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Flood Risk Measuring under the Flood Protection Embankment Construction in Dhaka Metropolitan Zone

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Abstract The flooding is a common feature for problem solution in rapidly urbanizing Dhaka city. In this research, evaluation of flood risk of Dhaka city in Bangladesh has been developed by using an integrated approach of GIS, remote sensing with socio-economic data. The purpose of the study is to evaluate the flooding risk concerning with the flood protection embankment in remarkable flooding events (1988, 1998 and 2004) and urbanization of Dhaka metropolitan zone. In this research, we considered the Dhaka city into two parts east Dhaka where is outside the flood protection embankment and west Dhaka where is inside the flood protection embankment. Using statistical data we explored the socio-economic status of the study area population by comparing density of population, land price and income level. We have drawn the cross section profile of the flood protection embankment into three different points for realizing the flooding risk in the study area, especially in the historical flooding year (1988, 1998 and 2004). According to the physical condition of the study area, the land use/land cover map has been classified into five classes. Comparing with each land cover unit, historical weather station data and the socio-economic data the flooding risk has been evaluated. Although various adaptation strategies for prevention infrastructure was developed on basis of 1988 memorial flood. As a result, urban area expansion has driven by infrastructure development by 10% and population growth by 5% inside the embankment area. The socio-economic development such as; the average total income inside of embankment has been increased 10 USD while the income outside the embankment remain same.

Keywords: *Land use/ land cover change, Socio-economic, Dhaka city, GIS, Flood*

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1. Introduction

Urban flood is a common problem for megacity Dhaka. It occurs to be accelerated surface runoff due to inadequate drainage facilities for disposing of such runoff in many cities of developing countries [1,2]. Direct inundation by river floods and inland inundation are the other type of urban flood problem, particularly for those cities located in low-lying floodplain environments like Dhaka city. Moreover, the higher rate of increase population against the limited amount of land (Figure 1) has recently been accelerated flooding vulnerability in every year. Dhaka City, the capital of Bangladesh, although located on a slightly elevated tract of land above the surrounding floodplains of the Buriganga River and its tributaries, experiences both types of flood problems. While flash floods on streets following heavy rainfall have become routine events in recent years, large areas of the city, including its business districts and administrative headquarters, were inundated during the catastrophic flood of 1988, 1998, 2004 and 2007 [3].

Almost every year, floods have been threatening to rural and urban inhabitants of Bangladesh. Dhaka city has been experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998, 2004 and 2007 (Figure 2) due to the over flow of surrounding rivers [4]. Vast amount of area of this country including the Capital City of Dhaka city were flooded to an unprecedented degree. With a population of about 17.6 million Dhaka city has been suffered several of the most serious and devastating floods on record in 1988, 1998, 2004 and 2007. In Dhaka City, it is estimated that, in the big flooding years, such as 1988, 1998, 2004 and 2007 about 200 km^2 where 77% of the total area of 260 km^2 is, was submerged to depths ranging from 0.3 m to over 4.5 m [5].

In 1998 flood event, peaked very early than that of the 1988 event. On the other hand, duration of days above danger level of the water level was also higher than the 1988 event. It is found that, water level of all the rivers around the city started to rise in the third week of July in 1998 and remained until the last week of September. Thus, the 1998 event was prolonged for more than two months making it the longest flood in memorable time. It is believed that the 1988 flood was become severe due to excessive transboundary inflow and lack of flood protection in the city [6] while the 1998 event became severe due to hydraulic leakage as well as huge monsoonal rainfall. In addition to that, drainage congestion, inadequate pumping, lack of institutional coordination are auxiliary factors that made the flood situation critical [7,8].

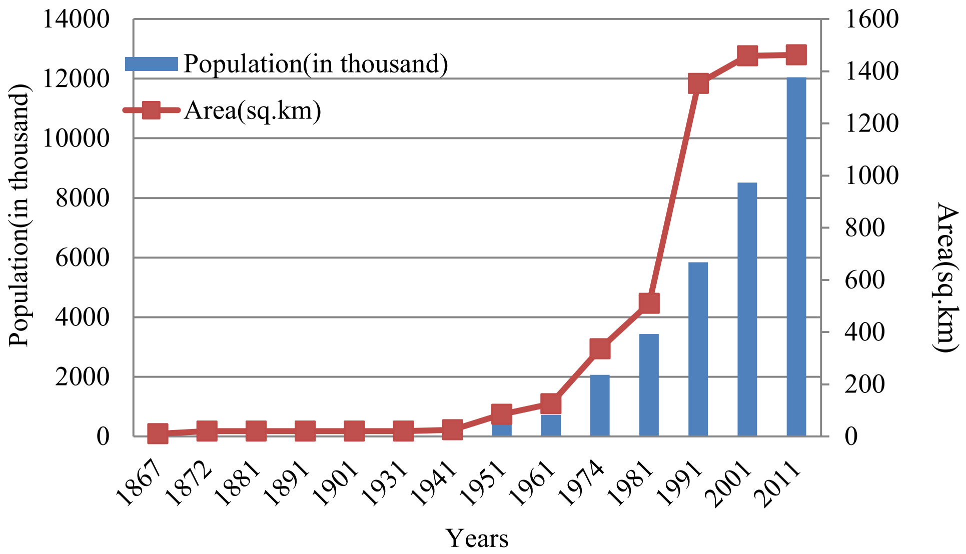


Figure 1. Increasing Population of Dhaka city against the limited amount of land

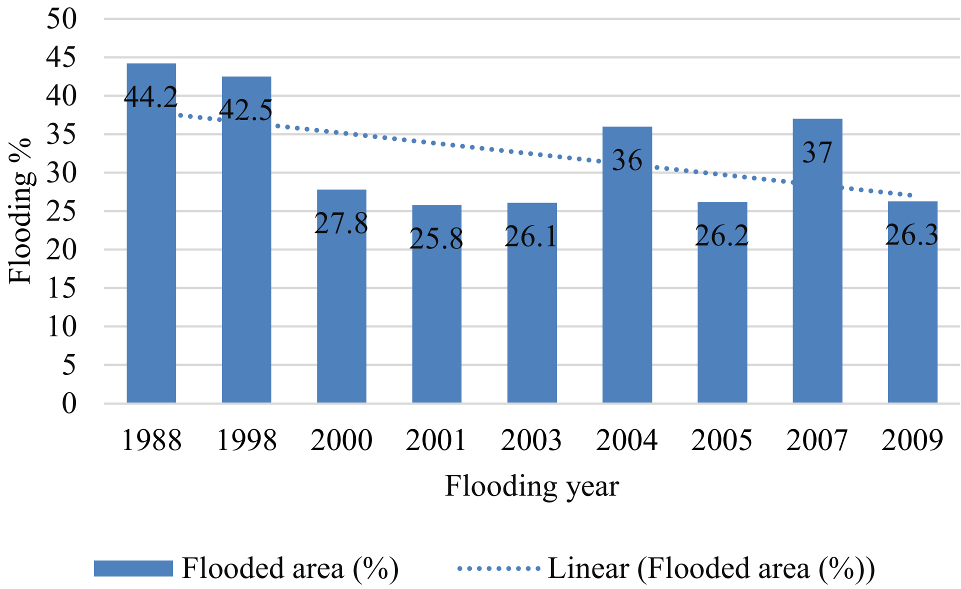


Figure 2. Flooding trend of Dhaka city

1.1. The Dhaka City Flood Control Project

The Dhaka City Flood Control Project covers an area of 265 km^2 and can be divided into two distinct phases. The first phase of the project, which began in 1989 and was completed by late 1990, consists of a 30 km embankment along the western perimeter of the metropolitan area, stretching from Tongi in the north to the bank of the Burhiganga River in the southwest. The second phase consists of a plan to construct a 29 km embankment along the eastern perimeter, stretching from Uttara in the north to the Shitalakhya River in the southeast. The existing Dhaka-Narayanganj-Demra (DND) embankment in the south would eventually connect the western and the eastern components, creating a continuous system of ring embankment around the metropolitan area.

