Chapter 17
Exploring the Spatio-temporal Patterns and Driving Forces of Urban Growth in Dhaka Megacity from 1990 to 2020

Kazi Jihadur Rashid, Tahmina Akter, A. S. M. Imrul Kayes, and Md. Yachin Islam

Abstract Dhaka is one of the most populous megacities, facing rapid urbanisation and population growth. It has been undergoing vast territorial expansion and infrastructural development in recent decades. These uncontrolled changes in the city degrade the environmental quality and reduce the health status of city dwellers. Understanding patterns and drivers is critical to regulating these changes and practising sustainable management. Therefore, this chapter aims to identify urban growth patterns and their pivotal driving forces in the megacity. Landsat (TM, OLI sensors) satellite imageries from 1990 to 2020 were used at decadal intervals to identify change patterns. Urban LULC was prepared using a hybrid classification method (combining supervised and unsupervised techniques). Afterward, the driving forces of urban growth in the city were investigated using spatial data layers in *geodetector* and data obtained through questionnaires survey, and previous literature. According to the analysis, the urban area increased by 40%, whereas green space declined by 41%. Major driving forces are anthropogenic, such as economic opportunities, education, and medical facilities, which worked as pull factors for rural–urban migration resulting in urban population growth. Natural determinants, such as drainage systems, inundated lands, suitable soil types and textures for building infrastructures; artificial determinants, such as distance from the city core, roads and railways worked together in shaping the spatial locations of the city expansion. To transform Dhaka into a sustainable city, policymakers should regulate or control these determinants.

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Introduction

Worldwide Urbanisation Trend

Over the last few decades, urbanisation has sped up worldwide (Grimm et al. 2008; United Nations 2021). Though the global north has more urban areas, the global south tends to have more rapid and high dynamics of urbanisation (United Nations 2018a; Wolvers et al. 2015). The number of people living in cities has grown from 12% in 1990 (Grimm et al. 2008) to more than 50% in 2011 (United Nations 2012). Despite only covering roughly 0.5% of the terrestrial surface of the earth, urban areas have higher population densities and growth rates than other types of land (Schneider et al. 2009). The size of urban areas worldwide increased fourfold from 1970 to 2000 (Seto et al. 2011) and is projected to rise by another three-quarters from 2000 to 2030 (Seto et al. 2012). This dramatic surge is typically the result of rapid population growth. Population expansion over the past few decades has led to massive urbanisation, which is becoming more common in developing nations (Liu et al. 2011). More than fifty percent of the world's population already lives in the urban region, and by 2050, this percentage is anticipated to increase by more than 68% (Lutz et al. 2001; United Nations 2018b). Approximately, 90% of the increase in the urban population will tend to happen in Asia and Africa (Yadav and Ghosh 2021). This upsurge has led to the formation of megacities with populations exceeding 10 million (Aguilar et al. 2003). Megacities worldwide are seeing extremely high levels of urban expansion, both vertically and horizontally, along with an increasing population rate (Florczyk et al. 2019; Kraas 2003). In 1950, there were just two megacities: New York and Tokyo (Gurjar and Lelieveld 2005). The number of megacities had risen to 33 by 2018, with 43 expected by 2030 (United Nations 2018b). Urban growth is higher in emerging countries than in industrialised nations and the majority of the world's megacities will be in developing countries by 2030 (United Nations 2019). As a result of growing populations and urbanisation, the form and pattern of urban land use and land cover have changed significantly and are anticipated to continue in the future decades (Fang et al. 2005).

Process of Urbanisation

Urban expansion is a complex spatial pattern influenced by internal growth and immigration into existing urban areas. Substantial rural–urban migration frequently accompanies economic development, resulting in massive urban agglomerations

(Ramachandra et al. 2015). Urbanisation mainly refers to the economic transformation of an agriculture-based into manufacturing and service-based (Mandal 2000). However, urbanisation has led to a decline in the area of rural landform and a rise in the area of urban landform over the past few decades, particularly in developing countries (Dewan et al. 2012; Dewan and Yamaguchi 2009; Jat et al. 2008). Social, political and ecological systems have unavoidably changed due to these rapid population movements and their interactions with the natural and artificial environments (Ahmed et al. 2012). The main drivers of urban growth are biophysical, or natural, and socio-economical, or anthropogenic. Biophysical or natural elements such as climate, geomorphic processes, topography, soil type and drainage patterns are important determinants of urban expansion (Fu et al. 2006; Opršal et al. 2016; Serra et al. 2008; Thapa and Murayama 2010).

Moreover, population expansion, large-scale rural–urban movement, rural–urban income disparity, industrialisation, economic globalisation (Rimal et al. 2018; Schneider et al. 2015) and government policy and regulations supporting urban-centric economies influence the natural factors. New land development occurs dispersed and irregularly beyond the city centre in the first stage of urban growth (Schneider and Woodcock 2008). As the process proceeds, the urban fabric becomes more continuous. Spatially compact and continuous structures of settlements in cities may experience a movement of spread urbanisation followed by a fresh wave of continuous expansion, merging formerly dispersed communities (Salvati et al. 2013). These processes are contingent upon the history and prior formation of cities, and they are intrinsically linked to the land policies that permit or prohibit land dynamics driven by urbanisation affecting global climate (Ceccarelli et al. 2013; Yao et al. 2015). Along with worsening climate, the effects on a wide range of biophysical systems will last very long (Serneels et al. 2007). This unplanned urbanisation and the associated change in land cover are the leading causes of habitat alteration, biodiversity loss, extensive exploitation of valuable agricultural land (Lambin and Meyfroidt 2011), degradation and isolation of wildlife habitats (Serneels et al. 2007), disruption of hydrological processes (Brown et al. 2012), degradation of green space (Asgarian et al. 2015) and risk to human health (Moore et al. 2003a).

