Urban Land Cover Mapping and Change Detection Analysis Using Remote Sensing Techniques

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ABSTRACT

Dhaka, as the capital city of Bangladesh, encounters a host of problems perpetuating for decades. With the growing importance of the city and mounting up pressure of population, the problems are getting more and more precarious every year. Amid all the problems, uncontrolled urban growth is perhaps the most irritating one particularly for the planning and development control authorities.

The unwanted urban growth originates not only due to ineffective development control but also due to failure of the equilibrium between demand and supply of buildable and liveable urban land. Therefore, regular monitoring of the plan implementation is necessary together with the urban development trend in new areas.

It is possible to analyze land cover change dynamics using time series of remotely sensed data. The incorporation of remote sensing techniques can help analyzing this kind of research in variety of ways like land cover mapping; detecting and monitoring of land cover changes over time.

The primary objective of this research is to quantify and investigate the characteristics of urban land cover changes (1989-2009) using the Landsat satellite images of 1989, 1999 and 2009. Dhaka City Corporation (DCC) and its surrounding impact areas have been selected as the study area.

A fisher supervised classification method has been applied to prepare the base maps with five land cover classes. To observe the change detection, some post-classification change detection techniques have also been implemented. Then it is found that the 'builtup area' land cover type is increasing in high rate over the years. The major contributors to this change are 'fallow land' and 'water body' land cover types.

Keywords: Remote Sensing, Land Cover, Change Detection, Satellite Images

1. Introduction

1.1. Background of the research

Like many other cities in the world Dhaka, the capital of Bangladesh, is also the outcome of spontaneous rapid growth without any prior or systematic planning. 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.

Dhaka City has undergone radical changes in its physical form, not only in its vast territorial expansion, but also through internal physical transformations over the last decades. These have created entirely new kinds of urban fabric.

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.

This new urban fabric is to be analyzed to understand the changes that have led to its creation. Therefore it is necessary to track the changes of modern Dhaka City which mainly includes the changes in the physical form of the city.

1.2. Problem identification

Dhaka is now attracting a huge amount of rural-urban migrants from all over the country due to well-paid job opportunities, better educational, health and other daily life facilities (Dewan et al. 2007). This kind of increasing and over population pressure is putting adverse impacts on Dhaka city like converting wetlands/natural vegetation/open space/bare soil to urban built-up areas (Khan, 2000). All these are creating numerous problems like unplanned urbanization, extensive urban poverty, water logging, growth of urban slums and squatters, traffic jam, environmental pollution and other socio-economic problems (Dewan *et al*. 2007).

1.3. Literature review

Remote Sensing (RS) and Geographic Information Systems (GIS) techniques are being widely used to assess natural resources and monitor environmental changes. It is possible to analyze land use/ land cover change dynamics using time series of remotely sensed data and linking it with socio-economic or bio-physical data using GIS. The incorporation of RS can help analyzing this kind of research in variety of ways like land cover mapping, detecting and monitoring land cover change over time, identifying land use attributes and land cover change hot spots etc (Lambin, 2001).

With the advancement of technology, reduction in data cost, availability of historic spatio-temporal data and high resolution satellite images, RS techniques are now very useful for conducting researches like land cover change detection analysis (Das, 2009).

1.4. Objective of the research

The general objective of this research is to map, detect, quantify and analyze and the land cover changes of Dhaka City over time. This research has been conducted to achieve the following broad objective:

- **i.** To quantify and investigate the characteristics of urban land cover changes (1989-2009) within the study area using satellite images.

2. Materials

2.1. Study area profile

The proposed study area for this research is Dhaka City Corporation (DCC) and its surrounding impact areas (Figure 1). This selected study area almost covers the biggest urban agglomeration and is the central part of Bangladesh in terms of social and economic aspects. Therefore, this area has huge potentiality to face massive urban growth in near future based on the current trend of rapid urbanization.

