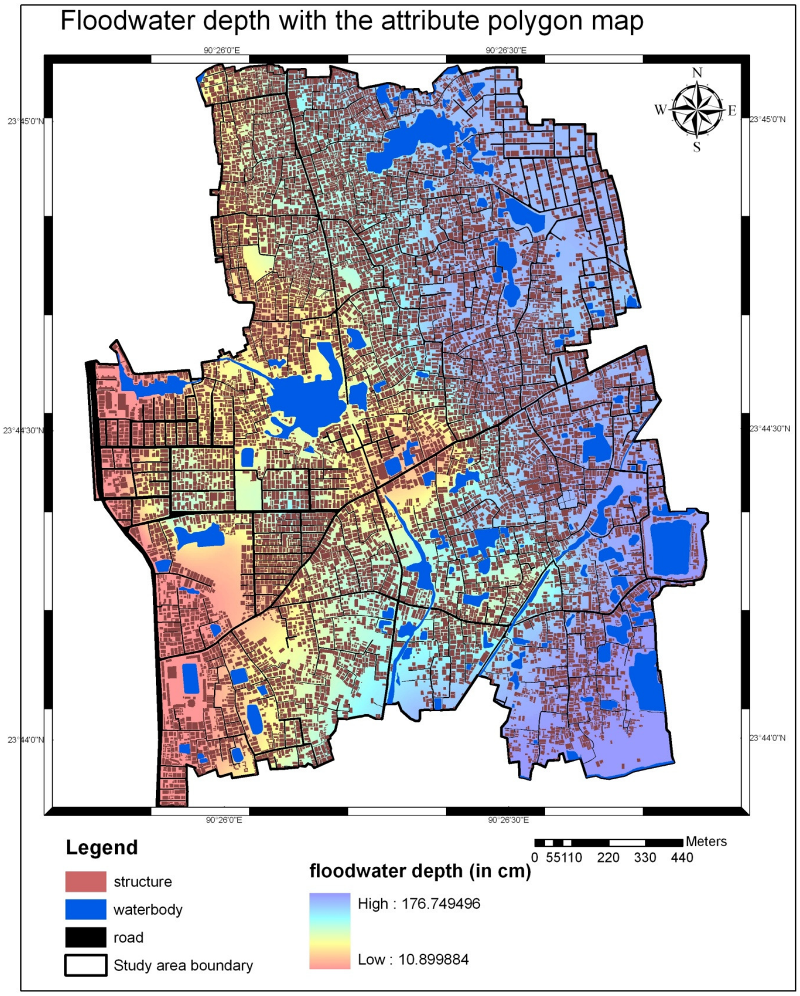


Fig. 7: Linking map of water depth map and element at risk map.

- The commercial sector will be mapped with a larger detail, being more specifically about the type of shop. The importance of doing so lies in the fact that the distribution and vulnerability of the products inside a shop depends on the type of products on sale.
- Once knowing the water depth interval affecting each element at risk, the corresponding vulnerability value is assigned to this element, according to its structure type. This is done by using a GIS function similar to this one:

Table 2: Vulnerability function for primary school.

	Depth of flood water	Criteria/ if function
Vulnerability of a primary school	0	If depth=0
	0.02	If depth $\leq$ 10
	0.30	If depth$\leq$50
	0.45	If depth$\leq$100
	0.6	If depth$\leq$150
	1	If depth>150

- A correction factor is applied in order to incorporate to the analysis the attribute class Number of floors. The vulnerability value is multiplied by 0.7 in case the element at risk has more than one floor. The only exception has to be done for the hospitals, because the definition of the loss function for this landuse already takes into account this aspect and it is found that all the hospital in the study area are in the second floor and above.

Table 3: Corrected vulnerability function.

		Criteria/if function
Corrected vulnerability	Vulnerability original	If landuse= Hospital
	Vulnerability original	If floors = 1
	Vulnerability original*0.7	If floors $\neq$ 1

- The final vulnerability map for a specific return period is obtained after classifying the values in different vulnerability categories (high, moderate, low or no vulnerability). A Slicing operation is used. These categories have been defined as follows:

Table 4: Final vulnerability function.