The embankment has been built through the low lying topography of the Burhiganga River and the Turag River floodplains. It cuts across several pre-existing abandoned channels. These channels and associated depressions retained stagnant water following construction of the embankment. The design of the embankment was adjusted to suit the topographic setting and the nature of human settlements along the alignment of the embankment. The northern section from Uttara to Mirpur is a continuous earth embankment designed to provide protection from a 100-year flood, with crest elevation of 8.2 m, which is about 0.4 m higher than the maximum water level of the 1988 flood [9]. Near the township of Uttara, the embankment enclosed relatively high ground and did not cause major water-logging. Further south, significant accumulation of water took place inside the embankment, but there were very few settlements along this low-lying section. The middle section between Mirpur and Nawabganj is predominantly an earth embankment, but concrete walls have been interposed across a number of smaller segments through some of the existing homesteads [10]. High density residential areas are located all along the embankment south of Mirpur, particularly in the Rayer Bazar and Nawabganj areas. These areas experienced the most severe problems with stagnant water due to drainage congestion.

1.2. JICA Flood Control Measure Project

In 1991, the western part of Dhaka city have been encircled by embankments, flood walls, raised roads to give protection against riverine flood [11]. Important components of flood protection measures are: a) About 30 km of earthen embankment along Tongi Khal, Turag and Buriganga river, b) About 37 km of raised road and floodwalls in few locations of old Dhaka along the river Buriganga where intensive infrastructures do not allow any further road improvement. c) A total of 11 regulators at the outfall of canals to the surrounding rivers along the embankment. d) 1 regulator and 12 sluice gates on the canals at the crossing with Biswa road, Pragati Sarani, Mymensingh road and Railway line at Uttar Khan. e) Three pump stations namely Kallyanpur, Goranchat Bari and Dholai Khal pumping stations and to drain out rainwater from some protected parts of Dhaka West. They are all together called flood control structures and are supposed to keep Dhaka West free from riverine floods, These flood control works were prepared and rearranged based on the study of flood mitigation and storm water drainage plan in the Master Plan for Greater Dhaka Protection Project [12,13].

There are several researches has been done on flood in Dhaka metropolitan area at the local and government level. Harun Rasid (1996) described about the importance of synchronizing the construction of drainage facility structures with that of the embankment systems and by underlining policy implications for flood-vulnerable land use adjacent to embankments [14]. S.K. Bala (2009) describes the performance of various flood control works around Dhaka city and tries to find out the causes of external and internal flooding of protected Dhaka during major floods in the recent past [15]. B.M. Alam (1996) investigated the flood mitigation measures and described the socio-economic factors in the Dhaka metropolitan area concerning with the Dhaka flood protection project [16]. M. Faisal (2003) explained about to develop a set of long-term strategies and flood mitigation for Dhaka metropolitan area, This study also suggests a set of non-structural measures for flood mitigation that include protecting the retention ponds, raising public awareness on maintaining the city drains, introducing land zoning and flood proofing in the eastern part of Dhaka [6]. B. Das (2010) wrote about the nature and trend of encroachment of retention pond areas and canals proposed and designated in FAP-8B project since 1989 [17].

These reports and maps are not concerned with the flood protection embankment in big flooding events (1988, 1998, 2004 and 2007) and urbanization of Dhaka metropolitan zone. Realizing the situation this research has been conducted on Dhaka metropolitan area, where the major focus to evaluate the flood inundation situation based on the satellite data and socio-economic data compare with the land use/land cover change.

The objective of the study is to examine the spatial variations and temporal changes in various land use with GIS data and to find out the flooding risk concerning with the flood protection embankment in big flooding events in Dhaka metropolitan area. Specifically, the purpose of the study is to measure the flooding risk concerning with the flood protection embankment in big flooding events (1988, 1998, 2004 and 2007) and urbanization of Dhaka metropolitan area.

