ASSESSING RELATIONSHIP BETWEEN WATER LOGGING AND DIARRHOEAL CASES USING FLOOD SIMULATIONS AND SOCIAL EPIDEMIOLOGICAL ANALYSES IN LOW-INCOME COMMUNITIES OF DHAKA CITY, BANGLADESH

バングラデシュ・ダッカの低所得者地域における洪水氾濫解析手法と社会疫学的分析手法を用いた浸水形態と下痢症の関係解析

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ABSTRACT

Diarrhoea associated with flooding is the most common waterborne diseases in humans. It is a specifically significant problem in urban areas in developing countries, where disease easily spread due to poor sanitary condition and high risk of flooding because of insufficient sewer and drainage networks. The relationship between waterborne disease and flooding has been investigated in previous studies; however, the relationship between flooding and diarrhoel morbidity is not fully understood. For example, sociodemographic variables such as household income and level of education need to be considered to thoroughly understand this problem. In this study, the author assesses the relationship between flooding and diarrhoeal cases, using flood simulation and social epidemiological and statistical analyses. The incidence of diarrhoea caused by flooding in Dhaka City, Bangladesh is used as the case study. Dhaka City is representative of locations where diarrhoea has become a serious problem due to repeated floods.

As noted above, previous research into the relationship between flooding and diarrhoea in developing countries has been widely conducted. However, most of them have not evaluated the issue in detail and, in particular, has not quantitatively studied flooding. In addition, in the case of low-income urban areas, no approach has been proposed that takes into account the social epidemiological factors because collecting this data is difficult. In this study, we aim to quantitatively examine flooding using a flood simulation model and statistically evaluate the influence of flooding on diarrhoea using sociodemographic data from Dhaka City, Bangladesh. This study incorporates the following analyses: 1) Flooding analysis using a flood simulation model of an urban area in a developing country, 2) Simple regression analysis of flooding and diarrhoeal cases in pre-, mid-, and post-monsoon seasons, and 3) Multiple regression analysis and multilevel logistic regression analysis of flooding and diarrhoeal cases alongside sociodemographic data.

Simulation of the flooding in Dhaka City was based on data collected through field surveys and our interviews with local experts. Simulation results were validated by satellite images and the qualitative information of residents. The simulation shows good agreement with the satellite image and qualitative data regarding the flooding extent and flooding depth. On this basis, we can infer that the flooding model can reasonably simulate the flooding in Dhaka City.

The flooding simulation was compared with diarrhoeal morbidity data by a simple regression analysis. The comparison results revealed increased morbidity in almost all communities affected by flooding. Furthermore, a positive correlation was found between flooding parameters and diarrhoeal morbidity, and the correlation coefficient was found to be slightly different in each season. Therefore, we found that the gradient of diarrhoeal vulnerability is affected by predisposing factors such as socioeconomic status; this

influence persists throughout the rainy season, although morbidity increased when flooding occurred.

To consider the social variables such as water utility and attitude, factors associated with diarrhoeal morbidity were analyzed by multiple regression analysis. Factors found to be significantly associates with diarrhoea were water disposal to open land, continual use of pit latrines without removing excreta, and flooding.

Social status such as the mother's education level and income of the household were also considered by multilevel logistic regression analysis. From logistic regression analysis, factors initially found to be significantly associated with diarrhoeal morbidity were flooding, hand washing, defecation place, and water resource from surface water. After the variance of area was considered, only defecation place and hands washing were associated with diarrhoeal morbidity.

This study was an attempt to clarify the relationship between flooding and diarrhoeal morbidity. The proposed method integrates engineering and epidemiology, using flood simulation and analysis as well as social epidemiological techniques to quantitatively demonstrate the influence of flooding on diarrhoeal morbidity. Specifically, the novelties of this study are as follows.

1. Proposal of quantitative methods to demonstrate the influence of flooding on diarrhoeal morbidity, including flood simulation models and social epidemiological statistical techniques.

2. Use of primary data obtained from low-income areas in urban areas of developing country to perform multi-level analysis.

Items for further research include incorporating detailed infrastructure data from the target area evaluating reproducibility of the flood model, and continuing to identify social factors that impact diarrhoeal morbidity. To take efficient measures to protect the public health, we hope that the results of this study will be further developed.

要約 (IN JAPANESE)

浸水に伴う下痢症は最も多い水系感染症被害であり，人類に多大な影響をおよぼしてきた．特に発展途上国の都市部は下水道網，排水路網の不十分な整備から浸水リスクが高く，更に生活廃棄物などの処理が不適切である地域では衛生状態が悪化し，高人口密度と合わさり水系感染症の蔓延につながる．ここで，浸水と水系感染症の関係は様々なケースを元に研究されてきたが，下痢症罹患リスクについてはまだ，その関係は把握されてはいない．また，下痢症罹患には様々な要因が絡んでおり，世帯の収入，母親の教育レベルなど社会疫学的な要因を考慮することは必須である．このように，浸水時の状況把握だけではなく，住民が本来持っている社会疫学的なバックグラウンドを考慮することが大変困難であるということが本研究の背景にある．そこで，本研究では，洪水氾濫モデルによる浸水形態の定量的な把握と，住民が持つ社会疫学的バックグラウンドを考慮した浸水と下痢症罹患リスクの関係解析を行う．

途上国における浸水が下痢症に及ぼす影響に関する研究は世界中で行われている．しかし，それらのほとんどは浸水を定量的かつ詳細に評価したものではなかった．また，都市部の低所得者地域を対象にした研究について言えば，社会疫学的要因を考慮したアプローチはない．この要求を満たすために，本研究では，氾濫モデルによるシミュレーション結果と，社会疫学的要因を考慮し，下痢症感染・浸水・社会疫学的要因を定量的に関係解析する手法を開発することを目的とした．本研究では，1) ダッカにおける氾濫解析，2) 浸水と下痢罹患リスクの単回帰分析，3) 社会疫学的要因を考慮した重回帰分析，多重レベルロジスティック回帰分析について行う．本解析手法は，バングラデシュ・ダッカの都市域での事例解析を通して開発された．

まず，対象地域の浸水形態を詳細かつ定量的に評価するために洪水氾濫モデルを用いて氾濫解析を行った．計算に用いられた都市排水路網などのインフラデータは筆者らによって収集された．衛星画像を使った空間的な検証からは，浸水範囲とその季節変化が良好に再現されたことが確認された．また，住民から得られた定性的な情報による検証によって計算結果の水深が妥当であることが示された．

次に，浸水と下痢症の単相関を調べるために単回帰分析を行った．手法の中で用いられた健康調査データに既往研究により現地で得られた一次データを用いていることも本研究の特徴の一つである．さらに同既往研究により得られた社会疫学的要因も導入し，先に挙げた健康調査データとともに，浸水との関係解析を行った．結果より，雨季の前・中・後といった全ての季節で正の相関が見られ，罹患率と洪水の関係が示された．また，浸水が起こっていない雨季前でも正の相関が見られたことから，浸水の直接的な影響以外に地域が持つ要因が示唆された．

さらに，住民の社会疫学的バックグラウンドに関するデータを考慮するために，10 地域を対象に重回帰分析を行った．その結果，浸水が有意に影響していることが示され，さらに生活排水の空き地への廃棄と汲み取り式便所の継続利用をしている世帯の多さが，地域の下痢症罹患リスクに有意に影響があることが確認された．また，これにより詳細な社会疫学的要因が特定された．

そして，707 人の 5 歳未満児の個々の詳細な属性を考慮するため，多重レベルロジスティック分析を行った．その結果，浸水，手洗いの習慣，排便場所，水源を表層水にしていることが下痢症罹患率に有意に影響していることを示した．さらに，下痢症の地域間分散を考慮すると，排便場所，手洗いの習慣のみが有意に地域間で差が現れることを示した．また，地域レベルの分散を考慮することで浸水の影響が有意でなくなることも示した．さらに，地域による下痢症罹患リスクの違いについて，地域間分散の各 10%が浸水と社会ステータスによって説明できることがわかった．

全体として，本手法は疫学と工学が融合した研究手法を用いており，双方の手法を合わせることで，新しい研究手法が提案されたものである．

本研究の新規性は次の通りである．

1. 洪水氾濫モデルと社会疫学的統計手法を用いた定量的な関係解析手法の提案．
2. 途上国の都市部における低所得者地域で得られた一次データを用いたマルチレベル分析を用いた下痢症罹患リスク要因のもつ寄与率の特定．

本研究は，浸水と下痢症罹患リスクの関係を洪水氾濫解析モデルと社会疫学的統計手法を用いて明らかにする最初の試みであった．今後の研究では，対象地域の詳細なインフラデータ等を入力することで，洪水氾濫モデルの再現精度を高めることが期待される．浸水と下痢症罹患リスクの関係が示されたとは言え，社会疫学的要因の考慮は改善の余地があるため，考えられる全ての下痢症罹患因子について研究していくことが，関係解析の発展のために不可欠であると考えられる．最後に，効率のよい公衆対策をとるという目標のために，本研究が持つ適用性がさらに発展することを祈念するところである．

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LIST OF ABBREVIATIONS

ADRC	Asian Disaster Reduction Center
AMSL	Above mean sea level
BCAS	Bangladesh Centre for Advanced Studies
BWDB	Bangladesh Water Development Board
CUS	Centre for Urban Studies
FFWC	Flood Forecasting and Warning Centre, Bangladesh
GBM	Ganges-Brahmaputra-Meghna
ICDDR,B	International Centre for Diarrhoeal Disease Research, Bangladesh
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
JSCE	Japan Society of Civil Engineers
MODIS	The Moderate Resolution Imaging Spectroradiometer
MoEF	Ministry of Environment and Forests
MOFA	Ministry of Foreign Affairs of Japan
MOR	Median Odds Ratio
UNDESA	United Nations Department of Economic and Social Affaires
UNEP	United Nations Environment Program
UNFPA	United Nations Fund for Population Activities
UNICEF	The United Nations Children's Fund
PWRI	Public Works Research Institute
SPOT	Satellite Pour I'Observation de la Terre
SRTM	Shuttle Radar Topographic Mission
WASA	Water Supply and Sewerage Authority
WHO	World Health Organization

CHAPTER 1 INTRODUCTION

1.1. Background

To manage water resources and ensure water safely, it is necessary to consider quality and quantity. Waterborne disease is an issue of water quality. According to the World Health Organization, 1.8 million people lost their lives due to waterborne disease, and most of cases are believed to be due to water being obtained from an unsanitary environment (WHO, 2004). Flooding, on the other hand, is an issue of water quantity, particularly in the monsoon region in Asia. This region is flood-prone, mainly because of concentrated rainfall during the monsoon season. Predictive research indicates that flooding in this region will increase in the future (Alam *et al.*, 2007). Waterborne disease and flooding have been thoughtfully investigated in their respective fields, but very few researchers have studied the relationship between the two issues.

Every year, approximately 2.5 billion children under the age of five suffer from diarrhoea. More than half of these cases are in Africa and South Asia, where bouts of diarrhoea are more likely to result in death or other severe symptoms (UNICEF *et al.*, 2009).

Among South Asian countries, Bangladesh is representative of the high risk of diarrhoea and severe flooding. Approximately 51,000 children die from diarrhoea every year in Bangladesh; the country ranks seventh in the world in childhood deaths from diarrhoea (UNICEF *et al.*, 2009). In Dhaka City, the capital, numerous children die each year from diarrhoea. They are easily affected by it, particularly during periods of severe flooding. In August 2007, when a severe flood occurred, the number of diarrhoeal cases was three times higher than in previous observation periods that were less impacted by floods (ICDDR, 2007).

In particular, the situation is more severe in low-lying and low-income communities of the city. Because people tend to live in simple houses, they are more susceptible to environmental factors, such as temperature extremes, humidity, rainfall, and flooding

(Hashizume *et al.*, 2008; Hashizume *et al.*, 2009). Children are at higher risk because they lack the acquired immunity of adults and may play in the floodwaters.

Among environmental factors, flooding has a large deleterious impact on the hygienic environment (Baqir *et al.*, 2012). Therefore, health risks, including the incidence of diarrhoea from flooding, are associated with the extent and depth of flooding (Reacher *et al.*, 2004). Therefore, flood simulations may be important tools to mitigate the impacts of diarrhoea associated with flooding in urban areas.

1.2. Benefits of understand relationship between floodings and diarrhoea

A thorough understanding of the relationship between flooding and diarrhoea may make it possible to 1) develop a quantitative health risk evaluation method, 2) propose an effective public health strategy, and 3) present a cost-benefit analysis of drainage infrastructure that takes into account the risks associated with diarrhoea.

1.3. Framework

Figure 1-1 shows a study framework. First, we conducted field surveys to collect information and data related to flooding and diarrhoeal cases, in addition to the epidemiological data obtained by Mollah (2010). Second, we performed a flood analysis, using a flood simulation model to obtain flooding parameters such as maximum flooding depth, maximum flooding duration, and accumulated flooding depth. Third, we examined the relationship between flooding parameters and diarrhoeal morbidity that was obtained by Mollah (2010). Finally, we conducted a statistical analysis considering social epidemiological factors.

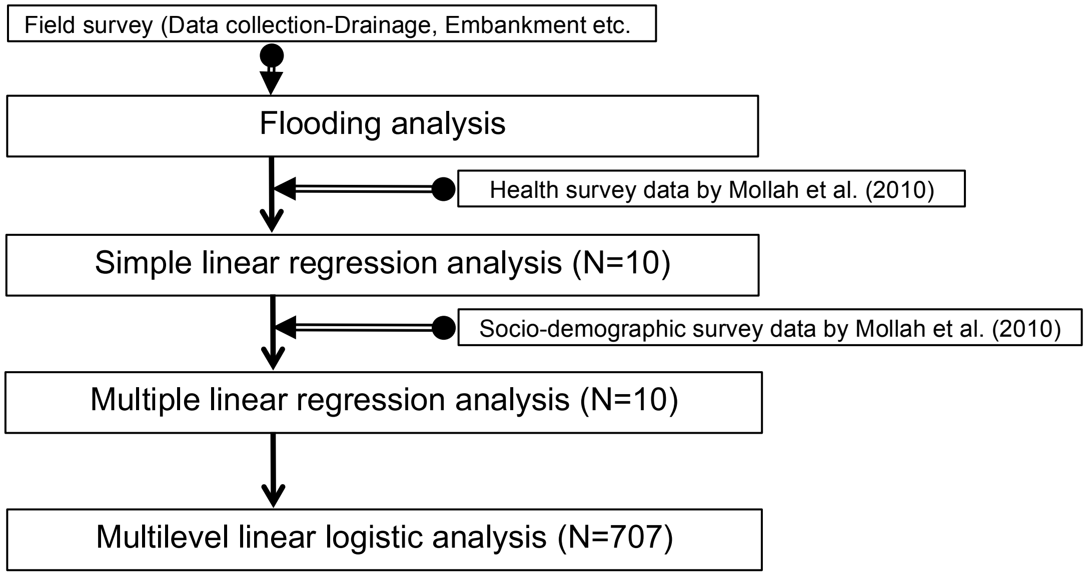


Figure 1-1 Framework of study

1.4. Research objective

The main objective of this study is to assess the relationship between flooding and diarrhoeal cases considering social epidemiological factors. To this end, a series of secondary objectives are presented, as follows.

— To quantitatively evaluate flooding in Dhaka City, using a flood simulation model.
— To evaluate the simple relationship between flooding and diarrhoeal cases by a simple correlation analysis in three different seasons, i.e., pre-, mid-, and post-monsoon.
— To evaluate the influence of flooding on diarrhoeal cases, using social epidemiological analysis.

1.5. Organization of the dissertation

The chapters of this dissertation elaborate on the methodology adopted in this study and discuss the relationship between flooding and diarrhoea. The methodology is demonstrated through the case study in Dhaka City, Bangladesh. The content and sequence of the thesis are as follows.

Chapter 1 Introduction

This chapter outlines the need for the research and objectives of the study.

Chapter 2 Literature review

This chapter reviews studies related to the relationship between flooding and diarrhoea, flooding in Dhaka City, and flooding analysis in developing countries.

Chapter 3 General description of Bangladesh and Dhaka City

This chapter introduces Bangladesh and Dhaka City, discussion their hydrology, geology, and sociology. It also records relevant aspects of the daily lives of people in low-income areas in and around Dhaka City.

Chapter 4 Flooding analysis

This chapter explains how the flood simulation was performed. It comprises introduction, data, calculation methods, and results..

Chapter 5 Relationship between flooding and

This chapter consists of the procedure of health data and results of comparisons between flooding and diarrhoeal cases.

Chapter 6

This chapter explains how social epidemiological factors were considered using a statistical method that consists of multiple regression analysis and multilevel logistic regression analysis.

Chapter 7 Summary of the Study

This chapter summarizes the study.

CHAPTER 2 LITERATURE REVIEW

2.1. Relationship between flooding and diarrhoea

Studies relating to flooding and water borne disease have been conducted all over the world. Such studies tend to be conducted in flood-prone areas, such as the Asian monsoon region (Biswas *et al.*, 1999; Pradhan *et al.*, 2007; Thi *et al.*, 2011; Baqir *et al.*, 2012; Ding *et al.*, 2013), and Africa (Shears, 1988; El Sayed *et al.*, 2000; Kondo *et al.*, 2002; Abaya *et al.*, 2009). Health hazards caused by flooding are a problem to which the whole world pays attention (Ahern *et al.*, 2005).

Among counties that have health problems related to flooding, Bangladesh is representative. Several researchers have studied the relationship between flooding and waterborne disease in Bangladesh, including Kunii *et al.* (2002), Harris *et al.* (2008) and Schwartz *et al.* (2006). However, only few studies have focused on low-income communities. The work by Mollah *et al.* (2009) is one exception. They studied low-income communities, and their results indicated that diarrhoea is more common in flood-prone areas than in area not subject to flooding. However, they couldn't evaluate the risk based on quantitative flood data, which left room for a study of diarrhoea incidence based on a quantitative analysis.

2.2. Flooding in Dhaka City

Studies of flooding in Dhaka City have used a variety of methods, including flood simulation models, satellite images, and other investigations. The differences between the studies are typically related to target area, scale, and the expected accuracy.

Mark *et al.* (1997), Mark *et al.* (1998), and Mark *et al.* (2004) studied a town block with high-accuracy simulation considering the sewerage network. Masood *et al.* (2012) conducted a city-scale study focused on east Dhaka City, an area which is not entirely urbanized. A city-scale focused on all of Dhaka City was conducted by Hashimoto *et al.* (2011).

A few researches have conducted studies using satellite images and a structured approach. The studies were started from delineation with DEM (Alam *et al.*, 2004); later studies identifying flooding extent were conducted (Dewan *et al.*, 2005; Dewan *et al.*, 2005). Then, many researchers shifted their approach to evaluating flood hazard (Dewan *et al.*, 2005; Dewan *et al.*, 2006; Dewan *et al.*, 2006). Finally, several studies examined the relationship between flooding and land-use change (Dewan *et al.*, 2007; Dewan *et al.*, 2010).

Several studies have evaluated the influence of flooding on the condition of the city (Tawhid *et al.*, 2004). One study indicated the increasing risk of flooding due to unplanned urbanization (Abdul, 2006), and another described an urban plan that would be suitable for Dhaka City's flood risk (Samarakoon, 2013). One study indicated the political measure for flooding (Barua *et al.*, 2011). Mechanisms of flooding in Dhaka City were studied, such as the city lake (Okubo *et al.*, 2010) and infiltration and changes due to climate change (Yahya *et al.*, 2010).

Some studies have examined flooding in all of Bangladesh. For example, Chowdhury (2000) studied the flood damage that occurred in 1998, A study of the long-term impact on nutrition due to the flooding in 1998 was conducted by Ninno *et al.* (2005). Haque (1993) studied human response to riverine hazards and Islam (2010) studied flood forecasting.

2.3. Flooding analysis in developing countries

A numerical flood simulation model is a useful tool for quantitatively evaluating flooding; however, the lack of sufficient data on developing countries make it difficult to implement such models. Mark *et al.* (2004) conducted a flood analysis of Dhaka City, accurately taking into account the drainage and sewerage system; however, the target area was only a part of Dhaka City. Our research team, on the other hand, conducted a flood analysis that targeted all of the Dhaka City. However, our flood simulation model didn't properly consider the drainage system, and simulation only focused on one month of the six months rainy season (Hashimoto *et al.*, 2012).

Flooding analyses in other developing countries include Sayama *et al.* (2012) , who studied the Indus River basin in Pakistan, Sayama *et al.* (2011), who targeted the Irrawaddy River basin in Myanmar, and Kazama *et al.* (2012), who targeted the Mekong River basin in Cambodia.

CHAPTER 3 GENERAL DESCRIPTION OF BANGLADESH AND DHAKA CITY

3.1. Overview of People's Republic of Bangladesh

3.1.1. *Terrain characteristics*

The People's Republic of Bangladesh is located at north 26.38–29.34 degrees and east 88.01–92.41 degrees (ADRC). Most of the country is in a delta of the Indian subcontinent that was formed along with the Bay of Bengal. The area of the whole country is 14,570km^2. More than 50% of the area is 7 m or less above sea level, 80% of the area is in the floodplain of three large rivers (the Ganges, Brahmaputra, and Meghna)（Figure 3-1）.

There is a hilly high-altitude area in the northeast of the country, but that area only accounts for 13% of the area of the whole country. There are many jungle and swamp areas rich in water and fertile soil that is suitable for paddy cultivations. However, these areas are vulnerable to drought and flood.

3.1.2. *Hydrological property*

The climate of Bangladesh is tropical monsoon and is characterized by high temperatures, humidity, and rainfall. Winter, from March to October, is warm due to the temperatures brought by the northeast monsoon. Average annual rainfall is 2200 mm and 80% or more of the total annual rainfall falls in the rainy season from October to May (Oka, 2004). Occasional cyclones hit the area before and after the rainy season. Storm surge damage or flooding often occurs due to the large amount of rainfall in a short period of time. There are regional differences; the annual rainfall is more than 3,000 mm in the southeast Cox's Bazar and northeastern Sylhet, and there is rainfall of approximately 1,600 mm–1,900 mm in the north and southwest. This rainfall comes from complicated interaction of atmospheric circulation (Terao *et al.*, 2002).

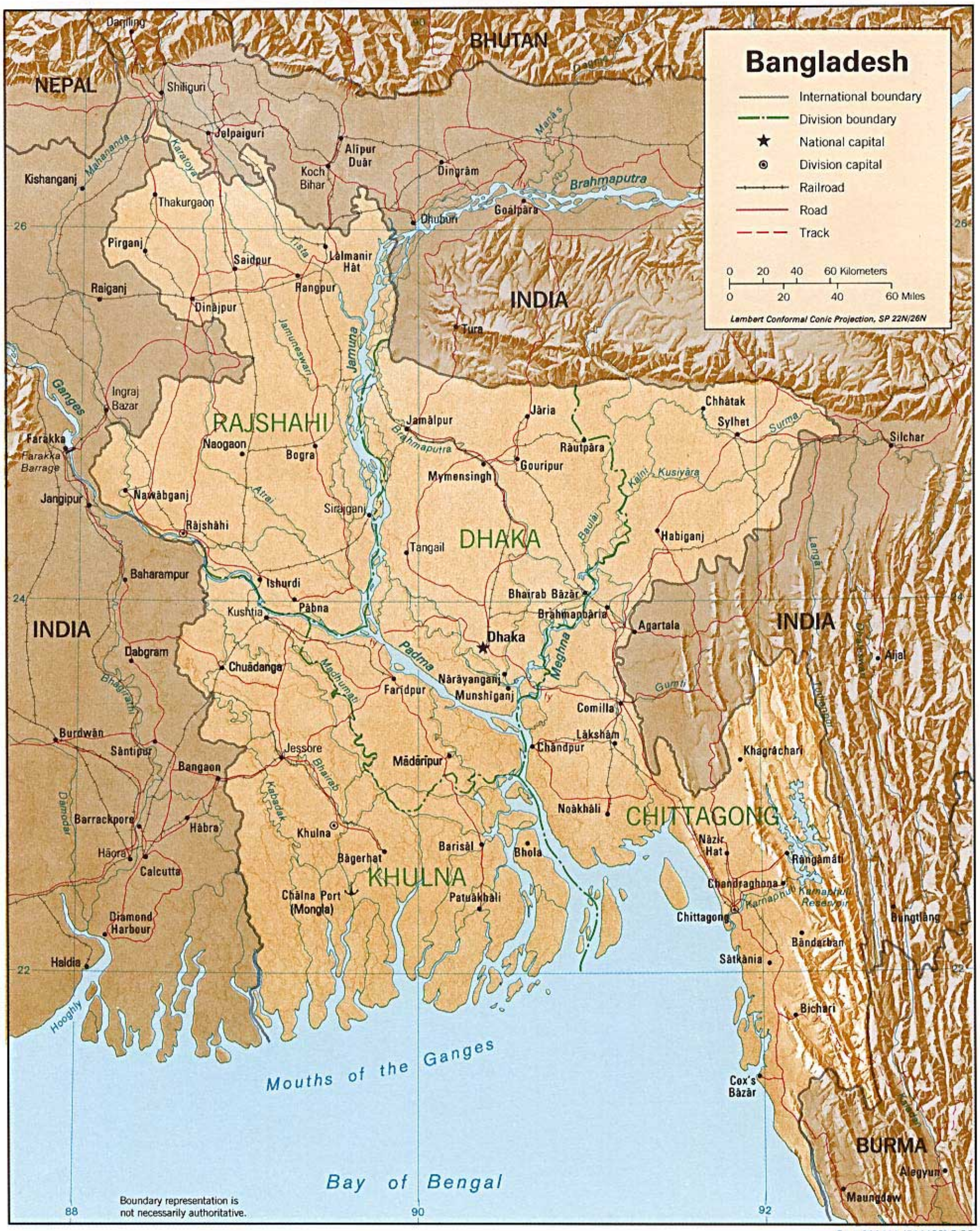


Figure 3-1 Map of Bangladesh

(Source: (Atlas) (http://www.asia-atlas.com)

Bangladesh has more than 200 streams of different sizes, and almost quarter of these are from river sources outside the country. In most cases, they are tributaries of the major rivers, the Ganges, Brahmaputra, and Meghna. The basin of these rivers is called the GBM basin and flows into the Bay of Bengal after having a catchment in China and India joined in Bangladesh（Figure 3-2）.

Bangladesh has the worst record of cyclones and storm surges in the world. They destroy crops; damage infrastructure, homes, and vital installations, and cause widespread health hazards for the people. Storm surges create short- and long-term problems because the salt water ruins the soil. They occur frequently and in such magnitude in Bangladesh that they have multiplied the problem of poverty and seriously challenged the efforts of the country towards self-reliance(ADRC). To address this serious situation, a study is being conducted to develop effective counter measures to reduce the damage from cyclones (Haque *et al.*, 2012).

During the last few decades, under the program of flood control and drainage improvement, the country has built 7,555 km of embankment (including coastal embankments of approximately 4,000 km), It has also built 7,907 hydraulic structures, including sluices, approximately 1000 river regulators, 1,082 river closures, and 3.204 km of drainage channels. The program has cost 10 billion taka and encompassed a total of 332 projects, aimed at freeing 3.5 million ha of land from floodwater, To date, 39% of the net cultivated area has been protected (Banglapedia).

Figure 3-2 Basins of the Ganges, Brahmaputra and Meghna Rivers

(Source: http://commons.wikimedia.org)

3.1.3. *Overview of flood in Bangladesh*

Rivers in Bangladesh are flooded almost every year. About once every 10 years, massive flooding occurs that damages crops and human life. Especially severe flood disasters occurred in 1974, 1987, and 1988 (Figure 3-3). In particular, in 1988 and 1998, more than 60% of the land area was damaged by flood (Chowdhury, 2000). Major flooding occurs because peak flow rates of the three major rivers overlap. Each river has a different characteristic. For example, the flow rate of the Brahmaputra River is high, and the flow velocity of the Meghna River is high. Some researchers pointed out that water-related disasters have increased because of climate change (Mirza, 2002; Yahya *et al.*, 2010).

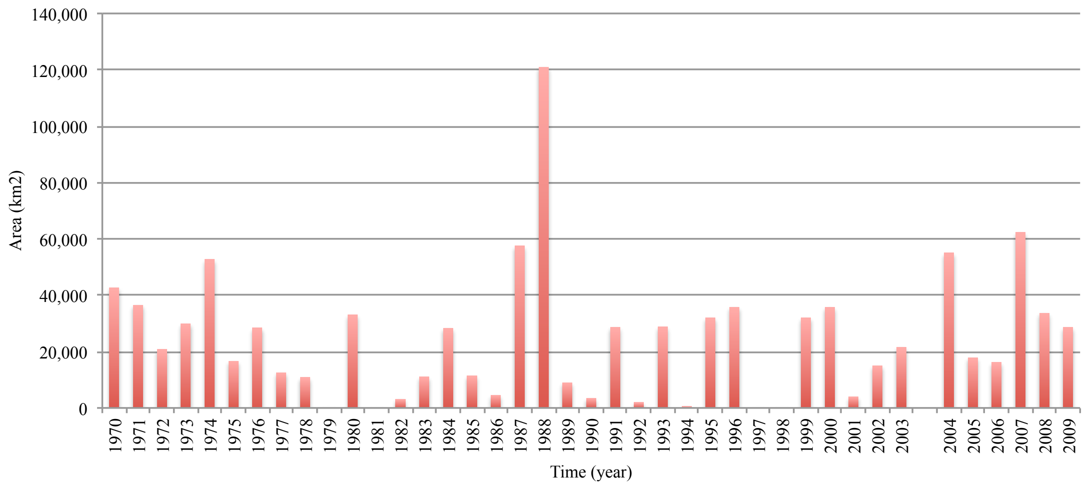


Figure 3-3 Flooding area in Bangladesh from 1970 to 2009

3.2. Overview of Dhaka City

Dhaka City is located almost in the center of the Ganges Delta, covering an area of about 360km^2. The population of the city is estimated to be approximately 7,001,000, and population density of Dhaka is approximately 19,450 people per km^2 (WPS, 2013). The elevation of this area is 2 to 12 m, which is relatively high compared with the surrounding delta area. Several rivers surround or flow through Dhaka City: the Tongi River (north), Balu River (east), Turag River (west), and Buriganga River (southeast). To prevent riverside water flooding, ring levees are being built on each rive in Dhaka City. While these measures protect the city from disaster, they are a disadvantage for people who do fishing and farming. Flooding protection measures are always associated with social adjustment (Thompson *et al.*, 1991).

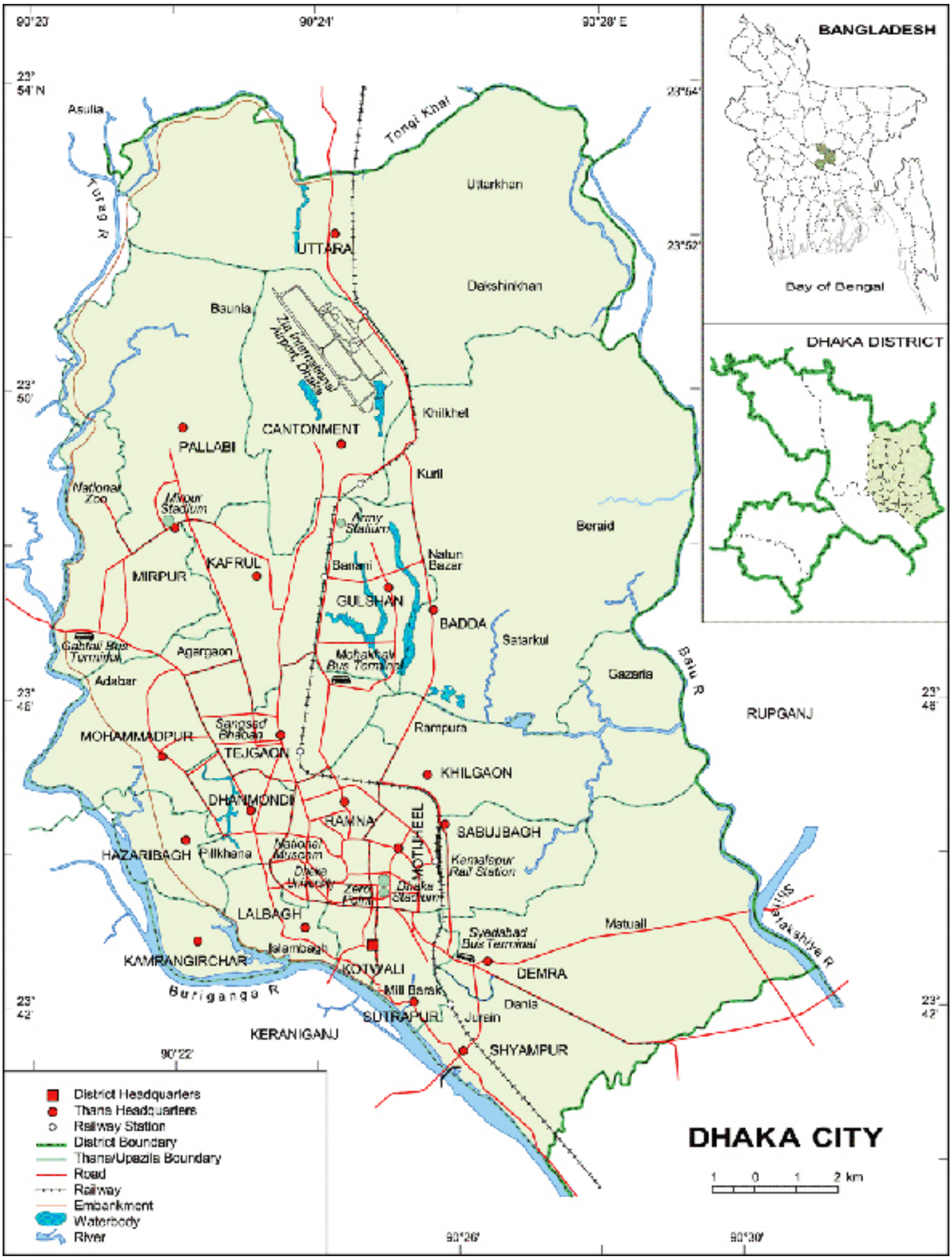


Figure 3-4 Map of Dhaka City

(Source: http://www.banglapedia.org)

Dhaka City has a tropical climate, designated as a savannah climate in the Köppen Climate Classification System. The annual average temperature is 25 degrees. The average monthly temperature is 18 degrees in January and 29 degrees in August.