Characteristics of Urbanisation in Bangladesh

Rural to urban migration has increased quickly in developing nations because of poor planning principles and the driver of economic development (Black and Henderson 1999). Asia's developing nations have the fastest rate of urbanisation expansion among the world's developing nations (United Nations 2019). In the 1950s, only 4% of Bangladesh's total population resided in urban areas, indicating a surprisingly low level of urbanisation across the nation. This percentage gradually increased after the country's independence in 1971 to approximately 5%, then accelerated quickly (Ahmed et al. 2012). Since the urban population in this group of nations is expanding faster than the rural population for the first time in decades, a historical shift has occurred throughout the decade (2000–2010) for low-income countries like Bangladesh (Weiss and Khan 2008). Around 25% of the population in Bangladesh lives in the urban regions, with more than half residing in the four main cities: Dhaka, Chittagong, Khulna and Rajshahi (BBS 2015; Helal uz Zaman et al. 2010). Even though Bangladesh is a rural-based country with a low urbanisation level in comparison with other Asian nations, the megacity of Dhaka has been experiencing a higher rate of urbanisation (Hassan and Southworth 2017). The capital city Dhaka produces 36% of the country's overall GDP and total employment of 31.8% (RAJUK 2016). It has witnessed a significant development in human settlements within (new settlement areas of 116 km^2) and around (234 km^2) the city between 1991 and 2019 (Roy et al. 2021). It is one of the world's most densely populated and rapidly urbanised cities, with a population that exploded from roughly 1 million in 1972 to 20 million or more in 2018 (UN-Habitat 2021; United Nations 2018b). The mega-urban centre of Dhaka is anticipated to have an annual population growth rate of 2.98% by 2030, with the total population in the city zone topping 27.37 million and beating the growth rates of other major urban centres such as Beijing, Shanghai and Mexico City (Ahmed et al. 2014; United Nations 2019). It seems unlikely that the population will stabilise or drop until 2060, when it could reach 230 million, with more than 70% living in metropolitan areas (Islam 2013). However, one of the essential factors of Dhaka's explosive expansion is the unstable rural economy, which compels hundreds of thousands of rural people to migrate to the city in search of improved lifestyles and better employment possibilities (Dewan and Yamaguchi 2009). With its rapid and unregulated expansion, the current urbanisation pattern has put Dhaka's environment, ecology and land resources at greater risk, especially with the closeness of extremely ecosensitive wetland areas of the city (Ahmed et al. 2005). The above makes the city one of the least livable places on earth, along with its intolerable traffic congestion, high levels of pollution and inadequate infrastructure and housing development (UN-Habitat 2021).

Application of Remote Sensing in Urbanisation Research

The ability to track the worldwide urbanisation of megacities has been made possible by the long-term remotely sensed collection of global images (Sun et al. 2021). Remote sensing is an important source of current and historical information about the earth's surface because it provides spatially consistent imageries of huge areas with high spatial resolution and temporal frequencies (Xiao et al. 2006; Zhang and Seto 2011). Geospatial data and technologies are frequently used in urban expansion research, with a particular emphasis on urban area extraction and spatio-temporal land cover classification to quantify urban dynamics (Chen et al. 2013; Sun et al. 2015). Traditional surveying and mapping techniques make updating information in areas undergoing fast land use changes difficult and time-consuming, making RS data especially useful. Multi-temporal RS data for examining the structural variation of LULC patterns (Liu and Phinn 2003) can be used to avoid the cumulative and irreversible impacts of urban growth (Yang et al. 2008) and is crucial to optimising the allocation of urban services (Barnsley and Barr 1996). Based on land use and land cover changes retrieved from remote sensing data, prior research has measured and studied the spatio-temporal dynamics of the urban landscape, driving forces and impacts of urbanisation (Ahmed et al. 2012; Barnsley and Barr 1996; Yadav and Ghosh 2021; Yin et al. 2011). Remote sensing data on land use and land cover can also be used to plan sustainable urban development and environmental planning (Jensen and Im 2007).

Rationale of the Study

Urbanisation is a global phenomenon that possibly represents the most extreme kind of irreversible land modification. It is the process by which a more significant proportion of individuals living in densely populated areas gain access to public utilities (Murtaza 2012). Population concentration in urban areas is increasing significantly around the globe, placing enormous pressure on land resources in particular. Since urbanisation drives environmental change at diverse stages, rapid urbanisation resulting from large-scale land use change in developing nations is a cause for grave concern (Dewan et al. 2012). Long-term urban expansion may be a better way to measure visible and hidden socio-economic changes in both developed and developing countries than other demographic and geographical factors (Gong et al. 2012; Weber and Sciubba 2019; Zitti et al. 2015). In the last several decades, under the effect of population increase and global migration, urbanisation has altered natural and social conditions to produce spatial shifts that continue to occur (Angel et al. 2011; Chen et al. 2014). Increasing human activity in urban areas has resulted in substantial changes in land use and landscape patterns on both the global and regional scales and is having a profound effect on the structure, function and dynamics of the ecosystem rendering vulnerable regions of urban areas (Deng et al. 2009; Weng 2007).

It is essential to assess the mechanisms involved in urban growth during the past many decades, particularly in the case of megacities, and to identify the driving forces to reduce the destruction (Sun et al. 2021). Due to the rapid rate of urban expansion in developing countries like Bangladesh, where intra- and inter-annual variation in land use patterns is significant, decadal changes are no longer sufficient (Hassan and Southworth 2017). Consequently, a greater frequency and a longer temporal sequence are necessary to study urban expansion. A complete view of the current state of different land use types and the physical direction and variety of their development dynamics in response to changing social and biophysical elements is necessary to provide the relevant authorities. This requires constant monitoring and comprehension of the rate of urban growth to sustain natural resources. Understanding the urbanisation process's growth and characteristics requires understanding urban areas, mainly their growth magnitude, shape geometry, driving forces and spatial pattern (Ramachandra et al. 2015). It is necessary to comprehend these interactions to address the global urban changes created by a complex combination of political, economic, cultural and environmental challenges.

As an essential aspect of urbanisation, urban expansion processes have been extensively examined in prior research. Research on the spatio-temporal characteristics of urban areas and their patterns can provide basic information and references for comprehending the driving forces of urbanisation and its processes on multiple levels, including international (Chakraborty and Lee 2019; Yin et al. 2011); national (Ahmed et al. 2013, 2012; Dewan and Yamaguchi 2009; Hassan and Southworth 2017). According to Hassan and Southworth (2017), flood-free higher land, the availability of a transportation network and the concentration of manufacturing-based employment centres are the key factors driving the city's northward expansion in Dhaka. Thus, this work's thematic map and spatial data enable a thorough understanding of urban expansion dynamics and land cover change patterns in Dhaka. Byomkesh et al. (2012) assessed the temporal fluctuation of greenspace in the city using several landscape matrices, such as patch density, number of patches and largest patch index. Based on LULC change research and urban growth studies conducted in South Asian cities, it has been shown that open space and vegetation (cropland and forest land) are predominantly transforming into urban areas (Yadav and Ghosh 2021). Although urbanisation brings economic and social benefits, it also affects the ecological status of the place and its surroundings.

