

Remote Sensing & GIS Based Spatio-Temporal Change Analysis of Wetland in Dhaka City, Bangladesh

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Abstract

Landscape of Dhaka city—one of the fastest growing mega cities in the world, is continuously changing due to un-planned urbanization. For example, the wetlands of the city have been shrinking. This study evaluates wetland changes in Dhaka Metropolitan Area (DMA), Bangladesh, between 1978 and 2009. Spatial and temporal dynamics of wetland changes were quantified using four Landsat images, a supervised classification algorithm and the post-classification change detection technique in GIS environment. Accuracy of the Landsat-derived wetland maps ranged from 87% to 92.5%. The analysis revealed that area of wetland and Rivers & Khals in Dhaka city decreased significantly over the last 30 years by 76.67% and 18.72% respectively. This changing trend of wetlands makes the drainage system of Dhaka City vulnerable, creating water logging problems and their consequences. Land filling and encroachment were recognized to be the main reasons for shrinking of the wetlands in the city. Development and alteration of the existing water bodies should consider the natural hydrological conditions.

Keywords: Wetlands, Remote Sensing, GIS, Dhaka City, Bangladesh, Change Analysis

1. Introduction

Dhaka City has been suffering from many environmental problems including flooding, water logging and other related problems. In the past the City was regarded as the Venice of the East or the City of Channels [1]. A few decades ago there were numerous lowlands, Khals and channels within and around Dhaka that would drain the City efficiently [2]. Khals of the city are used to be the connecting channels of the rivers surrounded by the greater Dhaka [3]. But nowadays, the situation is completely different. The City has spread over the years in all directions and such expansion has caused shrinkage of the natural drainage and wetlands [4]. Moreover, most of the khals have disappeared and banks of the surrounding rivers are encroached and/or grabbed gradually due to a number of reasons. The major causes are unplanned urbanization, encroachment, lack of co-ordination between government agencies, maintenance to the system and implement of pertinent laws [5]. As a result each year the city dwellers suffer acute water logging problems during the rainy season. In a report on Strategic Environment Assessment of Dhaka, water logging has been identified

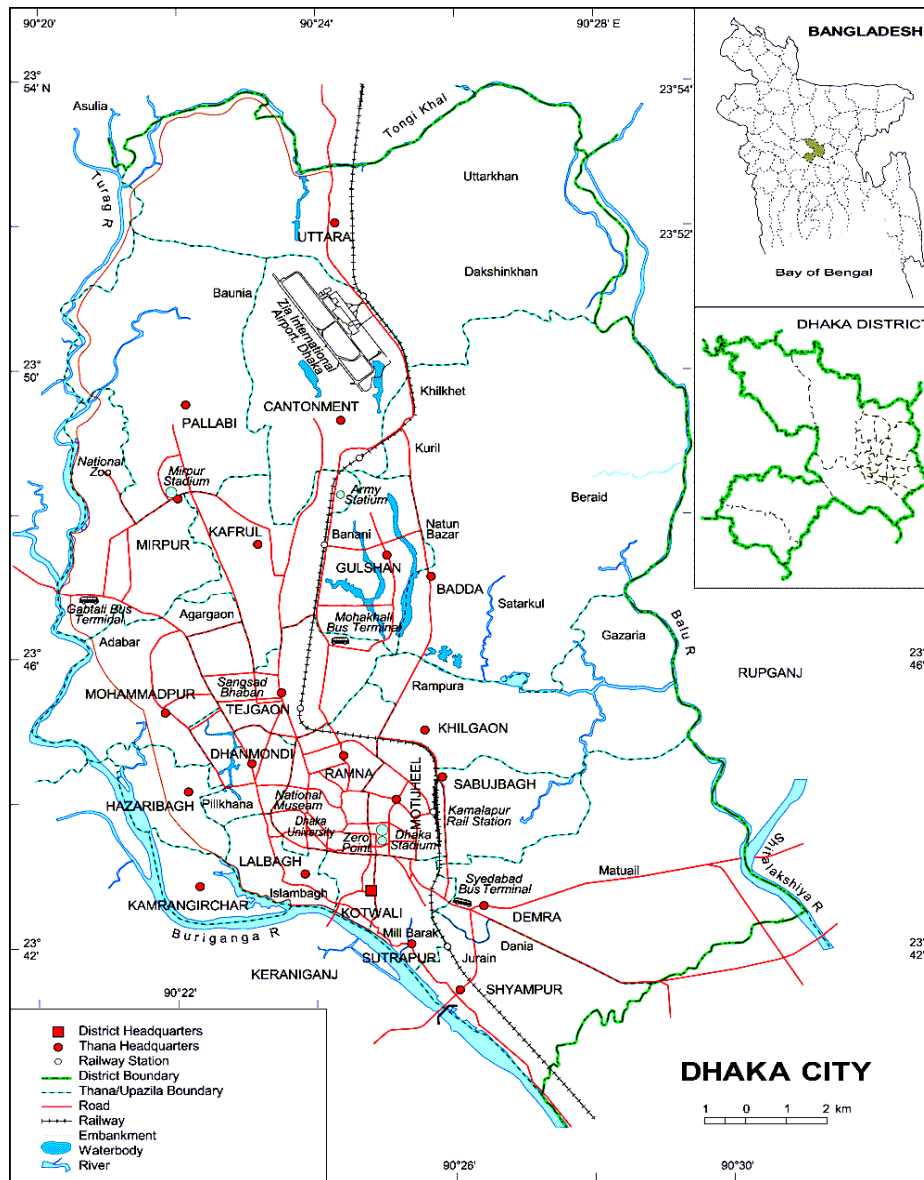
as one of the major problems of the City [6]. During monsoon rains, many areas of Dhaka go under water, because canals, being the primary drainage system of the city are blocked, cannot carry the huge volume of storm water [7]. The situation has turned very severe in recent years, and main streets now go under a meter of water after heavy monsoon shower [8]. There is no single authority for the management of wetlands in Dhaka City, thus creating a lack of coordination among the related organizations. Because water logging is one of the major problems of the City, there is an immediate need to implement land use regulations and strict enforcement mechanisms, restrictions to the land encroachment on the bank of the Khals in the city and implementations of cities' urban and drainage master plans [9]. On the other hand, there is no specific map or well-documented records of wetlands of the City. The land grabbers take this opportunity to encroach the wetlands [10]. It is urgent to identify the wetlands, evaluate its trend of changes and their consequences on the wetlands. The aims of this study therefore were to identify the past and present spatial extent of wetlands, their changing patterns during 1978-2009, and the physico-environmental consequences

