

Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005

Ashraf M. Dewan · Yasushi Yamaguchi

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Abstract This paper illustrates the result of land use/cover change in Dhaka Metropolitan of Bangladesh using topographic maps and multi-temporal remotely sensed data from 1960 to 2005. The Maximum likelihood supervised classification technique was used to extract information from satellite data, and post-classification change detection method was employed to detect and monitor land use/cover change. Derived land use/cover maps were further validated by using high resolution images such as SPOT, IRS, IKONOS and field data. The overall accuracy of land cover change maps, generated from Landsat and IRS-1D data, ranged from 85% to 90%. The analysis indicated that the urban expansion of Dhaka Metropolitan resulted in the considerable reduction of wetlands, cultivated land, vegetation and water bodies. The maps showed that between

1960 and 2005 built-up areas increased approximately 15,924 ha, while agricultural land decreased 7,614 ha, vegetation decreased 2,336 ha, wetland/lowland decreased 6,385 ha, and water bodies decreased about 864 ha. The amount of urban land increased from 11% (in 1960) to 34% in 2005. Similarly, the growth of landfill/bare soils category was about 256% in the same period. Much of the city's rapid growth in population has been accommodated in informal settlements with little attempt being made to limit the risk of environmental impairments. The study quantified the patterns of land use/cover change for the last 45 years for Dhaka Metropolitan that forms valuable resources for urban planners and decision makers to devise sustainable land use and environmental planning.

Keywords Dhaka Metropolitan · Land use/cover · Monitoring · Remote sensing · Change detection

A. M. Dewan
Department of Earth and Environmental Sciences,
Nagoya University,
Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

Y. Yamaguchi
Graduate School of Environmental Studies,
Nagoya University,
Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

A. M. Dewan (✉)
Department of Geography and Environment,
University of Dhaka,
Ramna, Dhaka 1000, Bangladesh
e-mail: hamim_2001@yahoo.com
e-mail: amd1971@univdhaka.edu

Introduction

Land use/cover change analysis is an important tool to assess global change at various spatial-temporal scales (Lambin 1997). In addition, it reflects the dimension of human activities on a given environment (Lopez et al. 2001). As global population increases rapidly, pressure exerts on the land resulting flimsy cohesion among environmental variables

(Green et al. 1994). The rapid changes of land use/cover than ever before, particularly in developing nations, are often characterized by rampant urban sprawling (Jat et al. 2008; Mundia and Aniya 2006), land degradation by agricultural development and tourism industry (Shalaby and Tateishi 2007), or the transformation of agricultural land to shrimp farming (Ali 2006) ensuing enormous cost to the environment (Abduallah and Nakagoshi 2005). This kind of changes profoundly affects local and/or regional environment, which would eventually affect the global environment. Human induced changes in land cover for instance, influence the global carbon cycle, and contribute to the increase in atmospheric CO₂ (Alves and Skole 1996). It is therefore indispensable to examine the changes in land use/cover, so that its effect on terrestrial ecosystem can be discerned, and sustainable land use planning can be formulated (Muttitanon and Tripathi 2005).

Like other developing countries, Bangladesh experienced a fast increase of urban population in the recent decades (14.1 million in 1981, 22.5 million in 1991, 31.1 million in 2001; BBS 2001), and 35 million in 2005 (CUS et al. 2006). Rapid urban growth leads to the transformation of rural lands to built-up areas, and it is estimated that each year more than 809 km² of agricultural land is being diverted to cities, roads and infrastructures in Bangladesh (BBS 1996). As agriculture is the mainstay of national economy, loss of cultivated land becomes grave concern that can contribute to the increase of landlessness and jeopardizing the economy. Furthermore, food shortage could be acute in the coming years, and it would be a great hurdle for Bangladesh to meet up the rising food demand for its ever growing population.

Dhaka, the capital of Bangladesh could be the best illustration of human activities and associated environmental change. Dhaka is expanding apace, at an average rate of 4.24%/year and is projected to be the third largest megacity in the world by the year 2020 (World Bank 2007). The growth of the city is phenomenal after independence (Chowdhury and Faruqui 1989) and highest among other cities in Bangladesh due to its socio-economic and political importance. The growth is mainly attributed to the large influx of rural to urban migration (Islam 1996). The population of Dhaka increased from 556,712 in 1961 to the current more than 12 million (World Bank 2007). Rapid urbanization on the other hand, led to

the deterioration of city's environment, particularly mounting flood risk potential (Dewan and Yamaguchi 2007), severe environmental pollution (Karn and Harada 2001; Karim 1999; Azad and Kitada 1998), and spectacular growth of informal settlements (CUS et al. 2006; Islam 1996).

Even though most of the developed countries are well equipped and updated with detailed land use/cover information, lack of and/or restricted access to geospatial database persists in developing nations, predominantly in Bangladesh. Aerial photograph, for instance, absolutely classified for public. For third world countries, remote sensing proved its effectiveness for spatial data updating (Dong et al. 1997) and particularly to provide accurate and timely geospatial information illustrating land use/cover dynamics of metropolitan areas (Yang 2002). Unfortunately, no such application is available for Dhaka or its part for land use/cover change assessment. Few studies however, used the geospatial technique to address some environmental issues of Dhaka City (Dewan et al. 2007a, b; 2006, 2005; Kamal and Midorikawa 2004; Maathuis et al. 1999). It is necessary to mention here that the city does not have any official statistics on land use pattern and even the Master Plans do not provide either a map or a quantitative statement of the existing land use (Islam 1996, 2005). Official land use statistics of Dhaka Metropolitan seems to have appeared in 1991 by ground observation (Islam 1996; FAP 8A 1991). Many factors including financial constraints, data scarcity, bureaucracy and/or lack of geoinformatics expertise in the planning agencies are responsible for the absence of historical as well as current land use/cover data. In addition, as many as 18 ministries are effectively involved in developing Dhaka (Mohit 1991) and such multiple involvements obviously result in meager coordination. In effect, a good number of private organizations have been evolved, generating "City Maps" by ground investigation and in an inefficient manner. Consequently, confusion and disparities in the data are widespread and fairly misleading.

