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Impact of Urban Expansion on Surface Water Bodies in Dhaka Metropolitan Area of Bangladesh: A Remote Sensing and GIS Based Analysis

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ABSTRACT

Purpose: In previous time, there were large amount of water bodies in Dhaka Metropolitan (DMP) area but due to various development activities, it has been shrinking with the passage of time. This research investigates the changes amount of water bodies in DMP area and find out how much built-up area are developed on water bodies in last 30 years.
Methodology: The Landsat satellite data of 1989, 2002 and 2019 have been generated with unsupervised classification techniques which is used here to identify the water bodies and built-up area with the help of remote sensing and GIS based software like ERDAS IMAGINE, Arc Map 10.6.
Findings: According to the study, the reduction rate of water bodies in DMP is high as the built-up area is increasing rapidly. In the last 30 years almost 2066.28 hectares water bodies are reduced while 1180.46 hectares are transformed into built-up area.
Limitations: To collect the data of total water bodies in DMP area would bring more elaborate information but it would be time consuming and involved more authentic survey by related authorities.
Practical Implications: As Bangladesh is highly populous country and its urban growth is rising rapidly, the balanced urbanization program for built up area is really needed according to ecological system. The diminishing of water bodies are happening for exploitation which is an alarming concept for scarcity of fresh water and proper drainage system.
Originality/Value: Findings from this study can contribute in the urban planning, drainage planning and balancing the systems with topical processes for the eradicating the reduction rate of water bodies.

1. Introduction

The term urbanization once conveyed an image of a city's radial expansion into its rural surroundings (Carlson & Traci Arthur, 2000). Urbanization is a gift to the human society

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if it is controlled, coordinated and planned. Whereas, unplanned urbanization is a curse (B. Ahmed, Raj, & Maniruzzaman, 2009). In 2008 more than half of the world's population were urban dwellers and the urban population is expected to reach 81% by 2030 (Mohan, Pathan, Narendrareddy, Kandya, & Pandey, 2011). Like many other cities in the world, Dhaka, the Capital of Bangladesh is also the outcome of spontaneous rapid growth. As the growth of population in Dhaka is taking place at an exceptionally rapid rate, it has become one of the most populous Mega Cities in the world (B. Ahmed & Ahmed, 2012). Over the last three decades, DMP have experienced extensive urban land expansion that has created various negative impacts on the urban ecosystem (Du, Ottens, & Sliuzas, 2010). A few decades ago there were numerous lowlands, khals and channels within and around Dhaka that would drain the City efficiently (Mamun, Mahmood, & Rahman, 2013). But nowadays, the situation is completely different. Due to various natural and human induced reasons, the wetlands of the DMP have been shrinking with the passage of time (Zakir, Islam, & Hossain, 2016). Moreover, most of the canals have disappeared and banks of the surrounding rivers are encroached and grabbed gradually due to a number of reasons (Ali, 2006). In the process of urbanization, the physical characteristics of Dhaka City are gradually changing as plots and open spaces have been transformed into building areas, open squares into car parks, low land and water bodies into reclaimed built-up lands, etc (Byomkesh, Nakagoshi, & Dewan, 2012).

Nowadays the remote sensing techniques are used widely to identify various features (B. Ahmed & Ahmed, 2012). So to identify the water body and built-up area in Dhaka Metropolitan, Remote sensing techniques can also be used. This research is designed to identify the changes amount of water body in DMP area and also try to find out how much built-up area are developed on water body in this area, where 30 years multi-temporal open source imageries are used in 13 and 17 year's intervals (1989, 2002 & 2019).

2. Aim and Objectives

2.1 Aim

The broad aim of the research is to find out the water body changes in DMP Area and detect Existing Built-up areas on water bodies from Satellite Imageries.

2.2 Objectives

- Considering the above aim of the research, underpinned the following very specific objectives in order to carry the study goals.
- To detect the water bodies in DMP area from satellite imageries based on elements of image/photo interpretation techniques;
- To calculate the changes in water bodies in 30 years interval; and

- To identify existing infrastructures built on the identified water bodies above.