on the area.

2. Study Area

Dhaka Metropolitan Area (DMA) is the study area of this study and it is located between longitude 90°20'E & 90°30'E and latitude 23°40'N & 23°55'N (Figure 1). The total area of Dhaka Metropolitan Area (DMA) area is 306 km² [11]. Total population is about 9.3 million [12]. Rivers all around bound the periphery of Dhaka. The strategic location of Dhaka connects it with the rest of the country with a network of rivers. At the beginning of urbanization, this region took the advantages of this river

system at full extent [13]. The river Buriganga lies in the south, the Balu River in the east and the Turag River in the north and west. James Rannell, who surveyed the rivers of east Bengal in 1765, wrote “the kingdom of Bengal, particularly the eastern part, is naturally the most convenient for trade within itself of any country in the world; for the rivers divided into such a number of branches that the people have the convenience of water carriage to and from any principal place” (letter from J. Rannell to the Reverend Gilbert Barrington, Vicar of Chudleigh, Devon, cited in Ahmed, 1986). Dhaka being situated in the center of the then east Bengal had a significant command on all these water routes [14].



Source: Banglapedia.

Figure 1. Study area.

3. Definition of Wetland

According to Ramsar Convention ‘Wetland includes a wide variety of habitats such as marshes, peat ponds, floodplain, rivers and lakes and coastal areas such as salt-marshes, mangroves, and sea grass beds but also coral reefs and others marine areas no deeper than six meters at low tide, as well as human made wetlands such as waste water treatment ponds and reservoir’ [15].

According to Khan *et al.*, ‘wetland holds water for a significant duration sufficient to support organism adapted to life in inundated or saturated soil condition and consists of wide variety of types ranging from lakes, rivers and coastal forest to deepwater paddy fields and ponds’ [9]. The built-up area of the city is traversed and surrounded by wetlands of different types.

This study indentified wetland on following categories.

1) Wetland: Wetlands comprises marshy and peaty inundated (during significant part of the year) low-lying areas of the Turag-Buriganga and the Balu floodplains [16].

2) Rivers & Khals: Turag, Buriganga, Balu rivers and canals (local name: Khals) are belongs to this category.