Dhaka metropolis and its peripheries have undergone an unexpected metamorphosis due to poor implementation of urban planning and a lack of long-term vision (Bhatta 2010). Thus, Dhaka, one of the world's fastest-growing cities, presents a fascinating case study for researchers (Dewan and Yamaguchi 2009; Rana and Parves 2011). As a result of its large population concentration and rapid development dynamics, Dhaka is attracting attention as the nation's economic, political and administrative centre. Hence, more research and analysis must be done on the trends, patterns and processes of urbanisation in their spatial and temporal context. Integrating remote sensing and spatial metrics enables the extraction of spatial information regarding urban expansion, structure, and dynamics, which contributes to the comprehension of urban growth processes (Deng et al. 2009; Ramachandra et al. 2012). This research felt the need to shed light on the spatio-temporal pattern, drivers and impacts of urbanisation scenarios in Dhaka. The primary objective of this chapter is, therefore, to investigate and analyse urban growth patterns using Landsat (TM and OLI sensors) satellite images from 1990 to 2020 that were prepared using a hybrid classification method (combining supervised and unsupervised techniques) and to identify the key driving factors that influence changes in Dhaka's built-up areas. A geographic statistical method called geodetector was also used to evaluate spatial factors, and factors from the questionnaire were ranked based on people's perceptions. Understanding the urbanisation process could help us deal with the rising difficulties connected to increased urban living, take advantage of the agglomeration benefits of city clusters and eventually construct a sustainable future.

Materials and Method

Study Area

The location of Dhaka is on the eastern bank of the Buriganga at 23° 42′ N 90° 22′ E (Fig. 17.1). The city has a tropical savanna climate (Köppen Aw) according to the Köppen-Geiger climate classification. It is one of the hottest regions in Bangladesh, with an average daily high temperature of 31 °C and annual rainfall of 2055 mm (Khatun et al. 2016; Rahman et al. 2017). The city has a natural boundary of rivers and 43 canals that are getting encroached and filled (Ishtiaque et al. 2014). Thus, the drainage system is getting worse, and the city suffers from flash floods during excessive rainfall. As Bangladesh's capital and primate city, Dhaka has experienced tremendous growth in different fields such as economic, social, industrial and educational and has become the hub after the liberation war of 1971. The level of urbanisation went up to 28.37% in 2011 from 7.78% in 1972, respectively (Panday 2017). Dhaka city provides many economic, environmental and social opportunities, a habitat of nearly 18 million residents (United Nations 2019); however, rapid population growth becomes a significant challenge. The population of Dhaka increased from 2.3 million in 1975 to around 15.4 million in 2011 (Trotter et al. 2017).

Data Description

Both secondary and primary data was used in this research. Secondary data such as satellite images for LULC and GIS layers for spatial factor analysis was used. A questionnaire survey as primary source data was used to understand the driving forces of urbanisation and its impact. Landsat is a widely used satellite for LULC classification in urbanisation research (Mushore et al. 2017). The US Geological Survey freely provides it for the most prolonged period among all the available satellites. Landsat (OLI and TM sensors) images at ten years intervals (1990, 2000, 2010, 2020) were used to retrieve information on the urban land cover of the recent three decades in the study area. All the images were collected in the same season to have fewer phenological variations, and the winter season was selected because of the cloud-free sky. SRTM elevation data was also collected from the US Geological Survey. Driving forces-related data such as inundation land type, soil characteristics, drainage system, water bodies and wetlands, roads and railways, city core and planned areas was collected from different GOs, NGOs and literature. These layers were selected based on empirical studies discussed by Kim et al. (2020). A semi-structured questionnaire survey was conducted to learn about city dwellers' experiences and perceptions of the factors driving Dhaka's urbanisation. The survey was distributed to 200 people via Google Forms, e-mail and in-person interviews. The survey was carried out using a technique known as probable random sampling. Data characteristics are shown in Table 17.1.

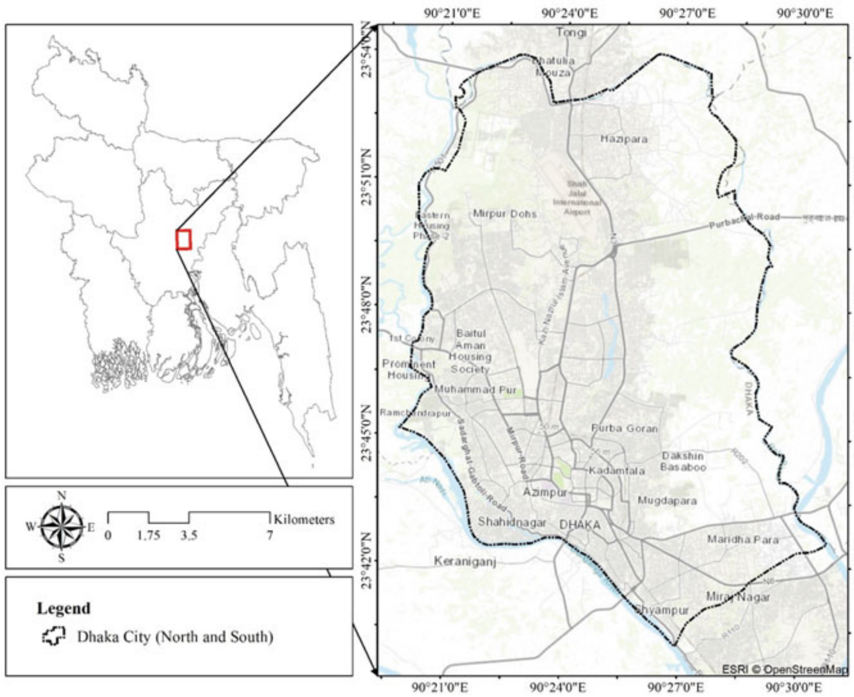


Fig. 17.1 Location map of the study area

Table 17.1 Description of data used in the study

Data type	Time	Source
Landsat OLI, ETM+ and TM sensors (30 m)	16 Jan 1990 13 Feb 2000 08 Feb 2010 06 Feb 2020	US Geological Survey
Inundation land type Topsoil texture General soil type Drainage	–	Bangladesh Agricultural Research Council (BARC)
Ponds and wetlands Rivers and canals	2020	WARPO/BWDB and Google map layer
Railway Major roads	2020	LGED
City core Planned area	2019 2020	Prepared by author based on Afrose et al. (2019) and Google map layer
Administrative boundaries		Govt. of Bangladesh (GoB)