3. Study Area

Dhaka Metropolitan Area is located at the central part of the Bangladesh. This is surrounded by the Buriganga River in the south, the Balu River in the east, the Tongi Khal in the north and the Turag River in the west (Sultana, Islam G. M. Tarekul, & Islam, 2009). The city is situated mainly on an alluvial terrace, popularly known as the Modhupur terrace dating from the Pleistocene period. The elevation of DMP is ranging between 6 to 8 m (Dewan & Yamaguchi, 2009). This is one of the most populated area in the world with a density of 23,234 people per square kilometer ("World Population Review," 2019).

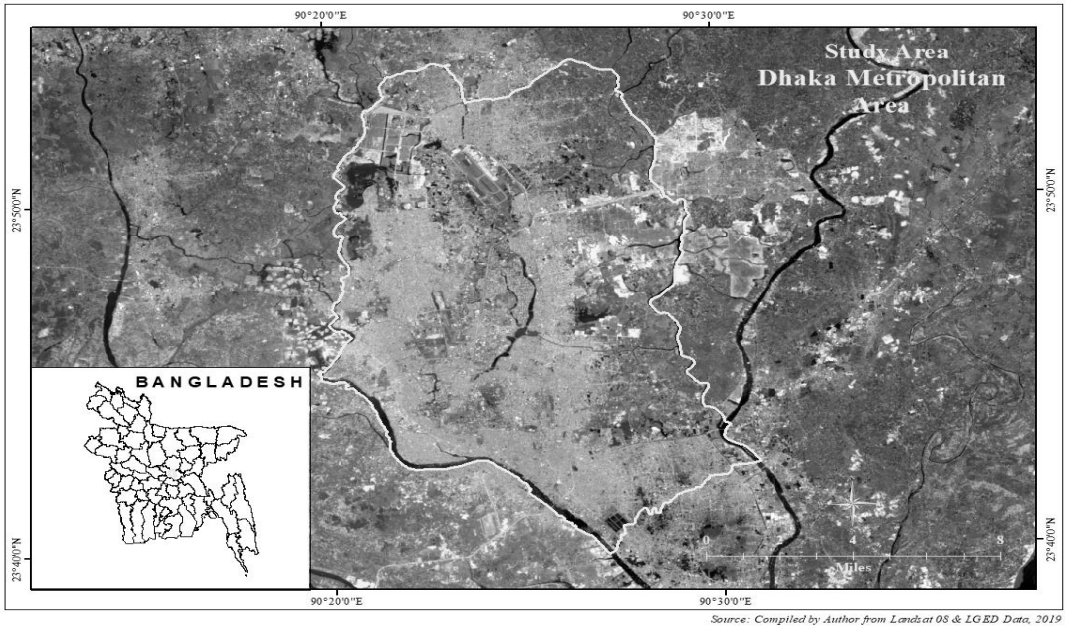

Figure 1. Location of the study area. Source: (Author, 2019)

4. Satellite Data

There are various types of open sources satellite data are found nowadays. Here in this study, we used the Landsat satellite data for its accessibility. The data are collected from the USGS server in the month of January and February. These months are considered as the cold and dry season of Bangladesh. In this season the cloud cover and the rainfall quantity are less. So, it gives more clear and accurate data for feature identification. In rainy season, due to rainfall water logged everywhere in the urban area specially in Dhaka city and many area which are not actually wetland also look like as water body which is another reason for using the data of winter season.

Table 1. Properties of Satellite imagery

Sensor	Year	Projection	Path-Row	Date Acquired	Spatial Resolution(m)	Cloud Cover
LS5 TM	1989	UTM	137-44	04/01/1989	30	01.00
LS7 ETM+	2002	UTM	137-44	01/02/2002	30	00.00
LS 8 OLI	2019	UTM	137-44	23/01/2019	10	00.02

Source: "U . S . Geological Survey," 2019

5. Materials and Methods

To identify the impact of urbanization on urban water body, the Landsat satellite data are used of the year of 1989, 2002 & 2019. For analyzing the satellite imagery the unsupervised classification techniques method are followed here. For raster reclassify, raster to polygon conversion, area calculation and map production ArcMap 10.6.1 are also used here. The methodological framework of this study is given below.