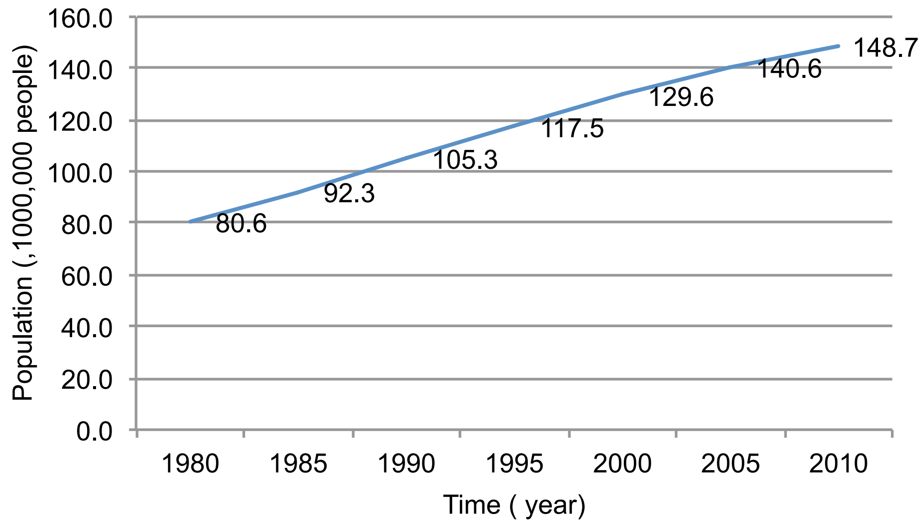
Eighty percent of the 1,854 mm annual rainfall is recorded from September to May. Cyclones and continuous rains during the rainy season cause flooding damage.

3.2.1. *Population growth and changes in land use*

The total population of Bangladesh is 150.5 million, and the population of the Dhaka metropolitan area is over 14.7 million (UNFPA, 2011). The population of the country is increasing (UNDESA, 2012), and GDP also continues to grow (WorldBank, 2012) (Figure 3-5). However, an increase in the number of urban poor is a problem due to rapid urban growth (Hossain, 2008). Plans are being developed in parallel with solutions to the poverty problem (MoEF, 2007).

Land use has also changed due to rapid population growth, and changes in storm water runoff form have led to an increase in flood damage and flood discharge (Dewan *et al.*, 2010). Infrastructure development in the city doesn't keep up with the rapid population growth, and the city is facing problems like traffic congestion, pollution, and lack of public services.

(a)



(b)

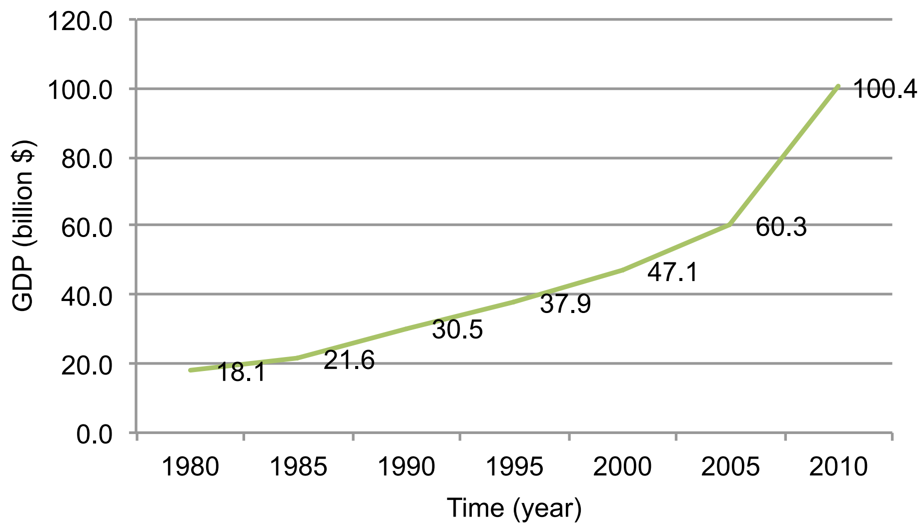


Figure 3-5 (a) Population growth in Bangladesh, (b) GDP growth (Sources: UNDESA (http://esa.un.org/unpd/wpp/index.htm) for population growth, World Bank (http://www.worldbank.org) for GDP growth)

3.2.2. *Flooding in Dhaka City*

Flooding occurs because of a long rainy season and heavy rains. Outside water flooding in Dhaka is mainly caused by the Balu River in the northeast and the Buriganga River in the north. Therefore, flood damage is concentrated in the eastern and north-west parts of Dhaka (Dewan *et al.*, 2010) When outside water flooding occurs, the city suffers massive flood damage. Following the flood damage in 1988 and 1989, the government built the ring levee surrounding Dhaka as a flood control measure (Hagihara *et al.*, 2003).

When flooding occurred in 1998, the flood control measures reduced direct damage caused by the flood. However, the damage in urban areas surrounded by a ring levee occurs, and approximately one-month water had remained in the city (Hagihara *et al.*, 2003).

However, while the results of damage of human life, destruction of facilities and property, the occurrence of infectious diseases, flood damage is made shall also support secure water resources, such as fisheries, the lives of residents (Kantipaul, 1995).

3.2.3. *Low-income areas in Dhaka City*

3.2.3.1. *Living situation in Dhaka*

Slum areas are distributed throughout Dhaka City (CUS *et al.*, 2006) (Figure 3-6). In 1988, there were 1,125 low-income communities with a total estimated population of approximately 1 million. By 1996, the number of low-income communities had increased to 3,007 and population was estimated at 1.5 million (MoEF *et al.*, 2006). In 2005, the population of low-income communities was 3.4 million, almost a quarter of the city's 12.6 million inhabitants (Gruebner *et al.*, 2011). The slum population has continued to increase; it is composed of people who come to visit relatives in town and people who have lost their homes to live in because of floods.

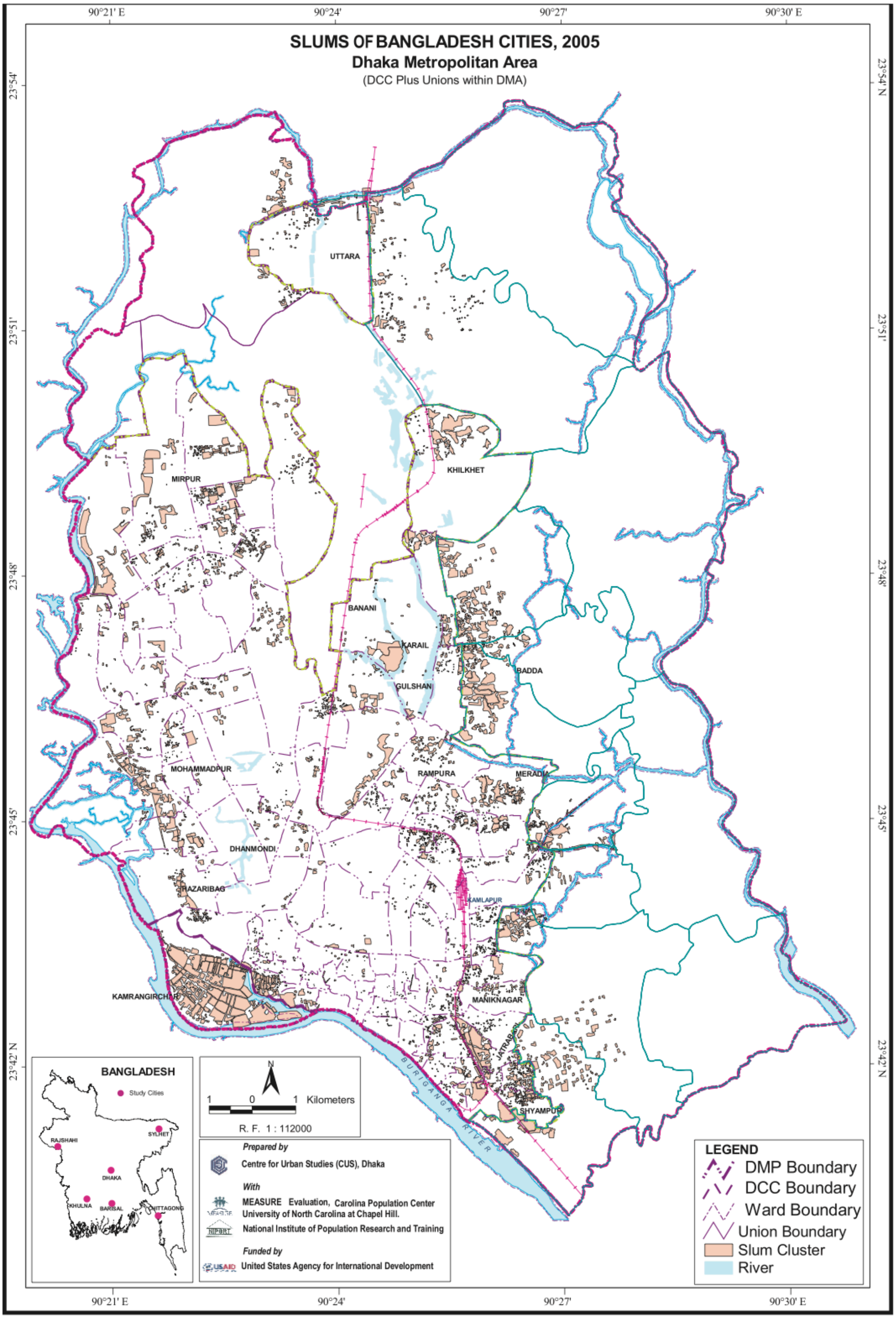


Figure 3-6 Distribution of low-income areas in Dhaka City

Source: (CUS *et al.*, 2006)

The population of low-income areas helps to keep the city alive by working and supporting various sectors, particularly the transportation, industrial, domestic, utility service, retail, and petty trading industries. These are the people who take low-level jobs and live in informal settlements under terrible conditions (MoEF *et al.*, 2006).

Because low-income areas tend to be located in low-lying areas near ponds or rivers, the settlements are particularly vulnerable to flooding, and thereby water borne disease. However, the people prefer to live in low-lying areas rather than relocate to less flood-prone areas (Rashid *et al.*, 2007).

3.2.3.2. *Drinking water*

The drinking water in low-income areas is taken from wells. The water is filled in plastic bottles or containers, and stored. If the well is unusable, water is purchased commercially. Those who cannot afford to purchase water sometimes use water from nearby sources, such as ponds or rivers. Experts say that water and sewage services have not spread to low-income areas because it is difficult for providers to recover usage fees from the residents.

Arsenic contamination in well water has become a problem in Bangladesh. Concentrations that are well over the allowable limits have been found in 60 counties in 64 districts (MOFA, 2004). Approximately 30% of the population drinks water containing levels of arsenic in excess of the allowable water quality standards (Wu *et al.*, 2011).

3.2.3.3. *Disposal sewage*

If there is a pond nearby, residents tend to dispose the wastewater in the pond. Thus, ponds play an important role in people’s maintenance of their personal domestic environments. However, this practice has obvious impacts on water quality and is a cause of waterborne disease. In addition to floods that spread sewage dumped in ponds, barn animals such as goats and chicken track water from the ponds back into the community.

Although not significant in a sanitary manner, but installation of pit latrine type of engraving has been recommended (Takahashi *et al.*, 2006). Further, since it is similarly to the water supply, and to recover the charges is difficult, the spread of the sewer is not enough.

3.2.3.4. *Health problems*

Because of poor nutrition and unsanitary living conditions, people in low-income areas are especially susceptible to health problems (Pryer *et al.*, 2002; Izutsu *et al.*, 2006), including mental health problems (Gruebner *et al.*, 2011). Diarrhoeal disease due to severe flooding is a serious problem in low-income areas (Siddique *et al.*, 1991). For example, children under 5 years of age are at higher risk of death than adults from tetanus and diarrhoea (Hussain *et al.*, 1999) . Figure 3-7 shows the trend of the patients who had care in ICDDR,B. Although it does not show the number of patients from low-income areas, we can find the trend of diarrhoeal outcome.

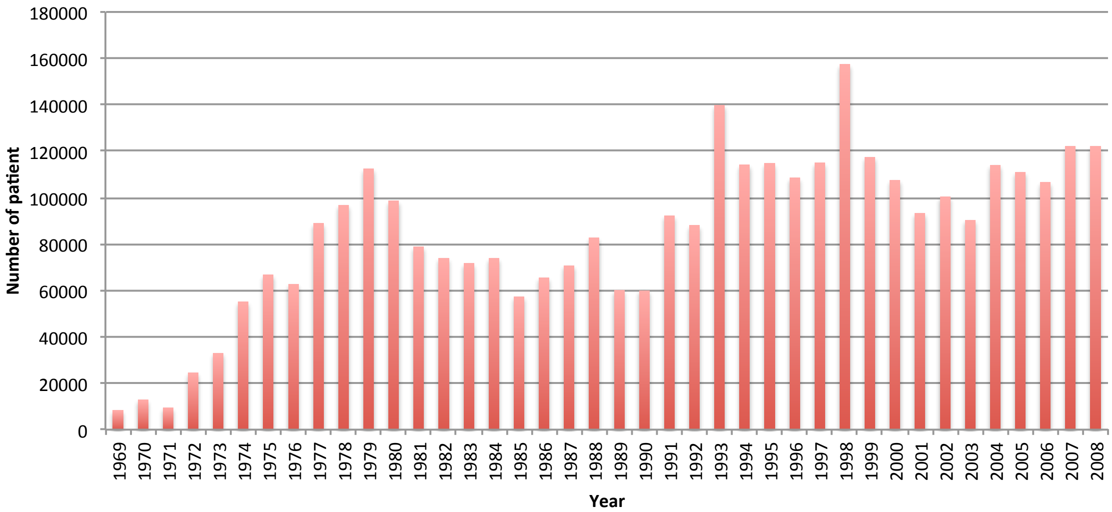


Figure 3-7 Trend of patients who had care in a hospital of ICDDR,B

(Source: ICDDR,B)

CHAPTER 4 FLOODING ANALYSIS IN DHAKA CITY

4.1. Introduction

This chapter explains the methodology adopted for flood simulation analysis. The main contents of this chapter are calculation method, datasets, and the accuracy of the simulation. This simulation was intended to provide the perspective needed for a temporal-spatial investigation of flooding. Parameters related to flooding and those obtained from the simulation are compared with diarrhea cases in the following chapter.

Studies of flooding in Dhaka City have been conducted mainly using satellite images to understand the flooding condition(Dewan *et al.*, 2005; Dewan *et al.*, 2005; Dewan *et al.*, 2006). However, satellite images are intermissive in many cases, and it is difficult to recognize the extent of flooding or get a temporal understanding of floods. Several studies using a flood simulation model were conducted but most of them targeted limited parts of Dhaka City (Mark *et al.*, 2004; Masood *et al.*, 2012). Bangladesh's Flood Forecasting & Warning Center, one of the official institutes forecasting flooding disasters, performs flood simulation. However, the target area is the whole of Bangladesh, so flooding in Dhaka City is not described precisely (Figure 4-1).

Flood simulation can be a useful tool to precisely understand flooding. It can be an alternative to collecting flooding information from a broad area, which takes much time and is difficult. Furthermore, modeling can be a helpful tool to forecast the changes of flooding extent caused by climate change (Yahya *et al.*, 2010).

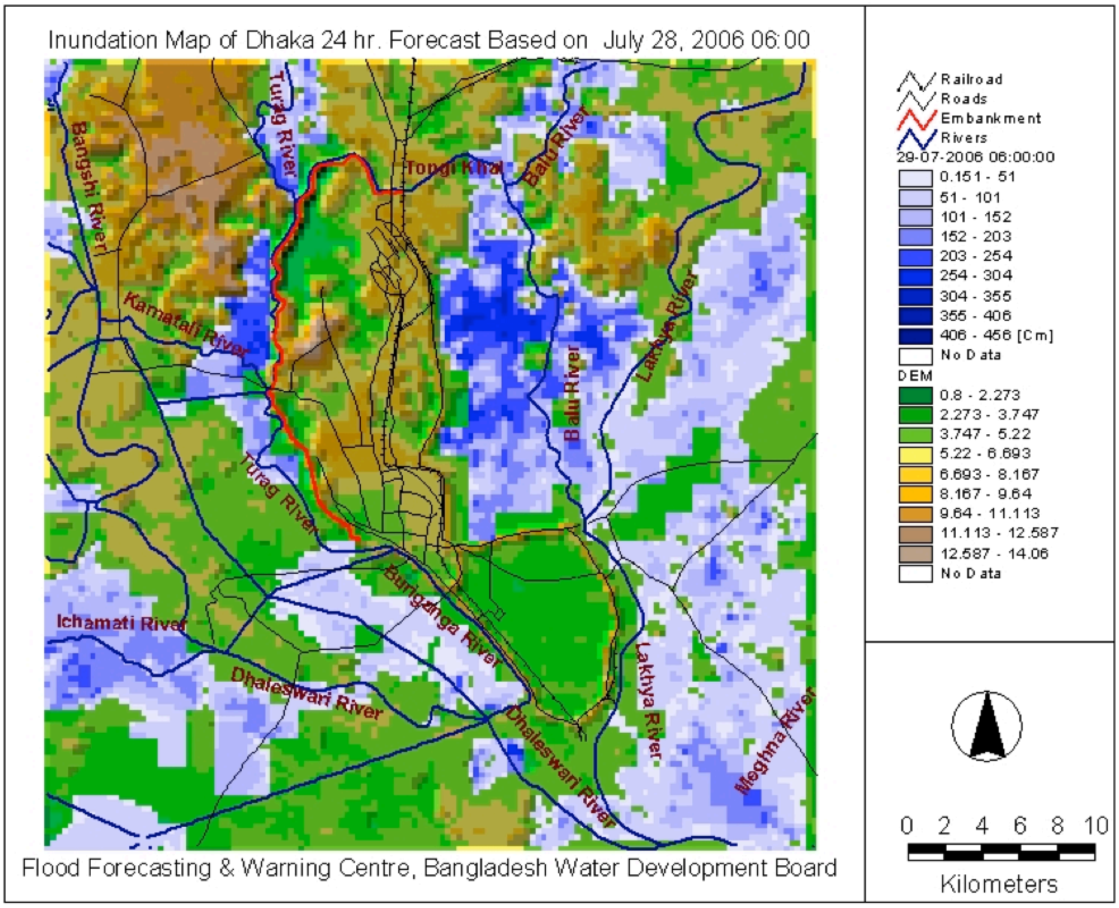
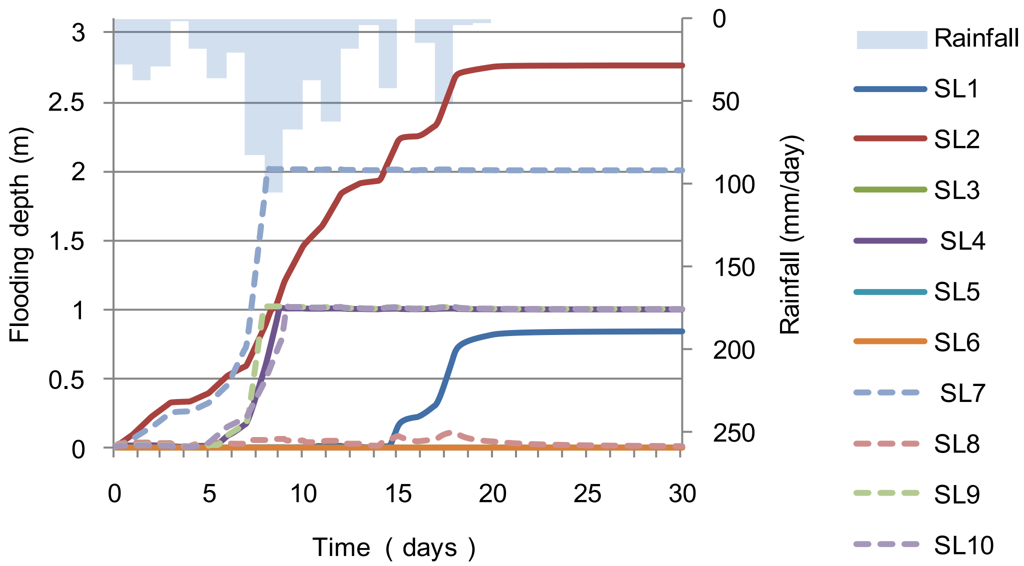


Figure 4-1 Real time inundation map of Dhaka City during the flood of 2006

Studies focusing on areas with limited hydrological datasets were conducted by several researchers (Kazama *et al.*, 2009; Sayama *et al.*, 2012), and some agendas were suggested, such as agricultural canals and embankments. We conducted flood simulation with sensitivity analysis for main flooding factors (Figure 4-2) and also discussed several agendas, such as consideration of sewerage and drainage (Hashimoto *et al.*, 2012). Thus, this study was conducted in a carefully controlled manner similar to the above studies. Figure 4-2 shows the results of flood simulation in Dhaka City. The study examined the influential flooding causes using a sensitivity analysis (Hashimoto, 2011).

(a)



(b)

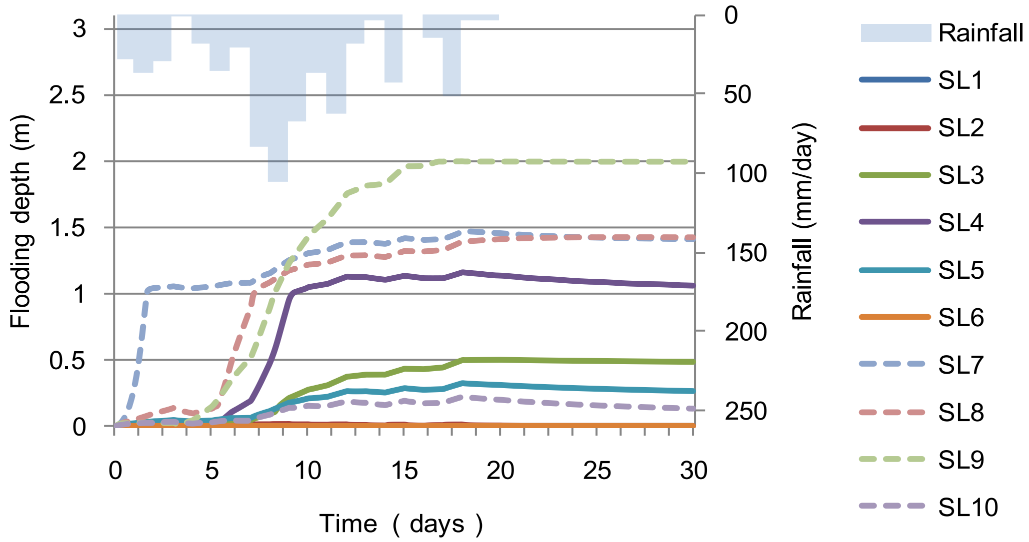


Figure 4-2 Flood simulation results of flooding depth over time

(a) Without drainage and building occupied ratio (b) With drainage and building occupied ratio

(Source: Hashimoto (2011))

4.2. Dataset and calculation method

4.2.1. *Study area*

The targeted area is an urban area of Dhaka City, the capital of Bangladesh (Figure 4-3). The total area of the city is 360 km^2. The area consists of flatland and is located mainly on an alluvial terrace surrounded by rivers. The surface elevation of the area ranges between 1m and 14m AMSL (JICA, 1991).

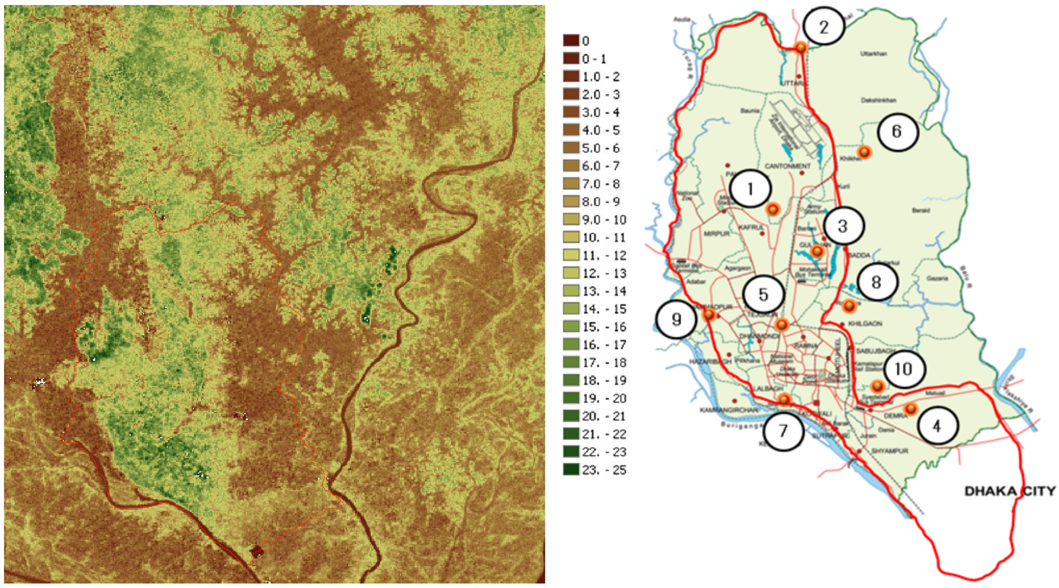


Figure 4-3 Calculation area

(Left: Elevation of area from SRTM, Right: Location of surveyed low-income areas)

Because urbanization has taken place rapidly in this area, the time to reaching peak runoff has become shorter. Built-up areas have increased from 11.1% of the total city area in 1960 to approximately 49.4% in 2005 (Dewan *et al*., 2009). Thus, rapid population growth and accompanying urbanization have led to deterioration in the hygienic environment and an increase in the risk of floods. Furthermore, narrow floodplains and bottlenecks in the river stream due to housing complexity lead to overflowing during rainy periods. Floods are also worsened by the inadequate sewerage system. Consequently, the polluted floodwaters can easily affect the inhabitants.

4.2.2. *Dataset of elevation*

Topographical data for the study area were obtained from the Shuttle Radar Topography Mission, with a spatial resolution of 90 m. Because the sizes of target low-income areas are several hundred meters, the resolution was sufficient. The format of the data is shown in Figure 4-4.

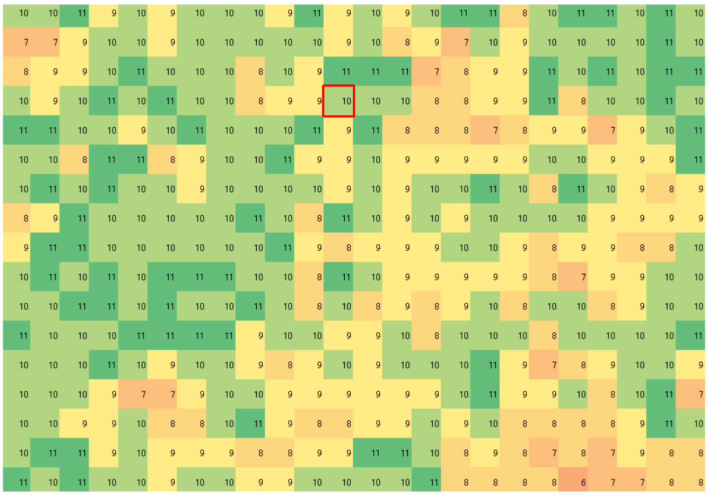


Figure 4-4 Image of elevation data

4.2.3. *Dataset of rainfall*

Daily precipitation data were obtained from the Dhaka-Banani precipitation observatory provided by the Bangladesh Water Development Board. The observatory is located almost in the center of the Dhaka City (Figure 4-5). Figure 4-6 shows the rainfall data from 2007. In this year, the peak rainfall was in June, and there was a large rainfall event in November because of a cyclone.

Figure 4-5 Location of rainfall observation station

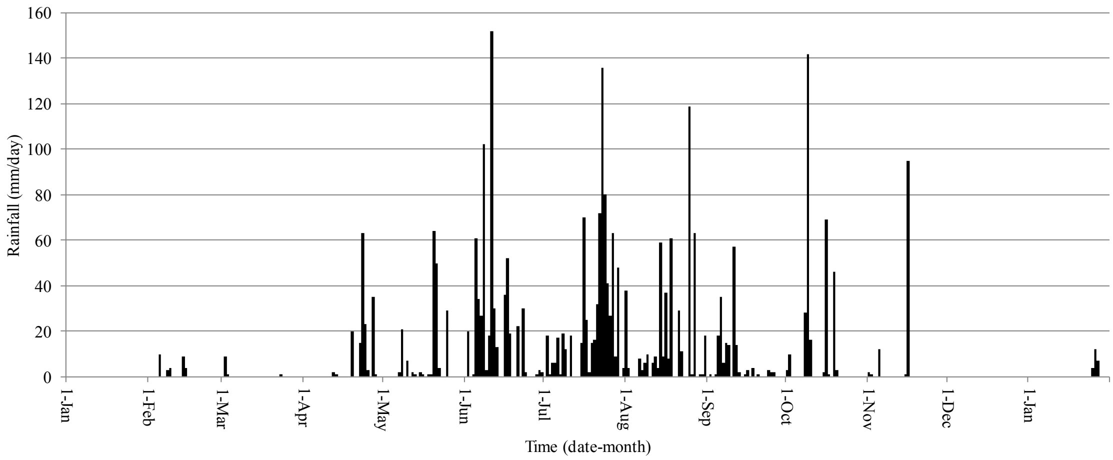


Figure 4-6 Rainfall from January 2007 to January 2008

4.2.4. *Flood flow*

The flood model used in the current study was a 2-D unsteady flow model with rainfall calculated according to a shallow-water equation (JSCE, 1999). The reason of choosing 2-D model is that Mark *et al.* (2004) suggested to use 2-D model to simulate flooding in Dhaka City as a result of their study with 1-D model. Because of the flat land of Dhaka City, flood analysis with 2-D model is an appropriate method for this area.