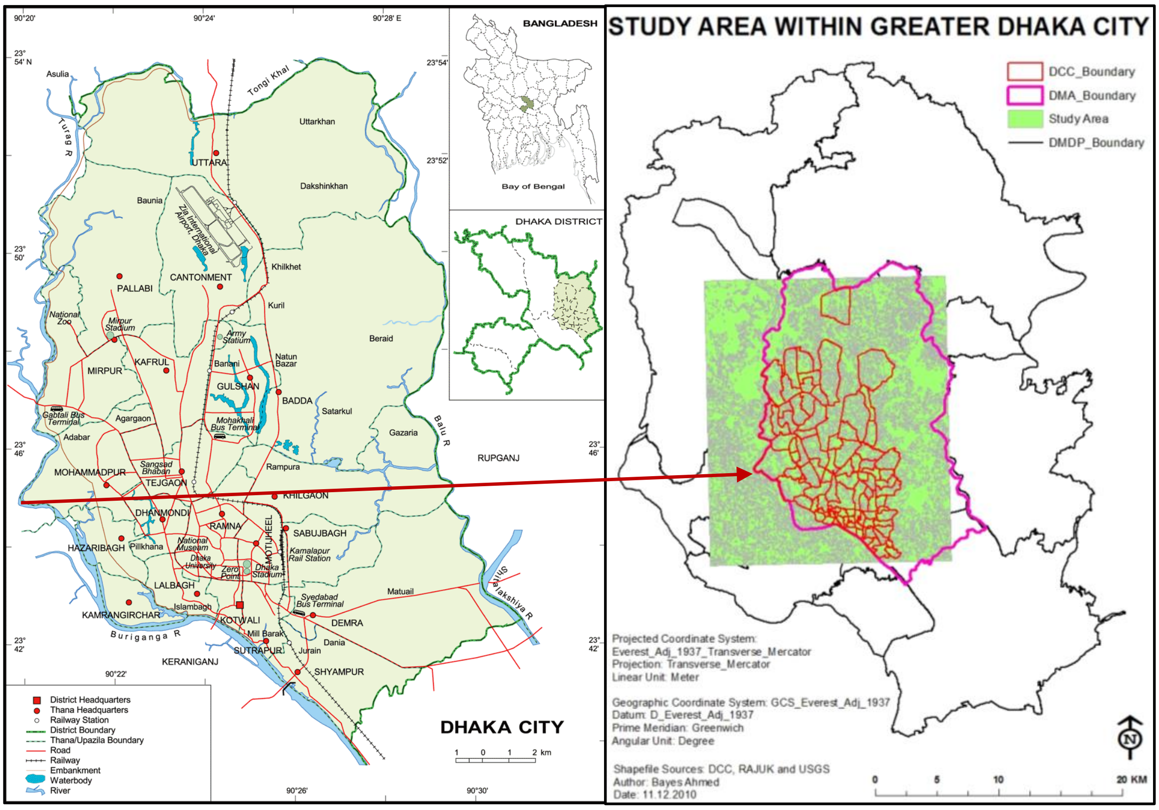

Figure 1: Location of the study area within greater Dhaka city, Source of left map: Banglapedia, National Encyclopedia of Bangladesh, 2011.

2.2. Satellite images

This research is dependent on secondary data. To prepare the base maps for analysis purpose and applying the different methods to achieve the research objectives, Landsat satellite images (1989, 1999 and 2009) have been collected from the official website of U.S. Geological Survey (USGS). Table 1 shows the details of the Landsat satellite images used for analysis.