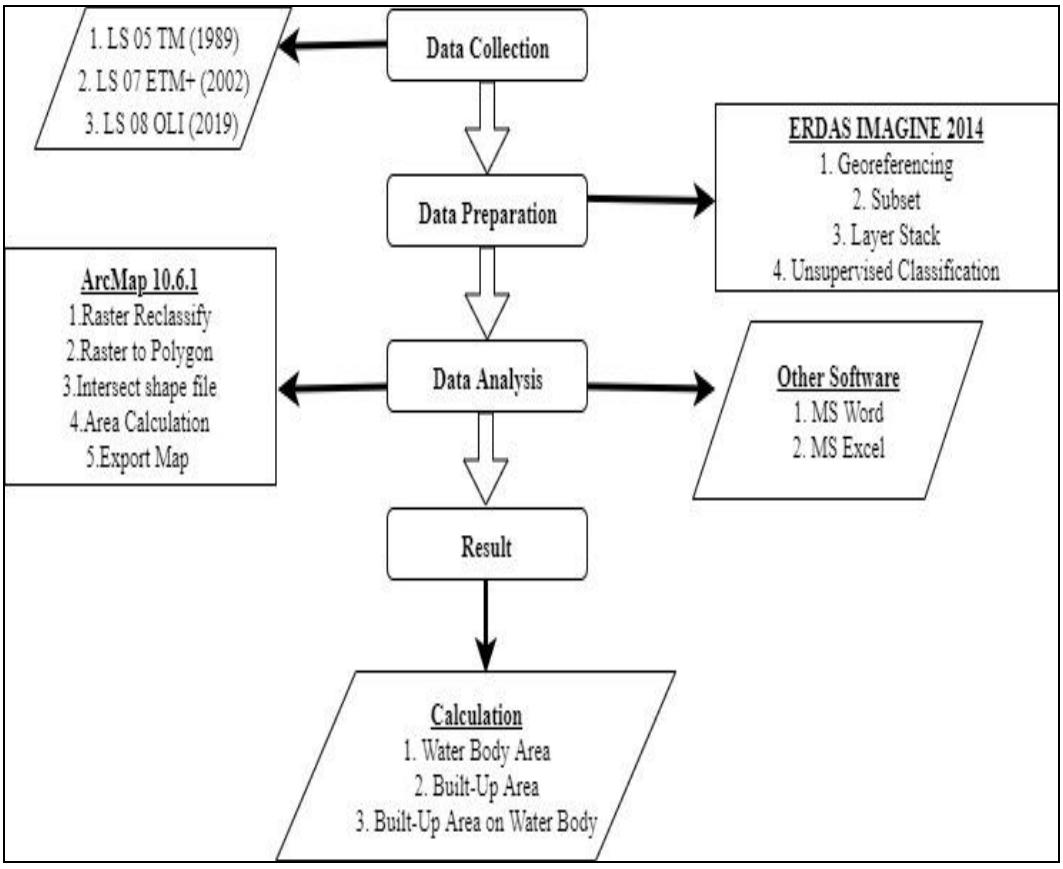

Figure 2. Methodological framework. Source: (Author, 2019)

6. Results

6.1 Water Body Area Identification and Calculation

By using the unsupervised classification techniques the water body of 1989, 2002 & 2019 are identified and calculated in this study. The calculated areas of water body in DMP for these years are tabulated in the (Table 2).