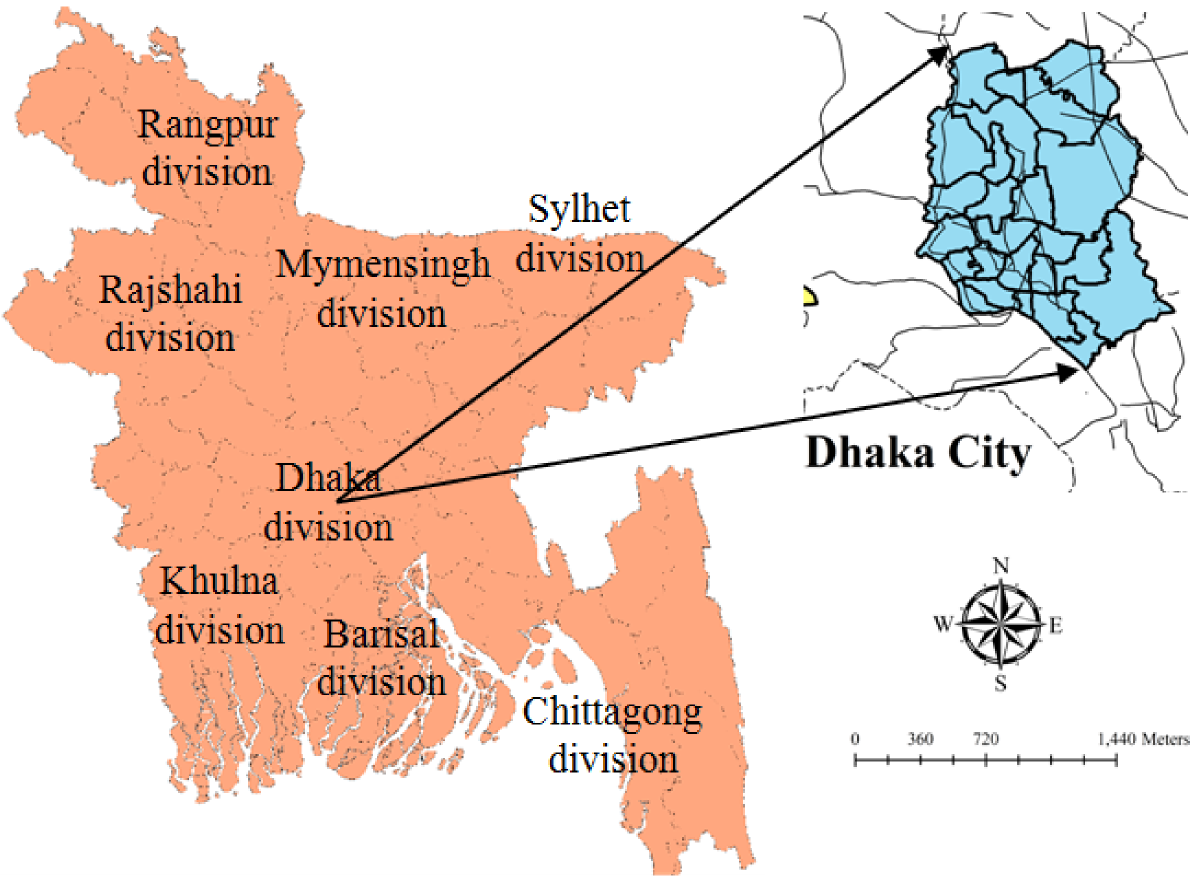


Figure 3. Geographical location of the study area

2. Study Area

The study area chosen for this research is the Dhaka metropolitan area of Dhaka city which is located (Figure 3) approximately in between longitude 90°19' E to 90°25' E and latitude 23°40' N to 23°53' N. It is surrounded by the Buriganga River to the south, the Turag River to the west, the Tongi River to the north and the Balu River to the east. Geographical location the study area has been flooded almost every year because of urbanization and poor discharge facility. The main causes of floods in the study area are water overflow from the surrounding rivers which responsible for river floods and runoff from rainfall in the upper Bramaputra Ganga Meghna catchment area. Thetotal area of the Dhaka metropolis is 136.5 km^2 consisting of 73 wards. It covers almost all of the built-up areas of the city with 73.6 % population of Dhaka City Corporation (DCC) area [18,19,20,21,22]. It includes the restricted areas like Zia International Airport, DhakaCantonment. Major land use in the study area is residential and it covers 51 % of the total land area. Lands used for residential purpose cover 14.7% as planned area and 36.3% as unplanned area. The road network covers about 9.2% area. The significant portion (11%) of lands are mixed land use [23]. The greater Dhaka city is located mainly on an alluvial terrace, popularly known as the Modhupur terrace of Pleistocene period. Topographically, Dhaka city is relatively a flat land, the surface elevation of the city ranges between 1 and 14 meters [24]. It belongs to sub-tropical monsoon zone and experience humid climatic conditions. Dhaka city experiences about 2000 mm annual rainfall of which more than 80 % rainfall take place during monsoon. Historically, Dhaka city is built up in a flood plain with numerous water bodies and canals that used to drain water from its upper reaches during monsoon season. As population increased, these areas were encroached [25,26].

3. Methodology and Data

The study has been carried out in a number of steps which include review of existing documents on past floods in Dhaka City, land use/land cover change analysis, field visits, interview with key professionals, and synthesis of the long-term flood mitigation strategies.

Principal components of the methodology adopted for this study (Figure 4) are as follows:

I. Land cover change analysis:

The issues of land use changes due to urbanization have been already discussed in a number of studies. Remote sensing, in conjunction with geographic information systems (GIS), has been widely applied and been recognized as an effective tool in detecting land use/land cover and land cover change [27]. After the big flood in 1988, the government made the embankment to protect Dhaka metropolitan area from flooding but after 10 years, in 1998, 2004 and 2007 happed and flooded inside the embankment area. In this study we will clarify the flood situation inside the embankment area in Dhaka metropolitan area especially in the following big flooding years 1988, 1998, 2004 and 2007. Satellite Image interpretation is the useful method for analyzing the trend of land use/land cover change. The Remote Sensing Images (TM, ETM and DEM) for this study were acquired of 28 Feb., 1989; 24 Nov., 1999; 8 Aug., 2009 and 10 Oct., 2011. Also, field investigation was conducted for the determination of the existing scenario of the land use. The Spatial data analysis was conducted with GIS software of Arc map 10.0.

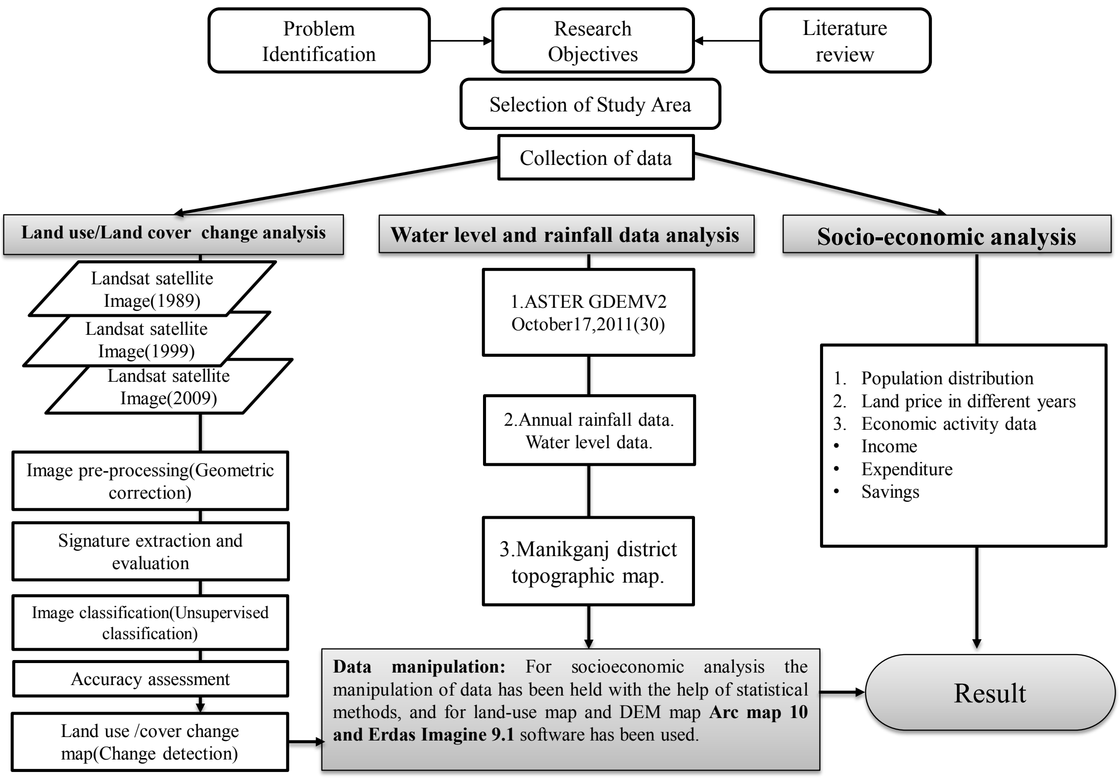


Figure 4. Methodology flow chart

II. Water level and rainfall data:

The cross section profile has been drawn in three river station points and compare with the water level data, we tried to find out the vulnerability of flooding risk over the embankment due to overflowing water. Natural drainage area or canalestablished areas are identified from Bangladesh water development survey map. We have been identified Land cover changes around the retention ponds and canal areas from our land use/ land cover change maps.

III. Socio-economic data analysis:

The socio-economic data has been collected from both primary and secondary data sources. In this section we tried to evaluate the socio-economic scenario of the people living inside and outside the embankment area. The data includes number of population, income and expenditure level, price of land and compare with the land use/land cover change scenario. Data were obtained from Bangladesh Population Census book (1991, 2001 and 2011), data and information relating to agriculture are obtained mainly from Statistical Year Book of Bangladesh (2003, 2005 and 2008) published by Bangladesh Bureau of Statistics (BBS).