Table 1: Details of Landsat satellite images

Respective Year	Date Acquired (Day/Month/Year)	Sensor	Quality (100% Cloud Free)
1989	13/02/1989	Landsat 4-5 Thematic Mapper (TM)	7
1999	24/11/1999	Landsat 7 Enhanced Thematic Mapper Plus (ETM+)	9
2009	26/10/2009	Landsat 4-5 Thematic Mapper (TM)	9

Landsat Path 137 Row 44 covers the whole study area. Map Projection of the collected satellite images is Universal Transverse Mercator (UTM) within Zone 46 N– Datum World Geodetic System (WGS) 84 and the pixel size is 30 meters. Figure 2 illustrates the location of DCC on the Landsat satellite images for different years. The surroundings of DCC have also been included within the study area for detecting land cover changes.

The Band Combination used, for the base Landsat satellite images (Figure 2), is 432 Red-Green-Blue (RGB). Map Projection used for DCC Boundary is Bangladesh Transverse Mercator (BTM) and datum is D_Everest_1830.

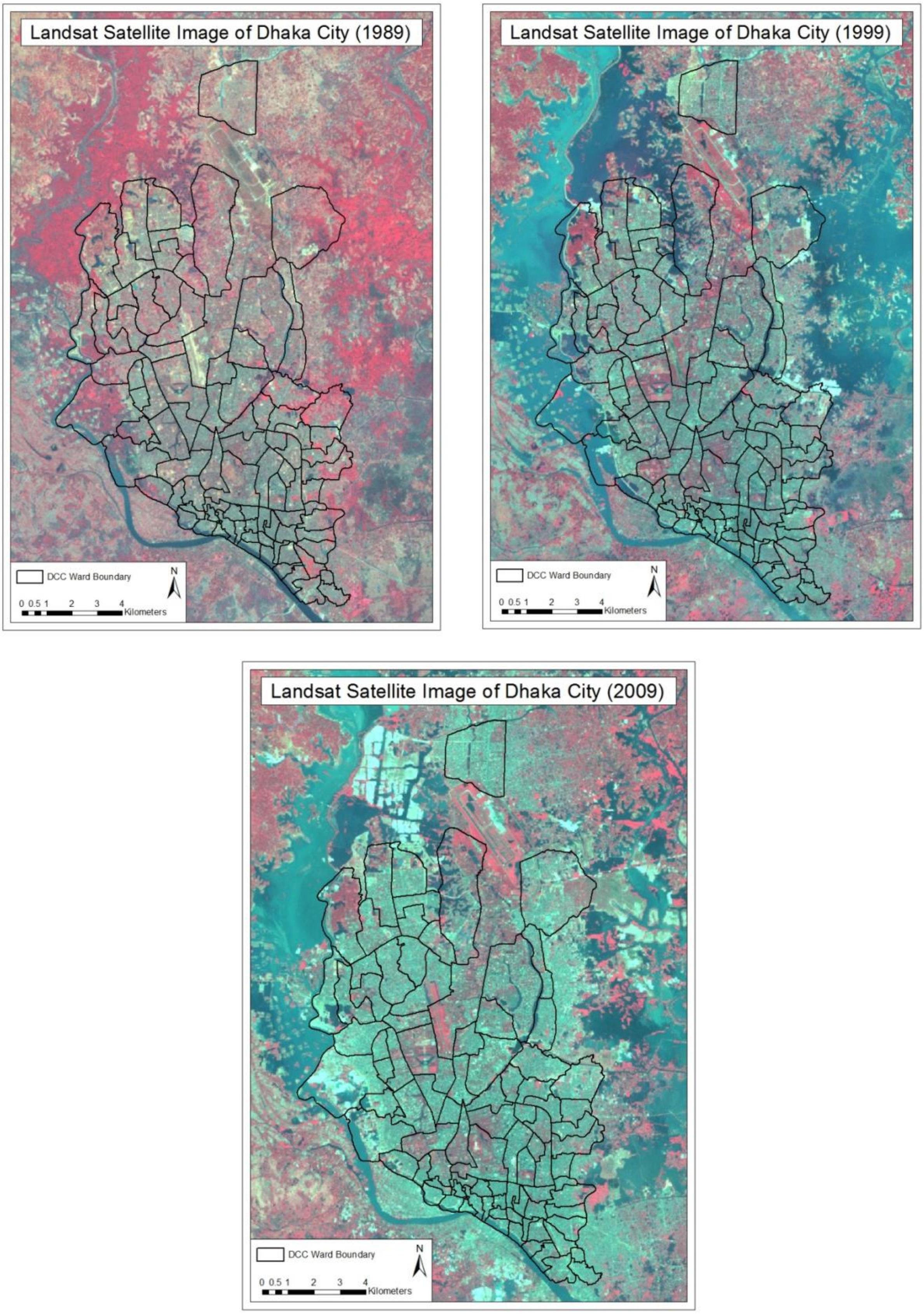

Figure 2: Dhaka City Corporation and its surroundings

[Map Prepared by the Researcher; Source: USGS, 2010 and DCC, 2008]

2.3. Reference data

For the purpose of ground-truthing/ referencing, several base maps of Dhaka City (for the year of 1987, 1995 and 2001) have been collected from the Survey of Bangladesh (SoB). Again, for comparing the images some other reference satellite images (IRS image of 1996 and Landsat satellite image of 2003) have been collected from the Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

The land use maps of all the wards of DCC (2008) have been collected from DCC and *Rajdhani Unnayan Kartripakkha* (RAJUK) or Capital City Planning and Development Authority. Google Earth is another option to get some ideas about the recent land cover pattern of Dhaka city. These reference data have been used for training site selection and preparing land cover maps.