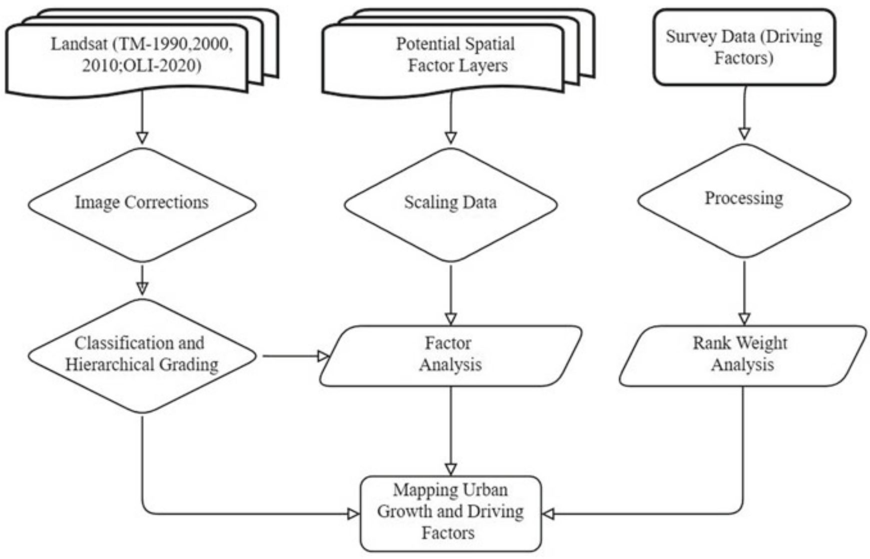
Methods

The data collection and processing procedures for the analysis and visualisation were carried out using ArcGIS, MS Excel and R programming. These tools were used based on their convenient application throughout the workflow (Flowchart 17.1).

Data processing

Landsat (TM and OLI/TIRS) data was collected from the US Geological Survey website. Level 1 terrain precision (L1TP) data was used in this study, which comes with geometric correction and is suitable for pixel-to-pixel change detection. Raw Landsat images were provided as DN (digital number) values. DN has no physical importance; thus, it must be converted into reflectance (Chavez 1989). The image was radiometrically calibrated and produced TOA (top of atmosphere) reflectance using the Semi-automatic Classification Plugin in QGIS (version 3.4). The TOA image was then corrected atmospherically using the DOS1 method (Pax-Lenney et al. 2001).

Natural and anthropogenic factors both have a significant impact on urban growth. This research examined the ten potential factors listed in Table 17.1 to see how they affected the urban growth pattern in Dhaka city. Euclidean distances were calculated for the spatial layers such as ponds and wetlands, rivers and canals, railways, major roads, city core and planned areas to generate continuous raster data. All the layers prepared for factor analysis were classified into four classes depending on their suitability for urbanisation. Figure 17.2 depicts the spatial distribution of all-natural



Flowchart 17.1 Methodological steps followed in this study

and anthropogenic factors. The questionnaire-derived data has been processed using MS Excel and R programming according to their ease of use.

Classification

For classification, this study used a hybrid classification method (combination of supervised and unsupervised techniques) for higher accuracy in classification results. Among different supervised methods, this study used the maximum likelihood classification (MLC) algorithm. MLC is one of the most popular and easy-to-use methods in remote sensing data analysis (Arai 2020; Tan et al. 2010). This method assumes a pixel's probability to a particular class based on multi-dimensional Gaussian probability density (Paola and Schowengerdt 1995). The mean vector and covariance matrix for the collected sample datasets are used to measure the probability density

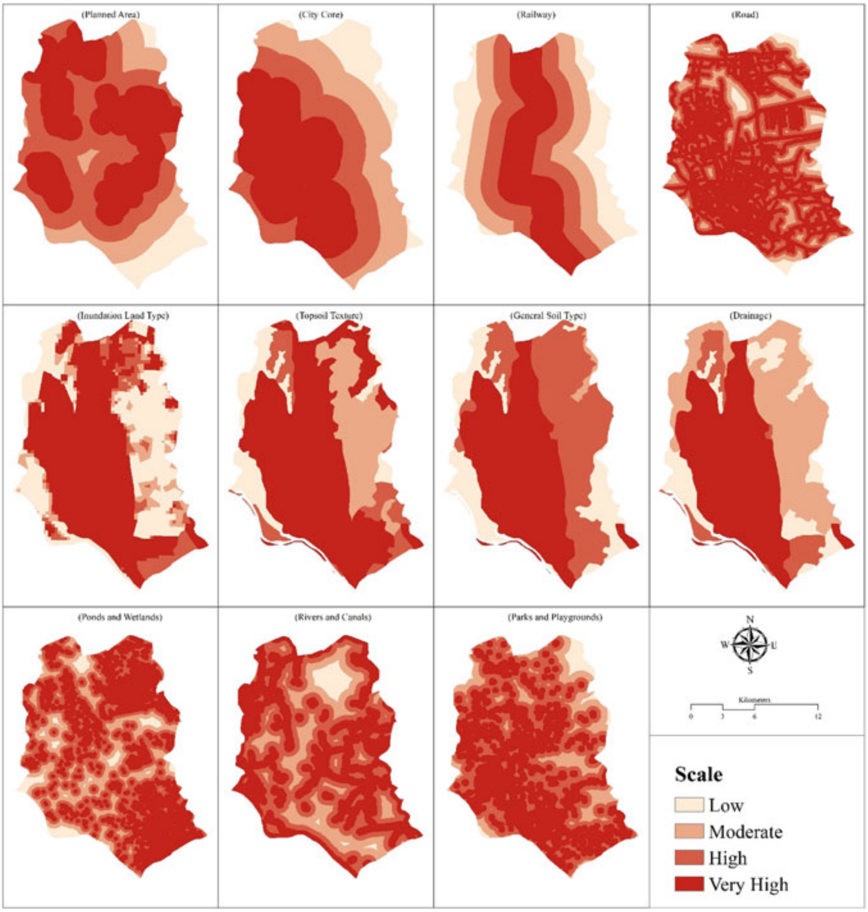


Fig. 17.2 Spatial data layers considered as potential factor of urban growth

parameters (Arai 2020; Paola and Schowengerdt 1995). These parameters are then used to classify pixels. The basic theory, however, assumes that the input data is normally distributed. This method tends to over-classify when dealing with large value signatures (Rawat and Kumar 2015). Several unsupervised classifiers, such as the Iterative Self-Organising Data Analysis Technique (ISODATA) and *K*-means clustering, are widely used for remote sensing data classifications (Karthik and Shivakumar 2021; Naikoo et al. 2020). For unsupervised classification, the *K*-means clustering technique has been adopted in the study. It is a partitional clustering method to classify data into non-overlapping categories (N'Cir et al. 2015). This technique divides n observations integrated with m-dimensional space into k clusters using the Euclidean mean value and helps handle numerical data (Karthik and Shivakumar 2021; Naikoo et al. 2020). Both the classified layers were combined to prepare the final LULC. The mapping accuracy was evaluated using the error matrix and the Kappa methods (Rwanga and Ndambuki 2017). In the study area, four types of land use/cover have been identified: green space, urban area, water bodies and open space (Table 17.2).