4. Data & Software Used

In order to compare the water bodies of Dhaka Metropolitan Area, Landsat MSS image of 1978, 1988 and Landsat TM image of 1998, 2009 were used. Spatial resolution of all of these images was 30m except the image of 1978 which was 60m in spatial resolution. Band 1, 2, 3 was used for image classification. Images represent wet season of DMA as they were captured June to August on different images. It was assumed that temporal changes of water bodies remained insignificant over the period of two months, at least for city wide change analysis.

The study has been carried out under the frame work of Geographic Information System (GIS) and Remote Sensing. The image processing task has been carried out using (Earth Resource Data Analysis System) ERDAS 9.2 image processing software (Leica Geosystems Geospatial Imaging, LCC, Norcross, USA). Data on wetland features has been extracted by ERDAS Imagine 9.2 software. However, GIS task has been carried out using ArcGIS 9.3.1 version (Figure 2).

5. Data Processing Analysis

Geometric correction was performed on all images using a Landsat MSS image of same area from 2009 as referenced. At least 30 ground control points (GCPs) were

used to register the image to Bangladesh Transverse Mercator (BTM) system. GCPs were dispersed throughout the DMA area yielding a RMS error of less than 0.5 pixels. A first order polynomial fit was applied and images were resampled to 30 m output pixels using nearest neighbor method. All three reflective bands were used in image classification. Parallelepiped was used as non-parametric rules.

GIS tools, such as area of interest (AOI) were applied to the data using visual analysis, reference data as well as local knowledge to split and record these covers so they more closely reflected their true classes [17]. By applying these techniques, the result obtained using supervised algorithm with Maximum likelihood technique as parametric rules and Parallelepiped as non-parametric rule which ultimately improved the output results.

In addition, geospatial data including municipal boundaries, road network, geomorphic units and elevation data were used to produce GIS layers from different sources.

A ground truth map was prepared for locating training pixels on the image and 80 reference points were collected using Global Positioning System (GPS). Magellan Triton 300 Handheld GPS was used for this task. This GPS information was overlaid with the image in GIS to select training areas and for accuracy assessments. Confusion matrix along with error of omission & error of commission [18] was used for accuracy assessment. Over all accuracy was 87% to 92.5%.

Classified images were analyzed using ArcGIS 9.3.1 software. With some additional shape file of permanent water bodies, rivers and DMA boundary, final output maps of wetlands of different years in DMA were prepared in GIS environment.

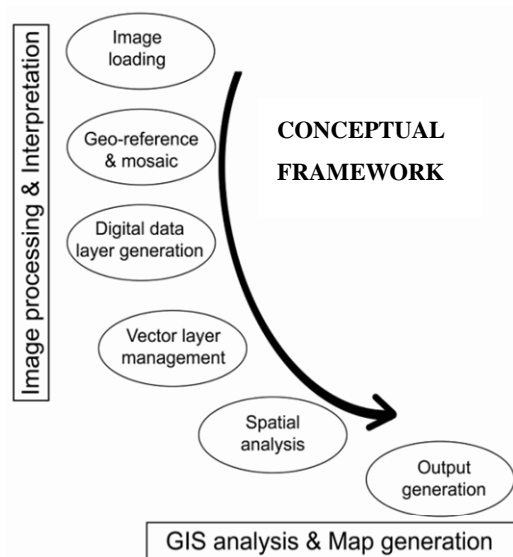


Figure 2. Conceptual framework.

6. Results & Discussion

In the beginning of urbanization phase (1978), about 29 km² of Rivers & Khals and about 130.17 km² of wetlands were found in Dhaka Metropolitan Area. In 2009, only 10.28 km² of Rivers & Khals and 53.6 km² of wetland is existed which is about 21% of Dhaka Metropolitan Area. However, this figure was about 52% in 1978.

Total 18.72 km² of rivers and Khals were lost during this 30 years interval from 1978 to 2009 which was about 64.55% of Dhaka Metropolitan Area (**Table 1**). There was a depiction between 1988 and 1998 when only 7.97 km² of Rivers and Khals were lost which was about 7.97% of total existing rivers and wetlands in 1978. In comparison to previous and following decades this number of lost is less significant. About 7.97 km² and 8.44 km² of Rivers & Khals were lost in the decades of 1978-1998 and 1998-2009 which was about 27.48% and 29.10% of existing rivers and Khals in 1978.