While current and accurate information on land use/cover is a prerequisite to the management and planning of urban areas, data paucity and up-to-date information on land use/cover exist in Dhaka. In the absence of such information, sustainable urban development cannot be achieved and may lead to the mismanagement of scarce resources which is prevalent in Dhaka (Hasan

and Mulamootil 1994). Thus, space-borne remotely sensed data is deemed to be predominantly important for Dhaka Metropolitan, as there is a lack of consistent spatial information. Timely and reliable land cover information is not only imperative to comprehend the past and present condition of the land but also used to facilitate the development of integrated resource management policies, to achieve sustainable urban development (Alphan 2003), and to derive sound environmental planning.

This paper describes the results of land use/cover classification in Dhaka Metropolitan of Bangladesh derived from topographic maps and multi-temporal remotely sensed data. Specifically, the aim of this paper is to dynamically map and monitor the land use/cover change and to analyze the changes with respect to the baseline of 1960. Since there is a lack of reliable data such as official land use maps and restricted access to aerial photographs, it was appropriate to use satellite data for the assessment of land cover change.

Description of study area

The study area is Dhaka Metropolitan of Bangladesh. Geographically, it is located between 23°58' and 23° 90' North latitudes and 90°33' and 90°50' East longitudes (Fig. 1). Topographically, the area is a flat land and is located mainly on an alluvial terrace, popularly known as the Modhupur terrace of the Pleistocene period (Miah and Bazlee 1968). The surface elevation of the area ranges between 1 and 14 m (Fig. 1) and most of the built-up areas located at the elevations of 6–8 m (FAP 8A 1991). The area of investigation covers 416 km² and is surrounded by four major river systems, namely the Buriganga, Turag, Tongi and Balu, which are flowing to the south, west, north and east sides, respectively. These rivers are mainly fed by local rainfalls and also receive spills from three mighty rivers crisscrossing the country, namely the Ganges, Brahmaputra and Meghna through their tributaries and distributaries in the monsoon. Regionally, the area is located in the central Bangladesh, and lies in the sub-tropical monsoon zone under the humid climatic condition. The city experiences about 2,000 mm annual rainfall, of which more than 80% occurs during the monsoon season (June–September). Currently, the annual pop-

ulation growth rate of the city is 5% compared with an annual average of 2.1% for Bangladesh (BBS 2001). The process of urbanization in Dhaka is providing both challenges and opportunities. For instance, Dhaka contributes 19% Gross Domestic Product (BBS 2001) to the national economy and is playing a pivotal role in terms of social development and cultural enhancement.

Data and methodology

Data acquisition and preparation

The topographic maps of 1960 (scale 1:50,000) were obtained from Survey of Bangladesh (SOB) and used to generate the 1960 land use/cover types. In addition, Landsat 1, 4, 5 and 7, and IRS-1D data were acquired for this study. Four Landsat data comprised of MSS (27 March 1975), TM (03 February 1988; 01 February 1999) and ETM+ (04 January 2003) were obtained and employed in this study. Furthermore, one IRS-1D LISS III data (26 December 2005) was also acquired and used for the 2005 land use/cover categorization. Please note that the Landsat and IRS thermal bands were not included to detect land cover change. Both ArcGIS (ESRI 2005) and Erdas Imagine (Leica Geosystems 2006) software were used to derive land use/cover classification in a multi-temporal approach.

First of all, the topographic maps of 1960 were scanned and rectified using a geometrically corrected image with the ArcGIS software. As unsystematic errors remain in commercially available remote sensing data, geometric correction was therefore needed to reduce the error. The images used in this study were geometrically corrected using a Landsat TM image of 1997 as a reference. At least 75 well distributed ground control points were used in the rectification process. The root mean square error (RMSE) varied from 0.25–0.45 pixels. Finally, a first-order polynomial fit was applied and all the data were resampled to 30 m pixel size using the nearest neighbor method. The Bangladesh Transverse Mercator System (BTM) was used as the coordinate system which is an area-specific standard UTM projection system for Bangladesh. Besides, a number of geospatial data including municipal boundaries, road networks, geomorphic units and elevation units have been constructed as GIS layers from diverse sources.

Reference data

A number of reference datasets were constructed in this study. Due to the retrospective nature, the study relied on a variety of sources to develop reference data for training area selection and accuracy assessment of land cover maps.

Reference data for the 1975 Landsat MSS image were obtained from the topographic maps of the study area (scale 1:50,000) published by SOB in 1973. The topographic maps were compiled from aerial photographs and subsequent ground truthing. In addition, the 1975 land-use map (scale 1:10,000) by the Center for Urban Studies (CUS 1975) was also used as reference. There are nine land use categories exist in the land use map developed by the CUS (1975). They are business, industrial, education, administrative, transport, open space, residential and non-urban.