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=q_{rain} \qquad \text{eq.4-1}$$

$$\frac{\partial M}{\partial t}+\frac{\partial uM}{\partial x}+\frac{\partial vM}{\partial y}=-gh\frac{\partial H}{\partial x}-gn^2u\frac{\sqrt{u^2+v^2}}{h^{\frac{1}{3}}} \qquad \text{eq.4-2}$$

$$\frac{\partial N}{\partial t}+\frac{\partial uN}{\partial x}+\frac{\partial vN}{\partial y}=-gh\frac{\partial H}{\partial y}-gn^2v\frac{\sqrt{u^2+v^2}}{h^{\frac{1}{3}}} \qquad \text{eq.4-3}$$

where h is the water depth (m); M, N are the x, y direction flux (m^2/s); u, v are velocity in the x, y direction (m/s); H is the water level (m); q_{rain} is the rainfall intensity per unit area (m/s); and g is the acceleration of gravity (m/s^2). To solve the equation, this method employed a leapfrog difference scheme using Cartesian coordinates. The differential equation was developed from basic equations. These equations are based on the calculation grid shown in Figure 4-7. In this procedure, discharge fluxes M and N at time $n+2$ are calculated from the water depth and level at time $n+1$ and flux at time n. Then, the water depth at time $n+3$ is calculated from fluxes at time $n+2$.

$$\frac{M^{n+2}_{i,j+1/2}-M^{n}_{i,j+1/2}}{2\Delta t}+convx(x)+convx(y)$$

$$=-g\frac{(h^{n+1}_{i-1/2,j+1/2}+h^{n+1}_{i+1/2,j+1/2})(H^{n+1}_{i+1/2,j+1/2}+H^{n+1}_{i-1/2,j+1/2})}{2\Delta x}$$

$$-gn^2_{i,j+1/2}\frac{(M^{n}_{i,j+1/2}+M^{n+2}_{i,j+1/2})\sqrt{(u^{n}_{i,j+1/2})^2+(v^{n}_{i,j+1/2})^2}}{2\left[(h^{n+1}_{i-1/2,j+1/2}+h^{n+1}_{i+1/2,j+1/2})/2\right]^{4/3}} \qquad \text{eq. 4-4}$$

$$\frac{N^{n+2}_{i+1/2,j}-N^{n}_{i+1/2,j}}{2\Delta t}+convx(x)+convx(y)$$

$$=-g\frac{(h^{n+1}_{i+1/2,j-1/2}+h^{n+1}_{i+1/2,j+1/2})(H^{n+1}_{i+1/2,j+1/2}+H^{n+1}_{i+1/2,j-1/2})}{2\Delta x}$$

$$-gn^2_{i+1/2,j}\frac{(N^{n}_{i+1/2,j}+N^{n+2}_{i+1/2,j})\sqrt{(u^{n}_{i+1/2,j})^2+(v^{n}_{i+1/2,j})^2}}{2\left[(h^{n+1}_{i+1/2,j-1/2}+h^{n+1}_{i+1/2,j+1/2})/2\right]^{4/3}} \qquad \text{eq.4-5}$$

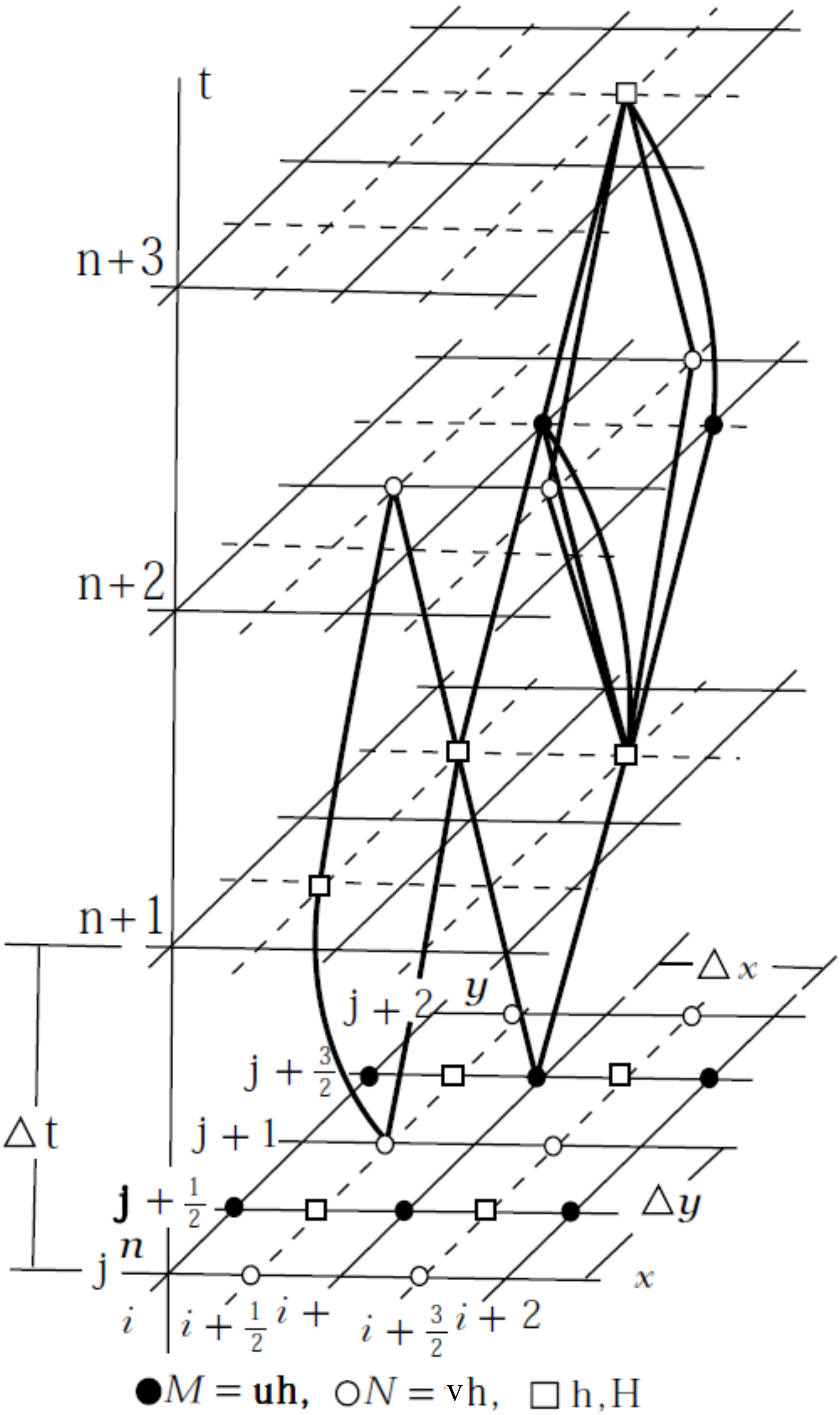


Figure 4-7 Simplified figure of leapfrog method

(Source:JSCE (2001))

$$\frac{h_{i+1/2,j+1/2}^{n+3} - h_{i+1/2,j+1/2}^{n+1}}{2\Delta t} + \frac{M_{i+1/2,j+1/2}^{n+2}}{\Delta x} + \frac{N_{i+1/2,j+1}^{n+2} - N_{i+1/2,j}^{n+2}}{\Delta y} = 0 \qquad \text{eq.4-6}$$

We only considered flooding caused by rainfall, because the city area is protected from flooding from the riverside by an embankment.

4.2.5. *River channel*

The river channel works as a drainage channel instead of the constructed drainage system, and it was set at the grid border in the model. Even though flooding flow is normally calculated by considering the flux between the surrounding grids, the discharge from the floodplain was calculated by using a hydraulic drop formula (eq.4-7). In the calculation, the riverbed was assumed to be sufficiently deep, and the flow discharge was unlimited. The hydraulic drop is described by the following equation (JSCE, 1999):

$$M, N = 0.35h\sqrt{gh} \qquad \text{eq.4-7}$$

The river line was identified from Figure 4-8. However there are more rivers in Dhaka City than the lines which are displayed in Figure 4-8, we considered rivers mainly as urban drainage.

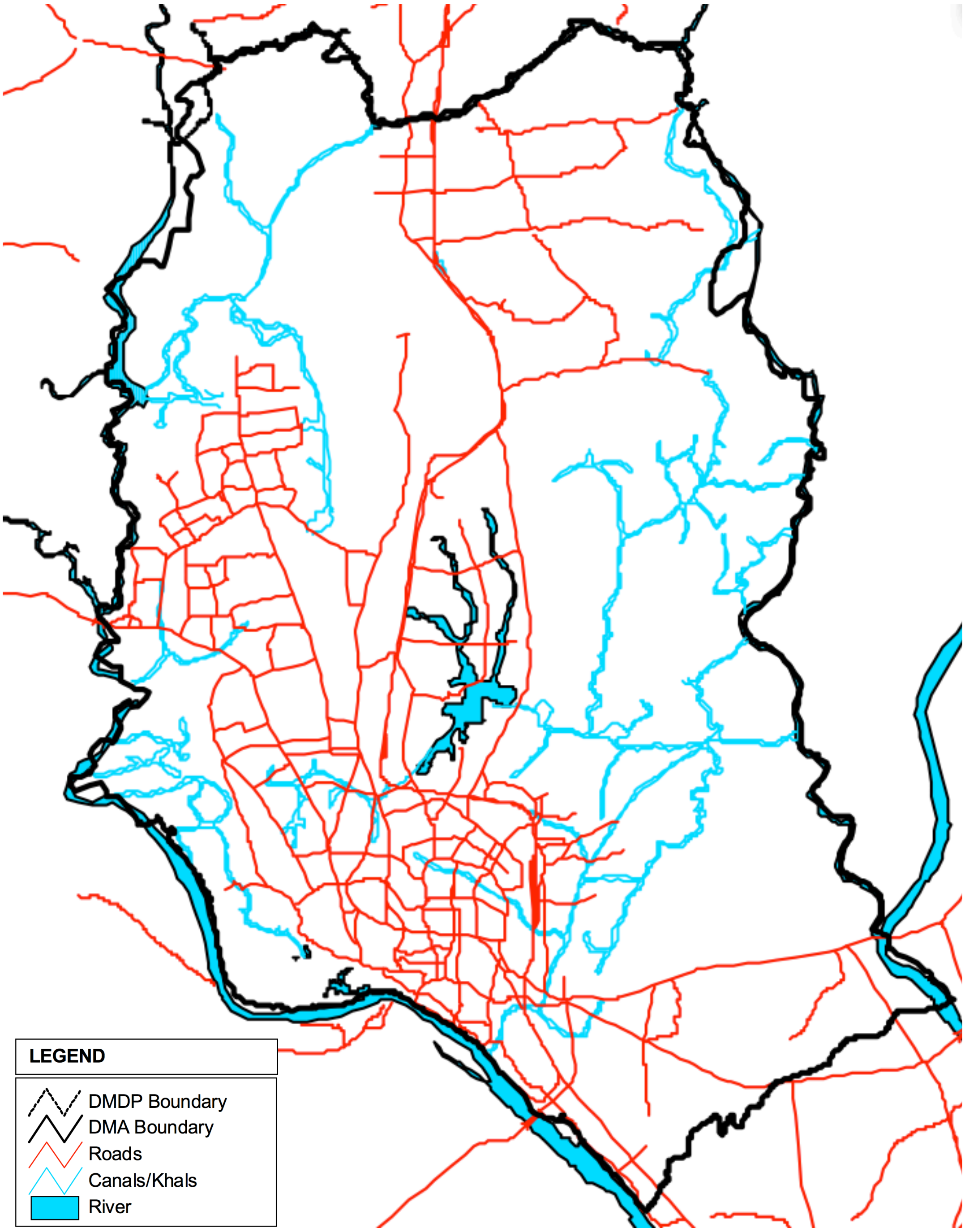


Figure 4-8 River line in Dhaka City

(Source: Tawhid et al. (2004) modified by the Author)

4.2.6. *Embankment*

Western Dhaka is protected from the flooding of the Briganga River by a surrounding embankment (Figure 4-9). However, when a severe rainfall occurs, it might impede water flow from the inside to the outside and cause flooding. There are two types of embankments, a concrete wall type (Figure 4-11) and a road embankment type. In this study, a concrete wall was uniformly presumed. In places where the flooding depth was higher than the embankment height, the following formulas were used to determine the overflow (JSCE, 1999):

$$M, N = 0.35h_1\sqrt{2gh_1}\left(\frac{h_2}{h_1} \leq \frac{2}{3}\right) \qquad \text{eq.4-8}$$

$$M, N = 0.91h_2\sqrt{2g(h_1 - h_2)}\left(\frac{h_2}{h_1} > \frac{2}{3}\right) \qquad \text{eq.4-9}$$

where h_1, h_2 are overflow depth (m) and flooding depth (m), respectively (Figure 4-10). The embankment was set between the grids, and the height was set at 2 m, which was established according to the field survey.

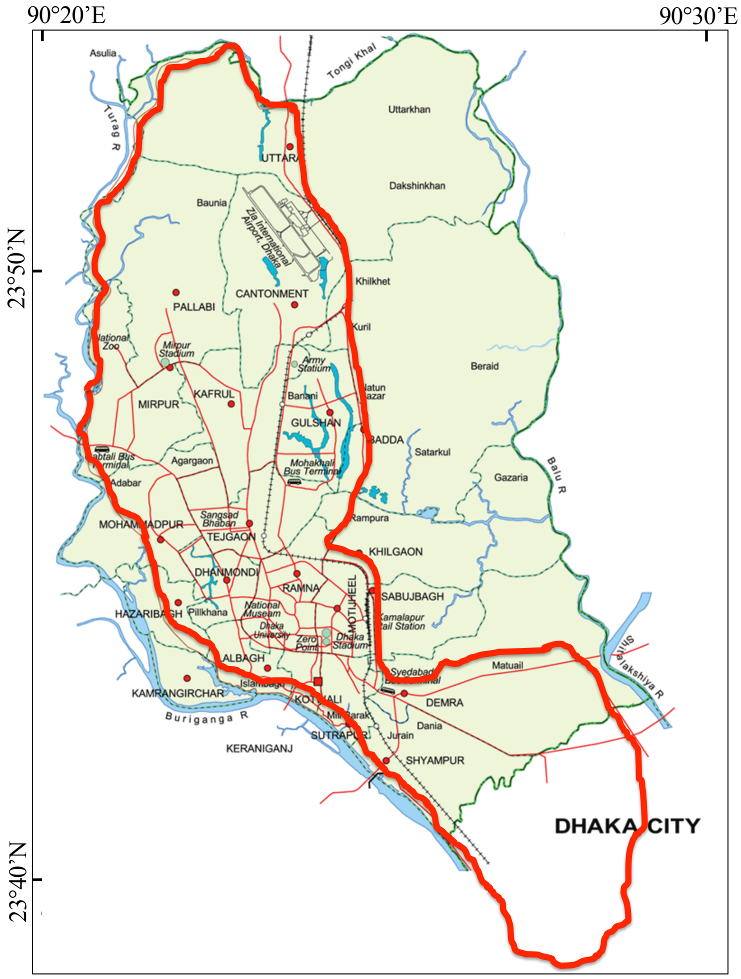


Figure 4-9 Location of the embankments

(Red line indicate the embankments)

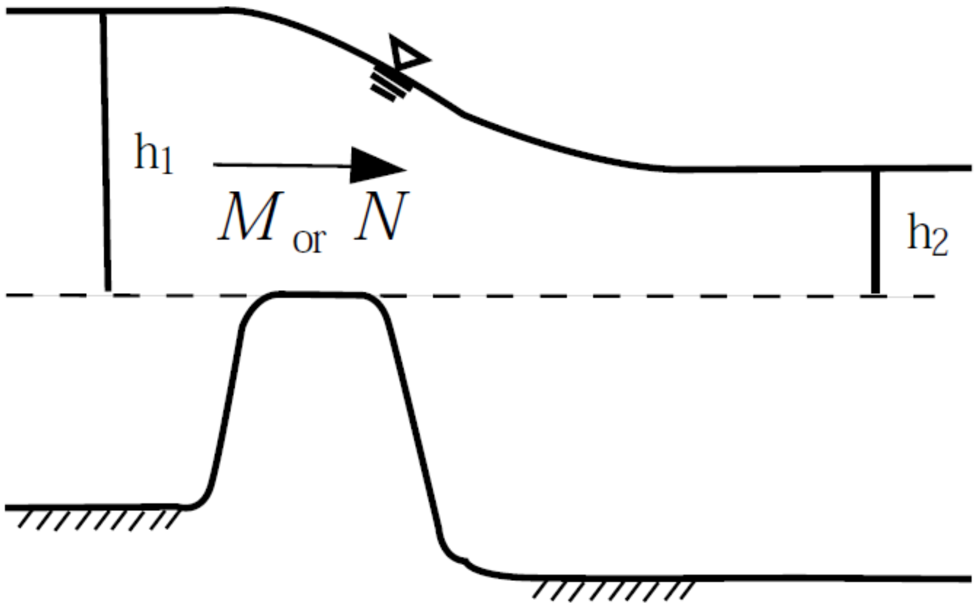


Figure 4-10 Simplified figure for formula of overflow

(Source: JSCE (2001))

Figure 4-11 Concrete wall-type embankment

4.2.7. *Ratio of land occupied by buildings*

Because buildings in Dhaka City are densely concentrated, we considered the ratio of land occupied by buildings. A roughness coefficient was calculated using the following equation:

$$n^2 = n_0^2 + 0.02 \times \frac{\theta}{1-\theta} \times h^{\frac{4}{3}} \qquad \text{eq.4-10}$$

$$n_0^2 = \frac{n_1^2 A_1 + n_2^2 A_2 + n_3^2 A_3}{A_1 + A_2 + A_3} \qquad \text{eq.4-11}$$

where n is the roughness coefficient, h is the water depth (m), θ is the ratio occupied by buildings, and A is the land area (m^2). Subscripts 1–3 denote farmland, road, and other land use. The roughness coefficients obtained from the model (PWRI, 1998) were 0.060, 0.047, and 0.050 for farmland, road, and other land use, respectively. The detail of classification was shown in Table 4-1. The ratios of land use were decided based on the satellite images (Figure 4-12, Figure 4-13).

Table 4-1 Building occupied ratio

Classification color	Building occupied ratio	Land use ratio (building: road:grassland:other)
White & Yellow	0	0:0:1:0
Blue	80	20:3:0:2
Light blue	50	2:0:1:1
Purple	0	0:1:0:0

In this method, the building ratio should be set uniformly for each grid. This ratio was classified into four types based on the following characteristics: a high density of buildings, 0.80 (blue); a low density of buildings, 0.50 (light blue); airports (purple); and empty space (yellow and white) as shown in Figure 4-14.

Figure 4-12 Satellite image of 80 percent building ratio

Figure 4-13 Satellite image of 50 percent building ratio

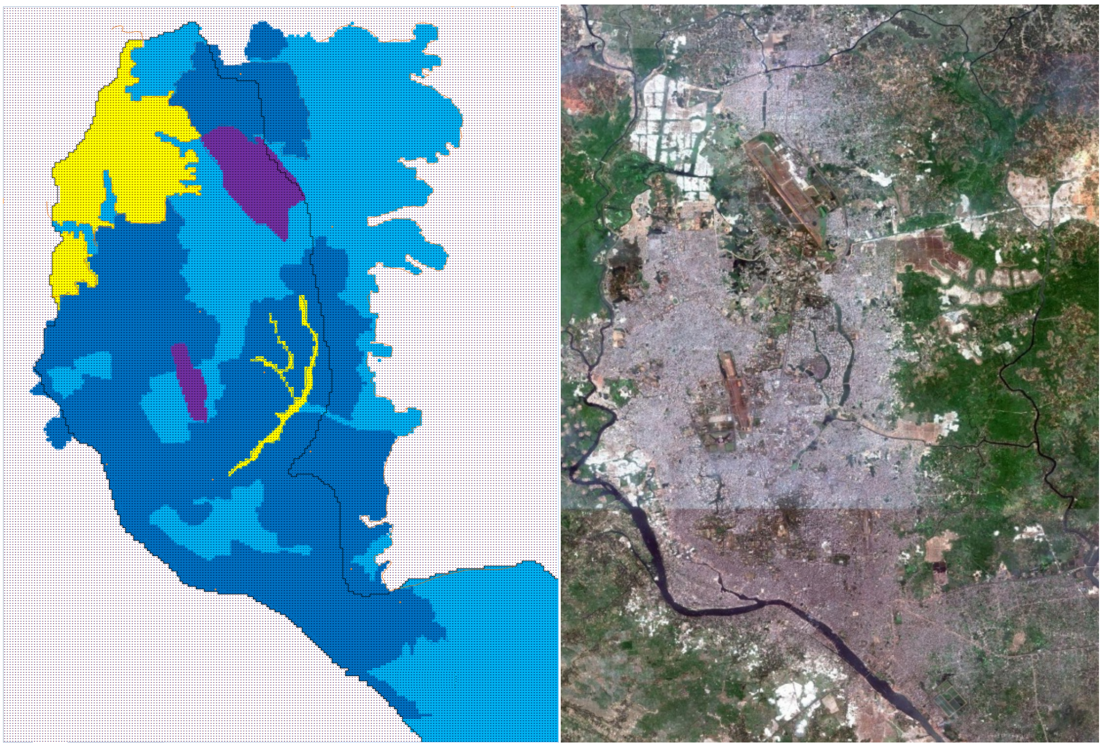


Figure 4-14 (a) Classification of ratio occupied by buildings: Blue indicates 0.80, light blue indicates 0.50, yellow and white indicate unoccupied space, and purple indicates an airport (b) Satellite image

4.2.8. *Method used to consider drainage and sewerage*

The sewerage and drainage system was considered in the flood model, taking particular note of the municipal effluent using a simplified method. As mentioned in the paragraph on the study area, Dhaka City is highly dependent on pumping system for its municipal effluent.

Therefore, we assumed that the total drainage capacity of each grid was the same as the total capacity of the pumps. Based on this assumption, regarding the pumps located along the Briganga River, each pump has a capacity of 22.5 m^3/s, 20.0 m^3/s, 22.5 m^3/s from the north, sequentially. The total capacity of the pumps was assigned to the area covered by the pumps, which was 150km^2, and this area was indicated by the building-occupied area colored blue and light blue in Figure 4-14.

Figure 4-15 shows the comparison between drainage and sewerage network managed by WASA and satellite image. However WASA has developed the drainage and sewerage network, there are small canal that is managed by residents. It should be considered to the flooding model, however, it is hard to obtain the data precisely. So, we also assumed that each grid of simulation was able to drain floodwater equally through entire rainy season, and each grid had a drainage capacity of 37 mm/day.

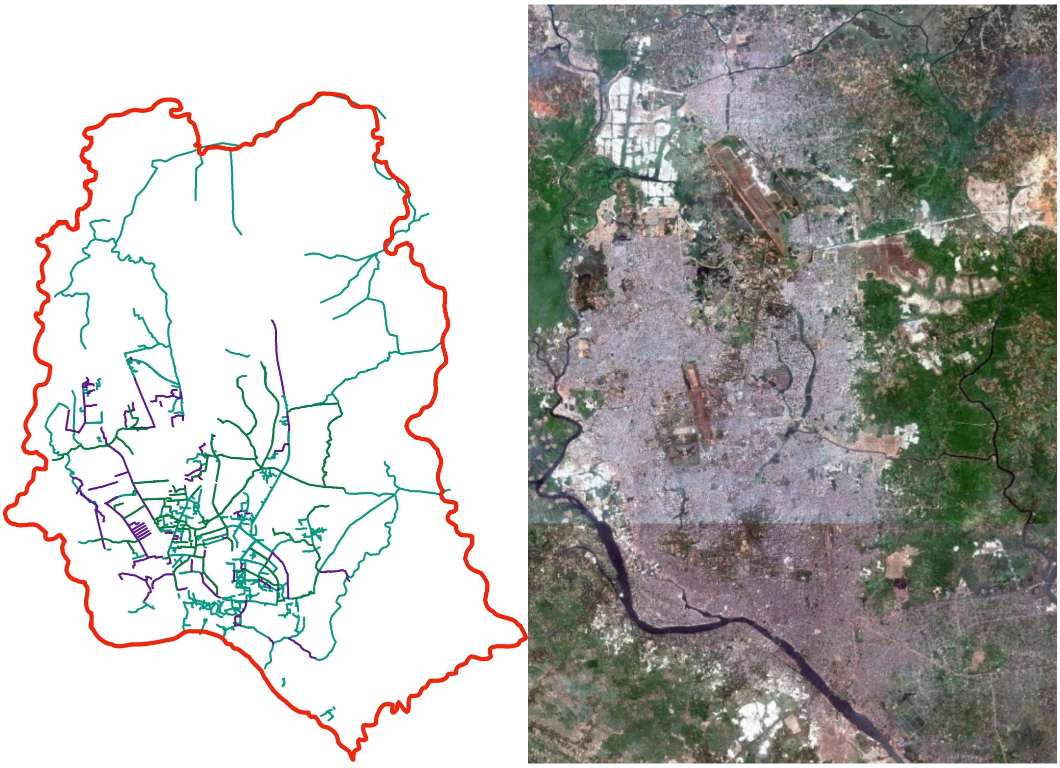


Figure 4-15 Sewage and drainage network and urbanized area

(Left: sewage and drainage network managed by WASA, Right: satellite image obtained from SPOT on February 27, 2010)

4.2.9. *Dataset for model validation*

4.2.9.1. *Satellite image*

The calculated results of the extent of the flood area were validated using satellite images taken by an Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) on May 1, June 20, and August 3, 2007, when Dhaka City was flooded due to severe rainfall.

4.2.9.2. *Qualitative information from residents*

The simulation results were validated by qualitative information from a survey completed through interviews with residents because no community is properly investigating the flood depth. Table 4-2 shows the results of the survey. Areas were chosen according to the classification of the flooding type. Area number 10 was chosen as a control area.

Table 4-2 Classification of areas based on flooding classifications

Community number	Flooding classification	Flooding duration
1 2 3	Short term	Several days
4 5 6	Long term	Several month
7 8 9	Persistent	Whole year
10	None	None

4.3. Result and discussion

4.3.1. *Validation with satellite image*

Figure 4-16 shows the results of the flood simulation. The simulated results of the extent of the flood area were validated using satellite images taken by an Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) on May 1, June 20, and August 3, 2007, when Dhaka City was flooded from severe rainfall. Compared with the flooded area in the satellite image, the simulation results successfully reproduced the extent of the flood area and its changes during several months of the rainy season. Although the part outlined in red is only the simulated flood results, this can be classified as an area with a very dense concentration of buildings; the extent of the flood area can't be clearly identified because of the resolution of the satellite image. From this comparison, it can be concluded that the flood simulation model can reasonably simulate the occurrence of flooding.

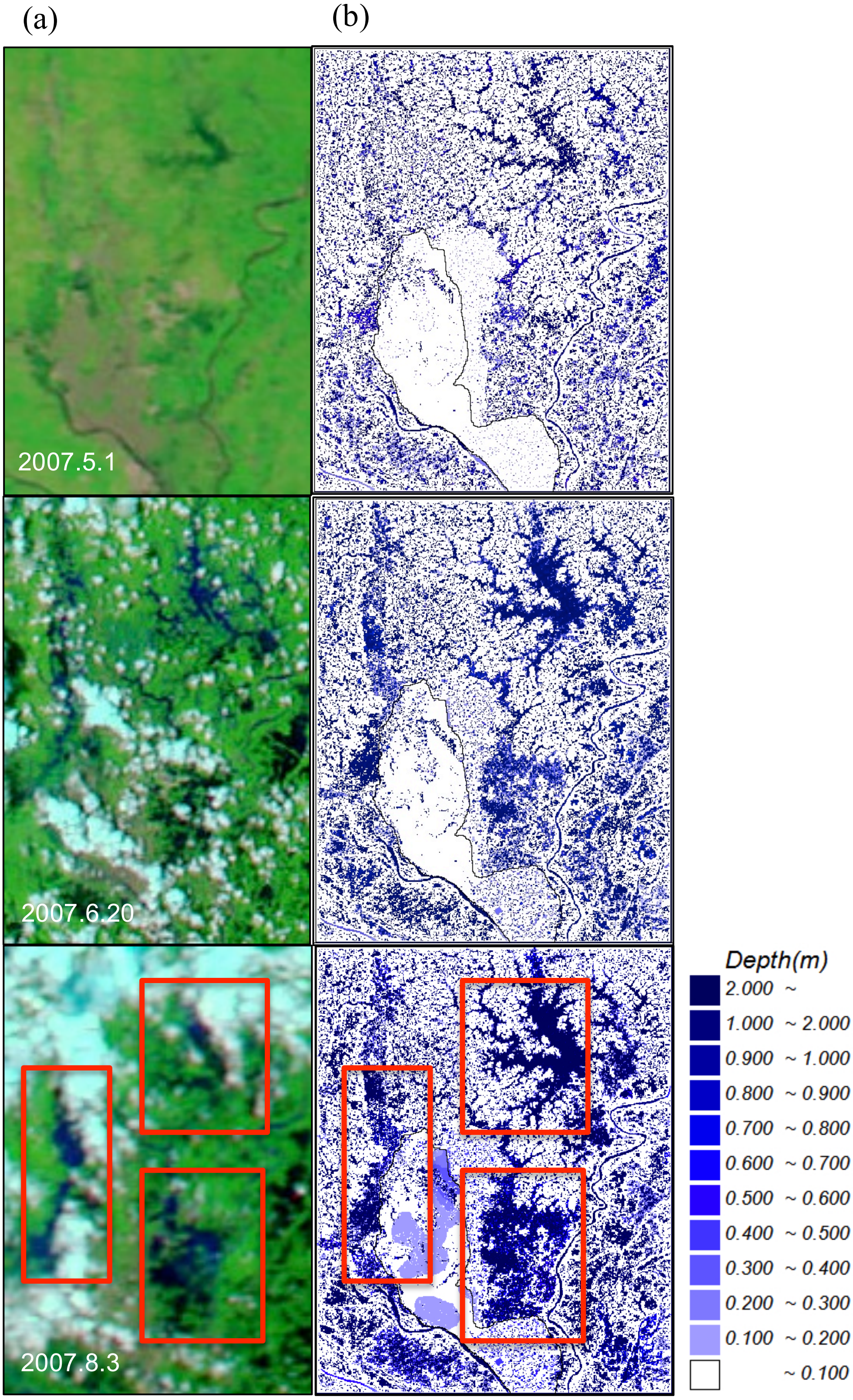


Figure 4-16 (a) Satellite images taken by Aqua MODIS on May 1, June 20, and August 3, 2007 (b) Simulation results

4.3.2. *Validation with information from residents*

The simulated flood depth over time is shown in Figure 4-17. According to the information collected from residential inhabitants, in the past 10 years the floodwater depth for residents in Dhaka City has usually been from ankle to chest height. Thus, in each flooded area identified, the flood depth is within the actual range. In addition, the difference in flood duration between persistently flooded areas (Nos. 7, 8, 9) and other areas that were classified as short duration (Nos. 1, 2, 3), long duration (Nos. 4, 5, 6) and non-flooded (No.10), was relatively reproduced.

This kind of qualitative validation was conducted also in the study by Ojima *et al*. (2008), and its results showed the flooding depth was about 90 cm in many cases based on the information from residents. So that the value fits within our results; the flooding depth of 90cm is almost equal to the waist height.

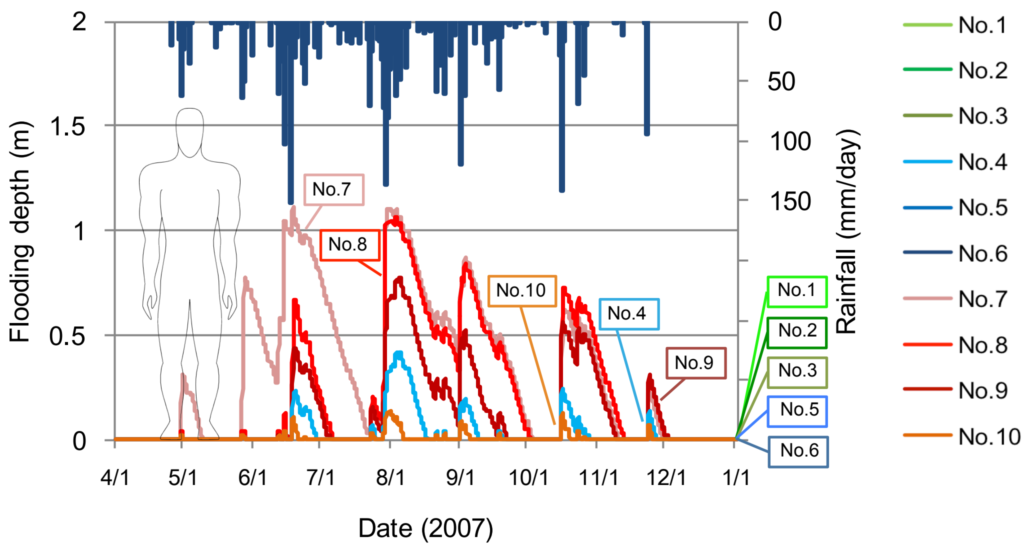


Figure 4-17 Flooding depths over time with rainfall

4.4. Summary

A flood simulation model successfully simulated the flooding that occurred in 2007. The results are not precise. There are differences of a few centimeters, between the simulation and actual flooding. However, the simulation can indicate the degree of ease flooded between areas.

Our study had several limitations. First, the data for drainage and sewerage were not considered. To be precise, operational record of the main pumps and emergency pumps and the location of the pipes where garbage clogs occurred were not considered in the flooding model. Waterlogging in several low-income communities occurs because of problems of the drainage system (Mollah *et al.*, 2009). Therefore, detailed drainage data should be collected for further research.

Second, the data for validating the results of the flood simulation were only image qualitative due to shortage of information. All the validation conducted in this study was qualitative. In order to validate the model quantitatively, a flood mark and flood depth record using a water-stage recorder would be helpful.