No vulnerably	Vulnerability = 0
Low vulnerability	Vulnerability $\leq$ 0.35
Moderate vulnerability	Vulnerability = 0.35 - 0.85
High vulnerability	Vulnerability = 0.85 – 1

Final Flood Vulnerability Map

A flood vulnerability map will be obtained for the specific (15 years) return period analyzed. After all the steps described in above Section were completed, the vulnerability map is being constructed. Blue color in the map indicates low vulnerability for the element at the risk, orange color in the map indicates medium vulnerability for the element at the risk and red color indicates high vulnerability for the element at the risk.

Damage Estimation and Risk Assessment

Risk is defined as the expected number of lives lost, persons injured, damage to property, or disruption of economic activity due to a particular natural phenomenon. Risk is the combination of vulnerability, cost of the elements at risk and the probability of occurrence of the event, and can be expressed as follows:

$$\text{Risk} = \text{Vulnerability} * \text{Costs} * \text{Probability}$$

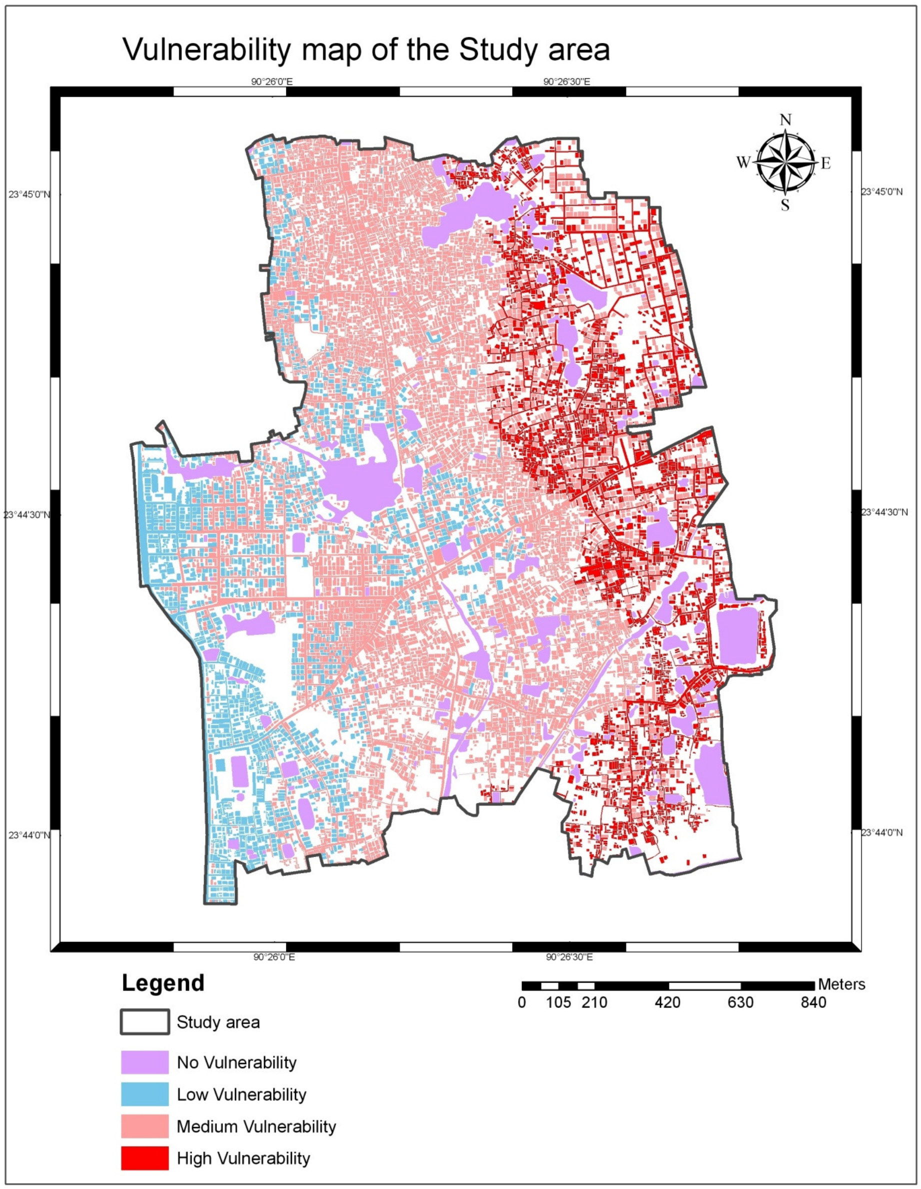


Fig. 8: Vulnerability map of the study area.