4. Result

4.1. Land Use/Land Cover Change

In 1989, agricultural land use amounted 129 km^2 (43%) and decreased to 73 km^2 (24%) in 2009 (Table 1), during the above mentioned 20 years, the decrease of agriculture land use was caused by development of infrastructure and factory in Badda, Demra and Kamrangirchar, business district in Motijhil, Tejgoan and Gulshan (Figure 5). Since 1999 to 2009, a significant decrease of agriculture land use is found in Dhaka metropolitan area and surrounding areas because of capital city Dhaka and transportation network development. The size of agricultural land mainly depends on the growth of the settlements, being an important factor influencing land-cover changes [28].

The built-up land use is composed of residential land use, commercial land use and industrial land use. The urban land use area was 76 km^2 (25%) and expanded to 178 km^2 (59%). The remarkable change had occurred during 1999 to 2009, including built-up area the important infrastructure such as airport, business district and other commercial sector has been developed inside embankment area. In 1998, the total road length was 825 km which increased to 1,790 km in 2011 in length. Conversion of agricultural infrastructure into urban infrastructure in the urban fringe of deltaic Asian cities [29]. Commercial and industrial land use changes have been observed also with the growth of the area. The major land-use change is caused by the increasing demand for non-agricultural land because of urban and infrastructure development [30]. The commercial land use includes shops, banks, hotels, restaurants, government office, cinema hall have been established gradually in the study area. The majority of urban land was acquired by converting areas that were previously agricultural land, vegetation and water bodies.

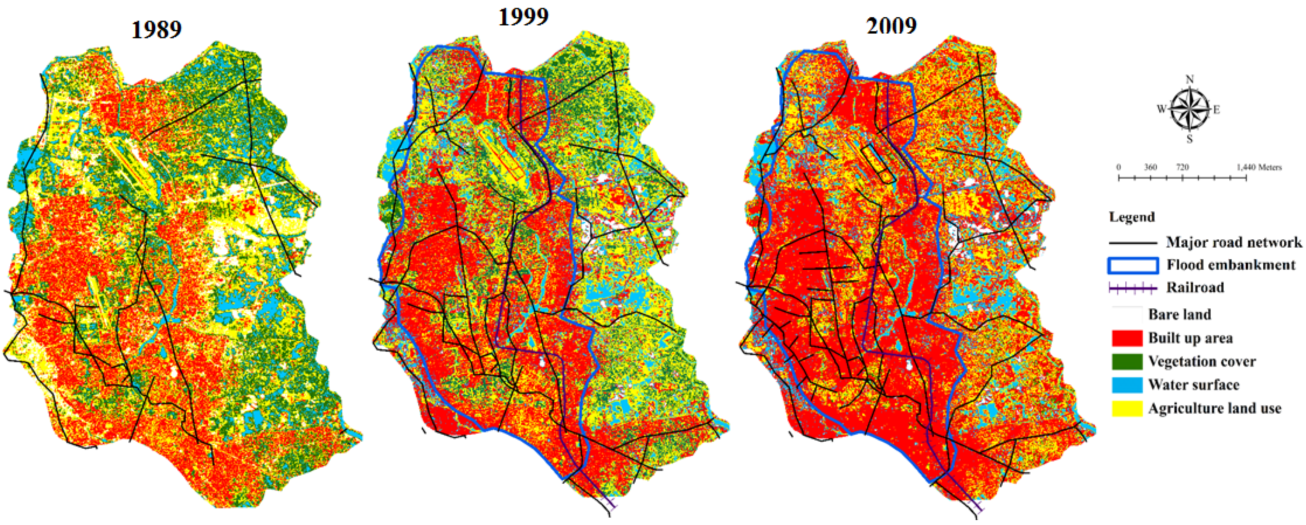


Figure 5. Land cover maps of Dhaka metropolitan area from 1989 to 2009

Table 1. Data for land cover change from 1995 to 2015 of the study area

	Area (in sq.km)			Area (in %)		
	2009	**1999**	**1989**	**2009**	**1999**	**1989**
Built-up	178	113	76	59.68	37.93	25.58
Agriculture	73	101	129	24.42	34.00	43.17
Water	23	38	42	7.84	12.67	14.23
Vegetation	9	15	18	2.89	5.10	5.90
Bareland	15	31	33	5.17	10.30	11.11
	298	298	298	100	100	100

In 1989, bare land amounted 33 km^2 (11%) and decreased to 15 km^2 (5%) in 2009 (Table 1). During the above mentioned 20 years, the bare land had decreased by the net bare land area had decreased because with the increase of population, the demand of food had increased too. As a result, the bare has been converted to both agriculture land use and urban land use. The water surface was 42km^2 (14%) in 1989 and dropped to 23 km^2 (7%) in 2009. The decrease of water surface was a result of the construction of residential, commercial and industrial zone to promote urban development (Figure 5). The vegetation cover was 18 km^2 (6%) in 1989 and dropped to 9 km^2 (3%) in 2009. The decrease of vegetation cover was a result of the construction of residential, commercial and industrial zone to promote urban development [31,32].

By comparing land use/land cover change maps with DEM data following results has been discovered:

From 1989 to 2009 the major land use/land cover have been changed in agricultural land and was occurred in low lying areas where is elevation ranging below 3 m (Figure 6). Increasing in built up areas is due to shrinkage of agriculture land use and mostly transformation into residential and commercial activity. Moreover this area is located into the low lying floodplain zone. Changes in built up area (20%) have occurred in almost all elevation range between 1 m and 6 m. Agricultural land use associated with high elevation range converted into bare land, and at the same time low elevated agricultural land is converted to build up zone to meet the demand for housing to accommodate growth in population. Vegetation cover has been increased substantially in low elevation range between 2 and 4 m, at the periphery of dried up water body and almost all low lying floodplain areas.

4.2. The Socio-economic Impact

The socio-economic impact resulting from the construction of the flood protection embankment can be described by the following parameters (Table 2).

Migration or displacement of people (Figure 7) (Table 2), Increasing population density, Land use/ land cover change, Transportation development, Land price, Occupation, income and Growth of business or other economic activities are the parameters for analysis of this study. The construction of embankment has bought a sense of safety and security to the people. 74% to 76%of the people living nearer to the embankment feels that they are able to live in the area without any risk of flood [33]. Displacement of people and in-migration took place during and after the construction of the embankment. The embankment has led to an increase of land values in the inner areas of the embankment due to being flood-free and easily accessible. According to the BBS 2011, 91% of the people surveyed in the embankment area are of the opinion that land value has appreciated due to the embankment construction. The main factors influencing the land market is that the area has been protected from the annual flooding.