CHAPTER 5 RELATIONSHIP BETWEEN FLOODING AND DIARRHOEAL CASES

5.1. Introduction

In this CHAPTER, we focused on the simple relationship between flooding and diarrhoeal cases. In addition, we examined what kind of flooding factors can we used.

Among several natural factors, flooding tends to largely affect the deterioration of the hygienic environment, and cases of this were reported in several countries (Baqir *et al*., 2012). Therefore, health risks, including the incidence of diarrhoea from flooding, are associated with the extent and depth of flooding (Reacher *et al*., 2004). For this reason, flood simulations and their abilities to estimate diarrhoea incidence are necessary to mitigate the damage and loss from flooding in urban areas.

As a representative study, Kazama *et al*. (2012) conducted a study on the use of numerical flood simulation models to estimate diarrhoea incidence around Phnom Penh City, Cambodia, and the study showed that a quantitative risk assessment using a flood simulation model is useful for reducing the risk of infection. However they focused on the contamination of flooding water, we just focused on the physical influence of flooding because the environmental hygiene is totally difference. We assumed that the flooding water in Dhaka City is highly contaminated by sewage.

In the previous research, Mollah *et al*. (2009) examined the relationship between flooding and diarrhoea in Dhaka City. However they found the relationship, the flooding information was qualitative and that was observed by resident dwellers. Thus we examined the relationship with flooding qualitative data that was obtained by flood simulations.

Therefore, the main aims of this chapter were to quantitatively clarify the relationship between flood-prone areas and diarrhoea incidence in the three different seasons (pre, mid and post monsoon) by simple correlation analysis.

5.2. Procedure and data collection

5.2.1. *Low-income communities' identification for study site*

Based on flood and inundation experience, low-income communities in Dhaka were selected from different representative water logging situations for duration of inundation. We proposed 4 levels based on duration of inundation (short-term, long-term, persistent and non-inundation). Ten sub-districts were selected by integrating information regarding water logging for the past 5-10 years that was obtained from interviews with the concerned authorities and dwellers as well as on-site measurements from a preliminary survey conducted in December 2006. The low-income communities selected were situated within 1 km from the Urban Development Centre Project offices of the Slum Development Department of the Dhaka City Corporation.

5.2.2. *Sample size*

Due to the limitation of time and budget, it was impossible to interview all households in all selected sub-districts of Dhaka. The unit of sample size was a household. Simple random sample size technique was chosen to calculate the number of sample following the equation

By applying eq.5-1, sample size (n) of the respondents was calculated.

$$n = \frac{N}{1 + Ne^2} \qquad \text{eq.5-1}$$

where: n=Sample size, N=Total of population, e=the acceptance of probability of error (equal to 95% or 0.05).

So, Dhaka mega city had 185,917 households (as of 1997) from all sub districts in Dhaka megacity was calculated following the equation eq.5-1, thus sample size;

$$n = \frac{185,917}{1 + 185,917 \times (0.055)^2} = 329.99 \approx 330$$

Therefore, the study survey for questionnaires and home based health surveillance was 350 households including around 5% more in each community, that was 35 households in each community, among ten sub districts in Dhaka, Bangladesh.

5.2.3. *Selecting study site*

Among the communities, ten low-income communities were chosen as target areas (Figure 5-1), selected in consideration of flood conditions over the past 5 to 10 years, such as short duration (Nos.1, 2, 3), long duration (Nos. 4, 5, 6), persistent flooding (Nos. 7, 8, 9) and no flooding (No. 10). Data were obtained from interviews with authorities and the residents concerned, as well as through onsite measurements. In this study, each "low-income community" was located within 1 km of the Urban Development Centre Project offices of the Slum Development Department of Dhaka City Corporation, and the number of children in the study area totaled 707 from 350 households.

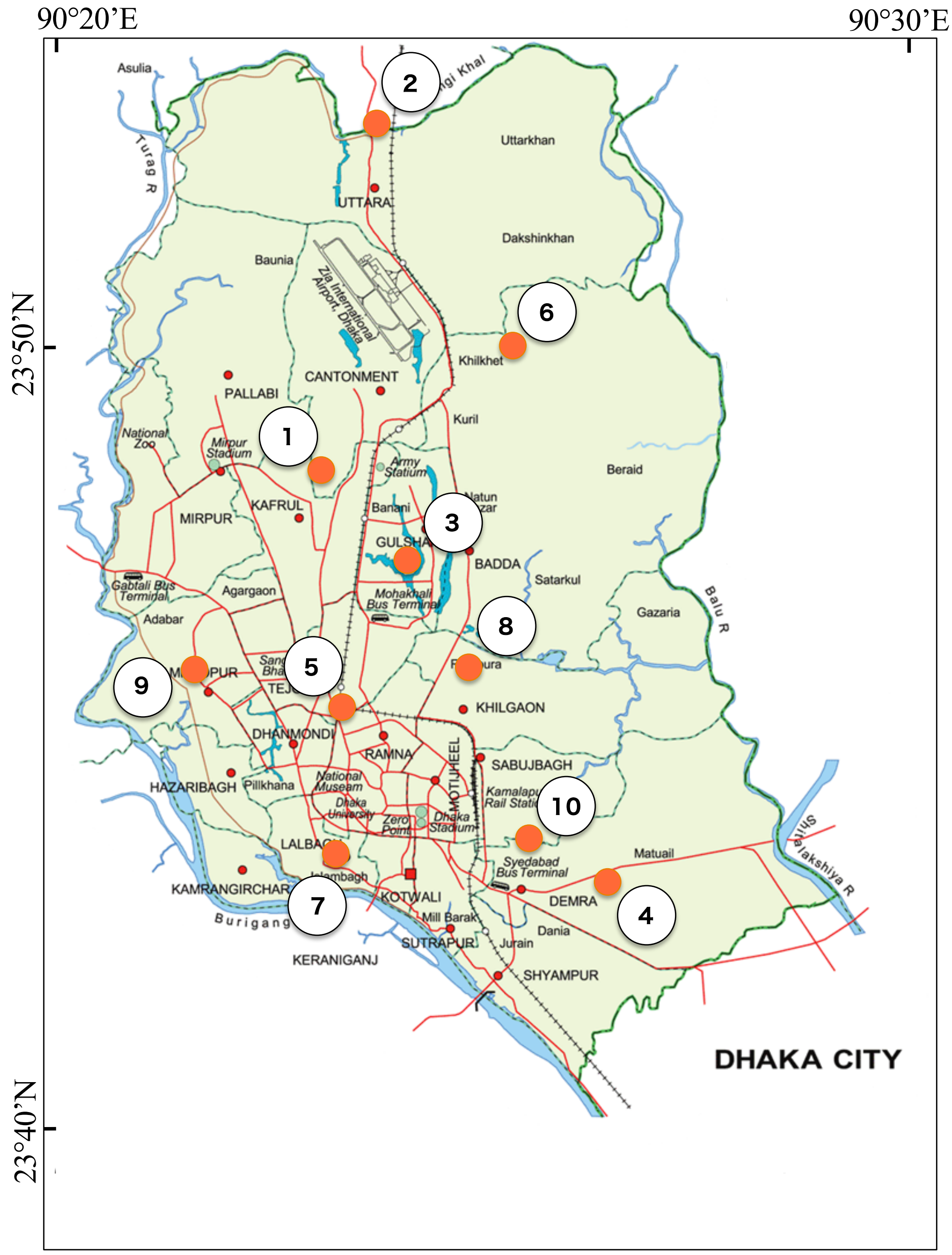


Figure 5-1 Study site

(Orange dots show the study sites, and the numbers with black circle indicate low-income community number)

5.2.4. *Study population*

A household was defined as people sharing the same cooking pot (Hussain *et al.*, 1999). Using this definition, 820 households in 10 sub-districts were identified during the preliminary survey. Of the 350 households satisfying the predefined criteria (35 households from each community), presence of children <5 years of age, water supply and no improvement in sanitation were selected for additional questionnaire surveys. Informed consent was obtained from the parents or guardians. Table 5-1 shows the description of each low-income area.

Table 5-1 Description of each low-income areas

	low-income community Number										
	1	2	3	4	5	6	7	8	9	10	Total
Household	35	35	35	35	35	35	35	35	35	35	350
No. of Children (% of in all area)	70 (10)	60 (8)	65 (9)	88 (12)	57 (8)	66 (9)	103 (15)	64 (9)	89 (13)	45 (6)	707
0-1 yr old (% of an area)	13 (19)	15 (25)	20 (31)	9 (10)	14 (25)	17 (26)	34 (33)	23 (36)	23 (26)	17 (38)	185 (26)
1-5 yr old (% of an area)	57 (81)	45 (75)	45 (69)	79 (90)	43 (75)	49 (74)	69 (67)	41 (64)	66 (74)	28 (62)	522 (74)

5.2.5. *Study period*

A series of surveys were performed, preliminary survey, pre-monsoon survey which is the base line survey in this study, monsoon survey and post monsoon survey. These were conducted in December 2006-January 2007, in April 2007, August 2007-September 2007, and December 2007-January 2008 respectively (Figure 5-2), and two weeks were spent for each survey.

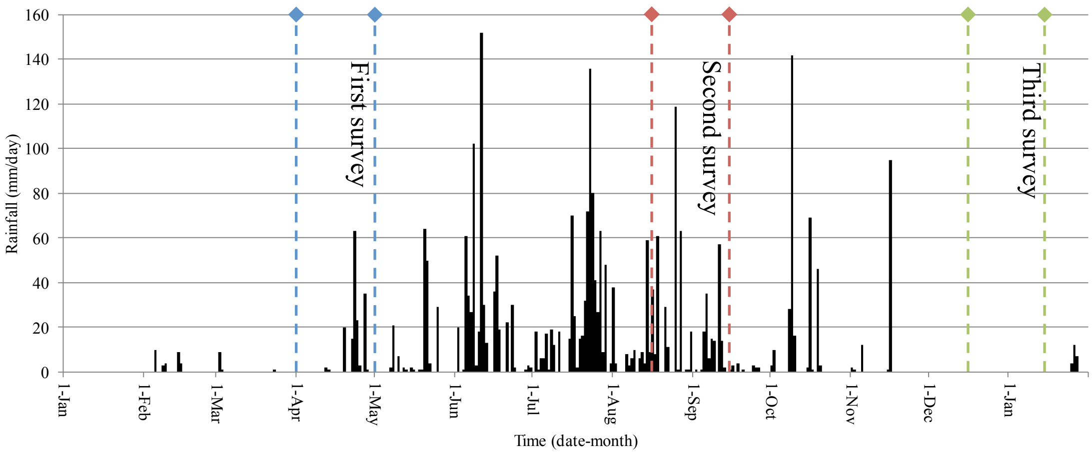


Figure 5-2 Study period with daily rainfall in Dhaka City

5.2.6. *Diarrhoea incidence*

Among water-borne diseases, diarrhoea is a condition of morbidity that is relatively easy to monitor; as it occurs rather frequently, respondent mothers easily understand its definition, and there is little symptom's variation from mother's perceptions (Killewo *et al.*, 1989): the occurrence of 3 or more loose, watery or mucous stools in the previous 24h. We followed the definition of acute diarrhoea by the World Health Organization (WHO) and UNICEF: an attack of sudden onset that usually lasts 3-7 days but may last up to 10-14 days (Park, 1997). We used a period of 3 intervening diarrhoea-free days to differentiate a new incidence of diarrhoea (Baqui *et al.*, 1991). The Child health Epidemiology Reference Group of WHO (WHO/CHERG) summarized a table for the definition of diarrhoeal deaths that was used in this survey for verbal autopsy, which has a very good agreement with hospital diagnosis (Kalter *et al.*, 1990; Pacque-Margolis *et al.*, 1990).

In consecutive 3 surveys, investigators asked each mother to follow her child/children for 2 weeks after recruitment, and during a preliminary visit, they described how to confirm the presence of diarrhoea. They also demonstrated how to mark the day that symptoms first started and the day that the illness ended or the child succumbed to the illness. The information was reported to investigators at the follow-up two weeks later. The 2-week interval was chosen because diseases and symptoms assessed and reported by inhabitants can be imprecise; high reliability depends on shorter recall periods (Byass *et al.*, 1994). Final data were input only if the data were consistent with the mother's performance levels in defining the symptoms and counting the days of illness. Table 5-2 shows the results of the survey.

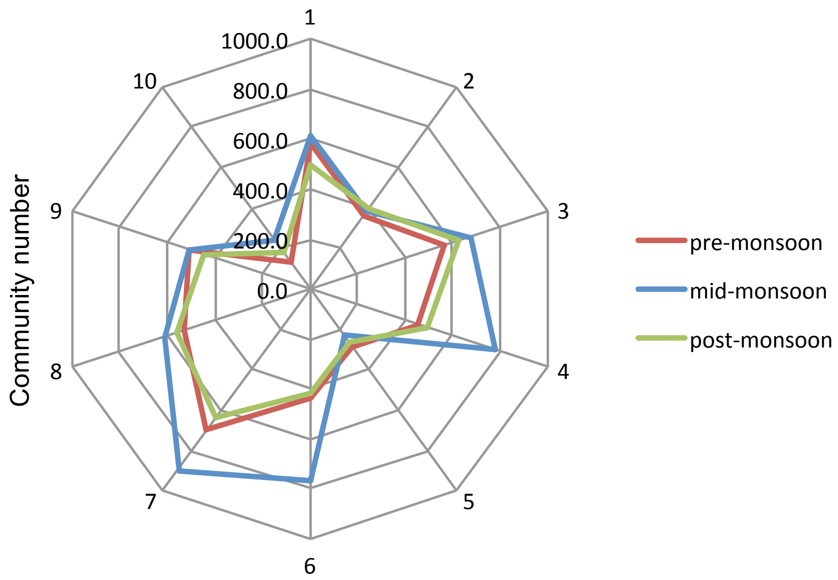
Table 5-2 Diarrhoeal morbidity and mortality on each low-income areas

Community No.	Pre-monsoon	Mid-monsoon	Post-monsoon
1	585.7	611.9	492.5
2	366.7	386.0	400.0
3	569.2	672.1	625.0
4	454.5	779.2	493.0
5	280.7	232.1	267.9
6	439.4	766.7	421.1
7	699.0	895.3	637.7
8	531.3	614.0	555.6
9	505.6	512.8	444.4
10	133.3	244.4	177.8

Units of the morbidity is /1000 children

Although we have data of mortality, these were calculated from the data of several people unit, and the seasonal variation is large (Figure 5-3). Further, previous studies of the relationship between flooding and diarrhoea was conducted using the data intended for people who got diarrhoea such as number of people visiting a hospital (Hashizume *et al*., 2008). Thus, we consider morbidity as the combined indicator of morbidity and mortality.

(a)



(b)

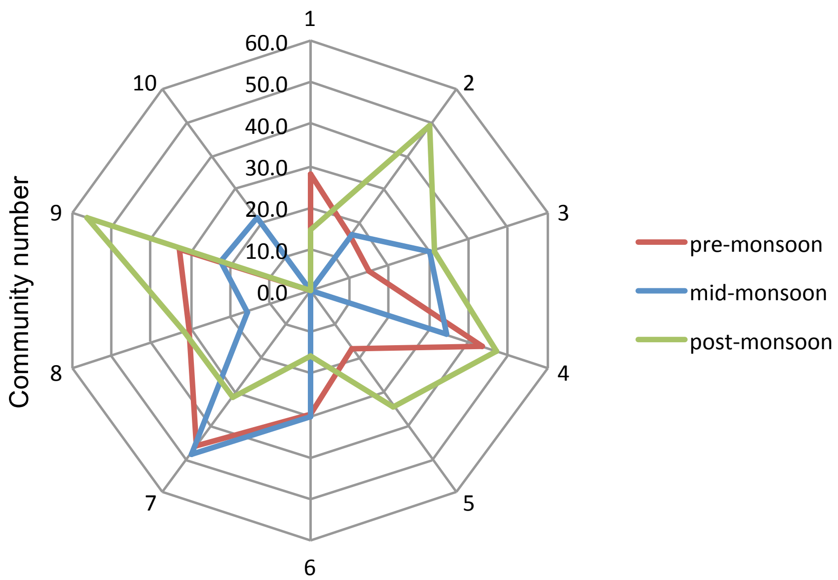


Figure 5-3 Health risk comparison on different rainy season (a) Morbidity (/1000 children), (b) Mortality (/1000 children)

5.2.7. *Flooding factors*

Flooding parameters that were compared with diarrhoeal cases were obtained from flooding simulation that was performed in CHAPTER 4. It consists of three parameters, which are maximum flooding depth, maximum flooding duration and accumulated flooding depth (Table 5-3). Maximum flooding depth means the highest value of the depth throughout whole rainy season. Maximum flooding duration means the period that flooding depth was over 0.1m. Accumulated flooding depth means that daily accumulated flooding depth.

Table 5-3 Flooding parameters

Flooding parameter	Low-income community number									
	1	2	3	4	5	6	7	8	9	10
Maximum flooding depth (m)	0.0	0.0	0.1	0.4	0.1	0.0	1.1	1.0	0.8	0.1
Maximum flooding duration (days)	0.0	0.0	0.0	29.3	0.0	0.0	113.6	70.4	64.4	4.0
Accumulated flooding depth (m・day)	0.0	0.0	0.0	55.3	0.0	0.0	568.8	324.3	184.5	3.7

5.2.8. *Diarrhoea incidence exposure*

In the interview survey that our research team conducted in September 2010, information about the route of infectious diarrhoea was collected for each low-income community. We visited the low-income-community areas one by one and obtained the answer of the question; 'Why did your children get diarrhoea in flooding condition?' Five to ten adults were randomly chosen per area. According to the survey results, it was found that children are mainly infected when they play in floodwater. This also supports the result of Rashid (2000). As mentioned in his paper, playing in a flooded place is one of the troubling hazards. Therefore, if the water depth is high, children can easily touch their mouths after their hands touch the floodwater. Furthermore, because the infectious route is complicated, we summarized the considerable infectious route by the information obtained by field surveys (Figure 5-4). The figure indicates infectious routes considering a life-style of residents.

Furthermore, Mollah *et al*. (2009) also mentioned the relationship between socioeconomic status and more severe flooding conditions. People in a lower socioeconomic position tend to live in worse flooding conditions, and this is a strong environmental hazard for diarrhoea. These people also tend to not be educated in terms of sanitation, which also seriously increases the risk for diarrhoea incidence.

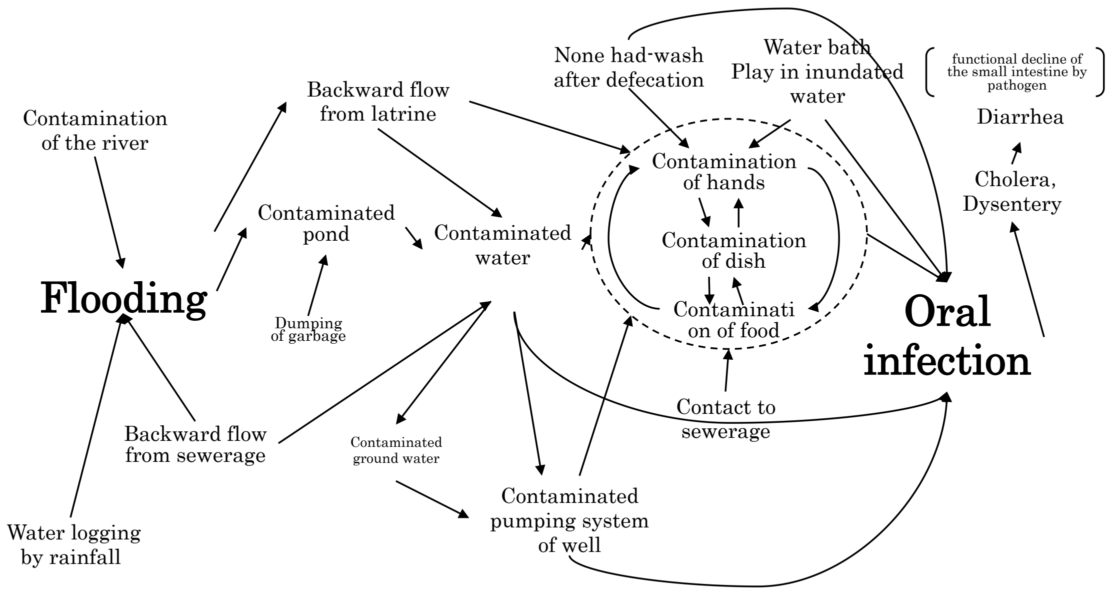


Figure 5-4 Infectious route made from the information of field survey

Hence, in relation to the risk of children being infected, we assumed that a high flood depth increased access to polluted water and long flood duration increased their opportunities to touch the polluted water. Therefore, in this study, we used maximum flood depth, maximum flood duration and accumulated flood depth as indexes to express the likelihood of an area being flooded. Then, the relationship between diarrhoea morbidity and each flooding factor was analysed using a Pearson correlation coefficient.

5.3. Relationship between flooding and diarrhoea

5.3.1. *Comparison between flooding and diarrhoeal cases*

Figure 5-5 shows the changes in flood depth and morbidity. First, we found that there were predisposing causes for contracting diarrhoea in the non-flooded areas because the morbidity was present in the pre- and post-monsoon season, even though flooding did not occur at that time. As Mollah *et al*. (2009) mentioned in their paper, this risk might be due to food, drinking water or hand-washing customs, which were not related to the flooding. Second, we found that flooding has an influence on diarrhoeal incidence because morbidity increased in the mid-monsoon season when flooding occurred, and this increase was observed in almost all communities (9 out of 10). In community No. 7, which was in the most flood-prone area, morbidity was the highest in each season and there tended to be a high rate of morbidity in long-duration flood areas (No. 4, 6) and persistent flooded area (No. 7). However, there is a possibility that the increased morbidity was not due to flooding only since an increase was also observed in community No. 10, which was chosen as a non-flooded area; this might also be influenced by rainfall, temperature and humidity in the mid-monsoon season.

Regarding the accuracy of flood depth over time using the flood simulation model, in the areas where morbidity increased significantly (Nos. 4, 6, 7), the flood depth was high in communities No. 7 and 4; however, flooding was not identified in community No. 6. Its flooding might be caused by flooding from riverside. In this point, the simulation was possibly difficult to simulate flooding from riverside accurately.

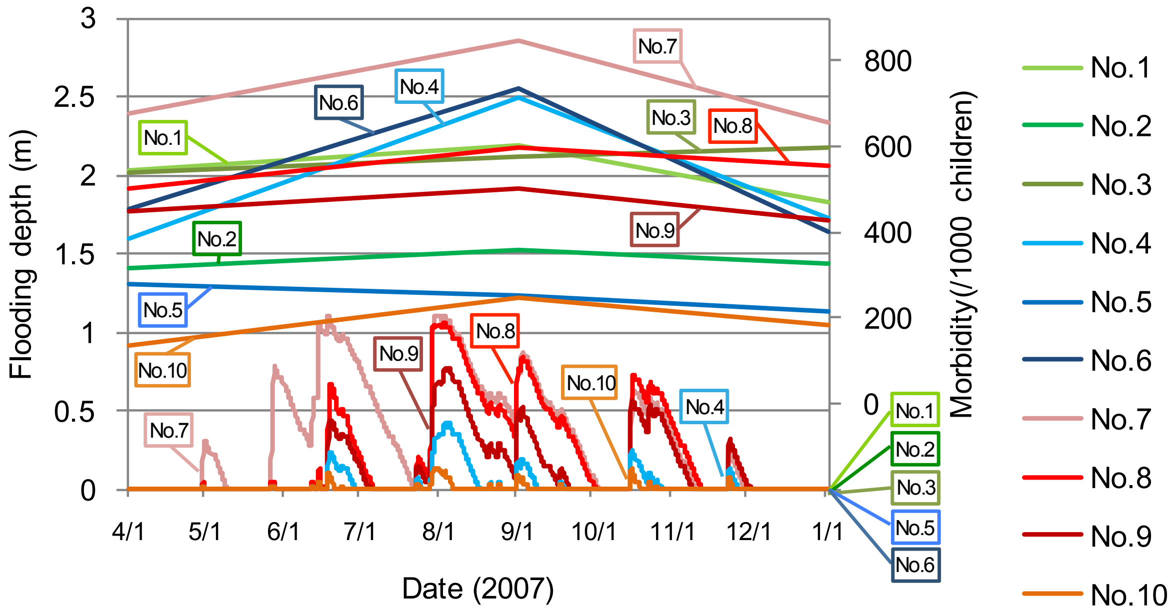


Figure 5-5 A comparison between flooding depth with time and changes in morbidity

5.3.2. *Comparison of each flooding factors*

Figure 5-6, Figure 5-7 and Figure 5-8 compare with the morbidity and maximum flood depth, maximum flooding duration and accumulated flooding depth in each season. First, in the case of maximum flooding depth, a positive correlation was observed not only in mid-monsoon season (correlation coefficient [CC] = 0.42, P-value [*P*]= 0.23) but also in the pre- (CC = 0.51, *P* = 0.13) and post-monsoon seasons (CC = 0.50, *P* = 0.14) that flooding did not occur (Figure 5-6). Also in the case of maximum flooding duration, relationship has positive correlation in pre-monsoon (CC = 0.57, *P* = 0.09), mid-monsoon (CC = 0.50, *P* = 0.15), and post-monsoon (CC = 0.53, *P* = 0.12)

(Figure 5-7). The relationship with accumulated flooding depth also has positive correlation in pre-monsoon (CC = 0.56, *P* = 0.08), mid- monsoon (CC = 0.48, *P* = 0.17), and post-monsoon (CC = 0.54, *P* = 0.10) respectively (Figure 5-8).

This relationship seems to be due to a predisposition for contracting diarrhoea unrelated to flooding. However, even though the correlation coefficient is not statistically significant, we observed a tendency of the high-morbidity area to have high flooding depth. One supposed cause of this relation is socioeconomic status. People in lower socioeconomic positions may live in areas with more severely waterlogged conditions (Mollah *et al.*, 2009). As a result, a positive correlation was observed in pre- and post-monsoon seasons.

Second, the correlation coefficient was not that different in each season. Although morbidity increased because of flooding, the gradient of diarrhoeal vulnerability seems to be due to socioeconomic status.

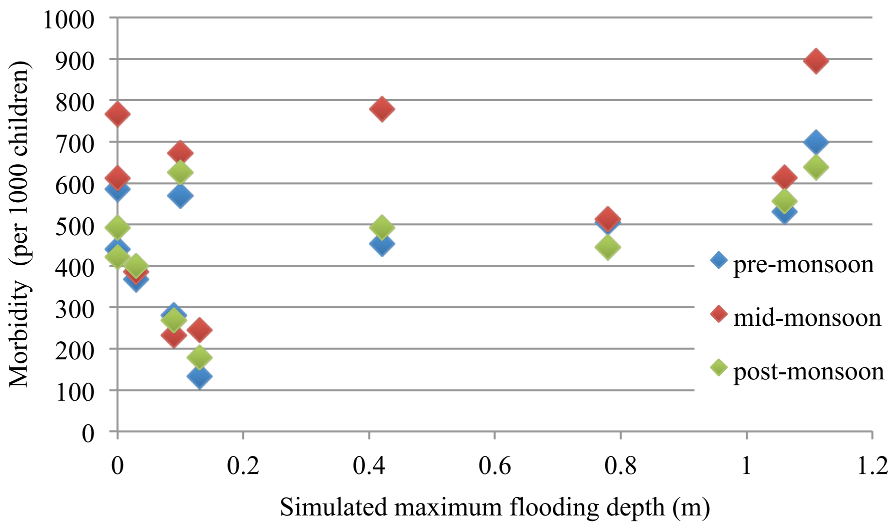


Figure 5-6 The relationship between morbidity and maximum flood depth in pre-, mid- and post-monsoon season

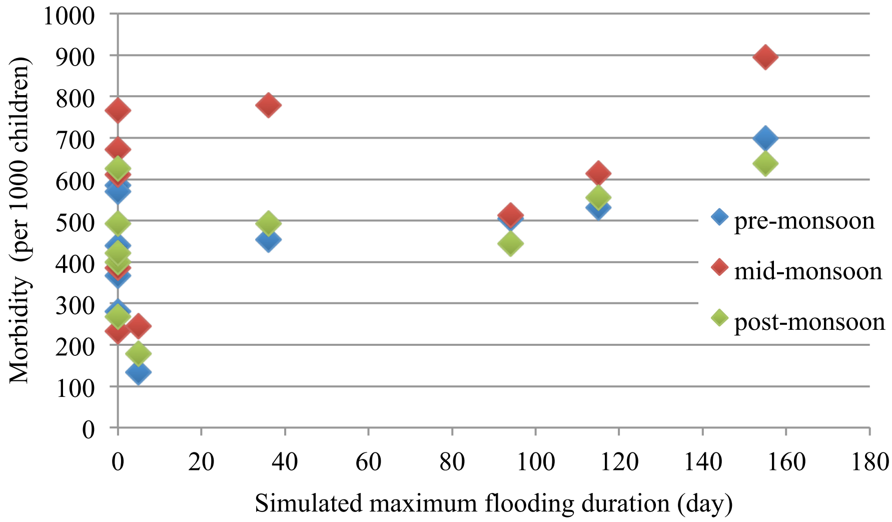


Figure 5-7 The relationship between morbidity and maximum flood duration in pre-, mid- and post-monsoon season

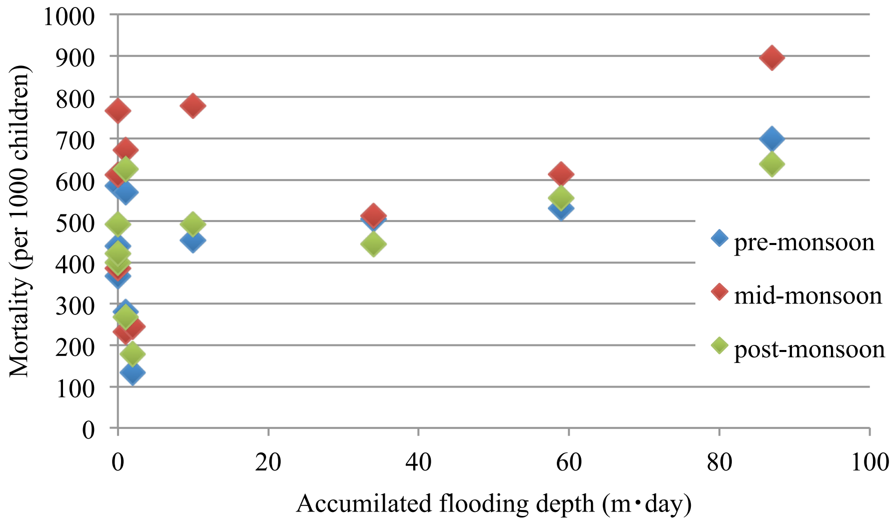


Figure 5-8 The relationship between morbidity and accumulated flood depth in pre-, mid- and post-monsoon season

Figure 5-9 compares the correlation coefficient regarding the relationship between flood factors and morbidity. We evaluated this relationship using not just maximum flood depth but also maximum duration and accumulated flood depth. Although the correlation coefficient was high in the case of duration, which was 0.57 in the pre-monsoon season, 0.53 in the mid-monsoon season and 0.61 in the post-monsoon season, the difference was not large. Flood duration tended to be high in areas where flood depth was also high. Therefore, we found that the correlation relationship was not different by a comparison between duration and accumulated flood depth, as well as by a comparison with flood depth.

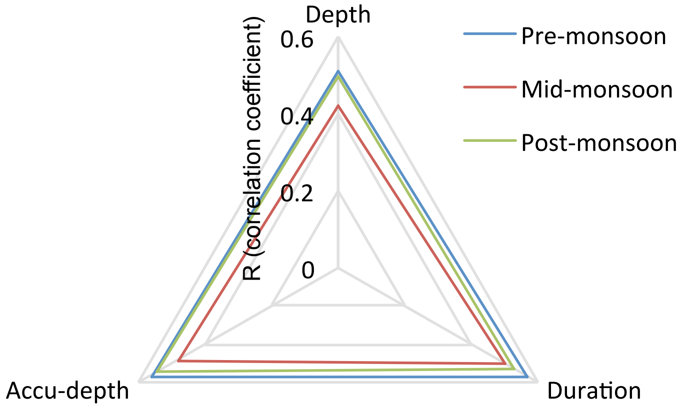


Figure 5-9 A comparison between morbidity and flooding parameters (maximum flood depth, maximum flood duration and accumulated flood depth

5.4. Summary

This CHAPTER quantitatively evaluated the changes and the relationship between flood parameters and morbidity throughout the rainy season. The results supported the theory by Mollah *et al*. (2009) that diarrhoea risk is high in flood-prone areas. Based on the foregoing, the flood simulation model can be a useful tool for evaluating the influence of flooding on diarrhoeal cases, although social conditions should be carefully considered (Hashimoto *et al*., 2013). In addition, this quantitative evaluation can enable us to estimate both the health risk in the entire Dhaka City without flooding observation data and changes of health risk associated with changes in the environment such as changes in the urban environment and climate changes.