The topographic maps of 1991 and one SPOT panchromatic image of 1989 (resolution 10 m) were used to develop reference data for the 1988 land cover. The reference data were used both for training area selection and evaluation of the result. The land use map of 1991 (FAP 8A, 1991) was also used to derive land cover information from Landsat image of 1988. It may be mentioned here that the 1991 map classified land use patterns of Dhaka into six broad categories. Among them, agriculture represented 45% and urban built-up areas constituted 39% of the total area in 1991.

The 1999 reference data were obtained from one IRS-1D panchromatic image (spatial resolution 5.8 m) of February, 2000. Additionally, topographic maps of 1997 and Dhaka Guide Map of 2001 (scale 1:20,000) were used to locate training samples on the image and to evaluate the map accuracy.

The 2003 reference data were acquired from two sources, primarily from the field and from one IKONOS panchromatic image (resolution 1 m) of April, 2003. An intensive fieldwork was also carried out in 2003 (6 February–22 March). The 200 reference points (Fig. 1) were collected in the field using a handheld GPS. This information was then brought into GIS for overlaying with the images for the selection of training areas and subsequent accuracy assessment. To do so, 100 reference points were used to train pixels and hundred GPS data were used for classification accuracy.

Again in 2007, a field study (12–24 February) was conducted in the study area to obtain reference data for 2005 image classification. Note that an image from the

Google Earth© and a false color composite of IRS-1D image (RGB 321) depicting different land cover types were printed on A0 size papers and taken to the field for data collection. In the field, these color hard copies were used to identify the existing land cover features and special attention was paid for the spectrally similar covers on the IRS data. Thus a ground truth map was prepared to locate the training pixels on the image. Additionally, 110 reference points (Fig. 1) were recorded by a GPS and put into a GIS for evaluating accuracy of the derived land cover of 2005.

Land use/cover classification and change detection

A modified version of the Anderson Scheme Level I (Anderson et al. 1976) was adopted to study the land use/cover change. Though the scheme was originally developed for the USA, it is the widely used land use/cover classification system across the world (Mundia and Aniya 2006; Shalaby and Tateishi 2007; Yuan et al. 2005). The system proposed multilevel land use/cover classification of which level I classes can be mapped from Landsat data or from high-altitude airphoto/imagery, whereas the extraction of information at levels II, III, and IV requires the use of high, medium, and low-altitude photographs, respectively. Six separable land use/cover types have been identified in this study as water bodies, wetland/lowlands, built-up, cultivated land, vegetation and bare soil/landfill (Table 1).

The 1960 land cover map has been developed from topographic maps which are created from aerial photographs taken in 1955 followed by extensive ground truthing in 1956. Two scanned topographic maps (sheet no. 79 I 5 and 6) were displayed on the computer screen. Using ArcGIS, the 1960 land cover map was digitized, edited, and leveled. Besides, a large scale map (1:20,000) of 1961 by Survey of Bangladesh (SOB) depicting the study area and its surroundings was employed to identify various land cover types in a GIS platform. The 1962 land use classification map with seven categories by Khan and Islam (1964) was also useful to distinguish the land use/cover information on topographic maps. Finally, vector land cover data were rasterized to perform raster-based change analysis.

All the satellite data were thoroughly studied using spectral and spatial profiles to ascertain the digital numbers (DNs) of different land cover types prior to classification. Training samples were selected through reference data and ancillary information mentioned