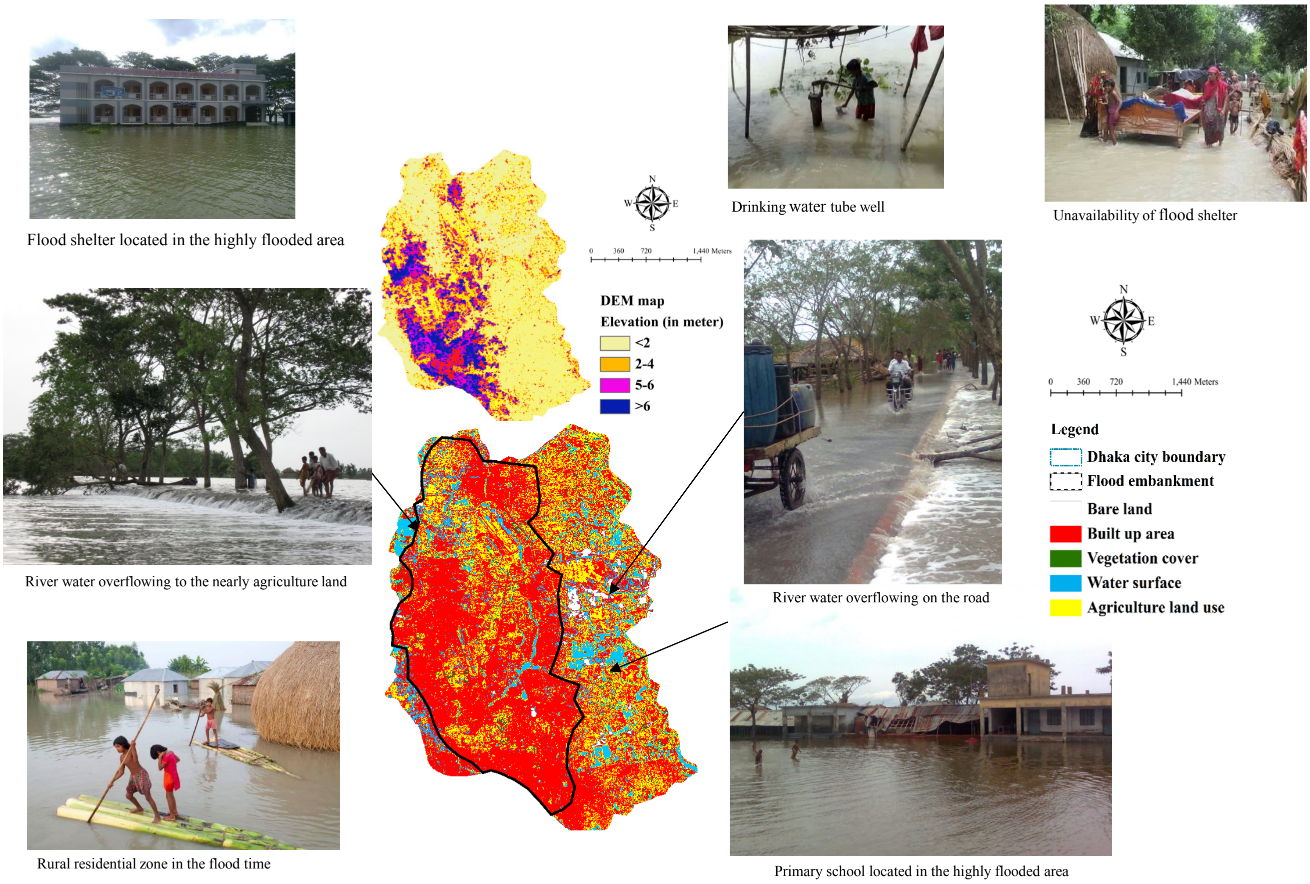


Figure 6. 2007 flooding situation in Dhaka metropolitan area with comparing DEM map

Table 2. Changing population pattern in Dhaka metropolitan area from 1991 to 2011

Police Station	Population in 2011	%	Population in 2001	%	Population in 1991	%
Badda	6,66,674	7.45	3,59,256	6.00	4,35,308	10.30
Cantonment and Airport	7,97,069	8.90	5,53,800	8.54	2,37,441	6.7
Uttra	6,72,087	7.51	3,45,097	8.00	5,93,603	14.20
Demra	19,50,589	21.79	14,48,144	24.00	11,87,205	30.80
Dhanmondi	17,78,553	19.87	12,87,114	19.80	5,14,456	13.00
Gulshan	11,27,649	12.60	7,82,685	12.50	3,56,161	9.50
Kamrangirchar	19,59,274	21.89	13,06,781	21.20	6,33,176	15.50
Total	89,51,895	100.0	60,82,877	100.0	39,57,350	100

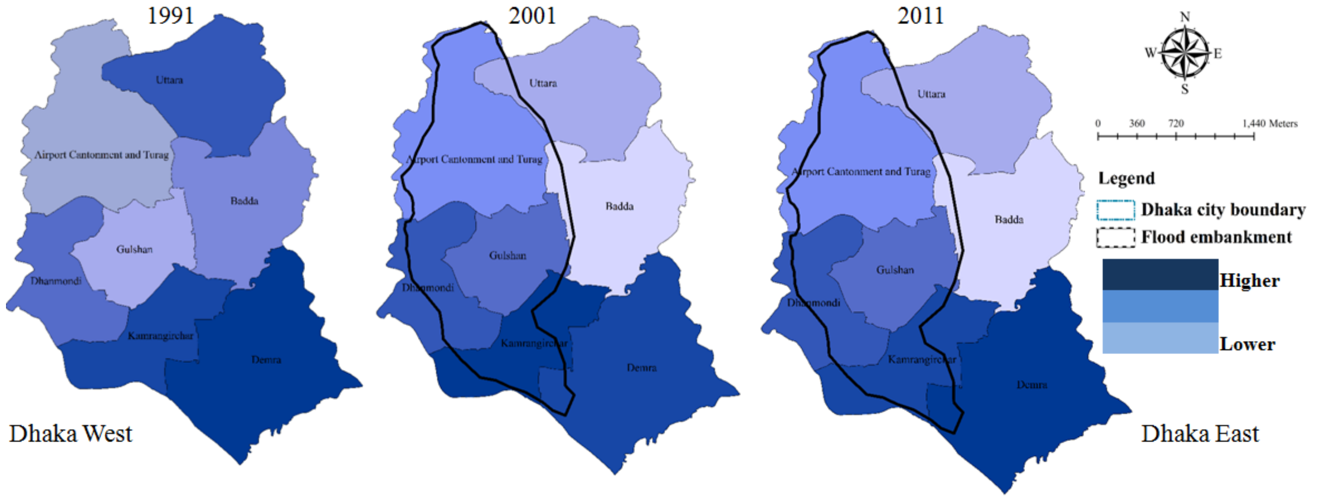


Figure 7. Changing population pattern in Dhaka metropolitan area

Table 3. Land Price increase in Dhaka City and Fringe area (USD/sq.m)

Area	1975 (USD/sq.m)	1990 (USD/sq.m)	2000 (USD/sq.m)	2010 (USD/sq.m)
Inside the Embankment				
Motijhil	9.5	226	659	5,661
Gulshan	4.7	113	471	3,774
Kamrangirchar			14	151
Outside the Embankment				
Badda	0.8	38	113	944
Demra	0.8	38	113	472