An ever increasing trend of wetlands loss is found in

DMA between 1978 and 2009. In 1978, 130.27 km² wetland existed which reduced to 127.85 km² in 1988 at a rate of 1.86 in that decade. This change was quite insignificant in comparison to next decades. About 20.92 km² of wetland was lost between 1988 and 1998 which was about 16.07% of existing wetlands in 1978. This rate of loss of wetland in DMA was almost tripled in next decades. About 40.96 km² of wetland was lost from 1998 to 2009 which was about 40% of existed wetland in 1978. Overall, about 76.67 km² of wetlands were lost between 1978 and 2009 (**Figure 3**).

Table 1. Wetland and Rivers & Khals in DMA between 1978 and 2009.

	Year			
	1978	1988	1998	2009
Wetlands	130.17	127.85	106.93	53.6
Rivers & Khals	29	21.03	18.72	10.28

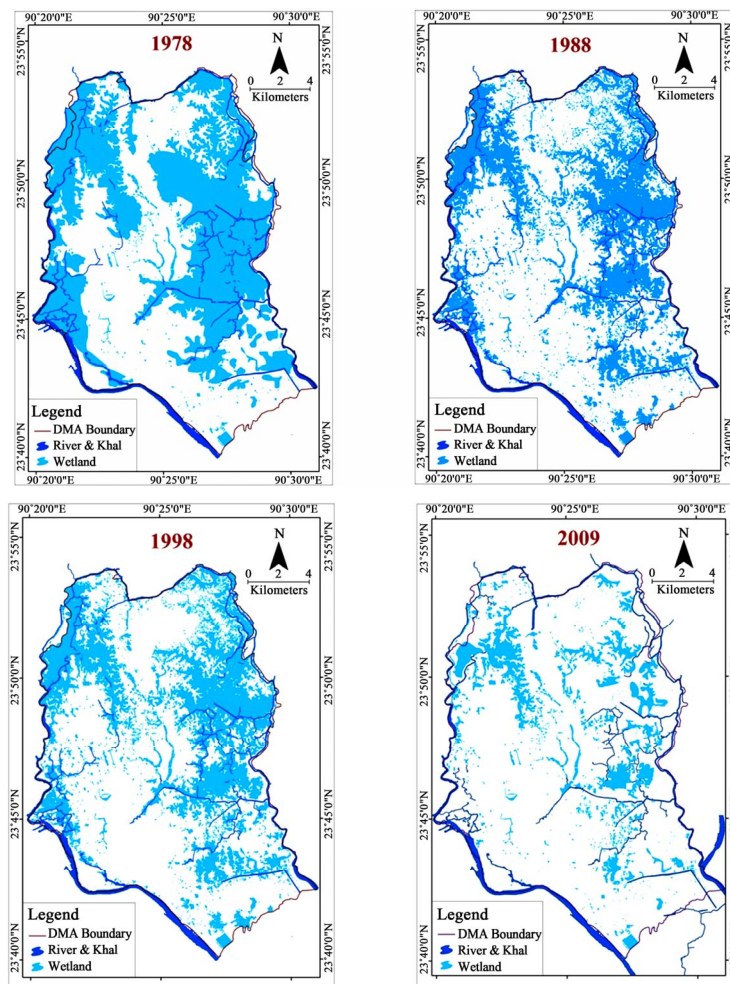


Figure 3. Wetland in Dhaka metropolitan area between 1978 and 2009.

To sum up, about 18.72 km² of Rivers & Khals and about 76.67 km² of wetland is lost during last 30 years from 1978 to 2009 (Figure 4). That means, about 60% of existing wetlands and about 65% of Rivers & Khals are lost in last three decades in Dhaka Metropolitan Area (DMA).

Urban expansion has been encroaching in the low-lying areas to cope with population growth, is the main reason for the reduction of wetland areas in the city. From the history of growth of the city, e.g. demonstrated that the city was remaining almost same up to the late 1980s. Area of water bodies in the western part of the city reduced to 91% of 1963 in 1990, which dropped to 63% of 1963 in 2000 [19]. Significant correlation of loss of wetland and Rivers & Khals are also found with increasing urban population and build-up area (Table 2).