Method for the Valuation of the Elements at Risk

Cost Calculation for Contents

The flood vulnerability assessment made previously in this research considered damage to contents due to different floodwater depths. The vulnerability values were assigned to every single category of elements at risk based on its specific definition of content. Then, the content's value for each element type will be calculated based on this definition too. Two main stages constitute the content's cost calculation: the assignment of a value to each landuse type and the creation of content's cost map of the study area.

Value Assignment

A value per structure or building is assigned. The number of floors, age and building material are assumed to have no influence on the content's value. Each landuse class is treated separately: different content items are considered and different assumptions are done in each case. Present market prices were assigned to the articles, based on field survey and on personal experience. For the road, value assignment is considered the present repair cost of road.

Creation of the Content's Cost Map

First, new attribute named 'cost' is added to the attribute table of the polygon map of the elements at risk. Then, the corresponding content's value will be assigned to each field of attribute table of element at risk, according to its landuse. So, to obtain the total content's value for each building within the study area. Then the average cost, calculated based on field collected data. This cost is considered for the 38 categories of structure and their sub categories.

Flood Risk Assessment

According to the definition of risk given at the beginning of this chapter, the risk assessment implies two stages: the damage calculation (vulnerability * costs) and the final risk calculation (damage * probability of exceedance). Because the flood vulnerability assessment considered only the vulnerability of buildings and road, the present risk assessment will be focused on them as well.

Flood Damage Calculation

The calculation of damage to contents of building and road due to floodwater is carried out considering costs, following the method applied also during the flood vulnerability assessment. First, the content's cost attribute is multiplied by attribute of each flood vulnerability function using GIS tool resulting in damage maps for the specific return periods. Finally, a total loss value is calculated adding up all the obtained damages per structure. The study area comprises with 1046512 square meters of road. Based on the information given by the specialist of Roads and Highway Department (RHD), cost of Tk.2000 per sq. m. is considered for pucca road. For the semi-pucca road, it is considered Tk. 500. In the study area, there is 986491.7 sq. km of pucca road and 41264 sq. km of semi-pucca road. Zero damage is considered for the katcha road, because the local people repairs their own katcha road.

Total content damage for structures = 54.86 crore taka

Total road damage = 93.74 crore taka

So, Total damage for the study area = 148.6 crore taka

Flood Return Period Calculation

For the present research, precipitation information from the Dhaka station (see Table 06) was obtained and a simple statistical approach was used to calculate the probabilities of occurrence for the different records. It is important to notice in this table that the highest daily precipitation in this station, since 1949, was registered the day of the flood of August 1998 (552 mm). The method followed for the calculation of the return periods (Gumbel method (Viessman et al., 1989)) is summarised.

Steps for Calculating Return period

- The precipitation records have to be sorted from lowest to highest.
- A rank value (J) is assigned to the records, starting with a value 1 for the lowest record, until a value n (= number of records) for the highest one.
- The probability of not-being exceeded is calculated with the formula Pmax = J/(n+1).
- In order to graph the results, a plotting position Y = -ln(-ln(Pmax)) is calculated and then the precipitations are plotted against it. After this, a line of best fit is constructed.
- From the line of this graph the value of y for different precipitations can be read from the equation of the line of best fit. Which is y = 0.009x – 2.297.here x is precipitation value.
- Now the return period can be simply calculated with the formula $P = e^{-e^{-y}}$
- P is then substituted in the formula of R given below-

The return period R = 1/ (1-P).

This flood depth map will be used as a basis for the further vulnerability and risk analysis, so it is necessary to approximate the return period of this event. The analysis is being done through an estimation based on precipitation data. The amount of rainfall registered on the flooding from 1953 to 2002, 50 years is collected from Bangladesh Meteorological Department.