Spatial factor analysis

Factors of the spatial distribution of LULC were analysed using the geodetector package in R. It is a tool for detecting heterogeneity of spatial layers and identifying influential factors (Wang et al. 2016). After processing dependent layers, the urban LULC (independent layer) classes of 2020 were graded hierarchically based on their utilisation (Cui et al. 2022; Liu et al. 2020). Grade values were assigned to four classes according to Table 17.3.

Table 17.2 LULC classification scheme used in the study

Class	Description
Green space	This category includes green surfaces with dense vegetation, such as natural or semi-natural tree covers, grassland, low lands with seasonal vegetations
Urban area	This category includes all forms of artificial surfaces such as residential, commercial, and industrial spaces, roadways and railways
Water bodies	This category includes open water bodies such as lakes, rivers, canals, ponds and marshes
Open space	This class includes bare surfaces, landfill sites for development, and fellow land with no vegetative cover

Table 17.3 Hierarchical grading of LULC classes in the study area

Land types	Uncultivated land	Ecological land	Agricultural land	Construction land
LULC classes	Open space	Water bodies	Green space	Urban area
Index values	1	2	3	4

Spatial stratified heterogeneity (SSH) helps us understand the diverse mechanisms of natural and social processes and their interdependence (Wang et al. 2016). Geodetector tool provides q-statistic, which measures the degree of SSH among spatial layers. This tool has four detecting functions: factor detector, interaction detector, risk detector and ecological detector. The factor detector function was used in this study to detect the influence of different factors on urban LULC. The explanatory power (q-statistic) of the influencing factors on the spatially heterogeneous characteristics of LULC can be measured by the following equation (Cui et al. 2022).

$$q = \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \tag{17.1}$$

where q is the determinant power of influential factors and the degree of stratified heterogeneity of LULC; N_h denotes the number of pixels in the subregions h; N denotes the total number of pixels in the study area; σ and σ_h denote the total variance, and variance in the pixels in subregion h, respectively. The value of q ranges between 0 and 1; $q = 0$ indicates no association between influential variables and heterogeneity of LULC, whereas $q = 1$ indicates that LULC is entirely determined by those variables (Wang et al. 2016).

Rank weight analysis

Influential factors in the view of city dwellers were collected from a questionnaire survey. Overall rank weight for each variable was measured based on the rank provided by the respondents. Rank gradings of the respondents were given weights ranging between 0 and 1, where 1 is assigned to the first attribute and 0 to the sixth attribute (Hemphill et al. 2002). The percentage of each variable was calculated for each assigned grade by respondents. Finally, the weighted sum for all the variables was measured using Eq. 17.2 (Aydi et al. 2013).

$$S = \sum_{i=1}^{n} W_i * X_i \tag{17.2}$$

where S is the weighted sum for effective measures of variables, W_i and X_i represent the weight and percentage of the ith variable.

Results and Discussion

Spatio-temporal Patterns of Urbanisation in Dhaka City

The city of Dhaka is rapidly growing in terms of both population and area. To meet the growing needs of the urban population, the urban areas, including human settlements, institutions, hospitals, industries, roads and railways are increasing quickly.

Population growth in developing cities has led to rapid changes in LULC and further environmental degradation (Holdgate 1993). To find the rate of city expansion and the patterns of land use change in Dhaka city, hybrid classification was used for the years 1990, 2000, 2010 and 2020. The results found from the analysis of multi-temporal satellite imageries, four different LULC types, i.e. green space, urban area, water bodies and open space have been identified in Dhaka city.

A comprehensive visualisation of the spatial pattern of urban growth has been shown in Fig. 17.3. According to Table 17.4, it has been found that the city has been witnessing significant urban growth since 1990. The urban areas were 6144.8 ha, 10,522.5 ha, 15,574.5 ha and 18,053.2, respectively, in the years 1990, 2000, 2010 and 2020, consisting of 20.4%, 35%, 51.7% and 60% of the total city areas (Table 17.4). So, the city followed an increase of 40% from 1990 to 2020. According to the historical statistics, the massive infrastructural development within the city resulted in an increasing pattern of urban development areas and the construction of a bridge over the Buriganga River accelerated the urban sprawl to the south and northwest. After 1990, Dhaka expanded further to the Buriganga River and the Turag River to the north and south, separately (Roy et al. 2019). Figure 17.4 shows a comparative exploration of LULC from 1990 to 2020, presenting the spatial encroachment of its urban areas.

On the contrary, Dhaka city experienced the most dramatic change in the green space category during this period. In 2020, it was only 32%, whereas it covered almost 73% of land in 1990. The green space areas, including forests, shrubs, artificial forests, home gardens and farming land, covered about 21,983.6 ha, 18,206.2 ha, 12,581.8 ha and 9704.3 ha in 1990, 2000, 2010 and 2020 consisting of 73.0%, 60.5%, 41.8% and 32.2% of the city area (Table 17.4). From 1990 to 2020, the amount of green space has significantly decreased and been replaced by urban areas. It has been found that around 12,279.24 ha of green spaces disappeared between 1990 and 2020 because of changes in the natural landscape in urban areas. The north and north-western parts of the city lost green space at a higher rate compared to the other parts of the city. A substantial decrease in green space areas occurred from 2000 to 2010.