1 USD ($) = 80 Taka. Source: RAJUK, 2011

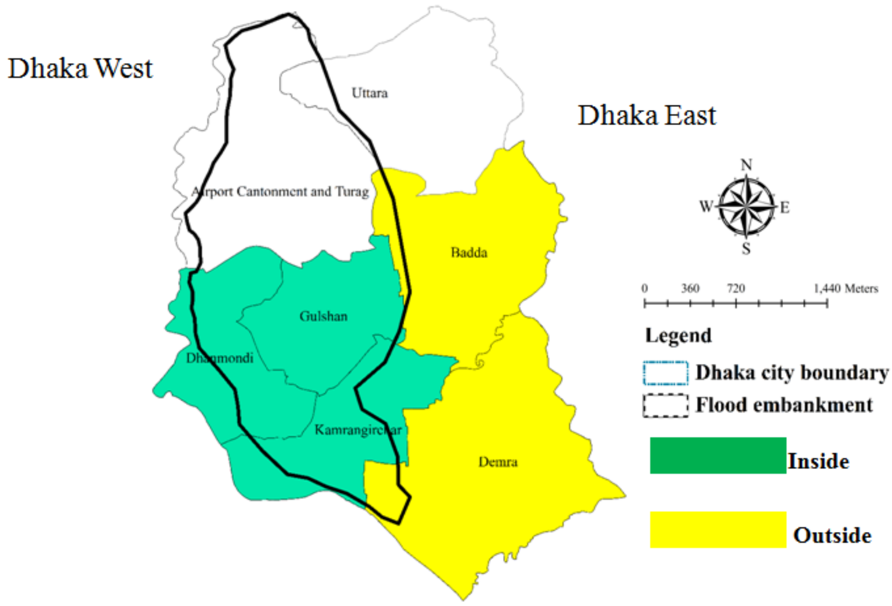


Figure 8. Land Price situation in Dhaka City and Fringe area

4.2.1. Land Price

As a low-income country such as Bangladesh, the land price in its capital area is absurdly high. Comparison of land price data in prime locations of the city and different suburbs areas is shows in (Figure 8) (Table 3). Data shows that, in the time span of 34 years, the residential areas of Motijheel, Baridhara and suburbs districts of outlying areas of Dhaka registered highest percentage increase compared to the fringe areas of Badda, Demra, and Eastern part of Uttra. Currently, land price in Dhaka is increasing at a rate which is much higher than the contemporary developed and developing cities in the world. The middle and lower middle classes of Dhaka are forced out of the land market, whereas about 50 percent of the populations are living in slums and squatter areas in Dhaka. Such phenomenal growth in land price has led to land speculation, particularly among land developers and individual plot buyers. At present prohibitive land prices in Dhaka city area pushed the land price up in sub-urban areas also. Most of the peripheral lands have been rapidly purchased by private developers for land and housing development projects, especially speculating on future price increases.

4.2.2. Income

The total monthly income inside the embankment has been increased after the construction of the embankment from68 USD/month to 86 USD/month. But on the other hand, outside of the embankment has been decreased from63 USD/month to 62 USD/month. As a whole, the total income amount has been increased from 66 USD/ month to 74 USD/month after the flood protection project. Because government considered this zone as a flood free zone and started socio-economic development. Residents are migrated themselves to the flood free area from surrounding embankment zone (Figure 9).

4.2.3. Expenditure

The average expenditure of both sides has been increased after the construction of the embankment while the total expenditure for the insiders before and after the construction of the embankmentis66 USD/month and 83 USD/month respectively; the values of 61 USD/month and 65 USD/month have been found for the outsiders. The total expenditure for all respondents has been increased from 64 USD/month to 74 USD/month (Table 4). It means that there is an increase in expenditure for the insider but for the outsiders it is not too high from the situation before the embankment was built. Moreover it could easily realise that, regarding to the socio-economic status the insider was much better compare to the outsider.

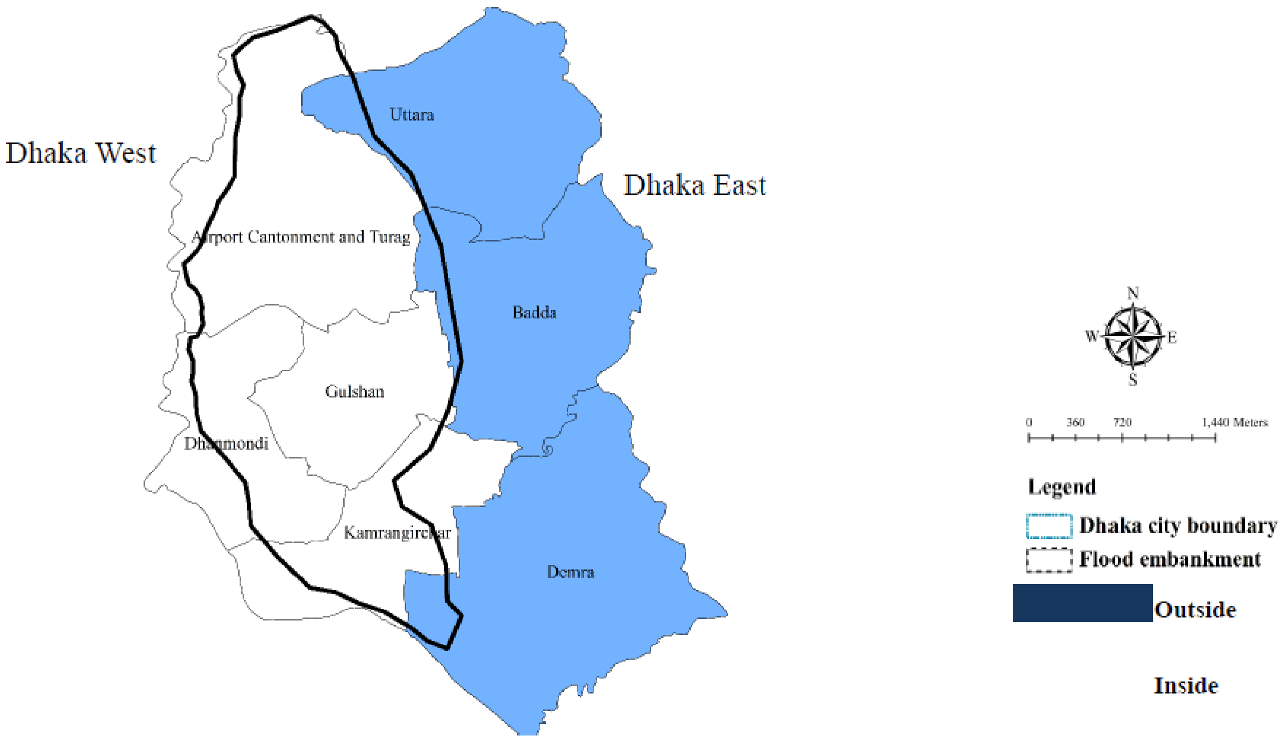


Figure 9. Effect of Embankment on overall Economic Condition of the People in Its Fringe Areas

Table 4. Effect of Embankment on overall Economic Condition of the People in Its Fringe Areas

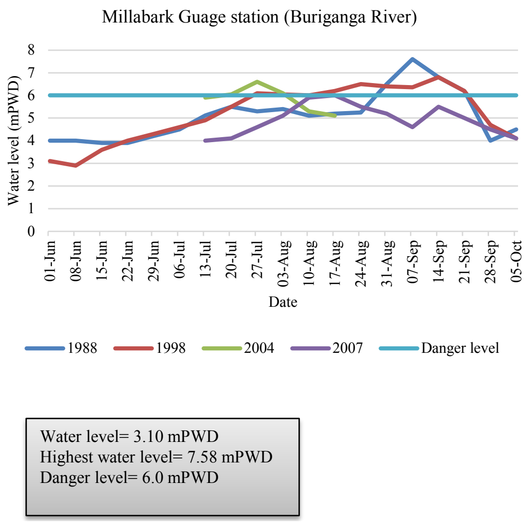
	Before construction of Embankment (USD/month)			After construction of Embankment (USD/month)		
Economic factors	**Inside the Embankment**	**Outside the Embankment**	**Average Total**	**Inside the Embankment**	**Outside the Embankment**	**Average Total**
Income	68	63	66	86	62	74
Expendature	66	61	64	83	65	74
Savings	1.8	2.2	2	2.6	2.3	2.5