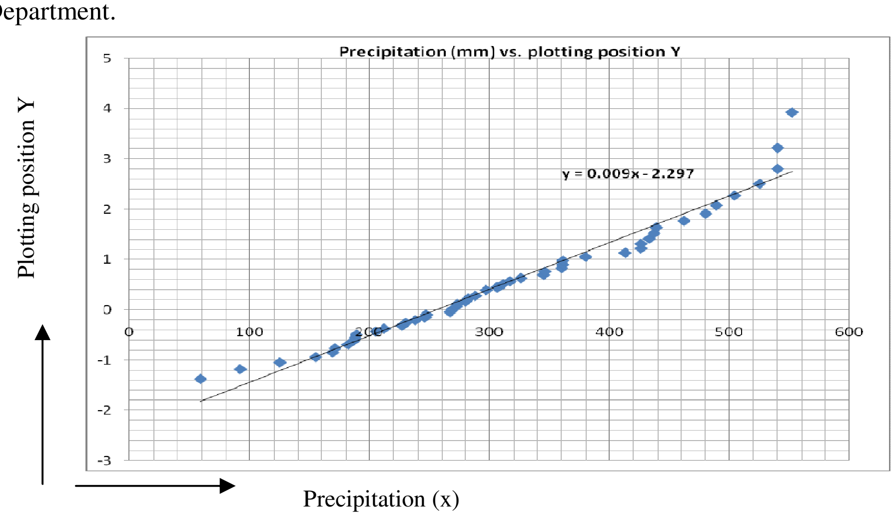


Fig 9: Precipitation with the plotting position graph

Flood Risk Calculation

The calculation of risk to content due to flood water is carried out considering damage to content and probability of exceedance of flood. Probability comes from the return period of the flood. Content's damage map is multiplied using GIS tools with the probability of the flood. Finally, total risk value is calculated adding up all the obtained risk per structure. The return period is calculated as 15 years.

Now probability of occurrence of such flood = 1/Return period

So, the probability of occurrence of such flood = 1/15 = 0.067

Total Risk = Total Damage * Probability of occurrence

= 148.6 * 0.067 = 9.96 crore taka per year

Average risk for buildings = 3058 taka

Table 5: Ranges of risk in the study area

No risk	Risk = 0 taka
Low risk	Risk < 1500 taka
Medium risk	Risk = 1500 – 5000 taka
High risk	Risk > 5000 taka

Findings of the Study

Four types of risk zones are found after the risk analysis and their characteristics are as follows:

1. There are 19 categories of structure found in high-risk zone. Total 2404 units of structure from these 19 categories are fallen in the high-risk zone. From the above table it can be seen that residential house and retail shop are the most prominent feature of the high risk zone. Total risk of these 2404 units of structure is 1.8 crore taka per year. An average risk of these structures is 7569 taka per year.
2. There are 5882 units of structure found in the medium risk zone from the 20 categories of structure. Around 50 percent of the total building falls in this medium risk zone.
3. 3600 units of structure found in the low risk zone of the study area. 3600 units of structure found in 20 categories of structure. Total risk of these 3600 structures is 2.9 million taka per year. Average risk of these structures is 792 taka per year.
4. In the zone of no risk it is found the open space, under construction buildings, hospitals and katcha bazaar. Open space and the under construction building has zero damage against flood. But in case of hospital it is found that all the hospital is started from the first floor, ground floor is not use for the purpose of hospital. This is why the damage of hospital against flood water is considered zero thus its risk is become zero. For katcha bazaar, this is like an open space before flood begins people close their all type of material from the katcha bazaar. This is why zero damage is considered for the katcha bazaar.