We found that there is a predisposing cause for contracting diarrhoea without flooding from a comparison of flood depth with time and changes in morbidity, obtained from interview surveys. Furthermore, we also found that flooding has an influence on contracting diarrhoea, where morbidity increased in 9 out of 10 areas, and the areas where this increase was large were those prone to long durations of floods areas and persistently flooded areas.

We quantitatively examined the relationship between morbidity and flooding using maximum flood depth, maximum flood duration and accumulated flood depth. As a result, we found that there was no significant difference with respect to a comparison of each flood factor. Furthermore, the relationship between flooding and morbidity was considered to be due to predisposing causes, as this relationship was present in the absence of flooding.

First limitation is a similarity of the relationship between diarrhoea and each flooding factors. It seems to be caused by simple consideration of sewage system. If the model can consider the sewage system precisely and also consider the solid waste congestion in the sewage pipe, we sill get the variance of the relationships of maximum flooding depth, maximum flooding duration and accumulated flooding depth.

As it was mentioned in the introduction, we only focused on the physical influence of flooding, and we have found its positive correlation. However, if we could obtain information of contamination of floodwater, it could be important information to explain the diarrhoeal cases.

CHAPTER 6 THE STATISTICAL ANLYSIS OF SOCIAL FACTORS

In this chapter, we primarily focus on the statistical analysis of the social epidemiological factors. In chapter 5, we examined the relationship between flooding and diarrhoeal cases by simple regression analysis and identified a positive correlation. However, the correlation coefficient (CC) was not strong and there were apparent predisposing social factors. In addition, several researchers indicated the social conditions influence diarrhoea (Kunii *et al.*, 2002; Mollah *et al.*, 2009). Therefore, we conducted a statistical analysis of these social factors, with the following three aims: 1) to examine the explanatory factors for cases of diarrhoea, and assess its influence through multiple regression analysis; 2) to examine the degree of flooding for variance between areas in diarrhoeal morbidity; and 3) to identify the influence of flooding and social epidemiological factors on cases of diarrhoea in flood conditions by multilevel logistic regression analysis.

6.1. Social epidemiological method

We performed multiple regression analysis using variables that appeared to be related to diarrhoea in flood conditions. Variables that were selected are listed in Table 6-2. Next, we performed multilevel logistic analysis. This involved examining the degree of flooding for variance in diarrhoeal morbidity between areas and comparing the influence of flooding and social factors on diarrhoeal morbidity. We have explained below in detail the social factors and statistical methods that were used in this analysis.

6.2.1. *Social epidemiological factors*

Social factors were obtained through a questionnaire. The survey requested demographic characteristics, hygiene practices, water supply, sanitation, household income, and maternal educational attainment.

6.2.1.1. *Community characteristics*

In Bangladesh, diarrhoeal diseases are endemic; however, outbreaks and epidemics of cholera and other diarrhoeal diseases occur during the hot and humid summer months and following the monsoon floods, causing peaks in April–May, September–October, and December–January. Community characteristics are described below, and comprise socio-demographic, socio-economic, household water supply, and sanitation.

6.2.1.2. *Socio-demographic factor*

Maternal age was the only socio-demographic factor considered. Figure 6-1 shows the percentages according to each age group, of which 10–19, 20–29 and 30–39 years accounted for almost three quarters.

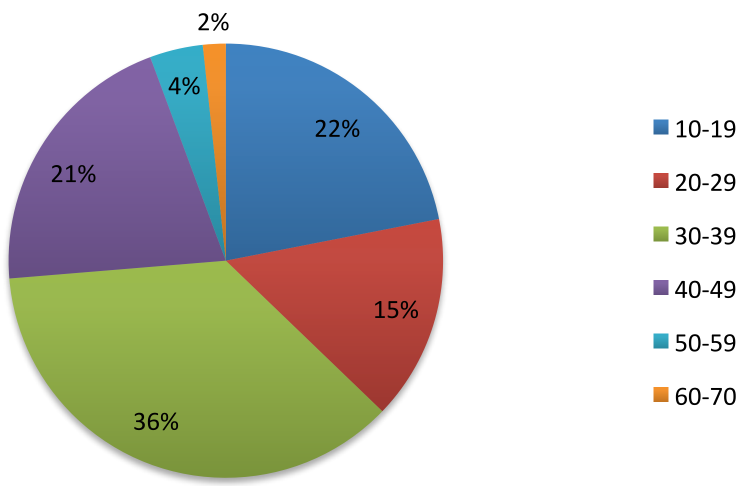


Figure 6-1 Percentage of participants according to maternal age group

The average maternal age was used (Table 6-1), for the multiple regression analysis, although the percentages per area were used to analyze other factors. Further, for multilevel logistic regression analysis, two maternal groups were created based on the mean age of 38-year-old as the age cut-off (age range 13–63).

Table 6-1 Average maternal age per community

	Community number									
	1	2	3	4	5	6	7	8	9	10
Average mother's age	30.0	33.1	31.9	31.9	35.8	31.1	34.8	28.2	32.0	33.1

6.2.1.3. *Socio-economic factors*

Socio-economic factors were: 1) occupation of the husband, 2) education level of the mother, and 3) household income. Over 80% of fathers reported private or self-employment, whereas only 4% of fathers were unemployed (Figure 6-2). The majority of the mothers had no higher education, and 14% were not educated above elementary level (Figure 6-3). There were households (44%) with monthly incomes <30 United States Dollars (USD) and 30–50 USD, and 12% had incomes >50 USD (Figure 6-4).

These factors are important as they impact the ability to purchase safe water and food. Many respondents described the need to ask water from their neighbors because they had no money. Some interviewees reported being unable to bear the thought of continually asking for water and being belittled in the process.

Many households had seven or more family members (40%) and monthly household incomes <30 USD. Excluding the non-inundated community (No.10), the number of illiterate mothers age <15-year-old was above the national average in this survey (>40%).

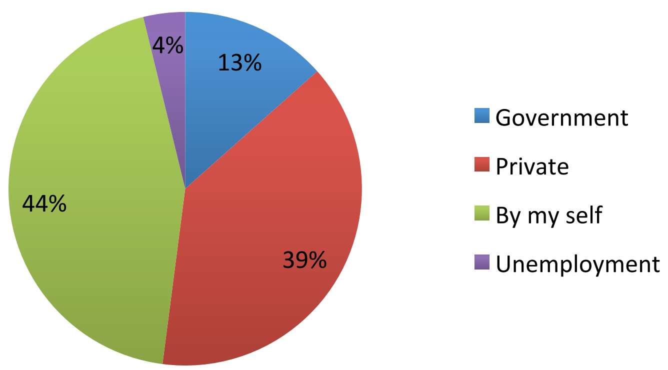


Figure 6-2 Percentage of paternal occupations

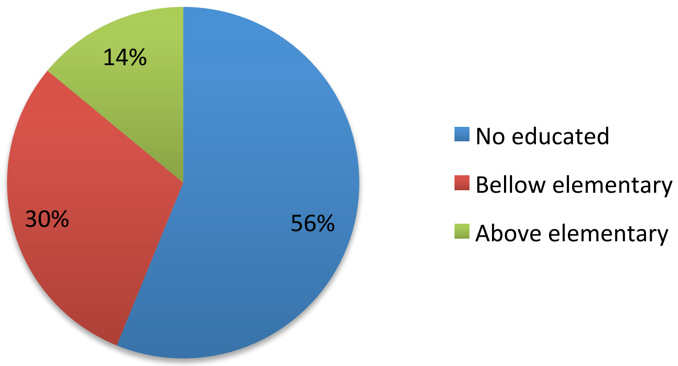


Figure 6-3 Percentage of educational attainment

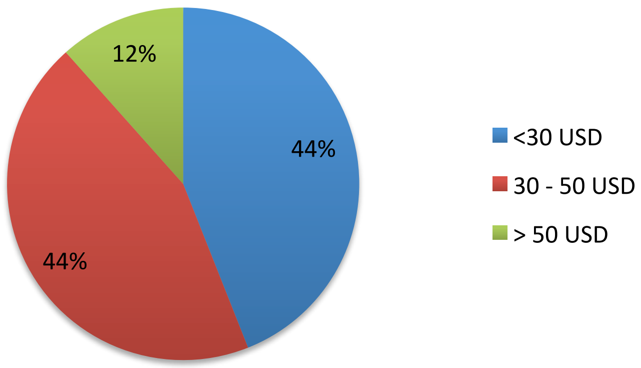


Figure 6-4 Percentage of household incomes

6.2.1.4. *Household water environment*

The household water environment comprised water disposal, water resources, latrine possession, and possession of a septage removal pit latrine. Participants primarily disposed water to wetlands (Figure 6-5), and the water resource was taps and ground water and few used rain water (Figure 6-6). Most respondents had their own latrines (Figure 6-7) and a quarter used a pit latrine (Figure 6-8).

In community No.10, tap water was used in 100% of households and 80% used sanitary latrines; other communities, only 23%–54% used tap water and 0%-9% used sanitary latrines (Table 6-2). In particular, low-income communities living in persistent water-logged conditions were likely to have worse sanitary conditions (i.e. relatively higher rates of no latrine or unsanitary hanging latrines) (Table 6-2).

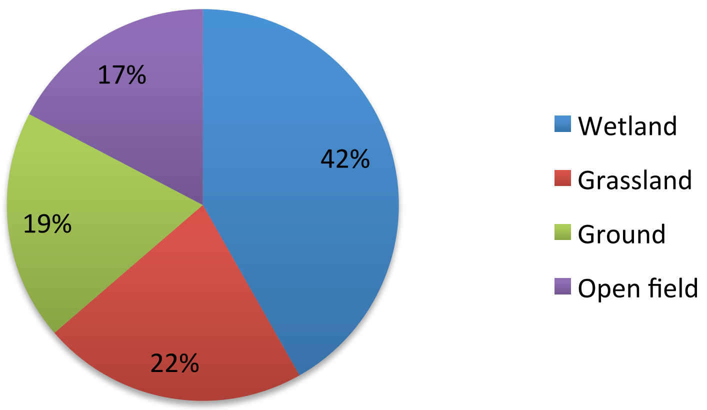


Figure 6-5 The locations of wastewater disposal

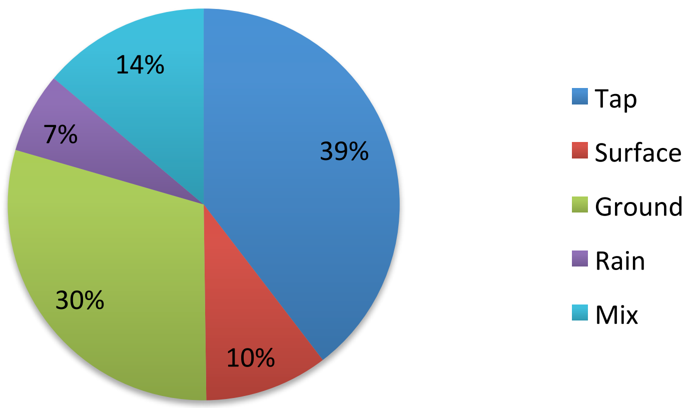


Figure 6-6 Water resources

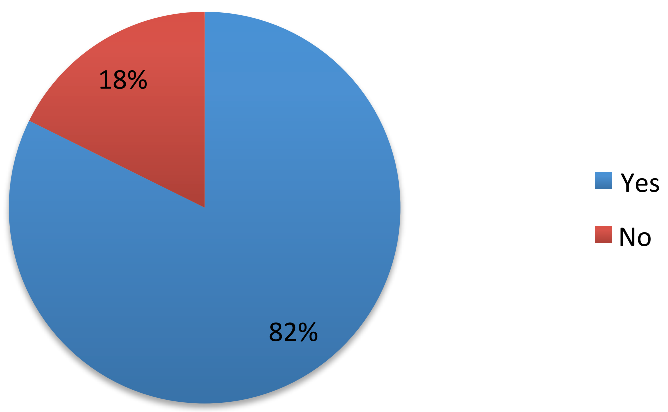


Figure 6-7 Rates of latrine possession

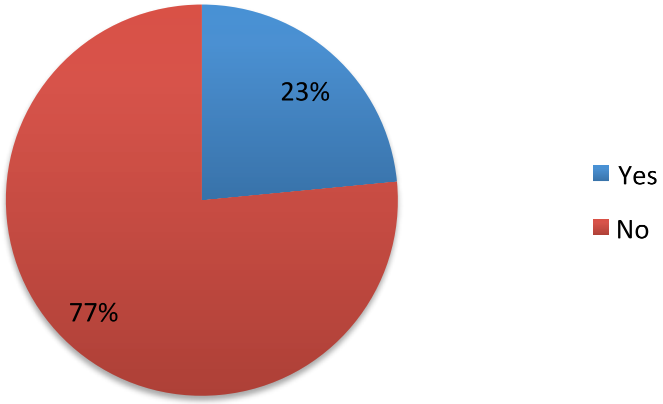


Figure 6-8 Rates of possession of septage pit latrines

(People who are use septage continually removing excreta)

6.2.1.5. *Sanitary behavior*

Sanitary behavior consisted of water treatment, defecation habit, and washing hands before meals and after defecation. Water was reported as untreated by 73% of respondents and as treated by almost 25% (Figure 6-9). More than half the children (52%) defecate on open land, and few people defecate in latrines (10%) (Figure 6-10). Furthermore, 42% and 54% of children did not wash their hands before meals (Figure 6-11) or after defecation (Figure 6-12), respectively.

Almost 67% of households did not practice any type of water treatment at home, whereas only 14% and 17% used simple cloth or boiled water filtering, respectively (Table 6-2). Children defecated in open-fields in 52% of all communities, except for community No.10, where this was uncommon. There were remarkable differences in hand washing among communities; Table 6-2 shows the rates both before eating and after defecation, with ranges of 17%-47% and 18%-85%, respectively. Almost all communities had a tendency to hand washing before eating, but not to hand washing after defecation. Community No.7 had a particularly high rate of not washing their hands after defecation (Table 6-2).

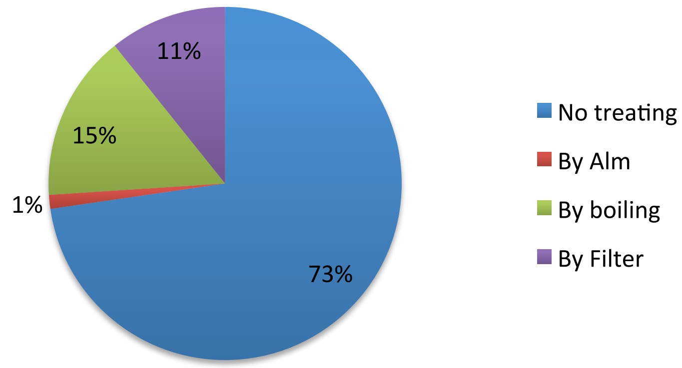


Figure 6-9 Water treatment rates

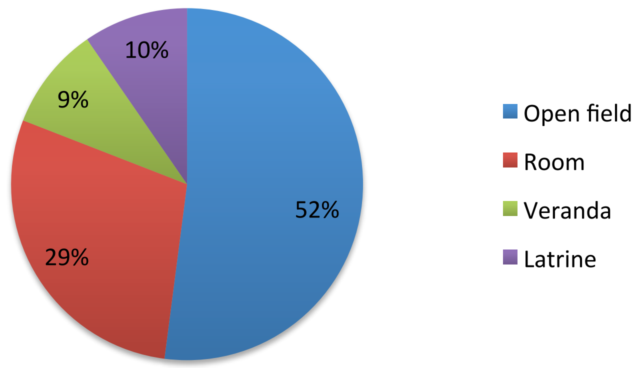


Figure 6-10 Defecation habits

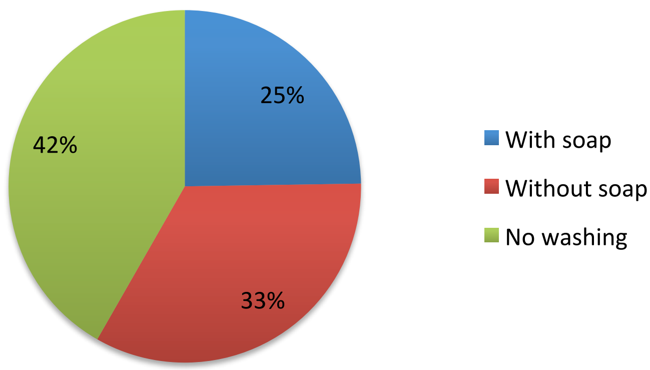


Figure 6-11 Rates of hand washing before meals

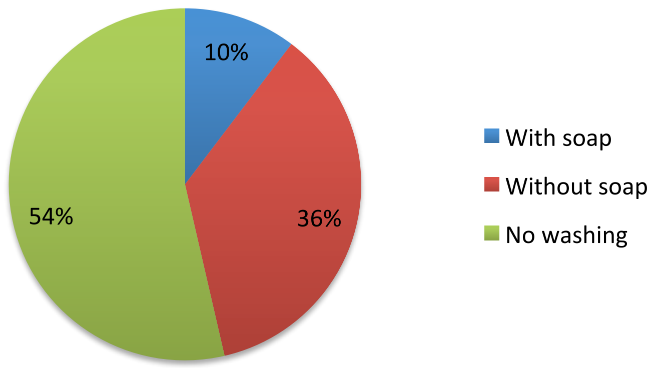


Figure 6-12 Rates of hand washing after defecation

Table 6-2 Descriptive of social factors

	Community number									
	1	2	3	4	5	6	7	8	9	10
Socio-demographic factors										
Mother's age										
<38	52 (74)	41 (68)	48 (74)	62 (70)	32 (56)	49 (74)	59 (57)	54 (84)	49 (55)	37 (82)
>38	18 (26)	19 (32)	17 (26)	26 (30)	25 (44)	17 (26)	44 (43)	10 (16)	40 (45)	8 (18)
Social Economic Factors										
Occupation of Father										
Unemployment	1 (1)	0 (0)	3 (5)	6 (7)	1 (2)	6 (9)	11 (11)	0 (0)	4 (4)	1 (2)
Government	4 (6)	17 (28)	7 (11)	1 (1)	13 (23)	6 (9)	0 (0)	15 (23)	7 (8)	25 (56)
Private	25 (36)	30 (50)	39 (60)	23 (26)	30 (53)	27 (41)	19 (18)	31 (48)	28 (31)	16 (36)
By my self	40 (57)	13 (22)	16 (25)	58 (66)	13 (23)	27 (41)	73 (71)	18 (28)	50 (56)	3 (7)
Mother's education level										
No	48 (69)	34 (57)	40 (62)	54 (61)	23 (40)	35 (53)	78 (76)	36 (56)	51 (57)	0 (0)
Bellow elementary	18 (26)	16 (27)	14 (22)	28 (32)	25 (44)	21 (32)	21 (20)	23 (36)	26 (29)	19 (42)
Above elementary	4 (6)	10 (17)	11 (17)	6 (7)	9 (16)	10 (15)	4 (4)	5 (8)	12 (13)	26 (58)
Income of household										
<30	41 (59)	13 (22)	26 (40)	58 (66)	14 (25)	30 (45)	74 (72)	15 (23)	40 (45)	0 (0)
31< <50	27 (39)	36 (60)	35 (54)	29 (33)	36 (63)	29 (44)	29 (28)	44 (69)	44 (49)	5 (11)
50 <	2 (3)	11 (18)	4 (6)	1 (1)	7 (12)	7 (11)	0 (0)	5 (8)	5 (6)	40 (89)
Household Water Environment										
Water disposal										
Open land	11 (16)	12 (20)	8 (12)	20 (23)	9 (16)	23 (35)	20 (19)	5 (8)	6 (7)	0 (0)
Grass land	24 (34)	15 (25)	16 (25)	33 (38)	27 (47)	28 (42)	38 (37)	52 (81)	42 (47)	0 (0)
Ground	22 (31)	18 (30)	19 (29)	19 (22)	10 (18)	15 (23)	16 (16)	7 (11)	18 (20)	0 (0)
Wet land	13 (19)	15 (25)	22 (34)	13 (15)	8 (14)	0 (0)	24 (23)	0 (0)	20 (22)	10 (22)
Other	0 (0)	0 (0)	0 (0)	3 (3)	3 (5)	0 (0)	5 (5)	0 (0)	3 (3)	35 (78)
Water resource										
Tap	29 (41)	31 (52)	23 (35)	17 (19)	31 (54)	18 (27)	31 (30)	26 (41)	29 (33)	45 (100)
Surface water	2 (3)	9 (15)	12 (18)	13 (15)	2 (4)	4 (6)	18 (17)	2 (3)	10 (11)	0 (0)
Ground water	31 (44)	11 (18)	20 (31)	30 (34)	2 (4)	29 (44)	32 (31)	16 (25)	39 (44)	0 (0)
Rain water	3 (4)	4 (7)	3 (5)	14 (16)	4 (7)	8 (12)	6 (6)	1 (2)	4 (4)	0 (0)
Mixed water	5 (7)	5 (8)	7 (11)	14 (16)	18 (32)	7 (11)	16 (16)	19 (30)	7 (8)	0 (0)
Latrine type										
No	8 (11)	5 (8)	6 (9)	14 (16)	7 (12)	12 (18)	41 (40)	10 (16)	22 (25)	0 (0)
Yes	62 (89)	55 (92)	59 (91)	74 (84)	50 (88)	54 (82)	62 (60)	54 (84)	67 (75)	45 (100)
Septage removal excreta)										
No	52 (74)	49 (82)	32 (49)	70 (80)	44 (77)	59 (89)	97 (94)	52 (81)	70 (79)	16 (36)
Yes	18 (26)	11 (18)	33 (51)	18 (20)	13 (23)	7 (11)	6 (6)	12 (19)	19 (21)	29 (64)
Sanitary behavior										
Water treatment										
No treating	67 (96)	30 (50)	43 (66)	74 (84)	32 (56)	48 (73)	95 (92)	44 (69)	78 (88)	3 (7)
By alm	0 (0)	0 (0)	2 (3)	1 (1)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	5 (11)
By boiling	2 (3)	18 (30)	11 (17)	4 (5)	15 (26)	9 (14)	3 (3)	13 (20)	3 (3)	30 (67)
By filter	1 (1)	12 (20)	9 (14)	9 (10)	9 (16)	9 (14)	5 (5)	7 (11)	8 (9)	7 (16)
Defecation habits of children										
Latrine	8 (11)	10 (17)	3 (5)	2 (2)	10 (18)	2 (3)	0 (0)	11 (17)	1 (1)	21 (47)
Open field	30 (43)	30 (50)	36 (55)	59 (67)	27 (47)	42 (64)	65 (63)	25 (39)	54 (61)	0 (0)
Room	16 (23)	13 (22)	20 (31)	17 (19)	14 (25)	18 (27)	34 (33)	24 (38)	29 (33)	19 (42)
Velanda	16 (23)	7 (12)	6 (9)	10 (11)	6 (11)	4 (6)	4 (4)	4 (6)	5 (6)	5 (11)
Hands washing before meal										
No wash	21 (30)	17 (28)	27 (42)	27 (31)	14 (25)	18 (27)	49 (48)	24 (38)	29 (33)	18 (40)
Wash with soap	11 (16)	16 (27)	27 (42)	15 (17)	23 (40)	19 (29)	0 (0)	29 (45)	22 (25)	16 (36)
Wash without soap	38 (54)	27 (45)	11 (17)	46 (52)	20 (35)	29 (44)	54 (52)	11 (17)	38 (43)	11 (24)
Hands washing after defecation										
No wash	40 (57)	30 (50)	37 (57)	42 (48)	26 (46)	30 (45)	88 (85)	28 (44)	39 (44)	19 (42)
Wash with soap	4 (6)	16 (27)	10 (15)	3 (3)	11 (19)	8 (12)	0 (0)	7 (11)	2 (2)	12 (27)
Wash without soap	26 (37)	14 (23)	18 (28)	43 (49)	20 (35)	28 (42)	15 (15)	29 (45)	48 (54)	14 (31)

6.2.2. *Health data*

We also considered diarrhoea-related morbidity. For multiple regression analysis, we used the baseline data for all areas (n=10). For the multilevel logistic regression analysis with children, we used pre-monsoon (n = 707), mid-monsoon (n = 644), and post-monsoon season (n = 602) data. The difference in the number of children between the three points in the monsoon season represents the loss of life.

6.2.3. *Flooding parameters*

The flooding parameters were obtained using the successful flood simulation performed in Dhaka City, and described in chapter 4. Three flooding parameters were obtained (maximum flood depth, maximum flood duration and accumulated flood depth). Because all of the flooding parameters correlated with each other, only the maximum flood depth was used for statistical analysis.

Table 6-3 Flooding parameters

Flooding parameter	Low-income community number									
	1	2	3	4	5	6	7	8	9	10
Maximum flooding depth (m)	0.0	0.0	0.1	0.4	0.1	0.0	1.1	1.0	0.8	0.1

6.2.4. *Statistical analyses*

6.2.4.1. *Simple correlation analysis*

We compared the social epidemiological factors, the diarrhoea-related morbidity, and the flood depth before checking the multicollinearity to create multivariable models.

6.2.4.2. *Multiple regression analysis*

We checked the linear relationship between several factors, using the integrated data for each area (n=10), which was continuous. The basic model is described in eq. 6-1 as

$$y = a_0 + a_1 x_1 + \cdots + a_n x_n \qquad \text{eq.6-1}$$

where, y is a dependent variable, a_0 is a constant value, a_1–a_n are partial regression coefficients, and x_1–x_n are independent variables.

This analysis allows comparison of the influence of factors on diarrhoea-related morbidity. However, few factors could be considered in this model because there were only target areas, which limited the number of independent variables to less than 10. Therefore, we built two models, one with the flood depth and socio-economic factors, and the other with flood depth, household water environment, and sanitary behavior. The models explained diarrhoea-related morbidity across the three points in the monsoon seasons, and we compared the standardized partial regression coefficients for each season. We carefully tested the multicollinearity of each factor. The analysis and model building were performed using SPSS software version 22 (SPSS Incorporated, Chicago, USA).

6.2.4.3. *Multilevel logistic regression analysis*

We used the individual data of each of the 707 children in this analysis. Because the data was categorical data, we used logistic regression analysis, which allowed more independent variables to be used than with multiple regression analysis, given the area base data (n = 10). The normal logistic regression model was described as:

$$l_i = \ln(\frac{p}{1-p}) = a_i + b_1 x_{i1} + \cdots + b_n x_{in} + \varepsilon_i \qquad \text{eq.6-2}$$

$$p = \frac{1}{1+\exp(-l)} = \frac{1}{1+\exp(-a_i - b_1 x_{i1} - \cdots - b_n x_{in} - \varepsilon_i)} \qquad \text{eq.6-3}$$

where l is logit (logarithmic odds), p is probability, a_0 is a constant value, a_1–a_n are partial regression coefficients, x_1–x_n are independent variables, and ε is error.

Multilevel logistic regression analysis can consider the variance between grouped samples, which is described as:

$$a_i = \mu_a + \delta_i \qquad \text{eq.6-4}$$

where μ_a is the common mean interception of a group and δ_i is the error.

Thus, eq.6-2 and eq.6-3 can be rewritten as:

$$l_i = \ln(\frac{p}{1-p}) = (\mu_a + \delta_i) + b_1 x_{i1} + \cdots + b_n x_{in} + \varepsilon_i \qquad \text{eq.6-5}$$

$$p = \frac{1}{1+\exp(-l)} = \frac{1}{1+\exp(-(\mu_a + \delta_i) - b_1 x_{i1} - \cdots - b_n x_{in} - \varepsilon_i)} \qquad \text{eq.6-6}$$

Multilevel analysis was used to consider the variance between communities. In this case, the level of each low-income community area was considered.

To examine the variance between areas, MOR (median odds ratio) was used. It described as:

$$MOR = \exp\left[\sqrt{(2 \times V_{macro})} \times 0.6745\right] \quad \text{eq.6-7}$$

where, V_{macro} is the macro level variance. If MOR = 1, there is no variance between the groups. If MOR > 1, there is variance between the groups.

The z-score is used to confirm the macro level variance, and is described as:

$$z - score = \frac{V_{macro}}{SE} \quad \text{eq.6-8}$$

where V_{macro} is the macro level variance and *SE* is the standard error. If z-score >2, the macro level variance is statistically significant. For all of these statistical analyses, we used STATA software version 12 (STATA Incorporated, Texas, USA).

6.2. Simple correlation analysis

Table 6-4 shows the results of the simple correlation analysis. In a previous study, the relationship between flood-prone areaa and the social status of the residents was indicated (Mollah *et al.*, 2009), however, in our study, only latrine possession was strongly correlated with the flooding depth (CC = –0.72, *p*-value [*p*] = 0.02). Although most factors weakly correlated with flood depth, the positive and negative relationship had a similar trend to the relationship with diarrhoeal morbidity.

Next, we determined that the socio-demographic factors weakly and negatively correlated with diarrhoeal morbidity through at all three points in the monsoon season.

Socio-economic factors with strong positive correlations to diarrhoeal morbidity included: paternal self-employed occupation, no maternal education, and household income < 30 USD/month. Factors with strong negative correlations to diarrhoeal morbidity included: paternal government-based occupation, maternal education above and below elementary level, and household income >50 USD/month.

Finally, we considered the water environment and sanitary behavior. Only tap and latrine possession in the household water environment were strongly and negatively correlated with diarrhoeal morbidity. No water disposal factors correlated with diarrhoeal morbidity. Concerning sanitation, only the lack of water treatment was strongly and positively correlated with diarrhoea. Conversely, water treatment by boiling, use of a latrine, and hand washing with soap after defecation were strongly and negatively correlated with diarrhoea.

Although these results clarify the characteristics of the various factors, we must take care when interpreting them due to the complicated interaction between factors.

Table 6-4 Simple correlation between flood depth, diarrhoeal morbidity, and social epidemiological factors

Factors	Flooding (p-value)	Morbidity pre (p-value)	Morbidity mid (p-value)	Morbidity post (p-value)
Socio demographic factor				
Average age	-0.13 (0.72)	-0.30 (0.40)	-0.31 (0.37)	-0.34 (0.33)
Socio economic factors				
Occupation of Father				
Unemployment	0.44 (0.21)	0.51 (0.13)	0.66 (0.04)	0.49 (0.15)
Government	-0.27 (0.45)	-0.83** (0.00)	-0.80** (0.01)	-0.75* (0.01)
Private	-0.45 (0.19)	-0.26 (0.47)	-0.45 (0.19)	-0.13 (0.73)
By my self	0.44 (0.20)	0.72* (0.02)	0.75* (0.01)	0.58 (0.08)
Mother's education level				
No	0.35 (0.33)	0.91** (0.00)	0.74* (0.02)	0.85** (0.00)
Below elementary	-0.18 (0.62)	-0.82** (0.00)	-0.69* (0.03)	-0.82** (0.00)
Above elementary	-0.37 (0.29)	-0.79** (0.01)	-0.63 (0.05)	-0.72 (0.02)
Income of household				
<30 USD	0.30 (0.41)	0.80** (0.01)	0.84** (0.00)	0.70* (0.03)
31 - 50 USD	0.05 (0.90)	0.17 (0.63)	-0.13 (0.72)	0.28 (0.53)
50 < USD	-0.28 (0.43)	-0.79** (0.01)	-0.63 (0.05)	-0.75* (0.01)
Household water environment				
Water disposal				
Open land	-0.26 (0.48)	0.27 (0.45)	0.54 (0.11)	0.25 (0.50)
Grass land	-0.39 (0.26)	0.48 (0.17)	0.30 (0.40)	0.45 (0.19)
Ground	-0.16 (0.65)	0.07 (0.86)	-0.15 (0.69)	0.11 (0.77)
Wet land	0.57 (0.09)	0.43 (0.21)	0.28 (0.43)	0.40 (0.25)
Water resource				
Tap	-0.31 (0.39)	-0.78** (0.01)	-0.80** (0.01)	-0.76* (0.01)
Surface water	0.21 (0.56)	0.53 (0.11)	0.53 (0.12)	0.65* (0.04)
Ground water	0.11 (0.77)	0.65* (0.04)	0.69* (0.03)	0.55 (0.10)
Rain water	-0.20 (0.59)	0.11 (0.77)	0.46 (0.18)	0.14 (0.70)
Mixed water	0.36 (0.30)	0.14 (0.71)	0.02 (0.97)	0.17 (0.64)
Latrine posessions				
Yes	-0.72* (0.02)	-0.72* (0.02)	-0.67* (0.03)	-0.59 (0.07)
Septage Removal (Removal excreta)				
Yes	-0.40 (0.26)	-0.52 (0.12)	-0.50 (0.14)	-0.40 (0.25)
Sanitary behavior				
Water treatment				
No treating	0.38 (0.29)	0.87** (0.00)	0.73* (0.02)	0.74* (0.01)
By alm	-0.28 (0.43)	-0.70* (0.03)	-0.52 (0.12)	-0.61 (0.06)
By boiling	-0.34 (0.34)	-0.85** (0.00)	-0.73* (0.02)	-0.75* (0.01)
By filter	-0.42 (0.23)	-0.70* (0.02)	-0.57 (0.08)	-0.52 (0.12)
Defecation habits of children				
Open field	0.20 (0.58)	0.66* (0.04)	0.67* (0.03)	0.64* (0.05)
Latrine	-0.28 (0.43)	-0.79** (0.01)	-0.76* (0.01)	-0.75* (0.01)
Room	0.44 (0.21)	-0.15 (0.68)	-0.16 (0.65)	-0.12 (0.75)
Velanda	-0.60 (0.07)	-0.12 (0.74)	-0.26 (0.48)	-0.20 (0.58)
Hands washing before meal				
No wash	0.57 (0.08)	0.39 (0.27)	0.49 (0.15)	0.47 (0.18)
Wash with soap	-0.26 (0.46)	-0.50 (0.14)	-0.58 (0.08)	-0.38 (0.28)
Wash without soap	-0.68* (0.03)	-0.13 (0.73)	-0.17 (0.64)	-0.29 (0.41)
Hands washing after defecation				
No wash	0.38 (0.28)	0.68 (0.03)	0.58 (0.08)	0.62 (0.06)
Wash with soap	-0.60 (0.07)	-0.79** (0.01)	-0.76* (0.01)	-0.66* (0.04)
Wash without soap	0.08 (0.83)	-0.09 (0.80)	-0.01 (0.98)	-0.13 (0.72)
Flooding				
Maximum flooding depth	1.00	0.51 (0.13)	0.42 (0.23)	0.50 (0.14)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

6.3. Result of multiple regression analysis

In the multiple regression analysis, we used the mid-monsoon morbidity data to consider the diarrhoeal outbreak during the flood condition. We considered that the flood water rises (flood condition) and has contaminated material, and then added social factors to the simple regression model. Two models were made comprising 1) socio-economic factors and 2) water environment and sanitary behavior.