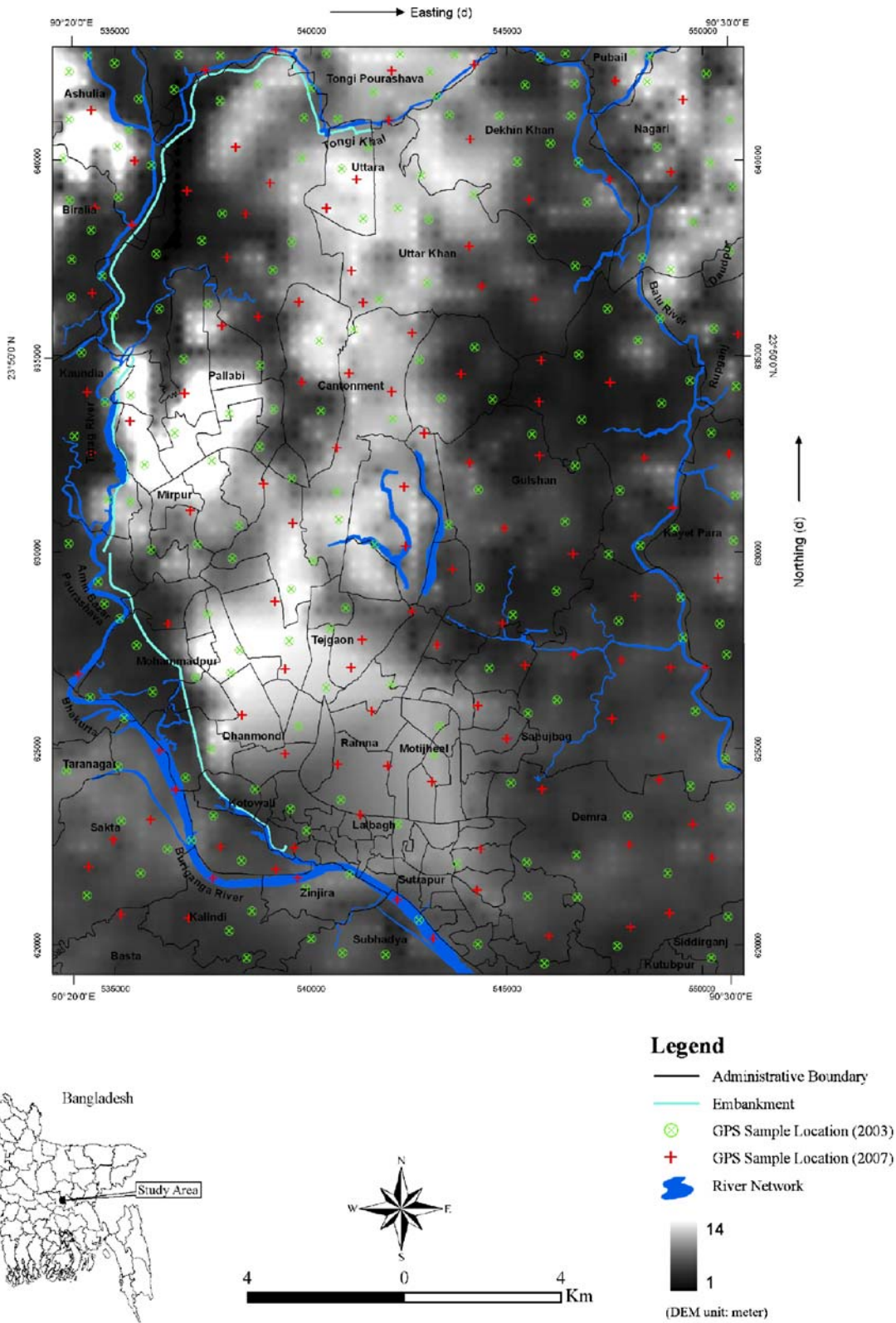


Fig. 1 Location of study area

Table 1 Land use/cover classification scheme

Land use/cover types	Description
Built-up	Residential, commercial and services, industrial, transportation, roads, mixed urban, and other urban
Bare soil/landfill	Exposed soils, landfill sites, and areas of active excavation
Cultivated land	agricultural area, crop fields, fallow lands and vegetable lands
Vegetation	Deciduous forest, mixed forest lands, palms, conifer, scrub and others
Water bodies	River, permanent open water, lakes, ponds and reservoirs
Wetland/lowlands	Permanent and seasonal wetlands, low-lying areas, marshy land, rills and gully, swamps

earlier. Sixty–seventy training sites varying in size from 286 to 8,914 pixels (5–46%) were used to locate training pixels on the images. Except for the bare soil/landfill category, training samples for each class were 5–12 subclasses. The training samples were then evaluated by using class histogram plots. Training samples were refined, renamed, merged, and deleted after the evaluation of class histogram and statistical parameters. A supervised maximum likelihood classification (MLC) algorithm was subsequently applied to each image which has generally been proven to obtain the best results from remotely-sensed data if each class has a Gaussian distribution (Bolstad and Lillesand 1991).

Misclassification was observed in the classified land cover categories obtained from the MLC classification. For example, certain urban surfaces were misclassified as landfill sites due to their similar spectral characteristics. Likewise, misclassification was also found between the wetland/lowlands category and the cultivated land, water bodies, and lowland/wetland category. It may be noted that initially the wetland category was identified as a separate class but eventually it merged with the lowland class as it was not possible to separate from the lowland category because of their alike spectral properties. Post-classification refinement, therefore, was used to improve the accuracy as it is simple, efficient and easily executable method (Harris and Ventura 1995). It is important to note that misclassification was higher in the MSS image among the datasets. To surmount the difficulty of misclassification, a number of strategies were considered. For example, thematic information (e.g. water bodies, vegetation, and bare soil) was first extracted from the V-S-W index (Yamagata et al. 1997). Then a rule-based technique using thematic information (DEM, municipal map and water bodies, etc.) was employed

to correct previously misclassified land cover categories in ERDAS's spatial modeler. Although application of the rule-based technique greatly improved the MLC classification, a small amount of misclassification was still found between wetland and cultivated lands. This was mainly attributed to their geographical contiguity. GIS tools such as Area of Interest (AOI) were afterward applied using visual analysis, reference data, and local knowledge to split and recode these covers into their original classes. It is necessary to mention that ground truth information was also of great value in the refinement process. Applying those techniques substantially improved the result of pre-classification by the supervised algorithm. A 3×3 majority filter finally applied to the classified land cover data to reduce the *salt-and-pepper* effect (Lillesand and Kiefer 1999).

To determine the changes in land use/cover at different years, a post classification comparison of change detection was used. Even though this technique presents few limitations (Singh 1989; Coppin et al. 2004), it is the most common approach (Jensen 1996; Mundia and Aniya 2006) to compare data from different sources and dates. The advantage of post-classification comparison is that it bypasses the difficulties associated with the analysis of images acquired at different times of the year and/or by different sensors (Yuan et al. 2005; Coppin et al. 2004; Alphan 2003). Moreover, the post classification method also answers the amount, location, and nature of change (Howarth and Wickware 1981). A major pitfall, however, is that the accuracy of the change maps depends on the accuracy of individual classifications and subject to error propagation (Yuan et al. 2005; Zhang et al. 2002). A comparison between the classified maps was carried out subsequently on a pixel-by-pixel basis (Jensen and Ramsey 1987).