1 USD ($) = 80 Taka

Source: BBS, 2011

4.3. Hydrologic Characteristics of Major Floods in Dhaka Metropolitan Area

Figure 10. Location of different weather station around the study



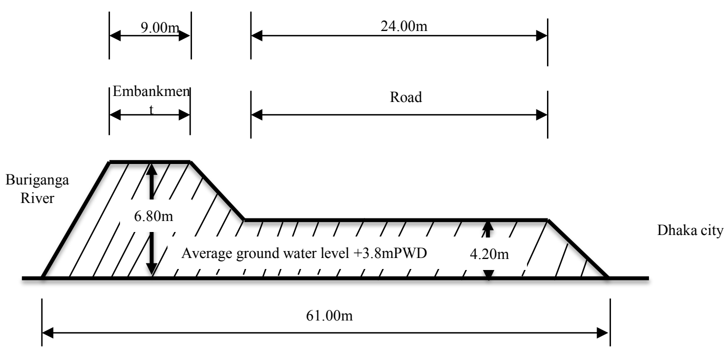


Figure 11. Cross-section profile of the multipurpose embankment along the Buriganga River

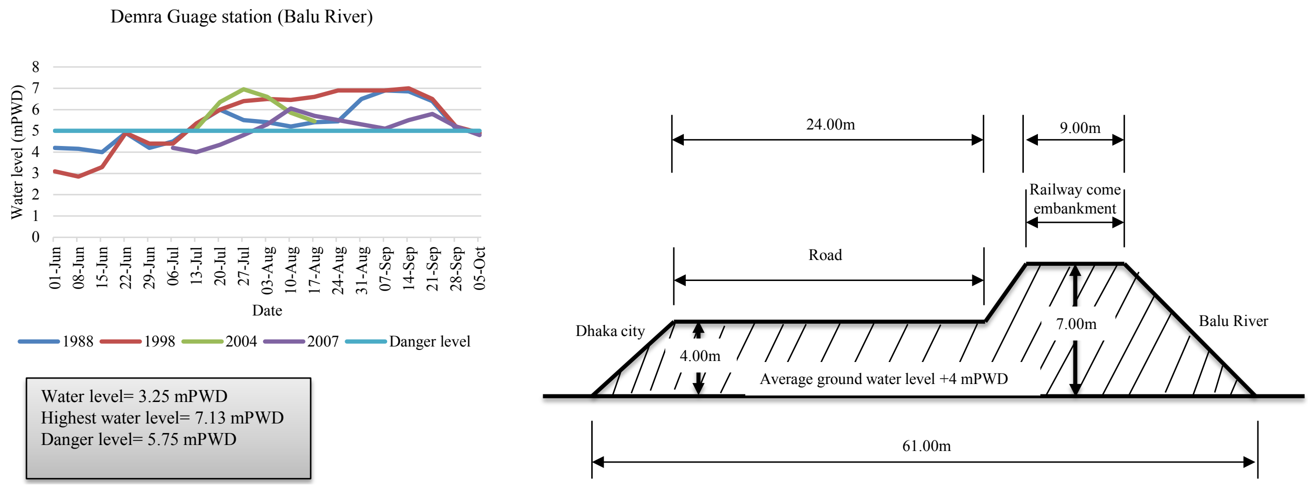


Figure 12. Cross-section profile of the multipurpose embankment along the Balu River

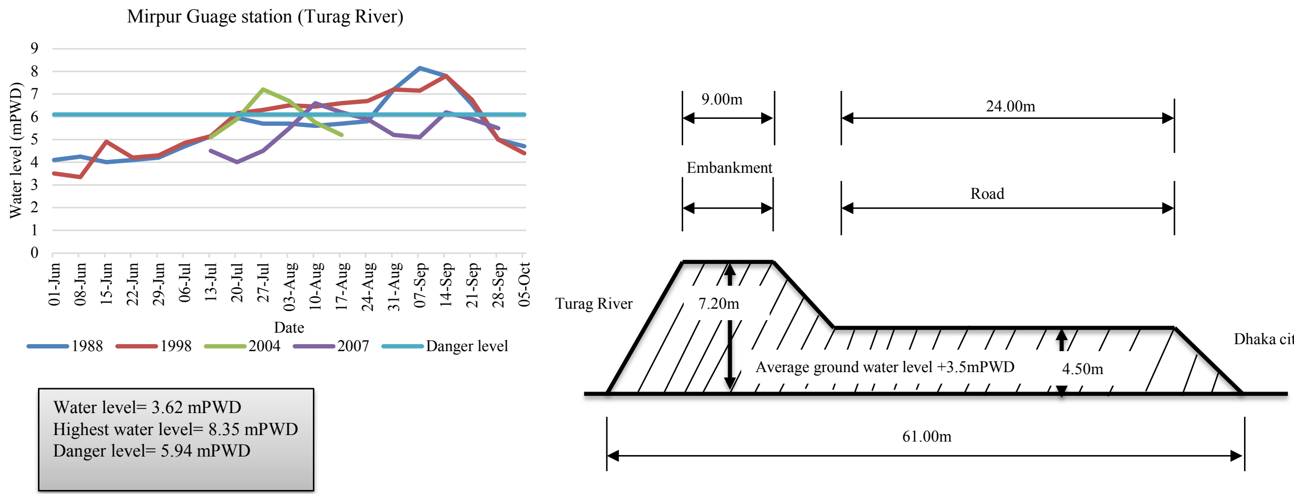


Figure 13. Cross-section profile of the multipurpose embankment along the Turag River

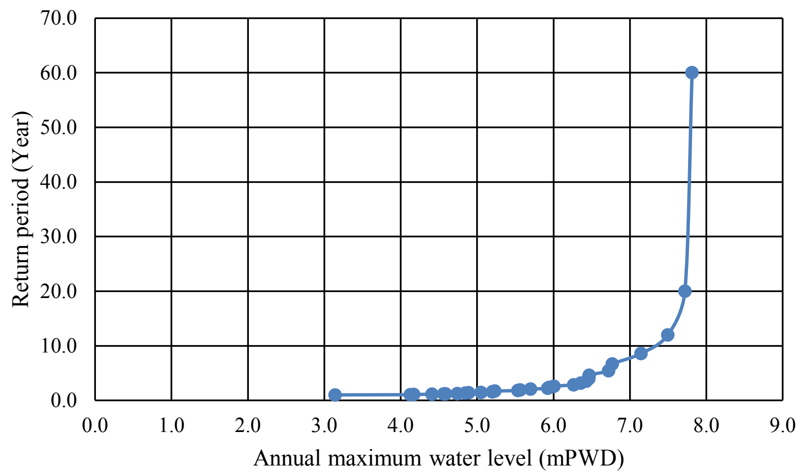


Figure 14. Flood return period scenario

Water level[1] data of three major stations in each of the four surrounding rivers of Dhaka city has been analyzed. Data from Dhaka station in the Buriganga River, Mirpur station in the Turag River and Demra station (Figure 10) in the Balu River were used to compare flood situation. Millbarak station, Demra station and Mirpur station (Figure 11, Figure 12 and Figure 13) shows water level hydrographs of surrounding rivers for four major flooding years, namely 1988, 1998, 2004 and 2007. In the next subsections, details condition of the rivers during the above four mentions major flood periods:

4.3.1. The Buriganga River at Dhaka (Mill barrack) Station

The magnitudes of the peak flows at Dhaka (Mill barrack) Hydro-station in the Buriganga River in 2007, 2004, 1998 and 1988 were found 0.1m, 0.8m, 1.31m and 1.45m PWD[1] above danger level[2] respectively. During

Flood 2007, water level in the Buriganga River crossed danger level[2]. Water level hydrographs of the Buriganga River at Dhaka station was plotted for floods in 2007, 2004, 1998 and 1988 and shown in (Figure 11). The start of crossing danger level in the Buriganga River was found on 22th July, 24th July, 27th and 9th September for floods in 2007, 2004, 1998 and 1988 respectively. Flood wave came later in 2007 than floods in 2004 & 1998 and earlier than flood in 1988. Floods 2007 was of the shortest duration, while Flood 1998 was of the longest in the Buriganga River. It can be concluded that in terms of magnitude and duration, Flood 2007 in the Buriganga River was less significant than those of other three floods of recent past.

4.3.2. The Balu River at Demra Station

The water of this river played a vital role for the flood situation to be worsening in every flooding year in Dhaka city. The height of peak flood level at Demra Hydro-station at Balu River in 2007 was 0.6m above flood danger level. During the other major floods 2007, 2004, 1998 and 1988, the danger level in the Balu River was not defined. Water level hydrographs of Demra River at Balu was plotted for floods in 2007, 2004, 1998 and 1988 and are shown in (Figure 12). The date of crossing danger level in Balu River was found on 8th August for flood in 2007. Balu River has had a significant impact on flooding in Dhaka city since eastern part of the city is yet to be brought under flood protection measure.

4.3.3. The Turag River at Mirpur Station

The magnitudes of peak floodwater levels at Mirpur Hydro-station in the Turag River in 2007, 2004, 1998, and 1988 were found 0.7m, 1.7m, 1.98m and 2.5mPWD above danger level respectively. Unlike the Buriganga River, the highest water level was found in this river in 1988. Water level hydrographs of the Turar River at Mirpur was plotted for floods 2007, 2004, 1998 and 1988 and are shown in (Figure 13). The dates of crossing of danger level in the Turag River were found on 4th August, 16th July, 19th July and 22th August for floods 2007, 2004, 1998 and 1988 respectively. Flood wave came later in 2007 than in floods 2004 and 1998. In general, flood wave crosses danger level in the Turag River earlier than in the Buriganga River.

4.3.4. Return Period of Flood Events

Figure 14 shows the graphical relationship of these two variables according to data. By using Hazen plotting position method, the above graph contained in the plotting of the 30 year data values of annual maximum water level (in mPWD) and return periods of occurrences, where annual maximum water level as a dependent variable and return period as an independent variables.

In last two decades, the development is more rapid then the previous. Rapid urbanization is mainly taken place in low lying areas around and within the embankment area which submerged during flooding season. Every year because of monsoon rainfall, the study area has been facing a serious drainage congestion which is one of the important factor to flood problem inside the embankment area. At the beginning of development of Dhaka metropolitan area most of the important infrastructure has been developed compare to the higher elevation area and later with the rapid increase of population the low lying agriculture area has been captured by built-up activity. Moreover unplanned development of Dhaka metropolitan area and land filling of natural channels, it becomes very difficult for the artificial system to carry out their pump operation to drain out vast amount of flood waters to the surrounding river.

5. Conclusion

This study evaluated the temporal and spatial changes of land use and urbanization of Dhaka city. In the study area urban land use has been increased by 12% during 1989 to 1999 and 22% from 1999 to 2009, which resulted in a significant decrease in the area of agriculture land use, water surface, bare land and vegetation cover. In the study area, the growing population and faster economic activities has been increased. But in opposite, the amount of agricultural land has reduced substantially, largely as a result of the increasing demand of land for urban land uses. In the study area during the above mentioned 20 years, a significant urban land use expansion has been largely driven by population growth and economic activity. The socio-economic impact of flood protection embankment has generated some positive impact as follows; increasing demand of land inside the embankment area, city development and increasing the amount of income and expenditure of living people. At the same time the flood protection embankment has some negative impact as follows; accelerating unplanned urbanization, increasing flood vulnerability and poor drainage condition. During 2004-2009 land prices increases per year in the South Asian cities of Kathmandu, Karachi, Kolkata were respectively 50, 70 and 50%, whereas that of Dhaka was 74% per year (2000 to 2010). About 57% of Dhaka's population owns no land while 4% of the population owns as much as 28% of land [34].

Compare with the DEM map and the land cover map, there are higher amounts of settlement and built-up zones are located in the low lying high hazard zones. Moreover the number of settlements and commercial activities are increasing in the recent decades (1999-2009) over the low lying agriculture land, which putting an extra pressure not only on Dhaka city [35] but also on the surrounding suburban city area. Built up area (22%) have been developed in all elevation range. Agricultural land use associated with high elevation range has been converted mostly into built up area and bare land, and at the same time low elevated agricultural land is converted to build up zone to meet the demand for housing to accommodate rapidly growing migrate population. Although various adaptation strategies for prevention infrastructure was developed on basis of 1988 memorial flood. As a result, urban area expansion has driven by infrastructure development by 10% and population growth by 5% inside the embankment area. The socio-economic development such as; the average total income inside of embankment has been increased 10 USD while the income outside the embankment remain same.

After the circle levee construction the land price inside area is absurdly high. The residential areas of Motijheel, Baridhara and Gulshan became the business center of Dhaka city simultaneously transportation and communication system has been developed by increased 12,000km road. Motijheel, Baridhara and Gulshan areas of Dhaka city registered highest amount increased by 5,300 USD compared to the fringe areas of Badda and Demra. Currently, prohibitive land prices in Dhaka city area pushed the land price up in low-lying suburban areas because of its rapidly growing urban population.

The findings of this research recommend the following measures such as; a. Increasing or protecting retention pond, canal and river from urbanizing activity. b. Improving drainage capacity. c. Improvement of pumping management system.

Notes

1. Water level:

Bangladesh water development board (BWDB) refer water levels to the Public Works Datum (PWD). PWD is a horizontal datum believed originally to have zero at a determined Mean Sea Level (MSL) at Calcutta. PWD is located approx. 1.5 feet below the MSL established in India under the British Rule and brought to Bangladesh during the Great Trigonometric Survey (GTS).

2. Danger level:

In Bangladesh danger level at a river location is the level above which it is likely that the flood may cause damages to nearby crops and homesteads. In a river having no embankment, danger level is about annual average flood level. In an embanked river, danger level is fixed slightly below design flood level of the embankment. The danger level at a given location needs continuous verification as e.g. embankments may be breached, but it is not done continuously by FFWC, whereby some danger levels may be not precise.

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