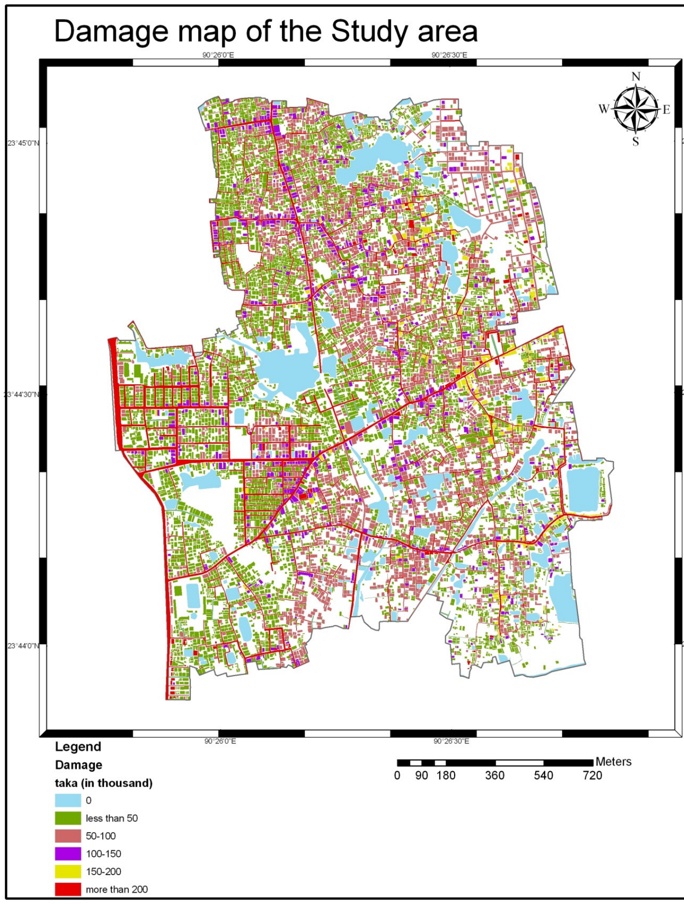


Fig. 10: Damage map of the study area.

Table 6: Return period of different precipitation obtained by the Gumbel method (Viessman et al, 1989)

Year	Precipitation (X)	Pmax	Y=-ln(-lnp)	y=0.009x-2.297	P= $_{e}$-e^{-y}	R=1/(1-P)
1989	59	0.019608	-1.3691	-1.766	0.002887	1.002896
1977	92	0.039216	-1.17517	-1.469	0.012973	1.013143
1957	125	0.058824	-1.04141	-1.172	0.039619	1.041254
1964	155	0.078431	-0.93434	-0.902	0.085049	1.092955
1988	169	0.098039	-0.8426	-0.776	0.113862	1.128493
1986	171	0.117647	-0.76084	-0.758	0.118362	1.134253
1992	182	0.137255	-0.68608	-0.659	0.144734	1.169227
1963	186	0.156863	-0.61647	-0.623	0.154972	1.183392
1981	188	0.176471	-0.55078	-0.605	0.160213	1.190778
1960	189	0.196078	-0.48811	-0.596	0.162863	1.194548

Year	Precipitation (X)	Pmax	Y=-ln(-lnp)	y=0.009x-2.297	P= $_{e}$-e^{-y}	R=1/(1-P)
2001	205	0.215686	-0.42783	-0.452	0.207743	1.262217
1968	212	0.235294	-0.36944	-0.389	0.228663	1.296451
1990	227	0.254902	-0.31253	-0.254	0.275499	1.38026
1997	230	0.27451	-0.25679	-0.227	0.285124	1.398845
1973	238	0.294118	-0.20194	-0.155	0.311095	1.451578
1994	246	0.313725	-0.14776	-0.083	0.337381	1.509163
1955	247	0.333333	-0.09405	-0.074	0.340682	1.516718
1958	267	0.352941	-0.04062	0.106	0.406804	1.685782
1980	269	0.372549	0.012694	0.124	0.413383	1.704691
2002	272	0.392157	0.06604	0.151	0.423227	1.733783
1962	273	0.411765	0.119569	0.16	0.4265	1.743678
1970	280	0.431373	0.173421	0.223	0.449277	1.815796
1999	282	0.45098	0.22774	0.241	0.455736	1.837344
1961	288	0.470588	0.282666	0.295	0.474957	1.904605
1974	297	0.509804	0.394927	0.376	0.503283	2.013219
1966	306	0.529412	0.452574	0.457	0.530901	2.131745
1975	307	0.529412	0.452574	0.466	0.533921	2.145559
1984	311	0.54902	0.511457	0.502	0.5459	2.20216
1985	317	0.568627	0.571762	0.556	0.56355	2.291215
1953	326	0.588235	0.633694	0.637	0.589267	2.434669
1991	345	0.607843	0.69748	0.808	0.640345	2.78044
1982	346	0.627451	0.763377	0.817	0.642907	2.800392
1995	360	0.647059	0.831678	0.943	0.677424	3.100046
1976	361	0.666667	0.90272	0.952	0.679792	3.122971
1996	361	0.686275	0.976897	0.952	0.679792	3.122971
1972	380	0.705882	1.054672	1.123	0.722309	3.601123
1959	413	0.72549	1.136602	1.42	0.785281	4.657244
1978	426	0.745098	1.223361	1.537	0.806521	5.168522
2000	426	0.764706	1.315784	1.537	0.806521	5.168522
1954	433	0.784314	1.414915	1.6	0.817179	5.469846
1983	437	0.803922	1.522098	1.636	0.823034	5.65081
1993	439	0.823529	1.639093	1.654	0.825899	5.74378
1987	462	0.843137	1.768284	1.861	0.855972	6.943118
1965	480	0.862745	1.913006	2.023	0.876115	8.071992
1956	489	0.882353	2.078137	2.104	0.885177	8.709061
1967	504	0.901961	2.271239	2.239	0.898917	9.892821
1979	525	0.921569	2.50497	2.428	0.915566	11.84354
1969	540	0.941176	2.803054	2.563	0.925822	13.48111
1971	540	0.960784	3.218742	2.563	0.925822	13.48111
1998	552	0.980392	3.921941	2.671	0.933156	14.96018