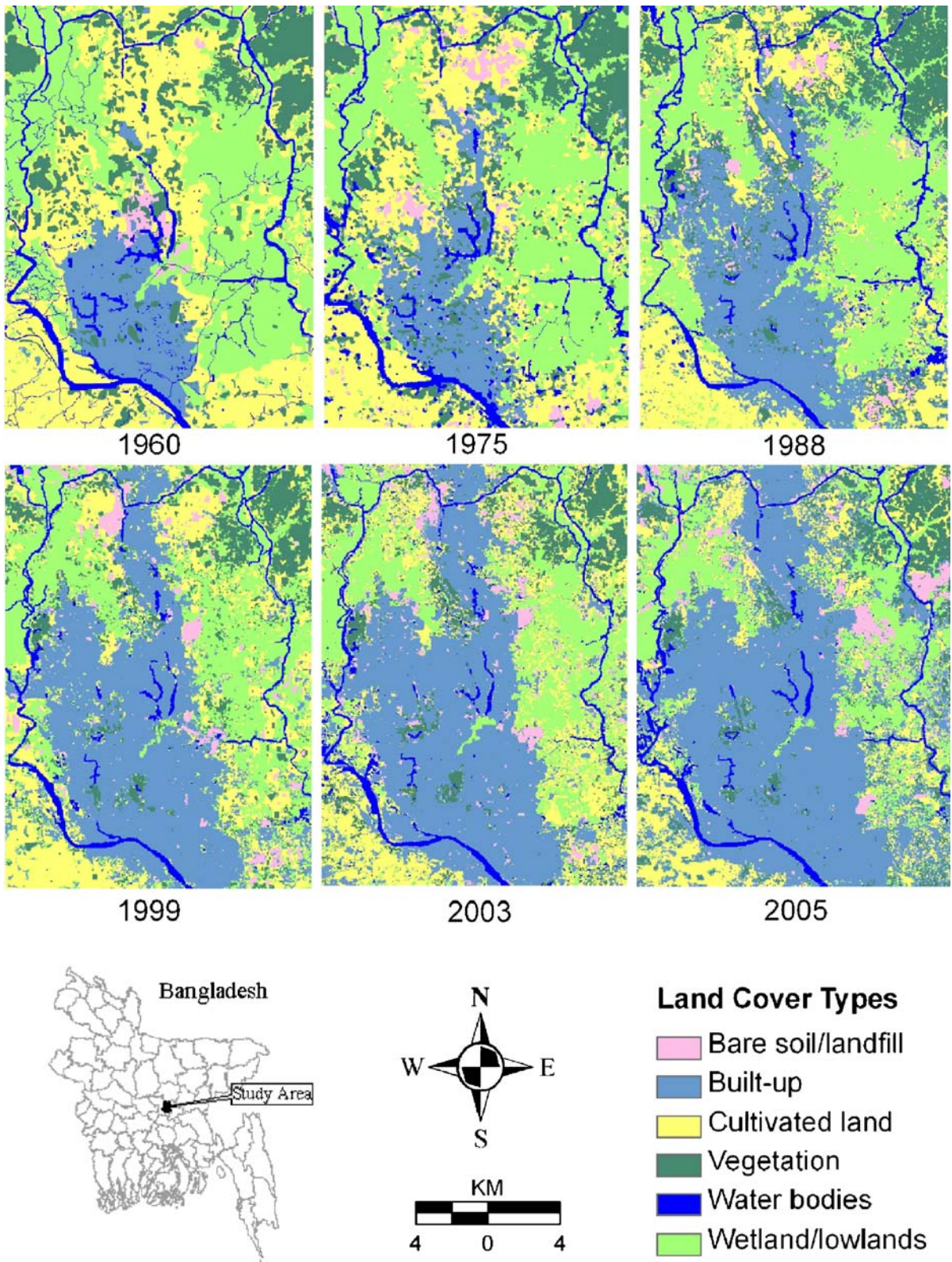


Fig. 2 Land cover classifications from 1960 to 2005 for Dhaka Metropolitan

Table 2 Summary of land use/cover classification statistics between 1960 and 2005 (area in hectares)

Land use/cover types	1960		1975		1988		1999		2003		2005	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Water bodies	2,965.2	7.1	2,976.1	7.2	2,101.5	5.1	1,886.7	4.5	2,050.9	4.9	2,101.1	5.1
Wetland/lowlands	13,514.4	32.5	13,155.2	31.6	12,715.6	30.6	10,797.3	26.0	9,124.0	22.0	7,128.8	17.2
Cultivated land	13,851.2	33.3	12,040.8	29.0	9,024.9	21.7	8,574.8	20.6	8,466.6	20.4	6,236.6	15.0
Vegetation	6,109.8	14.7	6,585.2	15.8	5,793.8	13.9	4,391.8	10.6	3,992.2	9.6	3,773.1	9.1
Built-up	4,625.4	11.1	5,550.5	13.4	10,858.9	26.1	14,486.0	34.9	16,104.6	38.7	20,549.7	49.4
Bare soil/landfill	498.0	1.2	1,256.2	3.0	1,069.4	2.6	1,427.5	3.4	1,825.7	4.4	1,774.6	4.3