Open spaces (fellow land, bare land and landfill areas) contained 418.3 ha, 482.0 ha, 921.9 ha and 891.5 ha in 1990, 2000, 2010 and 2020, consisting of 1.4%, 1.6%, 3.1% and 3.0% of the city area (Table 17.4). The amount of open spaces was higher in recent decades than in the previous by getting almost double. The increasing open spaces considered in this study were mostly landfill sites prepared for residential projects which were constantly converting into urban areas (Figure). Consequently, water bodies (rivers, canals, ponds and artificial lakes) comprised about 1550.1 ha, 886.1 ha, 1018.6 ha and 1447.8 ha in the years 1990, 2000, 2010 and 2020 consisting of 5.2%, 2.9%, 3.4%, and 4.8% of the city area (Table 17.4). This has revealed a moderate dropping in water bodies from the year 1990 to 2000. As land became scarce for urban growth, wetlands (water bodies, ponds and canals) turn into the target of urban expansion at this time. During this period, water bodies primarily transformed into urban built-up and green space resulting in 663.93 ha loss. This decrease compared to the 1990s total water bodies was the highest (2.3%) among the studied year. After 2000 the pattern had changed upward with an increase up to

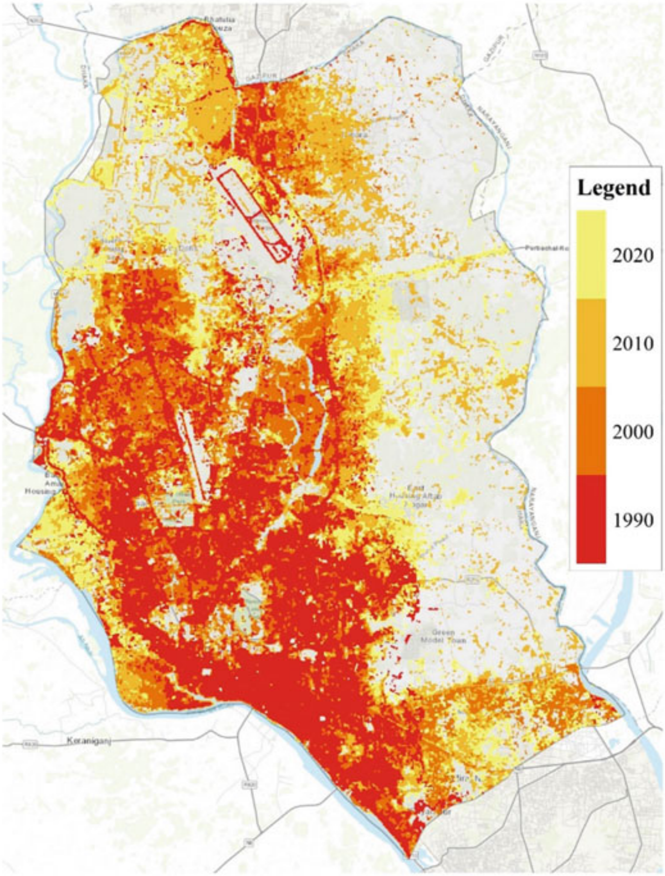


Fig. 17.3 Urban growth pattern from 1990 to 2020 prepared using urban land cover class extracted in Dhaka city

Table 17.4 Attribution of LULC classes retrieved in the study

	1990		2000		2010		2020	
Class	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Green space	21,983.6	73.0	18,206.2	60.5	12,581.8	41.8	9704.3	32.2
Urban area	6144.8	20.4	10,522.5	35.0	15,574.5	51.7	18,053.2	60.0
Water bodies	1550.1	5.2	886.1	2.9	1018.6	3.4	1447.8	4.8
Open space	418.3	1.4	482.0	1.6	921.9	3.1	891.5	3.0

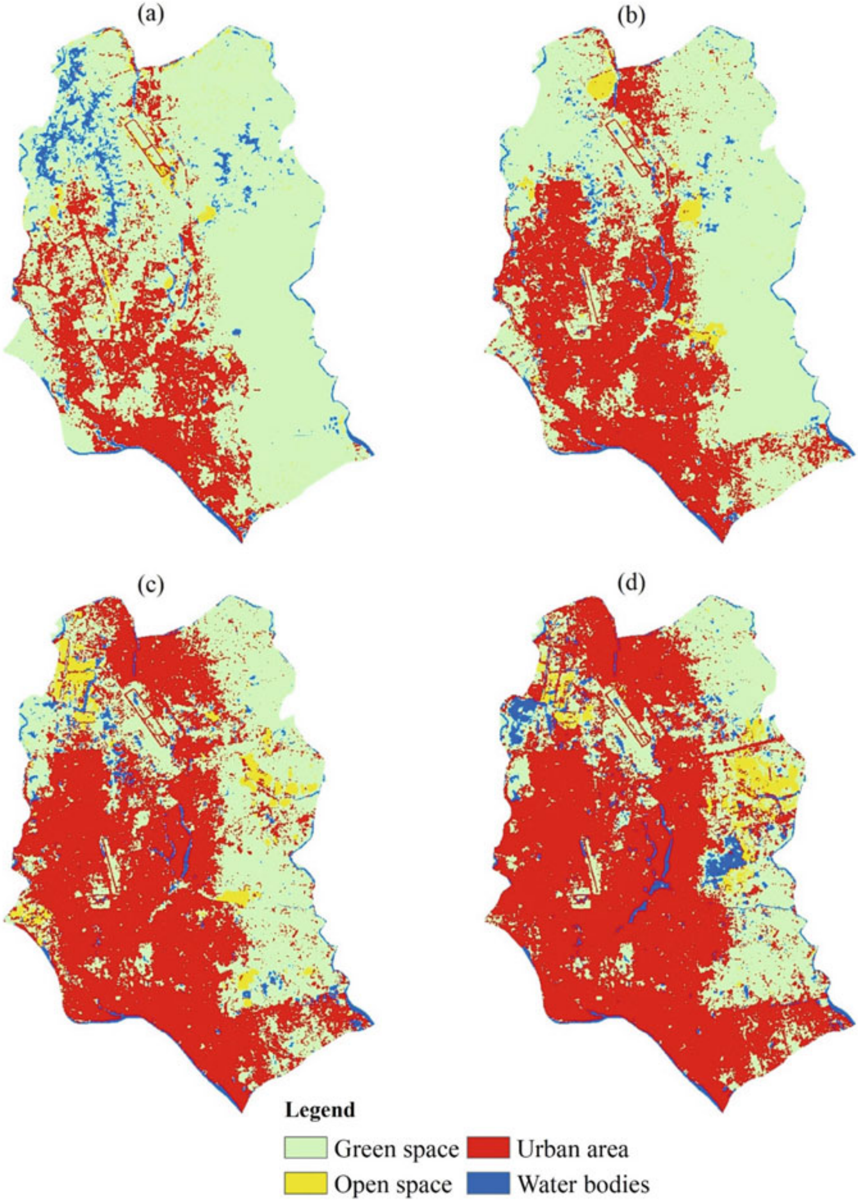


Fig. 17.4 LULC classifications of the study area where **a**, **b**, **c** and **d** represent 1990, 2000, 2010 and 2020, respectively

561.7 ha. The increase in water bodies has been largely attributed to the dredging of Hatirjheel Lake and the increase in fish farming on the outskirts of Dhaka (Islam et al. 2004).