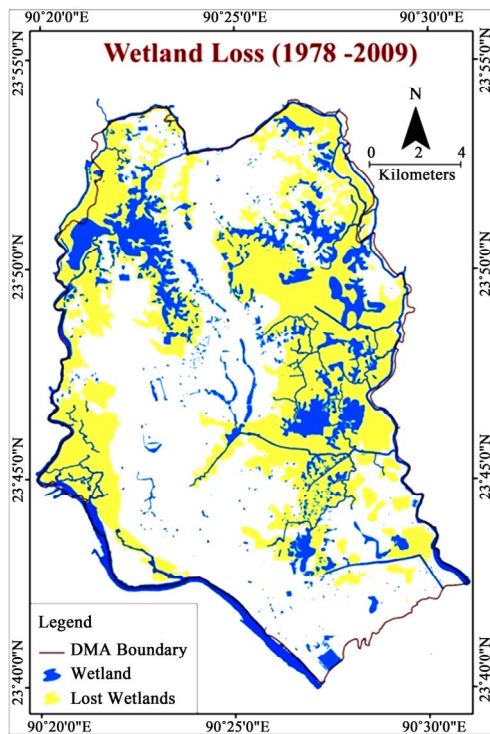


Figure 4. Wetland Loss in DMA between 1978 and 2009.

Table 2. Pearson’s Correlation between variables.

	Variables			
	Buildup Area	Wetland	Rivers & Khals	Population
Buildup Area	1.000	-0.957	-0.973	0.999
Wetland	-0.957	1.000	0.908	-0.967
Rivers & Khals	-0.973	0.908	1.000	-0.972
Population	0.999	-0.967	-0.972	1.000

7. Impact of Loss of Wetland in Dhaka City

7.1. Impact on Flooding Situation of Dhaka City

Wetlands of Dhaka metro area perform a significant role to reduce impact of flood [20,21]. Within the embankment area, these flood plain wetlands act as storm water retention areas. Outside the embankment they are active flood plains of adjacent rivers. Bangladesh atomic energy commission and SWMC (Bangladesh Atomic Energy Commission and SWMC, 2002) carried out a study on Ashulia flood plain area to find the impact of land filling activity on the surrounding hydrology. Findings of the research states that; the land development will increase the water level of the river, which may cause drainage problem in the areas and flow velocity of the river will also increase.

7.2. Decrease of Ground Water Recharge Area and Ground Water Level

According to a study conducted by SWMC (2000), about 95% of water supplied for Dhaka is extracted from underground and average annual decline of ground water within the city area during 1995 to 1999 varied from 1.02 m to 2.46 m [22]. Low land play significant role in ground water recharge function.

7.3. Destruction of Natural Drainage System

Lowland has dominant role in drainage function. Lowlands act as detention storage areas. Storm runoff from the surrounding areas is stored in the lowland areas [23]. The accumulated runoff is gradually drained to the peripheral rivers through drainage canals [24]. Drainage system of Dhaka city consists of forty three major Khals (canals). But many of them do not exist anymore. These Khals used to drain out the waste water (domestic and sewerage) and storm runoff to the surrounding rivers.

7.4. Disturbance of Local Ecology and Biodiversity

Wetlands have significant impact on local ecology and biodiversity [25]. In most of the wetland, especially the fertile flood plains have high agricultural value. Paddy and other crops are cultivated here in the dry season. During the wet season, these wetlands merge with the adjacent rivers and become fishing grounds. Agriculture and fishing in these wetlands are very much associated with the economy of local people.

7.5. Destruction of Aesthetically Pleasant Recreational Sites

Wetlands within the city are mostly depression areas, marshes and natural canals. These wetlands are typically ill maintained and sites for shanty dwellings and dumping site of liquid waste [21]. On the other hand vast floodplain areas at the periphery of the city are aesthetically pleasant and well visited recreational sites.

7.6. Increase of Impervious Surface

A large number of researches have been done to study the impact of urbanization on flooding situation. It is believed that urbanization increases the magnitude of floods and reduces the average interval between floods that exceed a given magnitude [9]. Impact of urban development on hydrologic aspect of the site by each individual small changes may not be significant but the aggregate effect of the land development process drastically change the physical characteristics of land surface which certainly influence the drainage pattern.

8. Conclusions

It is true that urbanization in Dhaka city would not be stopped [13], but these should be based on further specific studies and understanding of the hydrological system of the area, not just demand driven unplanned expansion. In addition, drainage in Dhaka city is strictly controlled by land-relief and hence by gravitational drainage [26]. Special care should be given to the development and alteration of the existing water bodies so that natural hydrological condition can cope with the artificial structural actions [27]. Water management must be the first concern for any development in Dhaka city because of its natural settings.

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