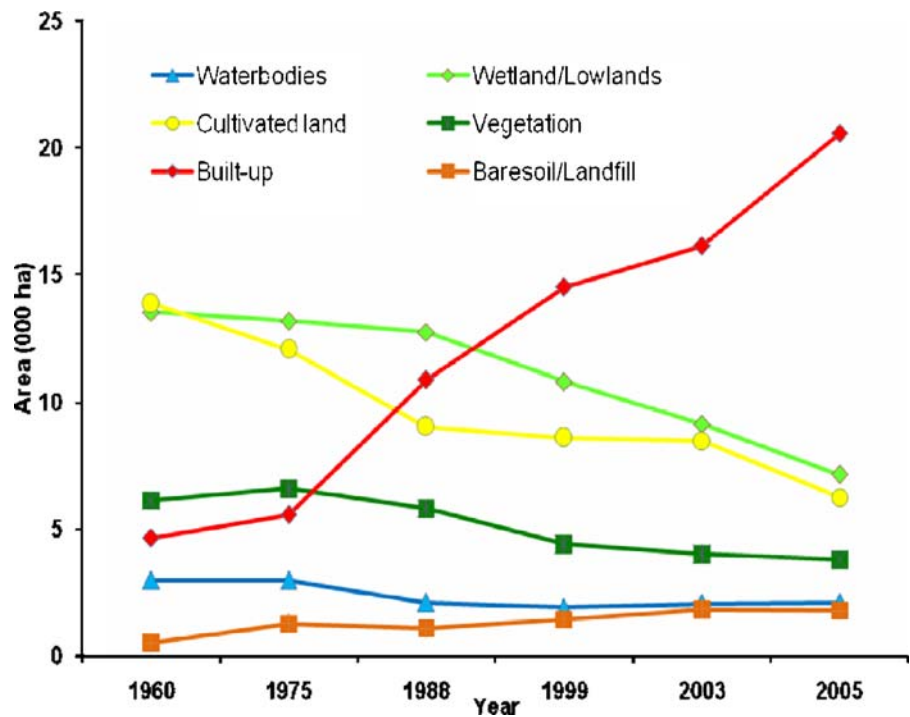
Assessing classification accuracy

Classified land cover maps from satellite data were further used for validation using ground truth data obtained from a variety of sources. For the 1975, 1988, and 1999 land use/cover maps, a total of 125 pixels were generated using the stratified random sampling method. Then using the geographical locations of features available on the land use maps, high resolution images, and Survey of Bangladesh topographic maps, accuracy evaluation of the derived maps were performed. To assess the accuracy of 2003 and 2005 land use/cover maps, reference data obtained from the field were utilized. In doing so,

100 reference data for 2003 and 110 field data for 2005 were used to assess the classification accuracy. Finally, accuracy reports of each land cover data in terms of overall accuracy, producers/users accuracy, and kappa coefficient have been generated.

Results and discussion

Land use/cover classifications from 1960 to 2005 in Dhaka Metropolitan of Bangladesh are presented in Fig. 2. Spatial patterns of land cover revealed that urban growth followed certain directions between 1960s and 1980s depending on the ground elevation.

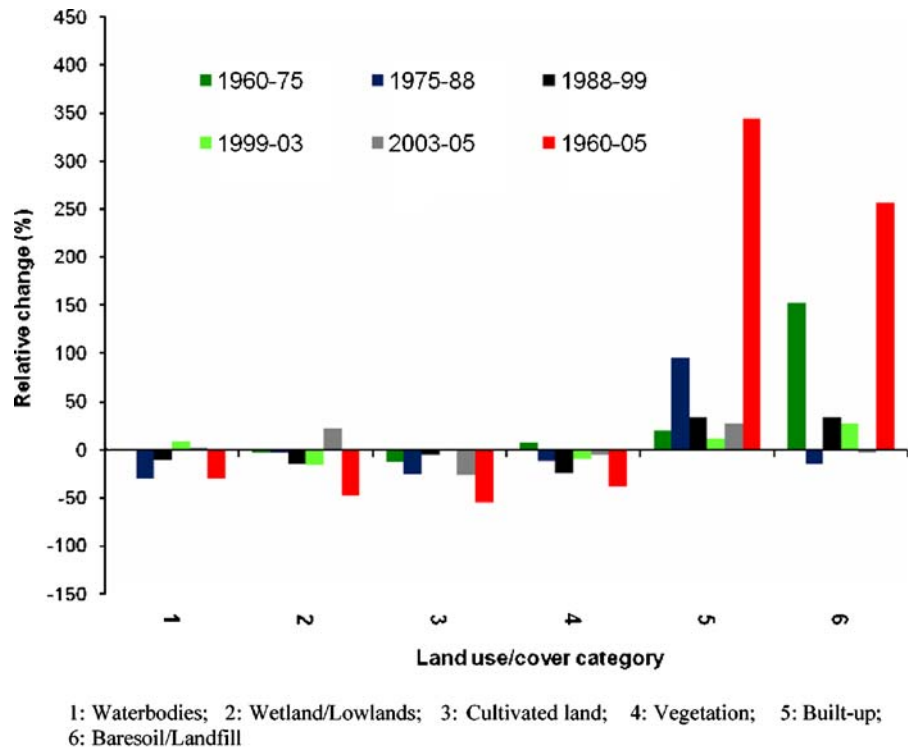
Fig. 3 Temporal pattern of land use/cover change