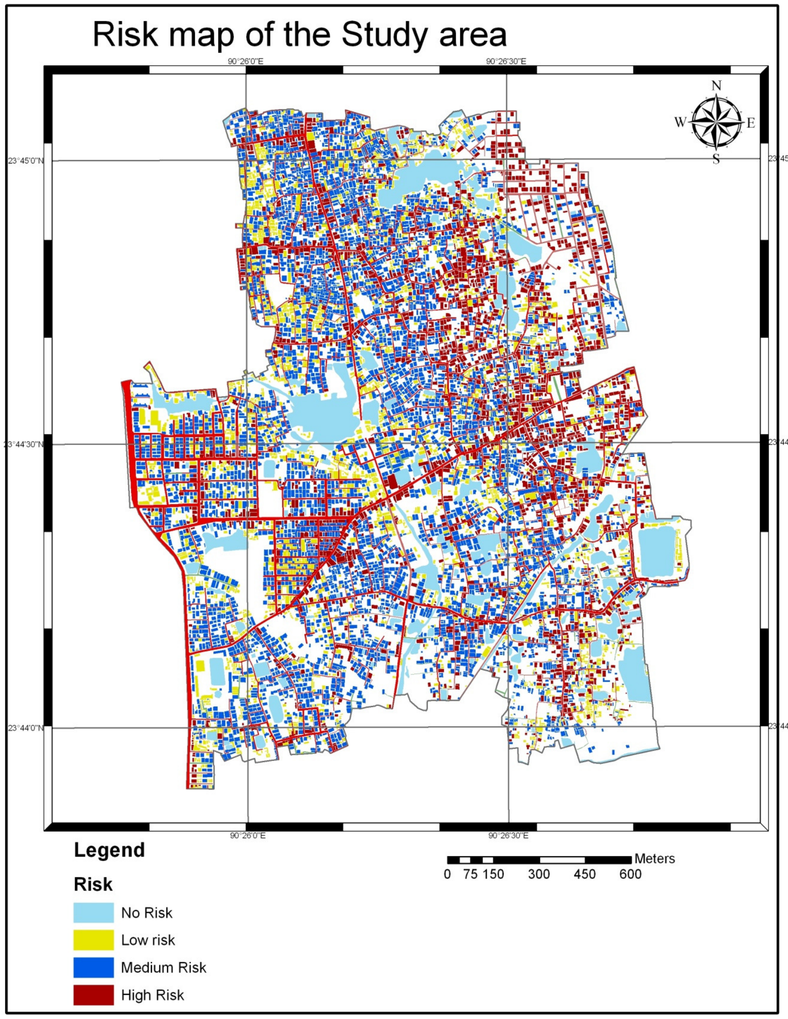


Fig. 11: Risk map of the study area.

Conclusion

Damage calculation and risk assessment methods are considered in this study are valid and applicable in other parts of Dhaka city and elsewhere. Using GIS potentiality, productive measures can be taken which can respond effectively pre, during and post disaster period. Taking flood as a common phenomenon for Bangladesh this type of measurement should be emphasized for better response.

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