From the analysis, urban area and green space showed an inverse proportional trend throughout the period (Fig. 17.5). Another noticeable fact is that an observable portion of 2.3% of water bodies decreased because of the encroachments of urban areas in the long run following a common convergence pattern (water bodies > green space > open space > urban area). Green space was the main land use type in 1990, followed by urban area, water bodies and open space, and the course of urban growth was northward. Land use patterns have changed exaggeratedly from 1990, when urban space replaced the majority of the green space, open space and water bodies. The earlier development projects had been undertaken informally by the public sector, and the areas had been used for the former development mainly free from inundation and previously used for agriculture; Gulshan, Banani, Dhanmondi and Uttara Model Town are examples of these development projects (Chowdhury 2003). Historic maps and literature suggest that after the independence the depressions and water bodies within the city had been lost quickly and the urban growth was largely attributed to housing, commercial, educational and business purposes (Siddiqui et al. 2000). Urban development has surely increased in greater Dhaka, especially through the process of suburban development, resulting in a reduction in green space and water bodies. Between 1990 and 2000, the city had been extended further to the north, northwest and west. The patterns of LULC change revealed that Dhaka started to expand in all directions, mainly at the expense of green space and water bodies (Fig. 17.4). After the provision of a new master plan in 1995 and the development of infrastructure, the rate of urban invasion of other land uses increased significantly (Siddiqui et al. 2000). During the studied period, the city became a business hub for the real-estate companies to build new apartments for the growing middle-income and upper-income population. Urban development was mostly observed along the existing main roads, in the north and northwest directions (Fig. 17.3). There were new settlements on the urban peripheries in wetlands and floodplains following the accelerated growth since 2005 (Ahmed et al. 2012).

Driving Forces Urbanisation in the City

The factors that cause urban growth are significant for the analysis of urbanisation. It is also necessary to understand the consequences or the impacts of urban growth for achieving sustainable urban development. To identify the major factors that influence urban growth scenarios in Dhaka city factor analysis (geodetector) and questionnaire survey have been done.

The main factors that influence the spatial locations of the study area are divided into two categories: natural and anthropogenic (Fig. 17.6). According to Table 17.5, drainage system, inundation land type and soil type were found to be highly influential natural factors. Anthropogenic factors such as distance from core areas and railways

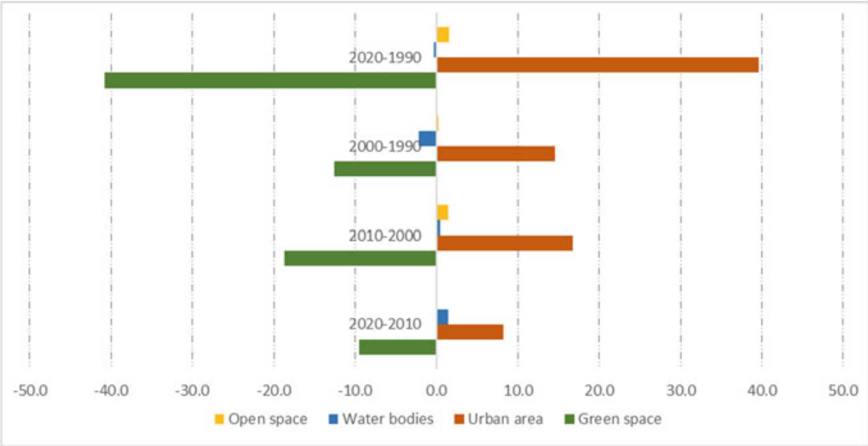


Fig. 17.5 Temporal change percentages of LULC classes

also worked as major determinants of spatial urban growth (Table 17.5). Primarily, new developments occur close to core areas considering drainage and inundation scenarios. Afterwards, low lands get converted into landfill sites for further urban development.

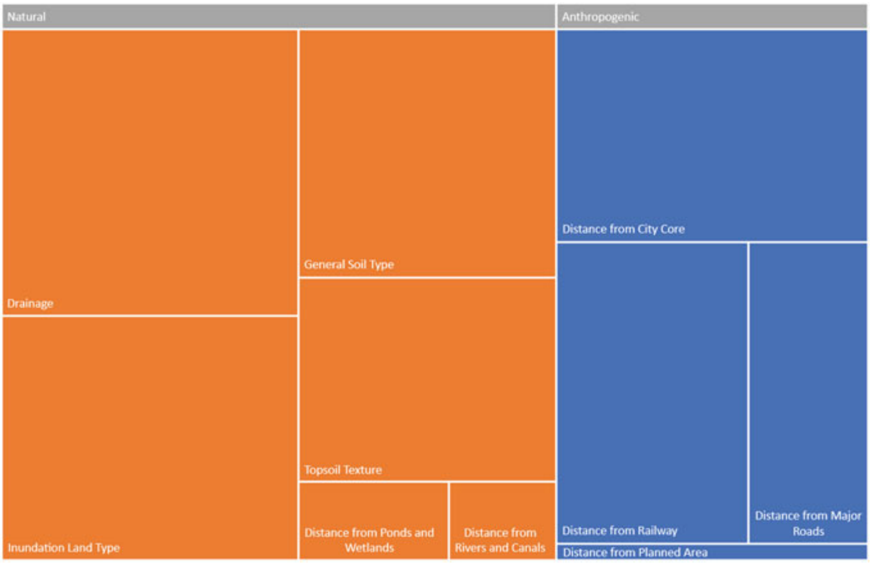


Fig. 17.6 Spatial determinants of urban growth in the area

Table 17.5 *q*-statistic results of spatial factor analysis

Groups	Variables	*q*-statistic	*p*-value
Anthropogenic	Distance from planned area	0.01	< 0.001
	Distance from city core	0.16	< 0.001
	Distance from railway	0.14	< 0.001
	Distance from major roads	0.09	< 0.001
Natural	Inundation land type	0.18	< 0.001
	Topsoil texture	0.13	< 0.001
	General soil type	0.15	< 0.001
	Drainage	0.21	< 0.001
	Distance from ponds and wetlands	0.03	< 0.001
	Distance from rivers and canals	0.02	< 0.001