Table 2. Water Body DMP Area from 1989 to 2019

Year	Water Body (ha.)	Water Body (%) (in total area)
1989	4146.98	13.22
2002	3252.94	10.37
2019	1842.70	6.63

Source: (Author, 2019)

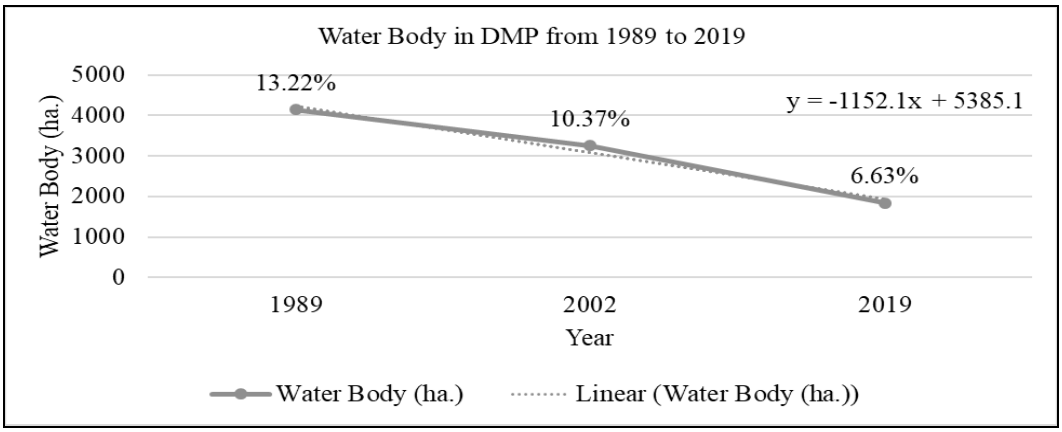

Figure 3. Water Body in DMP from 1989 to 2019. Source: (Author, 2019)

From the data and graph, it is seen that there is a negative change in the amount of water body. The total area of DMP is 31376 hectares. From the year 1989 to 2002, in this 13 years interval almost 894.04 hectares water body are reduced in this area and the reduction rate is 2.85%. Similarly, from the 2002 to 2019 in this 17 years interval 1410.13 hectares water body are reduced and the reduction rate is 3.74%. The graph 03 shows that the average reduction rate in every 15 years interval is -1152.1 hectares. But the trend line shows, from the year 1989 to 2002 the reduction rate is lower than the average value, on the other hand from the year 2002 to 2019 the reduction rate is higher than the average value and it is almost 1.58 times higher than the year 1989 to 2002. The overall change in water body area is -2066.28 hectares in these 30 years. The main causes of water body reduction in DMP area is the rapid growth of urbanization and industrialization process. The higher water body reduction rate in last 17 years indicates that these processes are also continuing nowadays.

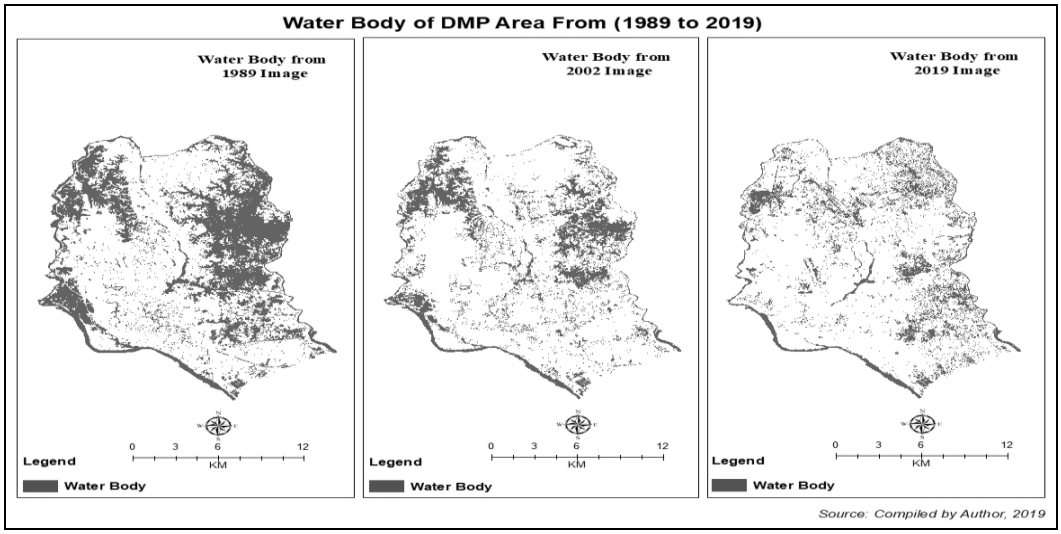

Figure 4. Water Body Map of DMP Area from (1989 to 2019). Source: (Author, 2019)