For example, the earlier direction of the built-up land was followed by north, north-west, and west trends but the current trend shows a horizontal expansion (Fig. 2). Historically, the direction of urban expansion of Dhaka has greatly been constrained by the low elevation of lands, surrounding rivers, and risk of flooding. Thus major development was on the high and medium terraces usually not liable to inundation. The interpretation of the 2003 and 2005 land cover maps, however indicated that Dhaka is being started to expand in all directions, specifically to north-east, south-east and southern trends by filling up low lying areas. In order to lessen the flood susceptibility, earth filling is a very popular means of land development in Dhaka Metropolitan. Three sectors, namely, public, private, and individual households, are responsible for rapid land use/cover change in Dhaka. Earlier land developments were mainly done by ad hoc planning by the public sector mainly onto agricultural lands. Currently, a tremendous increase of private sectors, particularly real state agencies, is noticeable in Dhaka, developing both wetlands and agricultural lands without considering the environmental consequences. In contrast, the individual household is largely responsible to develop the fringe zone (Islam 1996;

2005). Land conversion by individual for speculative purposes has greatly been influencing the development of suburb areas as observed during field visits. Furthermore, poor coordination among the organizations is equally accountable to the quick loss of natural covers. For instance, approximately 6,000 ha of Dhaka-Narayangonj-Demra (DND) project were originally retained for assisting the agricultural production, which is being converted to residential land apace since 1990s without any approval from the government (Islam 1996). This unauthorized land conversion is clearly implying the weakness of the involvement of multiple legislative agencies. Hence, unregulated expansion in Dhaka Metropolitan is underway, and leading to disarrayed growth.

The nature of land cover changes revealed that the built-up and bare soil/landfill categories have been increased significantly (Table 2). For instance, in 1960 built-up areas were 4,625 ha (hectares) which increased gradually to 5,550 ha in 1975, indicating only 20% growth within 15 years interval. Figure 3 shows the trends of land use/cover change during 1960–2005. This figure can be used to discern the incredible pressure of urbanization on natural land covers in Dhaka Metropolitan. Table 2 demonstrates

Fig. 4 Relative changes in land cover (%) in Dhaka Metropolitan



that between 1960 and 2005, urban built-up areas increased approximately 15,924 ha while agricultural land decreased 7,614 ha, vegetation decreased 2,336 ha, wetland/lowland decreased 6,385 ha, and water bodies decreased 864 ha. Analysis showed that built-up areas increased to about 344% in 2005 (Table 2) compared to 1960, whilst the increment of landfill/bare soils was about 256% with the greatest increase of built-up areas between 1975 and 1988 (95%). In the same period, water bodies reduced greatly followed by a large reduction of cultivated land. This result affirms the earlier findings made by different researchers using ground observation (Chowdhury and Faruqui 1989; Islam 1996). To accommodate the increasing population, the city has been expanded extensively compared to its early stage and concurrently its spatial expansion has been severely constrained by the physical factors. Therefore most of the development has been resulted in the loss of natural resources. It has been observed that the growth of Dhaka is extremely faster than the mega-cities of North America and Europe. A basic difference is noticed in the case of Dhaka's growth. For example, mega cities in the western world grew gradually which enables these cities to effectively develop the necessary services and management facilities for its people but the situation is just opposite in Dhaka Metropolitan due to the extreme pressure of population explosion. Consequently, local government is confronting diverse challenges to attain sustainable development which could be more acute in the coming years if planning regulations are not enforced.

To evaluate the results of land cover conversion, matrices of land cover change from 1960 to 1975, 1975 to 1988, 1988 to 1999, 1999 to 2003, 2003 to 2005, and 1960 to 2005 were calculated and relative changes between years have been determined (Fig. 4).

This calculation revealed that cultivated land was used for urban development in the 1960–1975, resulted in 13% loss. From 1975 to 1988, both water bodies (29%) and cultivated land (25%) were converted to built-up areas. Decadal population data were used to find the causes of such transformation, and found positive relationship between land cover change and population growth. The population of Dhaka for example, was only 0.55 million in 1961 which suddenly shot up to 2.6 million in 1974 with an annual growth rate of 9.32% during 1961–1974 (BBS 2001). In 1981, the population rose to 3.44 million when the growth rate surpassed all its previous records. During these periods the swamps and wetlands within the city started to disappear quickly and new areas of residential, administrative, business and commercial importance began to develop. In addition, slum and squatter settlements also sprang up in different areas of the city (Siddiqui et al. 2000). Thus the result of this study resembles to the observation made by Siddiqui et al. (2000) and Islam (1996, 2005).

As there was little opportunity left for urban expansion onto agricultural lands, pressure on the vegetative cover amplified in 1988–1999 and the highest loss of vegetation was observed in this period (24%). To meet up the growing demand of urban land, pressure exerts on wetland/lowland cover between 1999 and 2005 that resulted 15% loss in 1999–2003 and 21% decline in 2003–2005, respectively. This process of expansion evidently has detrimental impact on the environment, particularly the increase of flood risk susceptibility (Dewan and Yamaguchi 2007). It may be noted that the encroachment of low lying areas in the western rim of Dhaka has been intensified immensely after the construction of 32 km flood embankment along the Buriganga and

Table 3 Summary of classification accuracies (%) for 1975, 1988, 1999, 2003, and 2005

Land use/cover class	1975		1988		1999		2003		2005	
	Producer's	User's	Producer's	User's	Producer's	User's	Producer's	User's	Producer's	User's
Water bodies	89.5	85.0	100.0	75.0	94.7	90.0	93.8	100.0	83.3	100.0
Wetland/lowlands	80.0	90.9	73.3	100.0	91.3	95.5	100.0	94.1	84.2	84.2
Cultivated land	71.4	71.4	88.9	76.2	84.0	100.0	80.0	94.1	81.3	72.2
Vegetation	83.3	71.4	95.0	90.5	100.0	80.0	85.7	75.0	86.7	81.3
Built-up	91.3	100.0	76.9	95.2	90.5	86.4	86.4	95.0	93.1	100.0
Bare soil/landfill	100.0	95.0	100.0	80.0	85.7	90.0	100.0	80.0	100.0	86.7

Turag rivers in 1992 (Chowdhury et al. 1998). Studies demonstrated that the encroachment of floodplains in this side aggravated flood hazard in the city instead of securing people from persistent flooding in the monsoon (Dewan et al. 2004; Maathuis et al. 1999).