6.3.1. *Model with factors of socio-economic*

First, we built the socio-economic model using the flood depth, paternal unemployment and no maternal education as independent variables, as follows:

$$MB_{diar} = X + x_1 FLD + x_2 OCC + x_3 EDU \quad \text{eq.6-9}$$

where MB_{diar} = diarrhoeal morbidity, X = constant, FLD = maximum flood depth, OCC = paternal unemployment, and EDU = no maternal education.

The detailed coefficients are shown in Table 6-5, Table 6-6, and Table 6-7. The analysis explained 88% (p = 0.004), 71.4% (p = 0.045), and 78.4% (p = 0.020) of the variance in pre-monsoon, mid-monsoon, and post-monsoon diarrhoeal morbidity, respectively. In each model, the explanatory ability was enhanced by social factors.

Table 6-5 Coefficients for the socio-economic model in the pre-monsoon season

Coefficients			
Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
(Constant)	79.595		0.253
Maximum flooding depth	65.528	0.179	0.310
Occupation of husband (unemployed)	6.953	0.135	0.439
Education of mother (noschool)	6.249	0.794	0.002

R Square = 0.879, Significance = 0.004, Dependent Variable: MORBIDITY

Table 6-6 Coefficients for the socio-economic model in the mid-monsoon season

Coefficients			
Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
(Constant)	138.956		0.340
Maximum flooding depth	16.628	0.033	0.899
Occupation of husband (unemployed)	30.675	0.431	0.137
Education of mother (noschool)	6.173	0.566	0.057

R Square = 0.714, Significance = 0.045, Dependent Variable: MORBIDITY

Table 6-7 Coefficients for the socio-economic model in the post-monsoon season

Coefficients			
Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
(Constant)	135.873		0.121
Maximum flooding depth	60.832	0.186	0.422
Occupation of husband (unemployed)	6.213	0.135	0.559
Education of mother (noschool)	5.166	0.735	0.013

R Square = 0.784, Significance = 0.020, Dependent Variable: MORBIDITY

According to the comparison of standardized coefficients, we found that maternal education level (no education) had the strongest significant contribution to pre-monsoon (beta = 0.794, p = 0.02), mid-monsoon (beta = 0.566, p = 0.057), and post monsoon (beta = 0.735, p = 0.013) outcomes; other factors had lesser contribution. Maximum flooding depth and paternal occupation (unemployed) were not significant.

In pre-monsoon and post-monsoon seasons, the comparative difference of each factor's influence was similar. Only the influence of education level was remarkably high. Conversely, the influence of flooding was remarkably less in the mid-monsoon season, and the influence of occupation and education was insignificant.

This analysis identified a model that can explain the variance of diarrhoeal morbidity with flood depth and social factors. However, according to the comparison of standardized coefficients, the influence of flood depth was less than education level.

6.3.2. *Model with factors of sanitary behavior and household water environment*

Second, we built a water environment and sanitary behavior model with maximum flood depth, water disposal (open land), septage removal, and water treatment (no) as independent variables, as follows:

$$MB_{diar} = X + x_1 FLD + x_2 WD + x_3 SR + x_4 WT \quad \text{eq.6-10}$$

where MB_{diar} = diarrhoeal morbidity, X = constant, FLD = maximum flood depth, WD = water disposal to open land, SR = septage removal, and WT = no water treatment. The coefficients are summarized in Table 6-8,

Table 6-9 and Table 6-10. The analysis explained 92.0% (p = 0.029), 97.5% (p = 0.002), and 86.7% (p = 0.088) of the variance in pre-monsoon, mid-monsoon, and post-monsoon diarrhoeal morbidity, respectively. In each model, the explanatory ability was enhanced by social factors.

Table 6-8 Coefficients for the sanitary environment and household water environment model in the pre-monsoon season

Coefficients			
Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
(Constant)	-18.460		0.471
Maximum flooding depth	16.135	0.441	0.190
Water disposal (Open land)	0.512	0.305	0.423
Septage removal (Removal excreta)	0.448	0.493	0.261
Treating water before drinking (no)	0.567	0.915	0.015

R Square = 0.920, Significance = 0.029, Dependent Variable: MORBIDITY

Table 6-9 Coefficients for the sanitary environment and household water environment model in the mid-monsoon season

Coefficients			
Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
(Constant)	-78.404		0.009
Maximum flooding depth	47.647	0.941	0.002
Water disposal (Open land)	2.881	1.238	0.002
Septage removal (Removal excreta)	1.412	1.123	0.004
Treating water before drinking (no)	0.536	0.626	0.007

R Square = 0.975, Significance = 0.002, Dependent Variable: MORBIDITY

Table 6-10 Coefficients for the sanitary environment and household water environment model in the post-monsoon season

Coefficients			
Model	Unstandardized Coefficients	Standardized Coefficients	Sig.
	B	Beta	
(Constant)	-25.352		0.388
Maximum flooding depth	22.543	0.690	0.120
Water disposal (Open land)	0.934	0.622	0.220
Septage removal (Removal excreta)	0.680	0.838	0.150
Treating water before drinking (no)	0.441	0.797	0.054

R Square = 0.867, Significance = 0.088, Dependent Variable: MORBIDITY

Comparison of the standardized coefficients identified that the following had the strongest significant contribution to variance of diarroeal morbidity in the respective seasons: (1) not treating water before drinking in the pre-monsoon season, (beta = 0.915, p = 0.015), (2) open land water disposal in the mid-monsoon (beta = 1.238, p = 0.002), and (3) septage removal in the post-monsoon season (beta = 0.838, *p* = 0.150). This model was significant in the mid-monsoon season, i.e., in the flood condition. There was also good agreement between the significance of the model and the significance of each factor. These results showed that factors related to the floodwater contamination and to the removal of contamination were strongly associated with diarrhoeal morbidity during floods (the flood condition).

In conclusion, the flood condition had a small and insignificant influence in the socio-economic model but a large and significant influence in the water environment and sanitary behavior model. These results clarify our understanding of the relationship between diarrhoeal morbidity and its causes in the areas studied. However, this multiple regression analysis was limited by the small sample size (n = 10) for statistical analysis. As a result, the model included only a limited number of all the available factors.

6.4. Result of multi-level logistic regression analysis

We first examined the influence of the flood depth and social epidemiological factors on diarrhoeal morbidity, before considering the extent to which they explained the variance between areas.

Table 6-11 shows the analysis results, including whole season data (n=1953). Only the mid-monsoon data [adjusted odds ratio (AOR) = 1.75, 95% confident interval (CI) = 1.39–2.20] and latrine use (AOR = 0.59, 95% CI = 0.40–0.86) were significantly associated with diarrhoea.

6.5.1. *Discussion for the whole season multilevel and normal logistic* **regression analysis**

Diarrhoeal risk was highest in the mid-monsoon season (AOR = 1.75, 95% CI = 1.39–2.20) and lowest in the post-monsoon season (AOR = 0.97, 95% CI = 0.77–1.22). Similar to the results of chapter 5, an increased risk was also observed in this analysis. In addition, the mid-monsoon increase was statistically significant.

Compared with children lived in an area flooded to a depth of <0.37 m, those flooded to depths of 0.37–0.74 m and >0.74 m had 1.75 and 2.01 times increased risks of diarrhoeal morbidity, respectively. Therefore, children who lived in flood-prone areas had an increased risk of morbidity compared with those with less flooding. This applied through the whole season, and risk increased with increasing flood depth.

In terms of socio-demographic factors, children with mothers >38-year-old had lower risk than those with mothers <38-years-old (AOR = 0.85, 95% CI = 0.68–1.06). We consider this to be due to the greater experience of older mothers in caring for a child with diarrhea. Concerning the socio-economic factors, risk reduction was observed with occupation, and self-employed status had the lowest risk (AOR = 0.87, 95% CI = 0.54–1.43). In addition, lower risk was observed with educated mothers, although there was no difference between those educated bellow elementary level (AOR = 0.97, 95% CI = 0.77–1.22) and above elementary level (AOR = 0.97, 95% CI = 0.71–1.33).

The household water environment was important. Specifically, children who disposed water to open land had the lowest risk, whereas those who disposed water into other places such as a rivers had the highest risk (AOR = 1.43, 95% CI = 0.72–2.83). Furthermore, children consuming ground water had lower risk (AOR = 0.89, 95 % CI = 0.70–1.14), whereas those consuming rainwater had higher risk (AOR = 1.20, 95% CI = 0.78–1.86).

Sanitation was also important, with several key findings. Children using a latrine had a 1.20-fold greater risk than those without a latrine whereas children using septage with removal of excreta had a 0.88-fold increased risk compared with those not using septage. However, defecating in a latrine had the lowest risk (AOR = 0.59, 95% CI = 0.40–0.86), whereas defecating in open fields had the highest risk. Children drinking water treated with alum had the lowest risk (AOR = 0.92, 95% CI = 0.36–2.40), whereas those using filter methods had the highest risk (AOR = 1.08, 95% CI = 0.78–1.49).

In addition, hand washing was crucial; those children washing their hands without soap before a meal had the lowest risk (AOR = 0.90, 95% CI = 0.70–1.16), whereas children not washing their hands before eating had the highest risk. Further, children who washed their hands after defecation had lower risk (AOR = 0.89, 95% CI = 0.62–1.29), whereas children not washing their hands after defecation had a higher risk. Thus, hand washing can reduce the risk of diarrhoea (Shahid *et al.*, 1996); however, it may increase the risk due to the use of contaminated water or towels.

Table 6-11 Results of the multilevel logistic regression analysis (whole season)

	n (% of whole sample) (N=1953)	n (% of grouped sample) (N=1006)	AOR (95% Cl)	Sig.
Season				
pre monsoon	707 (36.2)	342 (48.4)	1.00	
mid monsoon	644 (33.0)	386 (59.9)	1.75*** (1.39 -2.20)	0.00
post monsoon	602 (30.8)	278 (46.2)	0.97 (0.77 -1.22)	0.81
Socio-demographic factors				
Mother's age				
<38	1359 (69.6)	712 (52.4)	1.00	
>38	594 (30.4)	294 (49.5)	0.85 (0.68 -1.06)	0.15
Flooding Factors				
Flooding depth				
<0.37m	1045 (53.5)	466 (44.6)	1.00	
0.37-0.74m	236 (12.1)	133 (56.4)	1.75 (0.47 -6.47)	0.40
>0.74m	672 (34.4)	407 (60.6)	2.01 (0.84 -4.78)	0.12
Social Economic Factors				
Occupation of Father				
Unemployment	95 (4.9)	58 (61.1)	1.00	
Government	273 (14.0)	104 (38.1)	0.89 (0.50 -1.57)	0.69
Private	737 (37.7)	367 (49.8)	0.92 (0.56 -1.51)	0.74
By my self	848 (43.4)	477 (56.3)	0.87 (0.54 -1.43)	0.59
Mother's education level				
No	1104 (56.5)	616 (55.8)	1.00	
Below elementary	571 (29.2)	279 (48.9)	0.97 (0.77 -1.22)	0.80
Above elementary	278 (14.2)	111 (39.9)	0.97 (0.71 -1.33)	0.86
Income of household				
<30 USD	851 (43.6)	482 (56.6)	1.00	
31-50 USD	868 (44.4)	451 (52.0)	1.08 (0.86 -1.36)	0.50
50 < USD	234 (12.0)	73 (31.2)	0.97 (0.61 -1.53)	0.89
Household Water Environment				
Water disposal				
Open land	318 (16.3)	165 (51.9)	1.00	
Grass land	737 (37.7)	415 (56.3)	1.34 (0.99 -1.81)	0.06
Ground	412 (21.1)	210 (51.0)	1.07 (0.78 -1.49)	0.67
Wet land	352 (18.0)	178 (50.6)	1.10 (0.77 -1.57)	0.59
Other	134 (6.9)	38 (28.4)	1.43 (0.72 -2.83)	0.31
Water resource				
Tap	785 (40.2)	363 (46.2)	1.00	
Surface water	205 (10.5)	120 (58.5)	1.03 (0.72 -1.47)	0.88
Ground water	576 (29.5)	308 (53.5)	0.89 (0.70 -1.14)	0.37
Rain water	120 (6.1)	70 (58.3)	1.20 (0.78 -1.86)	0.40
Mixed water	267 (13.7)	145 (54.3)	1.18 (0.85 -1.63)	0.33
Latrine type				
No	343 (17.6)	192 (56.0)	1.00	
Yes	1610 (82.4)	814 (50.6)	1.20 (0.91 -1.58)	0.19
Septage Removal (Removal				
No	1505 (77.1)	809 (53.8)	1.00	
Yes	448 (22.9)	197 (44.0)	0.88 (0.68 -1.13)	0.31
Sanitary behavior				
Water treatment				
No treating	1402 (71.8)	777 (55.4)	1.00	
By alm	27 (1.4)	8 (29.6)	0.92 (0.36 -2.40)	0.87
By boiling	303 (15.5)	116 (38.3)	0.99 (0.72 -1.36)	0.93
By filter	221 (11.3)	105 (47.5)	1.08 (0.78 -1.49)	0.65
Defecation habits of children				
Open field	1000 (51.2)	565 (56.5)	1.00	
Latrine	201 (10.3)	61 (30.3)	0.59** (0.40 -0.86)	0.01
Room	563 (28.8)	294 (52.2)	0.92 (0.73 -1.16)	0.49
Velanda	189 (9.7)	86 (45.5)	0.72 (0.51 -1.01)	0.06
Hands washing before meal				
No wash	791 (40.5)	450 (56.9)	1.00	
Wash with soap	511 (26.2)	233 (45.6)	0.94 (0.70 -1.25)	0.66
Wash without soap	651 (33.3)	323 (49.6)	0.90 (0.70 -1.16)	0.40
Hands washing after defecation				
No wash	1030 (52.7)	558 (54.2)	1.00	
Wash with soap	215 (11.0)	85 (39.5)	0.89 (0.62 -1.29)	0.55
Wash without soap	708 (36.3)	363 (51.3)	1.06 (0.84 -1.34)	0.60

* *P* value < .05.

** *P* value < .01.

*** *P* value < .001.

6.5.2. *Result of the multilevel and normal logistic regression analysis for the three monsoon seasons*

In the mid-monsoon season, 397 children (56%) developed diarrhoea, which was more than for the pre-monsoon (320 children, 45%) and post-monsoon (302 children, 42%) seasons. This displays a substantial burden of diarrhoea among low-income communities.

Out of the 707 children, 344 (48.7 %) lived in areas flooded to a maximum depth of greater than 0.37 m (Table 6-13), and 223 children (64.8 %) developed diarrhoea. Conversely, only 174 children (47.9%) who lived in areas flooded to a maximum depth of less than 0.37 m developed diarrhoea. Therefore, of the 397 children developed diarrhoea, 223 (56.2%) lived in flood-prone areas.

Logistic regression analysis allowed adjustment for socio-demographic, socio-economic, sanitary behavior, and household water environment factors. We then identified that children in flood-prone areas were more likely to develop diarrhoea compared with those who do not live in flood-prone areas; this applied to both the flooding depths of 0.37–0.74 m (AOR = 2.19, 95% CI =1.24–3.86) and >0.74m (AOR = 1.39, 95% CI = 0.93–2.07). However, both 0.37–0.74 m (AOR = 2.83, 95% CI = 0.72–11.20) and >0.74 m (AOR = 1.86, 95% CI = 0.73–4.73) became insignificant after performing multilevel logistic regression analysis.

Besides flooding, other factors were also significantly associated with diarrhoeal morbidity among children from low-income communities. These factors included defecation in open fields (AOR = 1.86, 95% CI = 1.29–4.62), in rooms (AOR = 2.65, 95% CI = 1.37–5.15), and in the veranda (AOR = 3.87, 95% CI = 1.74–8.59) as well as hand washing before eating (AOR = 1.86, 95% CI = 1.14–3.02). The details of these factors are given in Table 6-13.

6.5.3. *Discussion for the multilevel and normal logistic regression analysis for the three monsoon seasons*

Our data support the hypothesis that flooding is associated with diarrhoea and it has a significant impact, but the influence become insignificant when we consider the variance between areas. Although the influence of flooding was significant across Dhaka City, it become insignificant in some cases when we considered the target area to be a community area unit. In this case, based on the size of variance between areas (10%), another important variable may affect diarrhoea.

Children with mothers <38-year-old were more likely to get diarrhea than children with mothers >38-years-old, where maternal age presumably confers experience of dealing with diarrhea, thus preventing diarrhoea. Paternal unemployment increased the risk of diarrhoeal morbidity compared with employment, although the risk was highest for children whose fathers were self-employed. In addition, paternal income showed a similar tendency to that of maternal education; children from families with high incomes (> 50 USD/month) were less likely to get diarrhoea as were those with mothers educated above elementary level. This may imply that sufficient income can provide suitable nutrition for children and that an educated mother can instruct their children on how to avoid diarrhoea.

In terms of water utilities, only surface water consumption was significantly associated with diarrhoea, and that this was statistically significant during flood conditions ($p<0.05$). People using surface water were at a 1.84 times greater risk of diarrhoea than those using tap water. However, this also became insignificant after considering the variance between areas. During the flood season, surface water was probably contaminated by the flood water. On the other hand, groundwater showed a lower association with diarrhoea than tap water. Although water disposed to open land had a large influence on the multiple regression analysis, its influence was less in this analysis. There were no differences between the disposal sites (grassland, ground, wetland, and others).

Defecation sites were significantly associated with diarrhoea. Compared with children defecating in a latrine, those defecating in open land, in the veranda had, or in a room had 4.46-fold (CI = 2.00–9.95), 2.76-fold (CI = 1.46–5.22), and 2.7-fold (CI = 1.39–5.23) increased risks of diarrhoeal morbidity, respectively. Although defecation habits did not have a large influence on diarrhoea in the multiple regression analysis, it was a significant variable in this analysis. In addition, hand washing with soap before eating was positively associated with diarrhoea. This result supports the study by Mollah *et al.* (2009). It is possible that this results from people washing their hands with contaminated water and drying them with contaminated towels.

Table 6-12 Results of the normal and multilevel logistic regression analysis (pre-monsoon)

Factors	Number of Children (N=707), n (%)	Number of children with Diarrhoea (N=342), n (%)	Normal AOR (95% Cl)	Normal Sig.	Multilevel AOR (95% Cl)	Multilevel Sig.
Socio demographic factor						
Mother's age						
<38	483 (68.3)	236 (48.9)	1.00		1.00	
>38	224 (31.7)	106 (47.3)	0.90 (0.63- 1.29)	0.58	0.91 (0.63- 1.31)	0.61
Socio economic factors						
Occupation of Father						
Unemployment	33 (4.7)	21 (63.6)	1.00		1.00	
Government	95 (13.4)	34 (35.8)	0.49 (0.19- 1.26)	0.14	0.49 (0.19- 1.28)	0.14
Private	268 (37.9)	131 (48.9)	0.61 (0.27- 1.40)	0.24	0.58 (0.25- 1.35)	0.21
By my self	311 (44.0)	156 (50.2)	0.49 (0.22- 1.11)	0.09	0.45 (0.19- 1.03)	0.06
Mother's education level						
No	399 (56.4)	206 (51.6)	1.00		1.00	
Below elementary	211 (29.8)	98 (46.4)	0.96 (0.66- 1.40)	0.85	1.03 (0.70- 1.52)	0.88
Above elementary	97 (13.7)	38 (39.2)	0.99 (0.59- 1.67)	0.97	1.09 (0.63- 1.87)	0.76
Income of household						
<30 USD	311 (44.0)	168 (54.0)	1.00		1.00	
31 - 50 USD	314 (44.4)	146 (46.5)	0.80 (0.56- 1.15)	0.22	0.83 (0.57- 1.21)	0.34
50 < USD	82 (11.6)	28 (34.1)	0.56 (0.28- 1.11)	0.10	0.71 (0.32- 1.57)	0.40
Household water environment						
Water disposal						
Open land	114 (16.1)	56 (49.1)	1.00		1.00	
Wet land	275 (38.9)	150 (54.5)	1.30 (0.57- 2.10)	0.29	1.36 (0.83- 2.23)	0.23
Grass land	144 (20.4)	58 (40.3)	0.81 (0.58- 1.39)	0.44	0.78 (0.45- 1.36)	0.38
Ground	125 (17.7)	63 (50.4)	1.17 (0.47- 2.05)	0.59	1.13 (0.63- 2.04)	0.67
Other	49 (6.9)	15 (30.6)	1.10 (0.75- 2.62)	0.83	1.50 (0.50- 4.49)	0.47
Water resource						
Tap	280 (39.6)	123 (43.9)	1.00		1.00	
Surface water	72 (10.2)	38 (52.8)	1.02 (0.57- 1.82)	0.94	0.92 (0.51- 1.68)	0.79
Ground water	210 (29.7)	102 (48.6)	0.86 (0.58- 1.29)	0.47	0.80 (0.53- 1.22)	0.30
Rain water	47 (6.6)	23 (48.9)	0.94 (0.47- 1.87)	0.86	0.91 (0.45- 1.84)	0.79
Mixed water	98 (13.9)	56 (57.1)	1.26 (0.75- 2.11)	0.38	1.32 (0.78- 2.24)	0.31
Latrine posessions						
No	125 (17.7)	62 (49.6)	1.00		1.00	
Yes	582 (82.3)	280 (48.1)	1.36 (0.87- 2.12)	0.18	1.35 (0.86- 2.13)	0.20
Septage Removal (Removal excreta)						
No	541 (76.5)	267 (49.4)	1.00		1.00	
Yes	166 (23.5)	75 (45.2)	1.10 (0.74- 1.65)	0.63	1.07 (0.71- 1.62)	0.76
Sanitary behavior						
Water treatment						
No treating	514 (72.7)	276 (53.7)	1.00		1.00	
By alm	9 (1.3)	1 (11.1)	0.21 (0.02- 1.84)	0.16	0.24 (0.03- 2.15)	0.20
By boiling	108 (15.3)	36 (33.3)	0.56* (0.34- 0.93)	0.02	0.64 (0.37- 1.10)	0.11
By filter	76 (10.7)	29 (38.2)	0.71 (0.41- 1.22)	0.21	0.75 (0.43- 1.31)	0.32
Defecation habits of children						
Open field	368 (52.1)	194 (52.7)	1.00		1.00	
Latrine	68 (9.6)	21 (30.9)	0.67 (0.36- 1.25)	0.21	0.69 (0.36- 1.33)	0.27
Room	204 (28.9)	102 (50.0)	0.91 (0.63- 1.31)	0.61	0.92 (0.63- 1.33)	0.65
Veranda	67 (9.5)	25 (37.3)	0.55* (0.31- 0.97)	0.04	0.52* (0.29- 0.94)	0.03
Hands washing before meal						
No wash	295 (34.5)	173 (58.6)	1.00		1.00	
Wash with soap	175 (32.8)	61 (34.9)	0.47** (0.29- 0.75)	0.00	0.50** (0.30- 0.83)	0.01
Wash without soap	237 (32.7)	108 (45.6)	0.69 (0.44- 1.07)	0.10	0.73 (0.46- 1.17)	0.19
Hands washing after defecation						
No wash	379 (53.6)	204 (53.8)	1.00		1.00	
Wash with soap	73 (10.3)	22 (30.1)	0.70 (0.37- 1.32)	0.27	0.73 (0.38- 1.39)	0.33
Wash without soap	255 (36.1)	116 (45.5)	0.83 (0.56- 1.22)	0.35	0.85 (0.57- 1.26)	0.42
Flooding factors						
Maximum Flooding depth						
<0.37m	363 (51.3)	152 (41.9)	1.00		1.00	
0.37-0.74m	88 (12.4)	40 (45.5)	0.84 (0.49- 1.42)	0.51	1.04 (0.36- 3.02)	0.94
>0.74m	256 (36.2)	150 (58.6)	1.33 (0.90- 1.96)	0.15	1.61 (0.77- 3.37)	0.21

* *P* value < .05.

** *P* value < .01.

Table 6-13 Results of the normal and multilevel logistic regression analysis (mid-monsoon)

Factors	Number of Children (N=644), n (%)	Number of children with Diarrhoea (N=386), n (%)	Normal AOR (95% Cl)	Normal Sig.	Multilevel AOR (95% Cl)	Multilevel Sig.
Socio demographic factor						
Mother's age						
<38	447 (63.2)	265 (59.3)	1.00		1.00	
>38	197 (27.9)	121 (61.4)	1.07 (0.72- 1.58)	0.74	1.17 (0.76- 1.78)	0.48
Socio economic factors						
Occupation of Father						
Unemployment	31 (4.4)	20 (64.5)	1.00		1.00	
Government	89 (12.6)	37 (41.6)	1.22 (0.46- 3.24)	0.69	2.01 (0.70- 5.79)	0.20
Private	243 (34.4)	133 (54.7)	1.23 (0.52- 2.95)	0.64	1.75 (0.68- 4.51)	0.24
By my self	281 (39.7)	196 (69.8)	2.00 (0.84- 4.75)	0.12	2.62* (1.04- 6.61)	0.04
Mother's education level						
No	364 (51.5)	240 (65.9)	1.00		1.00	
Below elementary	187 (26.4)	104 (55.6)	0.82 (0.54- 1.23)	0.34	0.96 (0.61- 1.51)	0.86
Above elementary	93 (13.2)	42 (45.2)	0.80 (0.46- 1.40)	0.44	0.93 (0.51- 1.67)	0.80
Income of household						
<30 USD	279 (39.5)	193 (69.2)	1.00		1.00	
31 - 50 USD	289 (40.9)	170 (58.8)	0.82 (0.55- 1.22)	0.32	1.05 (0.67- 1.63)	0.84
50 < USD	76 (10.7)	23 (30.3)	0.51 (0.24- 1.07)	0.08	0.66 (0.29- 1.51)	0.32
Household water environment						
Water disposal						
Open land	106 (15.0)	71 (67.0)	1.00		1.00	
Wet land	240 (33.9)	148 (61.7)	0.63 (1.06- 1.07)	0.09	0.73 (0.40- 1.32)	0.30
Grass land	137 (19.4)	87 (63.5)	0.80 (0.67- 1.43)	0.45	0.85 (0.45- 1.60)	0.62
Ground	117 (16.5)	66 (56.4)	0.65 (0.78- 1.21)	0.18	0.72 (0.36- 1.42)	0.34
Other	44 (6.2)	14 (31.8)	0.66 (0.83- 1.75)	0.40	0.74 (0.22- 2.50)	0.63
Water resource						
Tap	260 (36.8)	136 (52.3)	1.00		1.00	
Surface water	68 (9.6)	49 (72.1)	2.05* (1.06- 3.96)	0.03	1.78 (0.87- 3.64)	0.11
Ground water	187 (26.4)	115 (61.5)	1.03 (0.67- 1.58)	0.91	0.92 (0.57- 1.46)	0.71
Rain water	38 (5.4)	26 (68.4)	1.74 (0.78- 3.87)	0.18	1.44 (0.61- 3.38)	0.41
Mixed water	91 (12.9)	60 (65.9)	1.46 (0.83- 2.59)	0.19	1.68 (0.90- 3.15)	0.11
Latrine posessions						
No	118 (16.7)	81 (68.6)	1.00		1.00	
Yes	526 (74.4)	305 (58.0)	0.85 (0.52- 1.38)	0.51	0.95 (0.56- 1.61)	0.85
Septage Removal (Removal excreta)						
No	503 (71.1)	319 (63.4)	1.00		1.00	
Yes	141 (19.9)	67 (47.5)	0.69 (0.44- 1.08)	0.11	0.65 (0.41- 1.05)	0.08
Sanitary behavior						
Water treatment						
No treating	461 (65.2)	294 (63.8)	1.00		1.00	
By alm	9 (1.3)	4 (44.4)	1.11 (0.19- 6.33)	0.91	1.13 (0.19- 6.81)	0.90
By boiling	99 (14.0)	42 (42.4)	0.87 (0.52- 1.48)	0.62	1.04 (0.58- 1.87)	0.89
By filter	75 (10.6)	46 (61.3)	1.15 (0.65- 2.03)	0.62	1.29 (0.69- 2.39)	0.42
Defecation habits of children						
Open field	330 (46.7)	212 (64.2)	1.00		1.00	
Latrine	67 (9.5)	20 (29.9)	0.40** (0.21- 0.76)	0.01	0.43* (0.22- 0.86)	0.02
Room	185 (26.2)	114 (61.6)	1.07 (0.71- 1.62)	0.73	1.11 (0.72- 1.72)	0.64
Veranda	62 (8.8)	40 (64.5)	1.35 (0.72- 2.53)	0.34	1.48 (0.75- 2.90)	0.26
Hands washing before meal						
No wash	260 (36.8)	157 (60.4)	1.00		1.00	
Wash with soap	171 (24.2)	104 (60.8)	1.28 (0.77- 2.14)	0.34	2.05* (1.17- 3.60)	0.01
Wash without soap	213 (30.1)	125 (58.7)	1.07 (0.66- 1.73)	0.80	1.61 (0.95- 2.73)	0.08
Hands washing after defecation						
No wash	335 (47.4)	203 (60.6)	1.00		1.00	
Wash with soap	72 (10.2)	42 (58.3)	1.52 (0.79- 2.92)	0.21	1.55 (0.78- 3.09)	0.21
Wash without soap	237 (33.5)	141 (59.5)	0.99 (0.65- 1.52)	0.98	1.02 (0.65- 1.59)	0.95
Flooding factors						
Maximum Flooding depth						
<0.37m	346 (48.9)	176 (50.9)	1.00		1.00	
0.37-0.74m	77 (10.9)	59 (76.6)	2.09* (1.11- 3.93)	0.02	3.00 (0.46- 19.49)	0.25
>0.74m	221 (31.3)	151 (68.3)	1.62* (1.06- 2.50)	0.03	2.42 (0.69- 8.45)	0.17

* P value < .05.