Several driving forces have been identified in the study that promotes urban growth such as economic opportunities, increasing population, transportation facilities, factories and industries and educational and health institutions (Fig. 17.7). Consequently, the increasing trend of urban population from both migration and internal birth causes uncontrolled urban growth that strains the city's capacity to offer better services such as transportation, sanitation, energy, educational, medical services and physical security. More and more people come to the city from the rural areas for economic opportunities and better living, but unfortunately, the city has already been overpopulated and has crossed its carrying capacity, which has led to the development of unplanned suburbs, especially the slums has increased since 1990. By the year 2016, the city had grown to cover a total area of 304.17 km^2, and its population had reached 8,749,468 (RAJUK 2016). Dhaka is undergoing a chaotic and unplanned transformation, which is being driven by the influx of people from surrounding areas, as shown by the city's pattern of spatial expansion (Islam et al. 2010). These informal communities are located close to embankments, open drains and sewer lines, dumping sites for solid garbage and railway tracks, all of which contribute to an exceedingly unhygienic environment (Islam 1999). The rapid urban expansion in Dhaka has led to widespread environmental degradation. Natural vegetation and biodiversity have been demonstrated to suffer as a result of urban expansion made possible by landfill disposal (Alphan 2003; Dewidar 2002). Since the majority of recent construction in Dhaka has occurred on landfill sites, the city's exposure to earthquake-related risks has also increased (Maksud Kamal and Midorikawa 2004). Moreover, most of the rural people pushed to migrate in Dhaka city because their life and livelihood severely affected by both anthropogenic, e.g. unemployment, political persecution, social conflicts and natural disasters, e.g. cyclone, drought, floods, salinity, etc.

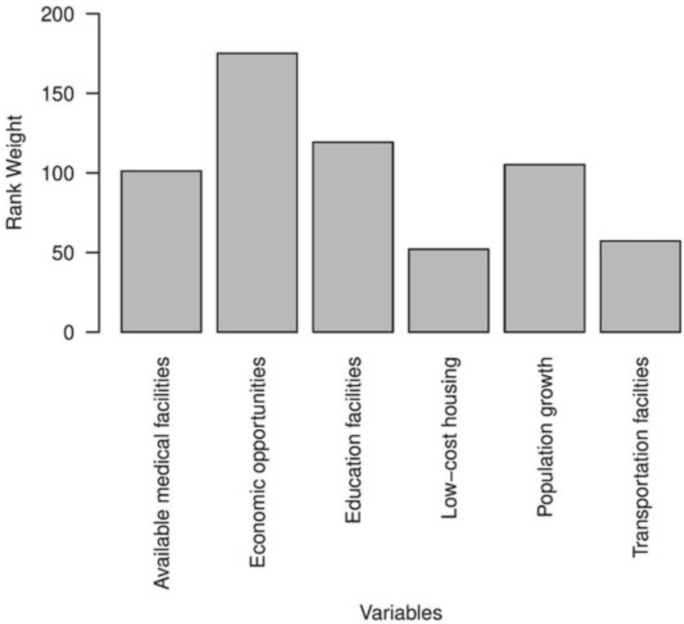


Fig. 17.7 Rank of different driving factors of urban growth according to people's perception

Impact on the Environment and Health

The impact of urban growth can have both positive and negative consequences. Economic benefits and better living conditions could be the positive impacts of urban growth. However, in Dhaka city, the negative impacts override the positive impacts because urban development in Dhaka is often uncontrolled or uncoordinated. Rapid and unplanned urbanisation is frequently associated with the degradation of the environment, infrastructure and human health. Due to uncontrolled urbanisation, environmental degradation has been appearing very unexpectedly and causing many problems, including deteriorating water quality (Srinivasan et al. 2013), excessive air pollution (Mahmood 2011), noise and waste disposal (Hokao et al. 2012), negative effects on human health (Moore et al. 2003b; Vlahov and Galea 2002; Zhu et al. 2011), traffic congestion (Rahman et al. 2020) and hazard risk (Rahman et al. 2015).

There are four impacts of urbanisation that were most pronounced by the respondents in this study, such as air pollution, hazard risk, traffic congestion and water pollution, where each respondent could answer more than one (Table 17.6).

The frequency was then computed based on the total answers given by the respondents. It was determined that one of the major impacts was air pollution, followed by hazard risk (fire hazard/road accidents), traffic congestion and water pollution. Air pollution due to the high degree of vehicle concentration, waste burning, indoor fuel burns and industrial fumes get more severe in the city (Mahmood 2011). Increasing

Table 17.6 Negative consequences of urban growth from people's perceptions

Impacts	Responses
Traffic congestion	153
Hazard risk	154
Air pollution	163
Water pollution	151

vehicles, such as private cars, bikes and public buses to meet the demand for transportation in the city also causes traffic congestion. Generally, private cars carry fewer people considering the spaces they occupy and public transport (bus, human holler) increases without following urban transport policies such as proper fitness of vehicles, education and medical fitness of the drivers and traffic lane disciplines (DTCA 2015; Rahman et al. 2020). These situations make the road unsafe and increase the rate of accidents. Fire incidents have also been considered under the hazard risks which is a concerning issue in densely urbanised residential areas with narrow roads (Rahman et al. 2015). Another major threat to the lives of city inhabitants is water pollution by the rapid spreading of water-borne diseases, amplifying contagion into an epidemic (Bashar and Fung 2020). Given the increasing extent and severity of urbanisation, the urban environment and health impacts depicted in the figure require significant attention.

Conclusion

From the above discussion, it is evident that Dhaka city has been witnessing rapid urban expansion. Four major land covers have been analysed to extract changing spatial patterns from 1990 to 2020. There has been substantial urban occupancy of other land cover classes, particularly in the periphery. Most of the green spaces have been converted to urban areas throughout the study period, following waterbodies and open spaces. Several reasons factored for these conversions of land. Major driving forces are anthropogenic, such as economic opportunities, education and medical facilities, which worked as pull factors for rural–urban migration, resulting in urban population growth. To meet the demands of the growing population, the city expanded its periphery. This spatial expansion also depends on several determining factors for urban built-up preferences. Natural determinants, such as drainage systems, inundated lands, suitable soil types and textures for building infrastructures; artificial determinants, such as distance from the city core, roads and railways worked together in shaping the spatial locations of the city expansion. All major determinants of urban growth trends and patterns along with the increasing need for infrastructural facilities such as residences, schools and medical centres lead to an uncontrolled expansion of the city. Therefore, the city is experiencing degradation in environmental quality as well as increasing health issues among its dwellers. To transform Dhaka into a sustainable city, these determinants should be regulated or controlled. During this investigation, there were some limitations faced by the authors such as partially available data layers compiled from multiple sources, which caused uncertainty and small sample data acquired in the questionnaire due to the lack of resources. Apart from the limitations, this chapter tried to establish a perspective for developing controlled and smart cities by focusing on their spatio-temporal drivers. It will help policymakers to focus on the most influential causes behind new developments and plan sustainably.

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