The figure 04 also shows that the water body area in DMP is reducing day by day. The reduction rate is higher in the north-eastern and north- western part of the study area. The north- eastern parts are the Badda, Uttarkhan, Dakshinkhan and the North-western part are the Uttara, Pallabi and Mirpur. Form the satellite image it is seen that, these are mainly converted with the settlement and maximum water body are filled up for housing and other purpose. Though DMP is one the most populated city in the world so for more accommodation and economic activities it needs more settlement and industry. That's the main reason for expanding city area. And the DMP is covered with many rivers, canals, wetland so finding no other way people fill wetland area as a result its amount is reducing day by day. So it is seen that, this land grabbing and water body reduction is mainly occurred for rapid urbanization and industrialization process.

6.2 Built-Up Area Identification and Calculation

By using the unsupervised classification techniques the built-up of 1989, 2002 & 2019 are also identified and calculated in this study. The calculated built-up areas in DMP for these years are also tabulated in the (Table 2).

Table 3. Built-Up Area in DMP from 1989 to 2019

Year	Built-Up Area (ha.)	Built-Up Area (%)
1989	3377.52	10.76
2002	5740.442	18.30
2019	9078.372	28.93

Source: (Author, 2019)

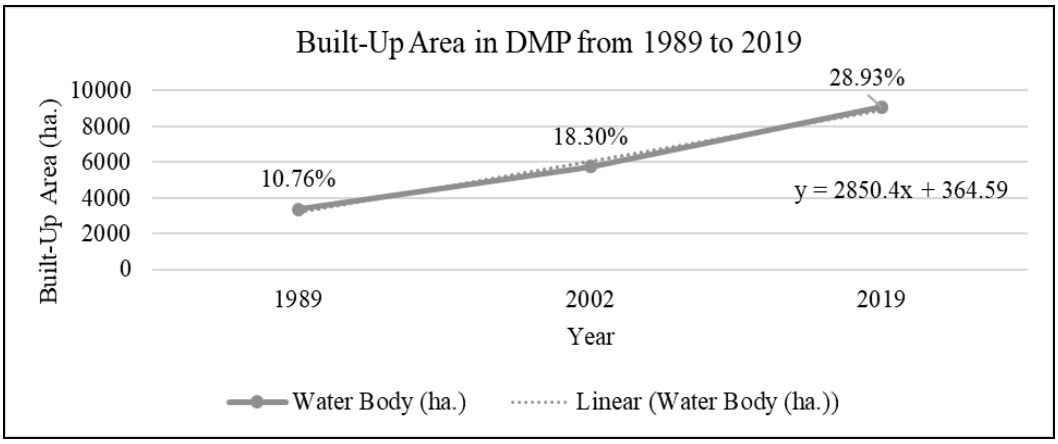

Figure 5. Built-Up Area in DMP from 1989 to 2019 Source: (Author, 2019)

Here the (Table 3) and the figure 05 indicate the built-up area status of last 30 years in DMP. From the data and graph, it is seen that there is a positive change in the amount of built-up area. From the year 1989 to 2002, in this 13 years interval almost 2362.93 hectares built-up are increased in this area and the increment rate is 7.54%. Similarly, from the 2002 to 2019 in this 17 years interval 3337.93 hectares built-up area increased and the increment rate is 10.63%. The graph 03 shows that the average increment rate in every 15 years interval is 2850.40 hectares. But the trend line shows, from the year 1989 to 2002 the increment rate is lower than the average value on the other hand from the year 2002 to 2019 the increment rate is higher than the average value and it is almost 1.41 times higher than the year 1989 to 2002. The overall increase in built-up area is 5700.86 hectares in these 30 years.