** P value < .01.

Table 6-14 Results of the normal and multilevel logistic regression analysis (post-monsoon)

Factors	Number of Children (N=602), n (%)	Number of children with Diarrhoea (N=278), n (%)	Normal AOR (95% CI)	Normal Sig.	Multilevel AOR (95% CI)	Multilevel Sig.
Socio demographic factor						
Mother's age						
<38	429 (71.3)	211 (49.2)	1.00		1.00	
>38	173 (28.7)	67 (38.7)	0.54** (0.36- 0.81)	0.00	0.55** (0.36- 0.84)	0.01
Socio economic factors						
Occupation of Father						
Unemployment	31 (5.1)	17 (54.8)	1.00		1.00	
Government	89 (14.8)	33 (37.1)	0.66 (0.25- 1.74)	0.40	0.68 (0.25- 1.83)	0.45
Private	226 (37.5)	103 (45.6)	0.74 (0.32- 1.73)	0.48	0.74 (0.31- 1.78)	0.51
By my self	256 (42.5)	125 (48.8)	0.71 (0.31- 1.63)	0.42	0.71 (0.31- 1.66)	0.43
Mother's education level						
No	341 (56.6)	170 (49.9)	1.00		1.00	
Below elementary	173 (28.7)	77 (44.5)	0.78 (0.51- 1.19)	0.24	0.83 (0.54- 1.28)	0.39
Above elementary	88 (14.6)	31 (35.2)	0.74 (0.42- 1.30)	0.30	0.79 (0.44- 1.41)	0.43
Income of household						
<30 USD	261 (43.4)	121 (46.4)	1.00		1.00	
31 - 50 USD	265 (44.0)	135 (50.9)	1.52* (1.00- 2.30)	0.05	1.59* (1.04- 2.45)	0.03
50 < USD	76 (12.6)	22 (28.9)	1.16 (0.55- 2.46)	0.70	1.33 (0.60- 2.94)	0.49
Household water environment						
Water disposal						
Open land	98 (16.3)	38 (38.8)	1.00		1.00	
Wet land	222 (36.9)	117 (52.7)	1.91* (0.59- 3.25)	0.02	2.00* (1.16- 3.47)	0.01
Grass land	131 (21.8)	65 (49.6)	1.78 (0.74- 3.19)	0.05	1.78 (0.98- 3.20)	0.06
Ground	110 (18.3)	49 (44.5)	1.62 (0.77- 2.97)	0.12	1.53 (0.81- 2.87)	0.19
Other	41 (6.8)	9 (22.0)	0.65 (0.39- 1.86)	0.43	0.73 (0.24- 2.22)	0.58
Water resource						
Tap	245 (40.7)	104 (42.4)	1.00		1.00	
Surface water	65 (10.8)	33 (50.8)	1.09 (0.59- 2.00)	0.78	1.00 (0.53- 1.87)	1.00
Ground water	179 (29.7)	91 (50.8)	1.15 (0.74- 1.77)	0.53	1.13 (0.73- 1.77)	0.58
Rain water	35 (5.8)	21 (60.0)	1.68 (0.77- 3.67)	0.19	1.71 (0.78- 3.77)	0.18
Mixed water	78 (13.0)	29 (37.2)	0.69 (0.39- 1.24)	0.21	0.72 (0.40- 1.30)	0.28
Latrine posessions						
No	100 (16.6)	49 (49.0)	1.00		1.00	
Yes	502 (83.4)	229 (45.6)	1.47 (0.89- 2.42)	0.13	1.46 (0.88- 2.42)	0.14
Septage Removal (Removal excreta)						
No	461 (76.6)	223 (48.4)	1.00		1.00	
Yes	141 (23.4)	55 (39.0)	0.92 (0.59- 1.44)	0.71	0.86 (0.54- 1.37)	0.53
Sanitary behavior						
Water treatment						
No treating	427 (70.9)	207 (48.5)	1.00		1.00	
By alm	9 (1.5)	3 (33.3)	2.02 (0.44- 9.40)	0.37	1.95 (0.40- 9.44)	0.41
By boiling	96 (15.9)	38 (39.6)	1.15 (0.67- 1.99)	0.61	1.21 (0.69- 2.13)	0.51
By filter	70 (11.6)	30 (42.9)	1.36 (0.76- 2.41)	0.30	1.37 (0.76- 2.45)	0.30
Defecation habits of children						
Open field	302 (50.2)	159 (52.6)	1.00		1.00	
Latrine	66 (11.0)	20 (30.3)	0.55 (0.29- 1.06)	0.07	0.56 (0.29- 1.10)	0.09
Room	174 (28.9)	78 (44.8)	0.82 (0.55- 1.23)	0.34	0.81 (0.54- 1.23)	0.33
Veranda	60 (10.0)	21 (35.0)	0.56 (0.31- 1.04)	0.07	0.56 (0.30- 1.04)	0.07
Hands washing before meal						
No wash	236 (39.2)	120 (50.8)	1.00		1.00	
Wash with soap	165 (27.4)	68 (41.2)	0.82 (0.50- 1.36)	0.45	0.90 (0.53- 1.53)	0.70
Wash without soap	201 (33.4)	90 (44.8)	0.85 (0.52- 1.37)	0.50	0.92 (0.56- 1.54)	0.76
Hands washing after defecation						
No wash	316 (52.5)	151 (47.8)	1.00		1.00	
Wash with soap	70 (11.6)	21 (30.0)	0.50* (0.26- 0.97)	0.04	0.51 (0.26- 1.00)	0.05
Wash without soap	216 (35.9)	106 (49.1)	1.06 (0.69- 1.63)	0.78	1.13 (0.73- 1.74)	0.59
Flooding factors						
Maximum Flooding depth						
<0.37m	336 (55.8)	138 (41.1)	1.00		1.00	
0.37-0.74m	71 (11.8)	34 (47.9)	1.29 (0.71- 2.32)	0.41	1.40 (0.57- 3.41)	0.46
>0.74m	195 (32.4)	106 (54.4)	1.44 (0.94- 2.21)	0.10	1.56 (0.84- 2.91)	0.16

* *P* value < .05.

** *P* value < .01.

6.5.4. *Recognition of variance in diarrhoeal morbidity between areas*

As a second step of multilevel logistic regression analysis, we examined the influence of flood depth and social epidemiological factors on the variance in diarrhoeal morbidity between areas (Table 6-15). The null model with no predictors (Model 1) revealed a significant variance in diarrhoeal morbidity between areas (σ_{α}^{2} = 0.77, standard error = 0.20), with the significance of the variance recognized by z-score (0.77/0.20 = 3.8 > 2.0). After maternal age was added to Model 1 (i.e., Model 2), the variance between areas remained unchanged, implying that maternal age did not explain the variance between areas.

Model 3 and Model 4 were then constructed to examine the influence of flood depth and socio-economic factors. Here the variance between areas changed from 0.774 to 0.639 in Model 3, and to 0.636 in Model 4. Thus, the influences of flood depth and socio-economic factors were 17.4% and 17.8%, respectively. In Model 5, the influence of both the flood and socio-economic factors were 30.2 %. However, Model 6 examined the influence of the household water environment and sanitary behavior, and identified a very small influence (–2.2%). Thus, flood depth and socio-economic factors each accounted for half of the variance between areas. However, neither fully explained all the variance between areas because the MOR did not reach nearly one (MOR=2.03).

Table 6-15 Fixed and random results for the multilevel analytical model

	model 1	model 2	model 3	model 4	model 5	model 6	model 7
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Season							
pre monsoon	1.00	1.00	1.00	1.00	1.00	1.00	1.00
mid monsoon	1.73*** (1.37 -2.17)	1.72*** (1.37 -2.16)	1.72*** (1.37 -2.17)	1.72*** (1.37 -2.16)	1.72*** (1.37 -2.17)	1.74*** (1.39 -2.20)	1.75*** (1.39 -2.20)
post monsoon	0.96 (0.77 -1.21)	0.96 (0.76 -1.21)	0.96 (0.77 -1.21)	0.96 (0.76 -1.21)	0.96 (0.77 -1.21)	0.97 (0.77 -1.22)	0.97 (0.77 -1.22)
Socio-demographic factors							
Mother's age							
<38		1.00	1.00	1.00	1.00	1.00	1.00
>38		0.86 (0.70 -1.06)	0.86 (0.70 -1.06)	0.86 (0.70 -1.07)	0.86 (0.70 -1.07)	0.85 (0.68 -1.07)	0.85 (0.68 -1.06)
Flooding Factors							
Flooding depth							
<0.37m			1.00		1.00		1.00
0.37-0.74m			1.89 (0.51 -6.93)		1.89 (0.53 -6.75)		1.75 (0.47 -6.47)
>0.74m			2.22 (0.94 -5.22)		2.19 (0.95 -5.05)		2.01 (0.84 -4.78)
Social Economic Factors							
Occupation of Father							
Unemployment				1.00	1.00	1.00	1.00
Government				0.91 (0.53 -1.56)	0.91 (0.53 -1.56)	0.89 (0.50 -1.57)	0.89 (0.50 -1.57)
Private				0.96 (0.59 -1.54)	0.96 (0.59 -1.55)	0.92 (0.56 -1.51)	0.92 (0.56 -1.51)
By my self				0.93 (0.58 -1.47)	0.92 (0.58 -1.47)	0.88 (0.54 -1.43)	0.87 (0.54 -1.43)
Mother's education level							
No				1.00	1.00	1.00	1.00
Below elementary				0.99 (0.79 -1.24)	0.99 (0.79 -1.24)	0.97 (0.77 -1.23)	0.97 (0.77 -1.22)
Above elementary				0.94 (0.69 -1.29)	0.94 (0.69 -1.29)	0.97 (0.71 -1.33)	0.97 (0.71 -1.33)
Income of household							
<30 USD				1.00	1.00		1.00
31-50 USD				1.10 (0.88 -1.37)	1.10 (0.88 -1.37)	1.08 (0.86 -1.36)	1.08 (0.86 -1.36)
50 < USD				0.97 (0.63 -1.50)	0.97 (0.63 -1.49)	0.97 (0.61 -1.53)	0.97 (0.61 -1.53)
Household Water Environment							
Water disposal							
Open land						1.00	1.00
Grass land						1.34 (0.99 -1.82)	1.34 (0.99 -1.81)
Ground						1.07 (0.77 -1.48)	1.07 (0.78 -1.49)
Wet land						1.10 (0.77 -1.57)	1.10 (0.77 -1.57)
Other						1.44 (0.72 -2.87)	1.43 (0.72 -2.83)
Water resource							
Tap						1.00	1.00
Surface water						1.03 (0.72 -1.47)	1.03 (0.72 -1.47)
Ground water						0.89 (0.70 -1.14)	0.89 (0.70 -1.14)
Rain water						1.20 (0.78 -1.85)	1.20 (0.78 -1.86)
Mixed water						1.18 (0.86 -1.64)	1.18 (0.85 -1.63)
Latrine type							
No						1.00	1.00
Yes						1.20 (0.91 -1.57)	1.20 (0.91 -1.58)
Septage Removal (Removal excreta)							
No						1.00	1.00
Yes						0.87 (0.67 -1.12)	0.88 (0.68 -1.13)
Sanitary behavior							
Water treatment							
No treating						1.00	1.00
By alm						0.92 (0.35 -2.38)	0.92 (0.36 -2.40)
By boiling						0.98 (0.71 -1.35)	0.99 (0.72 -1.36)
By filter						1.07 (0.78 -1.49)	1.08 (0.78 -1.49)
Defecation habits of children							
Open field						1.00	1.00
Latrine						0.59** (0.40 -0.86)	0.59** (0.40 -0.86)
Room						0.92 (0.73 -1.16)	0.92 (0.73 -1.16)
Velanda						0.71 (0.51 -1.01)	0.72 (0.51 -1.01)
Hands washing before meal							
No wash						1.00	1.00
Wash with soap						0.94 (0.70 -1.25)	0.94 (0.70 -1.25)
Wash without soap						0.90 (0.69 -1.15)	0.90 (0.70 -1.16)
Hands washing after defecation							
No wash						1.00	1.00
Wash with soap						0.89 (0.62 -1.29)	0.89 (0.62 -1.29)
Wash without soap						1.07 (0.85 -1.35)	1.06 (0.84 -1.34)
Variance between areas	0.705	0.706	0.598	0.689	0.581	0.676	0.595
(Standard error)	(0.168)	(0.169)	(0.146)	(0.171)	(0.147)	(0.182)	(0.161)
MOR	2.23	2.23	2.09	2.21	2.07	2.19	2.09

* *P* value < .05.
** *P* value < .01.
*** *P* value < .001

6.5. Summary

To examine the influence of flood depth (the flooding factor) and social factors on diarrhoeal morbidity, we built two multiple regression analysis models, which used appropriate social epidemiological factors to explain the diarrhoeal morbidity. In addition, we found that the influence of flooding depth was less than that of the social factors were considered in the model.

To examine the influence of flood depth and social factors on the variance between areas, we performed multilevel logistic analysis by adding social factors in a stepwise manner. As a result, we found that influences of flooding and socio-economic factors were larger than for the other factors, and explained 30% of the variance between areas. However, the MOR was approximately two, even when all the social factors were considered in the model.

To examine the influence of flood depth on diarrhoeal morbidity adjusted by all social factors, we performed multilevel logistic regression analysis and normal logistic regression analysis. Flooding was significantly associated with diarrhoeal morbidity in the normal logistic regression analysis. However, its significance disappeared in the multilevel logistic analysis. Further, several social factors were significantly associated with diarrhoeal morbidity.

CHAPTER 7 SUMMARY OF THE STUDY

7.1. Summary

First, we performed a flooding analysis in Dhaka City to evaluate the flood situation quantitatively. A flood simulation model successfully simulated the flooding that occurred in 2007. Because of disagreement in the validation of the extent of the floods, the results appeared to lack the precision to indicate differences of a few centimeters; however, it can indicate the degree of flooding between areas.

Second, simple regression analysis with flooding factors and diarrhoeal morbidity revealed minimal differences between the various flooding factors on the respective seasons. Furthermore, the relationship between flooding and morbidity existed in the absence of flooding, and therefore, was considered to be due to predisposing causes.

Third, we performed multiple regression analysis to consider the various social factors. The accuracy of explanation diarrhoeal cases improved by considering social factors, but not by considering flooding. These social factors included water disposal to open land, repeated use of a pit latrine, defecation in open land, hand washing after defecation, and water treatment.

Fourth, recognition of variance between areas with multilevel logistic regression analysis revealed that 20% of the variance between areas was explained by the variable considered in this study; half of the variance was explained by social status (including income, education level, and occupation) and the other half was explained by flooding.

Fifth, we performed multilevel logistic regression analysis and normal logistic regression analysis. In the normal logistic regression analysis, flooding was significantly associated with diarrhoeal morbidity. However, in the multilevel logistic regression analysis, its significance disappeared. Further, several social factors were significantly associated with diarrhoeal morbidity.

In this study, the relationship between water logging and diarrhoea was assessed using flood simulations and social epidemiological analyses. We found that the relationship between flooding factors (such as flooding depth and duration) and diarrhoeal morbidity was not statistically significant. However, in several analyses we found an increased risk of diarrhoea in flooded areas compared with non-flooded areas. The relationship between flooding severity and morbidity was difficult to clarify. This could be explained by some other factors that were not considered in this analysis because the median odds ratio was still not explained.

The main originality of this study was the consideration of quantitative flooding data to social epidemiological analysis. The statistical analyses that were conducted in this study were not possible without the quantitative flooding data. Therefore, one of worth result was the development of engineered and social epidemiological method. Using this, we can also make prediction for the diarrhoeal risk in the future as a favor of flood modeling.

A typical example of that is the most take advantage of the results of this study are to provide information to urban planning authorities. Because the flooding and urban planning has direct relationship, we can know how much diarrhoeal risk can be reduced by reducing the risk of flooding. We expect that effective urban planning will be conducted to reduce the diarrhoeal cases, and also hope that the health of many children is protected as many children as possible.

7.2. Recommendations for future research

Our study had several limitations. First, the data for drainage and sewerage were not considered. In deed, the flooding model did not consider the operational records of both the main and emergency pumps as well as the sites of the garbage blockages. It is known that waterlogging occurs in several low-income communities because of drainage problems (Mollah *et al.*, 2009). Therefore, detailed drainage data should be collected in any future research.

Second, the data for validating the results of the flood simulation were qualitative due to a shortage of information. Further, all validation conducted in this study was qualitative. To validate the model quantitatively, a flood mark and flood depth record using a water-stage recorder would be helpful.

Third, to more precisely clarify the relationship between flooding and diarrhoeal incidence, we must consider the social factors affecting diarrhoea. Moreover, a precise mechanism for identifying the route of infectious disease transmission would be beneficial. To obtain reliable numerical flooding simulation results, observing the water depth in low-income community areas would be indispensable for validation purposes.

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APPENDICES

Appendix A

Table 0-1 Results of simple correlation analysis (sociodemographic and socioeconomic)

Factors	Socio-demographic factor	Socio-economic factors			
	Average age	Unemployment	Government	Private	By my self
Socio demographic factor					
Average age	1.00	0.42	0.11	-0.13	-0.06
Socio economic factors					
Occupation of Father					
Unemployment	0.42 (0.23)	1.00	-0.54 (0.11)	-0.65* (0.04)	0.64* (0.05)
Government	0.11 (0.75)	-0.54 (0.11)	1.00	0.31 (0.38)	-0.86** (0.00)
Private	-0.13 (0.71)	-0.65* (0.04)	0.31 (0.38)	1.00	-0.73* (0.02)
By my self	-0.06 (0.87)	0.64* (0.05)	-0.86** (0.00)	-0.73* (0.02)	1.00
Mother's education level					
No	-0.20 (0.57)	0.37 (0.29)	-0.90** (0.00)	-0.19 (0.61)	0.74* (0.01)
Below elementary	0.11 (0.75)	-0.50 (0.14)	0.65* (0.04)	0.19 (0.60)	-0.54 (0.11)
Above elementary	0.21 (0.56)	-0.24 (0.50)	0.87** (0.00)	0.15 (0.68)	-0.72* (0.02)
Income of household					
<30 USD	-0.03 (0.93)	0.69* (0.03)	-0.94** (0.00)	-0.57 (0.08)	0.95** (0.00)
31 - 50 USD	-0.22 (0.55)	-0.49 (0.15)	-0.15 (0.67)	0.71* (0.02)	-0.22 (0.55)
50 < USD	0.17 (0.63)	-0.26 (0.47)	0.90** (0.00)	0.01 (0.98)	-0.66* (0.04)
Household water environment					
Water disposal					
Open land	0.05 (0.89)	0.23 (0.53)	-0.57 (0.09)	-0.10 (0.78)	0.40 (0.25)
Grass land	-0.13 (0.72)	-0.06 (0.87)	-0.61 (0.06)	0.27 (0.45)	0.31 (0.38)
Ground	0.45 (0.19)	0.31 (0.39)	0.04 (0.92)	0.03 (0.94)	-0.04 (0.91)
Wet land	-0.45 (0.20)	-0.16 (0.66)	-0.40 (0.25)	0.12 (0.75)	0.26 (0.46)
Water resource					
Tap	0.24 (0.50)	-0.39 (0.26)	0.94 (0.00)	0.16 (0.65)	-0.75* (0.01)
Surface water	0.26 (0.47)	0.60 (0.06)	-0.55 (0.10)	-0.11 (0.77)	0.41 (0.24)
Ground water	-0.50 (0.14)	0.16 (0.66)	-0.78 (0.01)	-0.19 (0.60)	0.67* (0.04)
Rain water	0.11 (0.76)	0.29 (0.41)	-0.57 (0.08)	-0.23 (0.52)	0.49 (0.15)
Mixed water	0.03 (0.93)	-0.07 (0.84)	-0.18 (0.61)	0.25 (0.49)	0.00 (0.99)
Latrine posessions					
Yes	-0.18 (0.63)	-0.73* (0.02)	0.70* (0.02)	0.58 (0.08)	-0.77** (0.01)
Septage Removal (Removal excreta)					
Yes	0.02 (0.96)	-0.22 (0.54)	0.65* (0.04)	0.31 (0.38)	-0.63 (0.05)
Sanitary behavior					
Water treatment					
No treating	-0.25 (0.49)	0.40 (0.25)	-0.96** (0.00)	-0.34 (0.34)	0.88** (0.00)
By alm	0.22 (0.53)	-0.08 (0.83)	0.78** (0.01)	0.02 (0.95)	-0.60 (0.07)
By boiling	0.21 (0.56)	-0.41 (0.24)	0.98** (0.00)	0.28 (0.43)	-0.86** (0.00)
By filter	0.29 (0.42)	-0.43 (0.21)	0.62 (0.06)	0.61 (0.06)	-0.78** (0.01)
Defecation habits of children					
Open field	0.04 (0.92)	0.44 (0.20)	-0.90** (0.00)	-0.13 (0.72)	0.69* (0.03)
Latrine	0.08 (0.83)	-0.49 (0.15)	0.96** (0.00)	0.17 (0.63)	-0.76* (0.01)
Room	-0.11 (0.76)	0.05 (0.90)	0.52 (0.12)	-0.03 (0.93)	-0.37 (0.29)
Velanda	-0.19 (0.60)	-0.40 (0.25)	0.07 (0.86)	0.06 (0.86)	-0.03 (0.94)
Hands washing before meal					
No wash	0.33 (0.35)	0.81** (0.00)	-0.24 (0.50)	-0.60 (0.07)	0.42 (0.22)
Wash with soap	-0.21 (0.57)	-0.68* (0.03)	0.58 (0.08)	0.84** (0.00)	-0.83** (0.00)
Wash without soap	-0.25 (0.48)	-0.49 (0.15)	-0.15 (0.69)	0.10 (0.79)	0.12 (0.74)
Hands washing after defecation					
No wash	0.33 (0.35)	0.78** (0.01)	-0.49 (0.15)	-0.47 (0.17)	0.53 (0.11)
Wash with soap	0.22 (0.54)	-0.60 (0.07)	0.85 (0.00)	0.61 (0.06)	-0.93** (0.00)
Wash without soap	-0.53 (0.12)	-0.36 (0.31)	-0.16 (0.66)	0.01 (0.97)	0.18 (0.62)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-2 Results of simple correlation analysis (socioeconomic)

Factors	Socio economic factors					
	Mother's education level			Income of household		
	No educated	Bellow elementary	Above elementary	<30	31 - 50	50 <
Socio demographic factor						
Average age	-0.20 (0.57)	0.11 (0.75)	0.21 (0.56)	-0.03 (0.93)	-0.22 (0.55)	0.17 (0.63)
Socio economic factors						
Occupation of Father						
Unemployment	0.37 (0.29)	-0.50 (0.14)	-0.24 (0.50)	0.69 (0.03)	-0.49 (0.15)	-0.26 (0.47)
Government	-0.90** (0.00)	0.65 (0.04)	0.87** (0.00)	-0.94** (0.00)	-0.15 (0.67)	0.90** (0.00)
Private	-0.19 (0.61)	0.19 (0.60)	0.15 (0.68)	-0.57 (0.08)	0.71 (0.02)	0.01 (0.98)
By my self	0.74 (0.01)	-0.54 (0.11)	-0.72 (0.02)	0.95** (0.00)	-0.22 (0.55)	-0.66 (0.04)
Mother's education level						
No educated	1.00	-0.76 (0.01)	-0.94** (0.00)	0.82** (0.00)	0.36 (0.31)	-0.94** (0.00)
Below elementary	-0.76 (0.01)	1.00	0.51 (0.13)	-0.67 (0.04)	0.01 (0.97)	0.56 (0.09)
Above elementary	-0.94** (0.00)	0.51 (0.13)	1.00	-0.76 (0.01)	-0.48 (0.16)	0.97 (0.00)
Income of household						
<30 USD	0.82** (0.00)	-0.67 (0.04)	-0.76 (0.01)	1.00	-0.15 (0.68)	-0.75 (0.01)
31 - 50 USD	0.36 (0.31)	0.01 (0.97)	-0.48 (0.16)	-0.15 (0.68)	1.00	-0.54 (0.10)
50 < USD	-0.94** (0.00)	0.56 (0.09)	0.97** (0.00)	-0.75 (0.01)	-0.54 (0.10)	1.00
Household water environment						
Water disposal						
Open land	0.50 (0.14)	-0.29 (0.41)	-0.52 (0.12)	0.53 (0.12)	0.11 (0.76)	-0.53 (0.12)
Grass land	0.69 (0.03)	-0.64 (0.05)	-0.59 (0.07)	0.48 (0.16)	0.41 (0.24)	-0.68 (0.03)
Ground	0.00 (1.00)	-0.47 (0.17)	0.24 (0.51)	0.04 (0.92)	-0.24 (0.50)	0.13 (0.72)
Wet land	0.48 (0.16)	0.07 (0.84)	-0.68 (0.03)	0.20 (0.57)	0.68 (0.03)	-0.63 (0.05)
Water resource						
Tap	-0.89** (0.00)	0.58 (0.08)	0.89** (0.00)	-0.82** (0.00)	-0.34 (0.33)	0.93** (0.00)
Surface water	0.59 (0.07)	-0.76 (0.01)	-0.40 (0.26)	0.53 (0.12)	0.07 (0.84)	-0.50 (0.14)
Ground water	0.68 (0.03)	-0.54 (0.11)	-0.63 (0.05)	0.68 (0.03)	0.14 (0.71)	-0.67 (0.03)
Rain water	0.38 (0.28)	-0.12 (0.75)	-0.45 (0.20)	0.56 (0.09)	-0.01 (0.99)	-0.47 (0.17)
Mixed water	0.24 (0.50)	0.32 (0.36)	-0.49 (0.15)	0.03 (0.94)	0.64 (0.04)	-0.45 (0.19)
Latrine posessions						
Yes	-0.66 (0.04)	0.49 (0.15)	0.64 (0.05)	-0.72 (0.02)	0.03 (0.94)	0.60 (0.07)
Septage Removal (Removal excreta)						
Yes	-0.73 (0.02)	0.28 (0.43)	0.83** (0.00)	-0.59 (0.08)	-0.36 (0.31)	0.74 (0.01)
Sanitary behavior						
Water treatment						
No treating	0.92** (0.00)	-0.62 (0.06)	-0.91** (0.00)	0.90** (0.00)	0.21 (0.55)	-0.91** (0.00)
By alm	-0.90** (0.00)	0.49 (0.16)	0.95** (0.00)	-0.62 (0.05)	-0.60 (0.07)	0.93** (0.00)
By boiling	-0.93** (0.00)	0.62 (0.05)	0.92** (0.00)	-0.89** (0.00)	-0.26 (0.46)	0.94** (0.00)
By filter	-0.54 (0.10)	0.43 (0.22)	0.51 (0.14)	-0.73 (0.02)	0.29 (0.42)	0.42 (0.22)
Defecation habits of children						
Open field	0.83** (0.00)	-0.57 (0.09)	-0.82** (0.00)	0.78** (0.01)	0.35 (0.33)	-0.89** (0.00)
Latrine	-0.89** (0.00)	0.67 (0.04)	0.84** (0.00)	-0.84** (0.00)	-0.30 (0.41)	0.91** (0.00)
Room	-0.51 (0.13)	0.23 (0.52)	0.57 (0.09)	-0.47 (0.17)	-0.27 (0.45)	0.58 (0.08)
Velanda	-0.02 (0.95)	0.01 (0.98)	0.03 (0.94)	0.01 (0.97)	-0.13 (0.72)	0.08 (0.84)
Hands washing before meal						
No wash	0.30 (0.40)	-0.46 (0.18)	-0.16 (0.65)	0.42 (0.23)	-0.40 (0.26)	-0.09 (0.81)
Wash with soap	-0.55 (0.10)	0.59 (0.07)	0.43 (0.22)	-0.78** (0.01)	0.50 (0.14)	0.33 (0.36)
Wash without soap	0.06 (0.88)	0.11 (0.76)	-0.13 (0.72)	0.09 (0.81)	0.11 (0.77)	-0.15 (0.69)
Hands washing after defecation						
No wash	0.56 (0.09)	-0.70 (0.02)	-0.39 (0.26)	0.63 (0.05)	-0.26 (0.46)	-0.36 (0.31)
Wash with soap	-0.71 (0.02)	0.47 (0.17)	0.70 (0.02)	-0.88** (0.00)	0.10 (0.77)	0.67 (0.03)
Wash without soap	-0.03 (0.93)	0.37 (0.30)	-0.14 (0.69)	0.03 (0.93)	0.19 (0.59)	-0.16 (0.66)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-3 Results of simple correlation analysis (household water environment)

Factors	Household water environment			
	Water disposal			
	Open land	Grass land	Ground	Wet land
Socio demographic factor				
Average age	0.05 (0.89)	-0.13 (0.72)	0.45 (0.19)	-0.45 (0.20)
Socio economic factors				
Occupation of Father				
Unemployment	0.23 (0.53)	-0.06 (0.87)	0.31 (0.39)	-0.16 (0.66)
Government	-0.57 (0.09)	-0.61 (0.06)	0.04 (0.92)	-0.40 (0.25)
Private	-0.10 (0.78)	0.27 (0.45)	0.03 (0.94)	0.12 (0.75)
By my self	0.40 (0.25)	0.31 (0.38)	-0.04 (0.91)	0.26 (0.46)
Mother's education level				
No	0.50 (0.14)	0.69* (0.03)	0.00 (1.00)	0.48 (0.16)
Below elementary	-0.29 (0.41)	-0.64* (0.05)	-0.47 (0.17)	0.07 (0.84)
Above elementary	-0.52 (0.12)	-0.59 (0.07)	0.24 (0.51)	-0.68* (0.03)
Income of household				
<30 USD	0.53 (0.12)	0.48 (0.16)	0.04 (0.92)	0.20 (0.57)
31 - 50 USD	0.11 (0.76)	0.41 (0.24)	-0.24 (0.50)	0.68* (0.03)
50 < USD	-0.53 (0.12)	-0.68* (0.03)	0.13 (0.72)	-0.63 (0.05)
Household water environment				
Water disposal				
Open land	1.00	0.53 (0.12)	-0.36 (0.31)	0.13 (0.72)
Grass land	0.53 (0.12)	1.00	0.25 (0.48)	0.04 (0.92)
Ground	-0.36 (0.31)	0.25 (0.48)	1.00	-0.66* (0.04)
Wet land	0.13 (0.72)	0.04 (0.92)	-0.66* (0.04)	1.00
Water resource				
Tap	-0.62 (0.05)	-0.60 (0.07)	0.19 (0.59)	-0.55 (0.10)
Surface water	0.29 (0.41)	0.48 (0.16)	0.55 (0.10)	-0.12 (0.75)
Ground water	0.53 (0.11)	0.57 (0.09)	-0.27 (0.45)	0.38 (0.28)
Rain water	0.82 (0.00)	0.41 (0.25)	-0.26 (0.48)	0.08 (0.82)
Mixed water	0.11 (0.77)	-0.10 (0.79)	-0.49 (0.15)	0.78** (0.01)
Latrine posessions				
Yes	-0.31 (0.38)	-0.05 (0.90)	0.08 (0.82)	-0.41 (0.24)
Septage Removal (Removal excreta)				
Yes	-0.66* (0.04)	-0.33 (0.36)	0.47 (0.17)	-0.63* (0.05)
Sanitary behavior				
Water treatment				
No treating	0.44 (0.21)	0.57 (0.08)	-0.11 (0.76)	0.52 (0.12)
By alm	-0.57 (0.08)	-0.65* (0.04)	0.28 (0.43)	-0.68* (0.03)
By boiling	-0.48 (0.16)	-0.62 (0.06)	0.09 (0.81)	-0.52 (0.13)
By filter	0.00 (1.00)	-0.13 (0.72)	0.04 (0.92)	-0.24 (0.50)
Defecation habits of children				
Open field	0.69* (0.03)	0.64* (0.05)	-0.06 (0.87)	0.41 (0.24)
Latrine	-0.59 (0.07)	-0.63* (0.05)	0.02 (0.96)	-0.43 (0.22)
Room	-0.67* (0.03)	-0.78** (0.01)	-0.01 (0.98)	-0.04 (0.91)
Velanda	-0.06 (0.87)	0.40 (0.25)	0.18 (0.63)	-0.31 (0.38)
Hands washing before meal				
No wash	-0.02 (0.95)	-0.27 (0.45)	0.24 (0.51)	-0.05 (0.89)
Wash with soap	-0.36 (0.31)	-0.23 (0.52)	-0.21 (0.57)	0.17 (0.65)
Wash without soap	0.31 (0.38)	0.53 (0.12)	-0.14 (0.70)	-0.07 (0.86)
Hands washing after defecation				
No wash	0.21 (0.56)	0.17 (0.63)	0.38 (0.28)	-0.10 (0.78)
Wash with soap	-0.22 (0.55)	-0.19 (0.60)	0.13 (0.71)	-0.45 (0.19)
Wash without soap	-0.05 (0.90)	-0.04 (0.92)	-0.51 (0.13)	0.47 (0.17)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-4 Results of simple correlation analysis (household water environment)