Urbanization in the study area has been very rapid on other land covers with discontinuous patches which resulted in rampant sprawling. Inadequate housing, unplanned and haphazard development, ubiquitous urban poverty, absence of proper land use policy, inequity of lands, pitiable coordination among responsible organizations and absence of reliable information on the current land use practice, all are contributing to the urban sprawling which is leading to the unconceivable emergence of slums and squatters. According to a study, for instance, the slum population in Dhaka has doubled in a decade, to reach 3.4 million in 2006 from 1.5 million in 1996, and the number of slum communities increased about 70% (CUS et al. 2006). In contrast, between 1991 and 2005 population of Dhaka also increased significantly with an annual average growth of 5% which outpaced the country's annual growth (BBS 2001; World Bank 2007). It is estimated that presently about 37% of the city's population live in slums (CUS et al. 2006), and the environment of slum is extremely unhygienic as they are located at sites such as solid waste dumps, open drains and sewers, embankment and often along the rail line (UN-Habitat 2003). In addition, the people living in slums are extremely vulnerable to natural hazards such as floods (Rashid 2000). Thus the accelerated growth of slum population fosters to the loss of expensive wetlands, vegetation cover, and also appallingly affecting both human and physical environments. On the contrary, the ever-increasing urban population and its poverty result in over-exploitation of natural resources to a level which is no longer sustainable for future.

Assessment of the classification accuracy of the derived land cover maps from satellite data was carried out. Error matrices were used to assess the classification accuracy and are summarized for all 5 years (excluding 1960 land cover) in Table 3. The overall accuracies for 1975, 1988, 1999, 2003, and 2005 were 85.6%, 86.4%, 90.4%, 90%, and 88.2% respectively, with Kappa statistics of 82.7%, 83.7%, 88.5%, 87.9%, and 85.6%. Producer's and user's accuracy was also consistently high, ranging from 71% to 100%. The MSS resulted in the lowest overall

accuracy (85.6%) among the dataset. It can be noted that the MSS imagery is too coarse to study land cover of urban environment and the accuracy gets reduced due to mixed pixels (Haack 1987). Moreover, decreases of image spatial resolution lead to spectral mixing of different categories produce spectral confusion between covers (Yang and Lo 2002). These could be the reasons to have the least accuracy for the land cover map derived from the MSS data in addition to registration error (Townshend et al. 1992). Misclassifications were between built-up areas and bare soil/landfill category. In addition, some water bodies were interpreted as wetland. Built-up areas are generally expected not to change to other cover types such as agriculture or wetland. The changes may have been resulted from classification errors. The examination of the accuracies of land cover data however, revealed that all the datasets met the minimum USGS total accuracy set out by Anderson et al. (1976), hence the application of rule-based post-classification refinement found to be effective that improved the map accuracy by 10–12%. It is necessary to mention here that all the images used in this study represented only the winter time, therefore other seasonal data, i.e. spring image can be considered to determine the seasonal spectral properties as well as land cover change characteristics of a highly dynamic urban environment.

Conclusions

Multi-temporal land use/cover classification in Dhaka Metropolitan of Bangladesh using topographic maps and remote sensing was described in this paper. Using a post-classification comparison, the dynamics of land use/cover change are presented. The result revealed that Dhaka has been experiencing rapid urban growth leading to the quick loss of rural and arable lands. Urban encroachment is rapid on other covers resulting rampant sprawling and environmental deterioration. Urban built-up areas increased significantly from 11% to 334% which is mainly attributed to the fast increase of population due to large rural–urban migration. Consequently, water bodies, cultivated lands, vegetation, and wetland/lowlands are reducing apace. It was found that much of the city's rapid growth in population has been accommodated in informal settlements with little attempt being made to limit

the risk of environmental impairments. To alleviate the adverse environmental impacts of urban expansion, planning regulations need to be enforced and effective coordination should be ensured to save the fast declining natural resource base for sustainable development. Urban expansion should be restrained on wetlands, vegetation and expensive floodplains or cultivated lands. This would save productive fertile soils from urbanization and also contribute to the ecological equilibrium. It is increasingly imperative to take a holistic approach to the management of urban area and its environment. Furthermore, regional and local land use management policy need to be revised, and integrated multi-disciplinary research should be initiated so that sustainable urban development strategy can be formulated.

The accuracy of the maps was satisfactory, the highest accuracy obtained for the Landsat TM data while the lowest accuracy attained for the MSS image. The study took the advantage of GIS and remote sensing techniques to quantify the land cover change in Dhaka Metropolitan over the last 45 years. Due to the deficiency of land use/cover maps of the study area and restricted access to aerial photographs/ geospatial database, satellite data can be operationally used to generate land use/cover dynamics, and are useful for Dhaka and elsewhere for sustainable land management and policy makings.

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