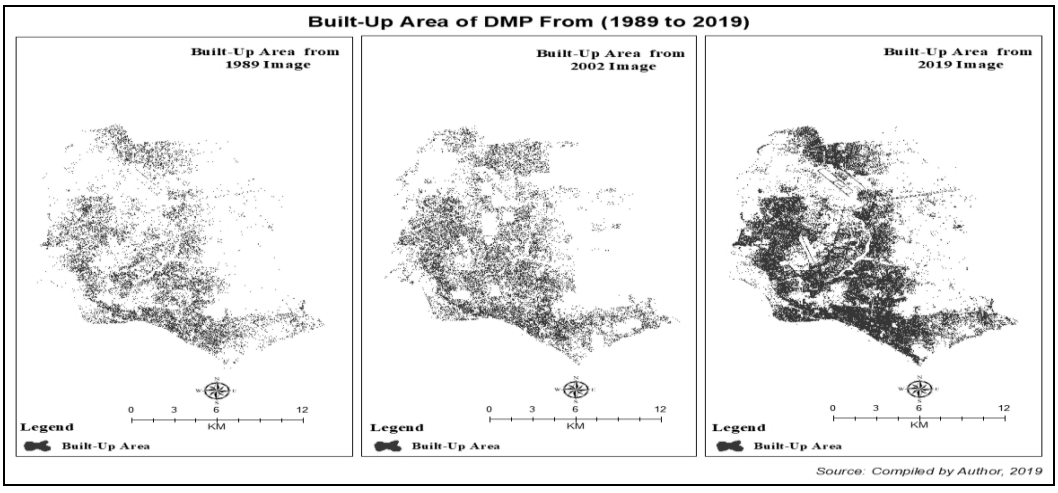

Figure 6. Built-Up Area of DMP from 1989 to 2019. Source: (Author, 2019)

The (Figure 6) shows that the built-up areas in DMP are increasing day by day. The increment rate is higher in the south-western, north- western and north-middle part of the study area. The south-western part are the Demra, Shampur, Sutrapur, Kotwali, Motijheel, Khilgaon, Ramna, Lalbagh,, Kamrangir Char, Tejgaon, Hazaribagh, Dhanmondi, Mohammadpur. The north-western parts are conjugated by Gulshan, Pallabi, Mirpur and kafrul and the north-middle parts are formed with some part of Uttara, Uttarkhan and Dakshinkhan (S. uddin Ahmed & Mohuya, 2013). Form the satellite image it is seen that, these are mainly converted with the multistoried building, infrastructure, roads etc. Though in the eastern part of DMP there is few built-up area but maximum of these land are converted into housing society from wetland. From the satellite image of 2019 it is clearly seen that, the land of this area are divided many plots by small boundary which means it may also be transformed into built-up area gradually with the passage of time and rapid urbanization process in the future ahead.

6.3 Identifying Built-Up area on Water Body

The built-up areas which are developed on the water body in the last 30 years are also identified here. For identifying the built-up area on water body we intersect the water body area with the built-up area.