Factors	Household water environment				
	Water resource				
	Tap	Surface water	Ground water	Rain water	Mixed water
Socio demographic factor					
Average age	0.24 (0.50)	0.26 (0.47)	-0.50 (0.14)	0.11 (0.76)	0.03 (0.93)
Socio economic factors					
Occupation of Father					
Unemployment	-0.39 (0.26)	0.60 (0.06)	0.16 (0.66)	0.29 (0.41)	-0.07 (0.84)
Government	0.94** (0.00)	-0.55 (0.10)	-0.78** (0.01)	-0.57 (0.08)	-0.18 (0.61)
Private	0.16 (0.65)	-0.11 (0.77)	-0.19 (0.60)	-0.23 (0.52)	0.25 (0.49)
By my self	-0.75* (0.01)	0.41 (0.24)	0.67* (0.04)	0.49 (0.15)	0.00 (0.99)
Mother's education level					
No	-0.89** (0.00)	0.59 (0.07)	0.68* (0.03)	0.38 (0.28)	0.24 (0.50)
Below elementary	0.58 (0.08)	-0.76* (0.01)	-0.54 (0.11)	-0.12 (0.75)	0.32 (0.36)
Above elementary	0.89 (0.00)	-0.40 (0.26)	-0.63* (0.05)	-0.45 (0.20)	-0.49 (0.15)
Income of household					
<30 USD	-0.82** (0.00)	0.53 (0.12)	0.68* (0.03)	0.56 (0.09)	0.03 (0.94)
31 - 50 USD	-0.34 (0.33)	0.07 (0.84)	0.14 (0.71)	-0.01 (0.99)	0.64* (0.04)
50 < USD	0.93** (0.00)	-0.50 (0.14)	-0.67* (0.03)	-0.47 (0.17)	-0.45 (0.19)
Household water environment					
Water disposal					
Open land	-0.62 (0.05)	0.29 (0.41)	0.53 (0.11)	0.82** (0.00)	0.11 (0.77)
Grass land	-0.60 (0.07)	0.48 (0.16)	0.57 (0.09)	0.41 (0.25)	-0.10 (0.79)
Ground	0.19 (0.59)	0.55 (0.10)	-0.27 (0.45)	-0.26 (0.48)	-0.49 (0.15)
Wet land	-0.55 (0.10)	-0.12 (0.75)	0.38 (0.28)	0.08 (0.82)	0.78** (0.01)
Water resource					
Tap	1.00	-0.57 (0.09)	-0.79** (0.01)	-0.64* (0.05)	-0.29 (0.41)
Surface water	-0.57 (0.09)	1.00	0.23 (0.52)	0.38 (0.28)	-0.10 (0.78)
Ground water	-0.79** (0.01)	0.23 (0.52)	1.00	0.43 (0.22)	-0.14 (0.70)
Rain water	-0.64* (0.05)	0.38 (0.28)	0.43 (0.22)	1.00	0.12 (0.73)
Mixed water	-0.29 (0.41)	-0.10 (0.78)	-0.14 (0.70)	0.12 (0.73)	1.00
Latrine posessions					
Yes	0.64* (0.05)	-0.45 (0.19)	-0.46 (0.18)	-0.22 (0.53)	-0.23 (0.52)
Septage Removal (Removal excreta)					
Yes	0.71* (0.02)	-0.24 (0.51)	-0.54 (0.11)	-0.50 (0.14)	-0.44 (0.21)
Sanitary behavior					
Water treatment					
No treating	-0.89** (0.00)	0.40 (0.26)	0.80** (0.01)	0.40 (0.25)	0.22 (0.55)
By alm	0.85** (0.00)	-0.36 (0.30)	-0.69* (0.03)	-0.42 (0.22)	-0.41 (0.24)
By boiling	0.94** (0.00)	-0.47 (0.17)	-0.80** (0.00)	-0.48 (0.16)	-0.23 (0.53)
By filter	0.41 (0.24)	0.01 (0.98)	-0.52 (0.13)	0.03 (0.93)	0.04 (0.92)
Defecation habits of children					
Open field	-0.95** (0.00)	0.67* (0.03)	0.70* (0.03)	0.71* (0.02)	0.26 (0.47)
Latrine	0.97** (0.00)	-0.65* (0.04)	-0.78** (0.01)	-0.58 (0.08)	-0.19 (0.59)
Room	0.52 (0.12)	-0.31 (0.38)	-0.34 (0.34)	-0.74* (0.01)	-0.12 (0.74)
Velanda	0.21 (0.55)	-0.33 (0.35)	-0.03 (0.93)	-0.05 (0.89)	-0.26 (0.46)
Hands washing before meal					
No wash	-0.11 (0.76)	0.40 (0.26)	-0.07 (0.84)	-0.17 (0.64)	0.00 (0.99)
Wash with soap	0.39 (0.26)	-0.41 (0.24)	-0.38 (0.28)	-0.32 (0.36)	0.30 (0.40)
Wash without soap	-0.17 (0.64)	-0.18 (0.62)	0.39 (0.27)	0.47 (0.17)	-0.24 (0.51)
Hands washing after defecation					
No wash	-0.31 (0.38)	0.54 (0.11)	0.10 (0.79)	-0.01 (0.99)	-0.03 (0.94)
Wash with soap	0.75* (0.01)	-0.30 (0.40)	-0.69* (0.03)	-0.31 (0.38)	-0.14 (0.71)
Wash without soap	-0.27 (0.45)	-0.34 (0.34)	0.45 (0.19)	0.26 (0.48)	0.14 (0.71)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-5 Results of simple correlation analysis (household water environment and sanitary behavior)

Factors	**Household water environment**		**Sanitary behavior**			
	Latrine posessions	Septage Removal	Water treatment			
	Yes	Yes	No treating	By alm	By boiling	By filter
Socio demographic factor						
Average age	-0.18 (0.63)	0.02 (0.96)	-0.25 (0.49)	0.22 (0.53)	0.21 (0.56)	0.29 (0.42)
Socio economic factors						
Occupation of Father						
Unemployment	-0.73* (0.02)	-0.22 (0.54)	0.40 (0.25)	-0.08 (0.83)	-0.41 (0.24)	-0.43 (0.21)
Government	0.70* (0.02)	0.65* (0.04)	-0.96** (0.00)	0.78** (0.01)	0.98** (0.00)	0.62 (0.06)
Private	0.58 (0.08)	0.31 (0.38)	-0.34 (0.34)	0.02 (0.95)	0.28 (0.43)	0.61 (0.06)
By my self	-0.77** (0.01)	-0.63 (0.05)	0.88** (0.00)	-0.60 (0.07)	-0.86** (0.00)	-0.78** (0.01)
Mother's education level						
No	-0.66* (0.04)	-0.73* (0.02)	0.92** (0.00)	-0.90** (0.00)	-0.93** (0.00)	-0.54 (0.10)
Below elementary	0.49 (0.15)	0.28 (0.43)	-0.62 (0.06)	0.49 (0.16)	0.62 (0.05)	0.43 (0.22)
Above elementary	0.64 (0.05)	0.83** (0.00)	-0.91** (0.00)	0.95** (0.00)	0.92** (0.00)	0.51 (0.14)
Income of household						
<30 USD	-0.72* (0.02)	-0.59 (0.08)	0.90** (0.00)	-0.62 (0.05)	-0.89** (0.00)	-0.73* (0.02)
31 - 50 USD	0.03 (0.94)	-0.36 (0.31)	0.21 (0.55)	-0.60 (0.07)	-0.26 (0.46)	0.29 (0.42)
50 < USD	0.60 (0.07)	0.74* (0.01)	-0.91** (0.00)	0.93** (0.00)	0.94** (0.00)	0.42 (0.22)
Household water environment						
Water disposal						
Open land	-0.31 (0.38)	-0.66* (0.04)	0.44 (0.21)	-0.57 (0.08)	-0.48 (0.16)	0.00 (1.00)
Grass land	-0.05 (0.90)	-0.33 (0.36)	0.57 (0.08)	-0.65* (0.04)	-0.62 (0.06)	-0.13 (0.72)
Ground	0.08 (0.82)	0.47 (0.17)	-0.11 (0.76)	0.28 (0.43)	0.09 (0.81)	0.04 (0.92)
Wet land	-0.41 (0.24)	-0.63* (0.05)	0.52 (0.12)	-0.68* (0.03)	-0.52 (0.13)	-0.24 (0.50)
Water resource						
Tap	0.64* (0.05)	0.71* (0.02)	-0.89** (0.00)	0.85** (0.00)	0.94** (0.00)	0.41 (0.24)
Surface water	-0.45 (0.19)	-0.24 (0.51)	0.40 (0.26)	-0.36 (0.30)	-0.47 (0.17)	0.01 (0.98)
Ground water	-0.46 (0.18)	-0.54 (0.11)	0.80** (0.01)	-0.69* (0.03)	-0.80** (0.00)	-0.52 (0.13)
Rain water	-0.22 (0.53)	-0.50 (0.14)	0.40 (0.25)	-0.42 (0.22)	-0.48 (0.16)	0.03 (0.93)
Mixed water	-0.23 (0.52)	-0.44 (0.21)	0.22 (0.55)	-0.41 (0.24)	-0.23 (0.53)	0.04 (0.92)
Latrine posessions						
Yes	1.00	0.73* (0.02)	-0.71 (0.02)	0.59 (0.07)	0.69* (0.03)	0.55 (0.10)
Septage Removal (Removal excreta)						
Yes	0.73* (0.02)	1.00	-0.70 (0.02)	0.88** (0.00)	0.70* (0.02)	0.30 (0.41)
Sanitary behavior						
Water treatment						
No treating	-0.71* (0.02)	-0.70* (0.02)	1.00	-0.84** (0.00)	-0.99** (0.00)	-0.74* (0.02)
By alm	0.59 (0.07)	0.88** (0.00)	-0.84** (0.00)	1.00	0.86** (0.00)	0.34 (0.34)
By boiling	0.69* (0.03)	0.70* (0.02)	-0.99** (0.00)	0.86** (0.00)	1.00	0.65* (0.04)
By filter	0.55 (0.10)	0.30 (0.41)	-0.74* (0.02)	0.34 (0.34)	0.65* (0.04)	1.00
Defecation habits of children						
Open field	-0.65* (0.04)	-0.73* (0.02)	0.81** (0.00)	-0.83** (0.00)	-0.87** (0.00)	-0.24 (0.51)
Latrine	0.71* (0.02)	0.68* (0.03)	-0.89** (0.00)	0.82** (0.00)	0.94** (0.00)	0.42 (0.23)
Room	0.00 (1.00)	0.46 (0.18)	-0.45 (0.19)	0.57 (0.09)	0.50 (0.14)	0.02 (0.96)
Velanda	0.54 (0.11)	0.26 (0.46)	0.02 (0.97)	0.09 (0.81)	0.03 (0.93)	-0.25 (0.48)
Hands washing before meal						
No wash	-0.72* (0.02)	-0.24 (0.51)	0.23 (0.52)	-0.04 (0.92)	-0.19 (0.61)	-0.43 (0.22)
Wash with soap	0.66* (0.04)	0.48 (0.16)	-0.58 (0.08)	0.34 (0.34)	0.54 (0.11)	0.65* (0.04)
Wash without soap	0.40 (0.25)	-0.08 (0.82)	0.16 (0.65)	-0.22 (0.54)	-0.19 (0.60)	0.03 (0.93)
Hands washing after defecation						
No wash	-0.68* (0.03)	-0.32 (0.37)	0.45 (0.19)	-0.26 (0.46)	-0.42 (0.23)	-0.52 (0.13)
Wash with soap	0.78** (0.01)	0.54 (0.10)	-0.89** (0.00)	0.57 (0.09)	0.86** (0.00)	0.84** (0.00)
Wash without soap	0.10 (0.79)	-0.09 (0.80)	0.23 (0.52)	-0.17 (0.63)	-0.24 (0.50)	-0.12 (0.74)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-6 Results of simple correlation analysis (sanitary behavior)

Factors	Sanitary behavior Defecation habits of children Open field	 Latrine	 Room	 Velanda
Socio demographic factor				
Average age	0.04 (0.92)	0.08 (0.83)	-0.11 (0.76)	-0.19 (0.60)
Socio economic factors				
Occupation of Father				
Unemployment	0.44 (0.20)	-0.49 (0.15)	0.05 (0.90)	-0.40 (0.25)
Government	-0.90** (0.00)	0.96** (0.00)	0.52 (0.12)	0.07 (0.86)
Private	-0.13 (0.72)	0.17 (0.63)	-0.03 (0.93)	0.06 (0.86)
By my self	0.69* (0.03)	-0.76* (0.01)	-0.37 (0.29)	-0.03 (0.94)
Mother's education level				
No	0.83** (0.00)	-0.89** (0.00)	-0.51 (0.13)	-0.02 (0.95)
Below elementary	-0.57 (0.09)	0.67* (0.04)	0.23 (0.52)	0.01 (0.98)
Above elementary	-0.82** (0.00)	0.84** (0.00)	0.57 (0.09)	0.03 (0.94)
Income of household				
<30 USD	0.78** (0.01)	-0.84** (0.00)	-0.47 (0.17)	0.01 (0.97)
31 - 50 USD	0.35 (0.33)	-0.30 (0.41)	-0.27 (0.45)	-0.13 (0.72)
50 < USD	-0.89** (0.00)	0.91** (0.00)	0.58 (0.08)	0.08 (0.84)
Household water environment				
Water disposal				
Open land	0.69* (0.03)	-0.59 (0.07)	-0.67* (0.03)	-0.06 (0.87)
Grass land	0.64* (0.05)	-0.63* (0.05)	-0.78** (0.01)	0.40 (0.25)
Ground	-0.06 (0.87)	0.02 (0.96)	-0.01 (0.98)	0.18 (0.63)
Wet land	0.41 (0.24)	-0.43 (0.22)	-0.04 (0.91)	-0.31 (0.38)
Water resource				
Tap	-0.95** (0.00)	0.97** (0.00)	0.52 (0.12)	0.21 (0.55)
Surface water	0.67* (0.03)	-0.65* (0.04)	-0.31 (0.38)	-0.33 (0.35)
Ground water	0.70* (0.03)	-0.78** (0.01)	-0.34 (0.34)	-0.03 (0.93)
Rain water	0.71* (0.02)	-0.58 (0.08)	-0.74* (0.01)	-0.05 (0.89)
Mixed water	0.26 (0.47)	-0.19 (0.59)	-0.12 (0.74)	-0.26 (0.46)
Latrine posessions				
Yes	-0.65* (0.04)	0.71* (0.02)	0.00 (1.00)	0.54 (0.11)
Septage Removal (Removal excreta)				
Yes	-0.73* (0.02)	0.68* (0.03)	0.46 (0.18)	0.26 (0.46)
Sanitary behavior				
Water treatment				
No treating	0.81** (0.00)	-0.89** (0.00)	-0.45 (0.19)	0.02 (0.97)
By alm	-0.83** (0.00)	0.82** (0.00)	0.57 (0.09)	0.09 (0.81)
By boiling	-0.87** (0.00)	0.94** (0.00)	0.50 (0.14)	0.03 (0.93)
By filter	-0.24 (0.51)	0.42 (0.23)	0.02 (0.96)	-0.25 (0.48)
Defecation habits of children				
Open field	1.00 (0.00)	-0.97** (0.00)	-0.61 (0.06)	-0.29 (0.42)
Latrine	-0.97** (0.00)	1.00 (0.00)	0.49 (0.15)	0.25 (0.48)
Room	-0.61 (0.06)	0.49 (0.15)	1.00 (0.00)	-0.45 (0.20)
Velanda	-0.29 (0.42)	0.25 (0.48)	-0.45 (0.20)	1.00 (0.00)
Hands washing before meal				
No wash	0.12 (0.73)	-0.20 (0.58)	0.35 (0.32)	-0.42 (0.23)
Wash with soap	-0.42 (0.23)	0.46 (0.18)	0.30 (0.39)	-0.10 (0.79)
Wash without soap	0.17 (0.64)	-0.11 (0.76)	-0.69* (0.03)	0.61 (0.06)
Hands washing after defecation				
No wash	0.34 (0.34)	-0.41 (0.23)	-0.03 (0.95)	-0.12 (0.75)
Wash with soap	-0.63 (0.05)	0.75* (0.01)	0.14 (0.70)	0.15 (0.68)
Wash without soap	0.14 (0.69)	-0.16 (0.66)	-0.08 (0.82)	0.01 (0.99)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-7 Results of simple correlation analysis (sanitary behavior)

Factors	Sanitary behavior					
	Hands washing before meal			Hands washing after defecation		
	No wash	Wash with soap	Wash without	No wash	Wash with soap	Wash without
Socio demographic factor						
Average age	0.33 (0.35)	-0.21 (0.57)	-0.25 (0.48)	0.33 (0.35)	0.22 (0.54)	-0.53 (0.12)
Socio economic factors						
Occupation of Father						
Unemployment	0.81** (0.00)	-0.68* (0.03)	-0.49 (0.15)	0.78** (0.01)	-0.60 (0.07)	-0.36 (0.31)
Government	-0.24 (0.50)	0.58 (0.08)	-0.15 (0.69)	-0.49 (0.15)	0.85** (0.00)	-0.16 (0.66)
Private	-0.60 (0.07)	0.84** (0.00)	0.10 (0.79)	-0.47 (0.17)	0.61 (0.06)	0.01 (0.97)
By my self	0.42 (0.22)	-0.83** (0.00)	0.12 (0.74)	0.53 (0.11)	-0.93** (0.00)	0.18 (0.62)
Mother's education level						
No	0.30 (0.40)	-0.55 (0.10)	0.06 (0.88)	0.56 (0.09)	-0.71* (0.02)	-0.03 (0.93)
Below elementary	-0.46 (0.18)	0.59 (0.07)	0.11 (0.76)	-0.70* (0.02)	0.47 (0.17)	0.37 (0.30)
Above elementary	-0.16 (0.65)	0.43 (0.22)	-0.13 (0.72)	-0.39 (0.26)	0.70* (0.02)	-0.14 (0.69)
Income of household						
<30 USD	0.42 (0.23)	-0.78** (0.01)	0.09 (0.81)	0.63 (0.05)	-0.88** (0.00)	0.03 (0.93)
31 - 50 USD	-0.40 (0.26)	0.50 (0.14)	0.11 (0.77)	-0.26 (0.46)	0.10 (0.77)	0.19 (0.59)
50 < USD	-0.09 (0.81)	0.33 (0.36)	-0.15 (0.69)	-0.36 (0.31)	0.67* (0.03)	-0.16 (0.66)
Household water environment						
Water disposal						
Open land	-0.02 (0.95)	-0.36 (0.31)	0.31 (0.38)	0.21 (0.56)	-0.22 (0.55)	-0.05 (0.90)
Grass land	-0.27 (0.45)	-0.23 (0.52)	0.53 (0.12)	0.17 (0.63)	-0.19 (0.60)	-0.04 (0.92)
Ground	0.24 (0.51)	-0.21 (0.57)	-0.14 (0.70)	0.38 (0.28)	0.13 (0.71)	-0.51 (0.13)
Wet land	-0.05 (0.89)	0.17 (0.65)	-0.07 (0.86)	-0.10 (0.78)	-0.45 (0.19)	0.47 (0.17)
Water resource						
Tap	-0.11 (0.76)	0.39 (0.26)	-0.17 (0.64)	-0.31 (0.38)	0.75* (0.01)	-0.27 (0.45)
Surface water	0.40 (0.26)	-0.41 (0.24)	-0.18 (0.62)	0.54 (0.11)	-0.30 (0.40)	-0.34 (0.34)
Ground water	-0.07 (0.84)	-0.38 (0.28)	0.39 (0.27)	0.10 (0.79)	-0.69* (0.03)	0.45 (0.19)
Rain water	-0.17 (0.64)	-0.32 (0.36)	0.47 (0.17)	-0.01 (0.99)	-0.31 (0.38)	0.26 (0.48)
Mixed water	0.00 (0.99)	0.30 (0.40)	-0.24 (0.51)	-0.03 (0.94)	-0.14 (0.71)	0.14 (0.71)
Latrine posessions						
Yes	-0.72* (0.02)	0.66* (0.04)	0.40 (0.25)	-0.68* (0.03)	0.78** (0.01)	0.10 (0.79)
Septage Removal (Removal excreta)						
Yes	-0.24 (0.51)	0.48 (0.16)	-0.08 (0.82)	-0.32 (0.37)	0.54 (0.10)	-0.09 (0.80)
Sanitary behavior						
Water treatment						
No treating	0.23 (0.52)	-0.58 (0.08)	0.16 (0.65)	0.45 (0.19)	-0.89** (0.00)	0.23 (0.52)
By alm	-0.04 (0.92)	0.34 (0.34)	-0.22 (0.54)	-0.26 (0.46)	0.57 (0.09)	-0.17 (0.63)
By boiling	-0.19 (0.61)	0.54 (0.11)	-0.19 (0.60)	-0.42 (0.23)	0.86** (0.00)	-0.24 (0.50)
By filter	-0.43 (0.22)	0.65* (0.04)	0.03 (0.93)	-0.52 (0.13)	0.84** (0.00)	-0.12 (0.74)
Defecation habits of children						
Open field	0.12 (0.73)	-0.42 (0.23)	0.17 (0.64)	0.34 (0.34)	-0.63 (0.05)	0.14 (0.69)
Latrine	-0.20 (0.58)	0.46 (0.18)	-0.11 (0.76)	-0.41 (0.23)	0.75* (0.01)	-0.16 (0.66)
Room	0.35 (0.32)	0.30 (0.39)	-0.69* (0.03)	-0.03 (0.95)	0.14 (0.70)	-0.08 (0.82)
Velanda	-0.42 (0.23)	-0.10 (0.79)	0.61 (0.06)	-0.12 (0.75)	0.15 (0.68)	0.01 (0.99)
Hands washing before meal						
No wash	1.00 (0.00)	-0.62 (0.06)	-0.78** (0.01)	0.88** (0.00)	-0.41 (0.24)	-0.61 (0.06)
Wash with soap	-0.62 (0.06)	1.00 (0.00)	0.00 (0.99)	-0.73* (0.02)	0.63 (0.05)	0.27 (0.45)
Wash without soap	-0.78** (0.01)	0.00 (0.99)	1.00 (0.00)	-0.55 (0.10)	0.03 (0.94)	0.56 (0.09)
Hands washing after defecation						
No wash	0.88** (0.00)	-0.73* (0.02)	-0.55 (0.10)	1.00 (0.00)	-0.45 (0.19)	-0.70* (0.02)
Wash with soap	-0.41 (0.24)	0.63 (0.05)	0.03 (0.94)	-0.45 (0.19)	1.00 (0.00)	-0.32 (0.37)
Wash without soap	-0.61 (0.06)	0.27 (0.45)	0.56 (0.09)	-0.70* (0.02)	-0.32 (0.37)	1.00 (0.00)

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 0-8 Influence of flooding and social factors to variance between areas (pre-monsoon)

	model 1	model 2	model 3	model 4	model 5	model 6
	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)
Socio-demographic factors						
Mother's age						
<38		1.00	1.00	1.00	1.00	1.00
>38		0.88 (0.63 -1.23)	0.87 (0.62 -1.22)	0.90 (0.63 -1.27)	0.90 (0.63 -1.27)	0.91 (0.63 -1.31)
Flooding Factors						
Flooding depth						
<0.37m			1.00		1.00	1.00
0.37-0.74m			1.29 (0.40 -4.18)		1.33 (0.39 -4.60)	1.04 (0.36 -3.02)
>0.74m			2.19** (1.00 -4.79)		2.29** (1.00 -5.24)	1.61 (0.77 -3.37)
Social Economic Factors						
Occupation of Father						
Unemployment				1.00	1.00	1.00
Government				0.58 (0.23 -1.46)	0.58 (0.23 -1.45)	0.49 (0.19 -1.28)
Private				0.72 (0.32 -1.61)	0.73 (0.33 -1.63)	0.58 (0.25 -1.35)
By my self				0.59 (0.27 -1.29)	0.59 (0.27 -1.29)	0.45 (0.19 -1.03)
Mother's education level						
No				1.00	1.00	1.00
Below elementary				1.04 (0.72 -1.49)	1.03 (0.72 -1.48)	1.03 (0.70 -1.52)
Above elementary				0.98 (0.59 -1.65)	0.98 (0.58 -1.64)	1.09 (0.63 -1.87)
Income of household						
<30 USD				1.00	1.00	1.00
31-50 USD				0.90 (0.63 -1.28)	0.89 (0.62 -1.27)	0.83 (0.57 -1.21)
50 < USD				1.17 (0.56 -2.41)	1.12 (0.54 -2.33)	0.71 (0.32 -1.57)
Household Water Environment						
Water disposal						
Open land						1.00
Grass land						1.36 (0.83 -2.23)
Ground						0.78 (0.45 -1.36)
Wet land						1.13 (0.63 -2.04)
Other						1.50 (0.50 -4.49)
Water resource						
Tap						1.00
Surface water						0.92 (0.51 -1.68)
Ground water						0.80 (0.53 -1.22)
Rain water						0.91 (0.45 -1.84)
Mixed water						1.32 (0.78 -2.24)
Latrine type						
No						1.00
Yes						1.35 (0.86 -2.13)
Septage Removal (Removal						
No						1.00
Yes						1.07 (0.71 -1.62)
Household Water Environment						
Water treatment						
No treating						1.00
By alm						0.24 (0.03 -2.15)
By boiling						0.64 (0.37 -1.10)
By filter						0.75 (0.43 -1.31)
Defecation habits of children						
Open field						1.00
Latrine						0.69 (0.36 -1.33)
Room						0.92 (0.63 -1.33)
Velanda						0.52** (0.29 -0.94)
Hands washing before meal						
No wash						1.00
Wash with soap						0.50*** (0.30 -0.83)
Wash without soap						0.73 (0.46 -1.17)
Hands washing after defecation						
No wash						1.00
Wash with soap						0.73 (0.38 -1.39)
Wash without soap						0.85 (0.57 -1.26)
Variance between areas	0.623	0.627	0.507	0.666	0.527	0.406
(Standard error)	(0.175)	(0.176)	(0.155)	(0.207)	(0.183)	(0.228)
MOR	2.12	2.13	1.97	2.18	2.00	1.84

* *P* value < .10.

** *P* value < .05.

*** *P* value < .01

Table 0-9 Influence of flooding and social factors to variance between areas (mid-monsoon)

	model 1	model 2	model 3	model 4	model 5	model 6
	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)
Socio-demographic factors						
Mother's age						
<38		1.00	1.00	1.00	1.00	1.00
>38		1.19 (0.80 -1.75)	1.18 (0.80 -1.74)	1.24 (0.83 -1.85)	1.23 (0.82 -1.84)	1.17 (0.76 -1.78)
Flooding Factors						
Flooding depth						
<0.37m			1.00		1.00	1.00
0.37-0.74m			3.84 (0.61 -24.19)		3.04 (0.57 -16.21)	3.00 (0.46 -19.49)
>0.74m			2.52 (0.75 -8.42)		2.12 (0.70 -6.36)	2.42 (0.69 -8.45)
Social Economic Factors						
Occupation of Father						
Unemployment				1.00	1.00	1.00
Government				1.43 (0.53 -3.89)	1.44 (0.53 -3.91)	2.01 (0.70 -5.79)
Private				1.48 (0.60 -3.64)	1.48 (0.60 -3.64)	1.75 (0.68 -4.51)
By my self				1.77 (0.74 -4.20)	1.74 (0.73 -4.14)	2.62** (1.04 -6.61)
Mother's education level						
No				1.00	1.00	1.00
Below elementary				0.96 (0.64 -1.46)	0.96 (0.63 -1.46)	0.96 (0.61 -1.51)
Above elementary				0.89 (0.51 -1.56)	0.90 (0.52 -1.58)	0.93 (0.51 -1.67)
Income of household						
<30 USD				1.00	1.00	1.00
31-50 USD				0.93 (0.61 -1.41)	0.94 (0.62 -1.42)	1.05 (0.67 -1.63)
50 < USD				0.45** (0.20 -0.97)	0.46** (0.21 -0.99)	0.66 (0.29 -1.51)
Household Water Environment						
Water disposal						
Open land						1.00
Grass land						0.73 (0.40 -1.32)
Ground						0.85 (0.45 -1.60)
Wet land						0.72 (0.36 -1.42)
Other						0.74 (0.22 -2.50)
Water resource						
Tap						1.00
Surface water						1.78 (0.87 -3.64)
Ground water						0.92 (0.57 -1.46)
Rain water						1.44 (0.61 -3.38)
Mixed water						1.68 (0.90 -3.15)
Latrine type						
No						1.00
Yes						0.95 (0.56 -1.61)
Septage Removal (Removal						
No						1.00
Yes						0.65 (0.41 -1.05)
Household Water Environment						
Water treatment						
No treating						1.00
By alm						1.13 (0.19 -6.81)
By boiling						1.04 (0.58 -1.87)
By filter						1.29 (0.69 -2.39)
Defecation habits of children						
Open field						1.00
Latrine						0.43** (0.22 -0.86)
Room						1.11 (0.72 -1.72)
Velanda						1.48 (0.75 -2.90)
Hands washing before meal						
No wash						1.00
Wash with soap						2.05** (1.17 -3.60)
Wash without soap						1.61 (0.95 -2.73)
Hands washing after defecation						
No wash						1.00
Wash with soap						1.55 (0.78 -3.09)
Wash without soap						1.02 (0.65 -1.59)
Variance between areas	0.969	0.972	0.823	0.839	0.732	0.820
(Standard error)	(0.241)	(0.241)	(0.210)	(0.222)	(0.197)	(0.220)
MOR	2.56	2.56	2.38	2.40	2.26	2.37

* *P* value < .10.
** *P* value < .05.
*** *P* value < .01

Table 0-10 Influence of flooding and social factors to variance between areas (post-monsoon)

	model 1	model 2	model 3	model 4	model 5	model 6
	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)	AOR (95% Cl)
Socio-demographic factors						
Mother's age						
<38		1.00	1.00	1.00	1.00	1.00
>38		0.64** (0.44 -0.93)	0.63** (0.43 -0.92)	0.62** (0.42 -0.91)	0.61** (0.41 -0.90)	0.55*** (0.36 -0.84)
Flooding Factors						
Flooding depth						
<0.37m			1.00		1.00	1.00
0.37-0.74m			1.45 (0.52 -4.05)		1.46 (0.57 -3.78)	1.40 (0.57 -3.41)
>0.74m			1.92 (0.96 -3.83)		1.80 (0.95 -3.41)	1.56 (0.84 -2.91)
Social Economic Factors						
Occupation of Father						
Unemployment				1.00	1.00	1.00
Government				0.74 (0.29 -1.86)	0.75 (0.30 -1.90)	0.68 (0.25 -1.83)
Private				0.77 (0.34 -1.74)	0.80 (0.35 -1.81)	0.74 (0.31 -1.78)
By my self				0.85 (0.39 -1.85)	0.85 (0.39 -1.85)	0.71 (0.31 -1.66)
Mother's education level						
No				1.00	1.00	1.00
Below elementary				0.90 (0.60 -1.34)	0.90 (0.60 -1.34)	0.83 (0.54 -1.28)
Above elementary				0.80 (0.46 -1.40)	0.80 (0.46 -1.40)	0.79 (0.44 -1.41)
Income of household						
<30 USD				1.00	1.00	1.00
31-50 USD				1.53** (1.03 -2.28)	1.53** (1.03 -2.28)	1.59** (1.04 -2.45)
50 < USD				1.01 (0.47 -2.19)	1.00 (0.47 -2.14)	1.33 (0.60 -2.94)
Household Water Environment						
Water disposal						
Open land						1.00
Grass land						2.00** (1.16 -3.47)
Ground						1.78 (0.98 -3.20)
Wet land						1.53 (0.81 -2.87)
Other						0.73 (0.24 -2.22)
Water resource						
Tap						1.00
Surface water						1.00 (0.53 -1.87)
Ground water						1.13 (0.73 -1.77)
Rain water						1.71 (0.78 -3.77)
Mixed water						0.72 (0.40 -1.30)
Latrine type						
No						1.00
Yes						1.46 (0.88 -2.42)
Septage Removal (Removal						
No						1.00
Yes						0.86 (0.54 -1.37)
Household Water Environment						
Water treatment						
No treating						1.00
By alm						1.95 (0.40 -9.44)
By boiling						1.21 (0.69 -2.13)
By filter						1.37 (0.76 -2.45)
Defecation habits of children						
Open field						1.00
Latrine						0.56 (0.29 -1.10)
Room						0.81 (0.54 -1.23)
Velanda						0.56 (0.30 -1.04)
Hands washing before meal						
No wash						1.00
Wash with soap						0.90 (0.53 -1.53)
Wash without soap						0.92 (0.56 -1.54)
Hands washing after defecation						
No wash						1.00
Wash with soap						0.51 (0.26 -1.00)
Wash without soap						1.13 (0.73 -1.74)
Variance between areas	0.515	0.518	0.419	0.447	0.356	0.301
(Standard error)	(0.156)	(0.157)	(0.142)	(0.169)	(0.153)	(0.152)
MOR	1.98	1.99	1.85	1.89	1.77	1.69

* *P* value < .10.

** *P* value < .05.

*** *P* value < .01