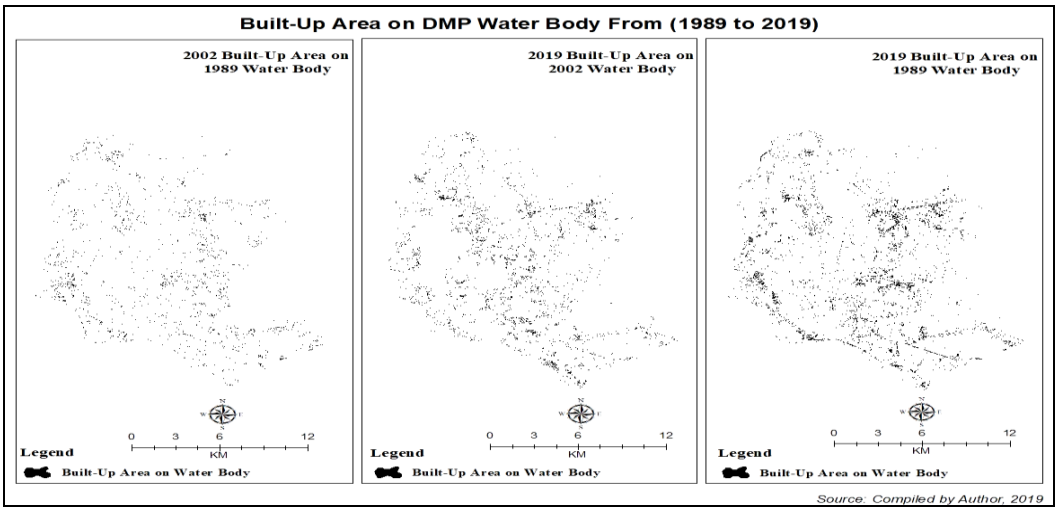

Figure 7. Built-Up area on DMP water Body From 1989 to 2019. Source: (Author, 2019)

Table 4. Built-Up area on Water Body from 1989 to 2019

2002 Built-Up Area on 1989 Water Body (ha.)	2019 Built-Up Area on 2002 Water Body (ha.)	2019 Built-Up Area on 1989 Water Body (ha.)
528.20	792.57	1180.46

Source: (Author, 2019)

The (Table 4) and figure indicate that the amount of built-up area on water body is increasing at a very higher rate. From the year 1989 to 2002 almost 528.20 hectares water body is transformed into built-up area on the other hand from the year 2002 to 2019 almost 264.37 hectares built-up area increased compared to the year 1989 to 2002. That means in last 17 (1989-2002) years the increment rate is 2.47 times higher compare to the last 13 (2002-2019) years. The table also indicates that overall 1180.46 hectares water body is converted into built-up area in last 30 years. From the map it is seen that almost in every part of DMP the water body is transformed into built-up area. And this process may be providence for the increment continuation day by day.

7. Discussion

Based on above discussion, it was found that the water body of DMP is rapidly decreasing. Estimates of water body using satellite images from 1989 to 2019 revealed that the rate of change in water body was consistently high, and in the last 30 years a total loss of 2066.28 ha. was observed in comparison to the base year of 1989 (Byomkesh et al., 2012). At present, for seeking work and better jobs several thousand population migrant into the city every year. Due to this overpopulation, Dhaka's urban infrastructure is highly stressed. As a result, water body are infringed and transformed into buildings and other infrastructures, resulting in more urban lands (Byomkesh et al., 2012). The causes of these changes in water body in the study area were identified. Among them, rapid population growth driven by rural–urban migration, economic development, and a lack of awareness among policymakers and city dwellers are contributing factors (Byomkesh et al., 2012). In addition, the use of political power to influence the illegal conversion, the role of real estate housing companies, a lack of appropriate rules and regulations to protect urban water body, a limited budget for the management of urban water body, and the mentality of the common people are also factors that contribute to the reduction of water body in DMP (Byomkesh et al., 2012).

8. Conclusion

For the excessive pressure of vast amount of population and their economic activities, Dhaka Metropolitan Area is expanding at an unplanned and uncontrolled way. Because of this rapid urbanization and industrialization process, the amount of wetland is decreasing at an alarming rate. It is also found that for construction of infrastructure, wetlands are randomly being filled up or encroached by mainly real estate housing companies and government organizations (Islam, Rahman, Shahabuddin, & Ahmed, 2010). From this study it is seen that, in 1989 the water body were 13.22 % compare to the total DMP are while it comes to 6.63% in the year 2019. But in case of built-up area it is completely different to the water body area. From the year 1989 to 2019 the built-up area increased 10.76% to 28.93%. If this built-up process and the water body reduction process will continue at this rate than one day there will be no water body in DMP. Then

the ecological balance of DMP will be destroyed and it will also create many of problems like, flooding, water logging, ground water depletion etc. So, it is the high time to take necessary steps for saving the existing water body in DMP area.

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