3. Base map preparation

The collected Landsat satellite images (1989, 1999 and 2009) have been used for preparing the base maps for land cover change detection analysis.

3.1. Image enhancement

Image enhancement is a kind of image modification that enables the capabilities of human vision to identify and select regions of interests (Billah *et al.* 2004). Composite generation technique has been performed for this particular research.

3.2. Composite generation

Landsat TM records 7 spectral bands. For visual purpose any 3 bands are combined that are acting a False Color Composite (FCC). Figure 3 shows several composites using different band combinations from the same TM images (Eastman, 2009).

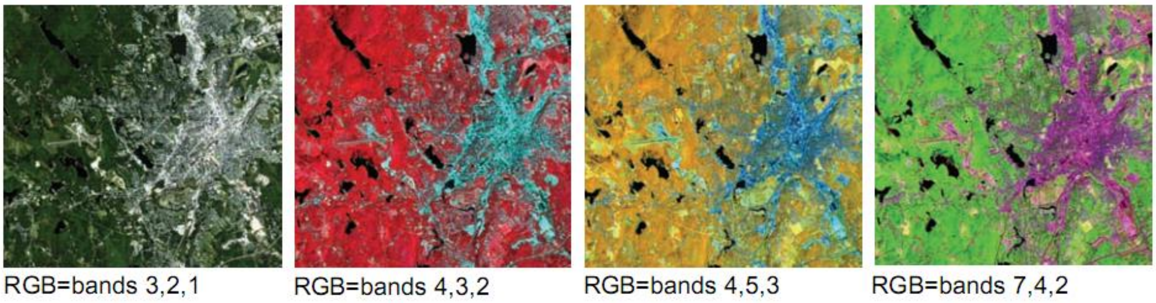

Figure 3: Composites using different band combinations

Using the basic colours red, green and blue (RGB) it is possible to prepare different FCC images (Eastman, 2009). These FCC images are useful to distinguish between different cover types or ground objects like buildings, roads, and vegetation.

The FCC of RGB= bands 4, 3 and 2 has been chosen for this research. This combination normally makes urban areas appear blue, vegetation red, water bodies from dark blue to black, soils with no vegetation from white to brown (Eastman, 2009). Figure 4 shows the FCC (RGB= bands 4, 3 and 2) image of the study area for different time periods.

The study area is selected by choosing the same geographic position of all 7 bands for the same time period. This helps to maintain the same number of rows and column.

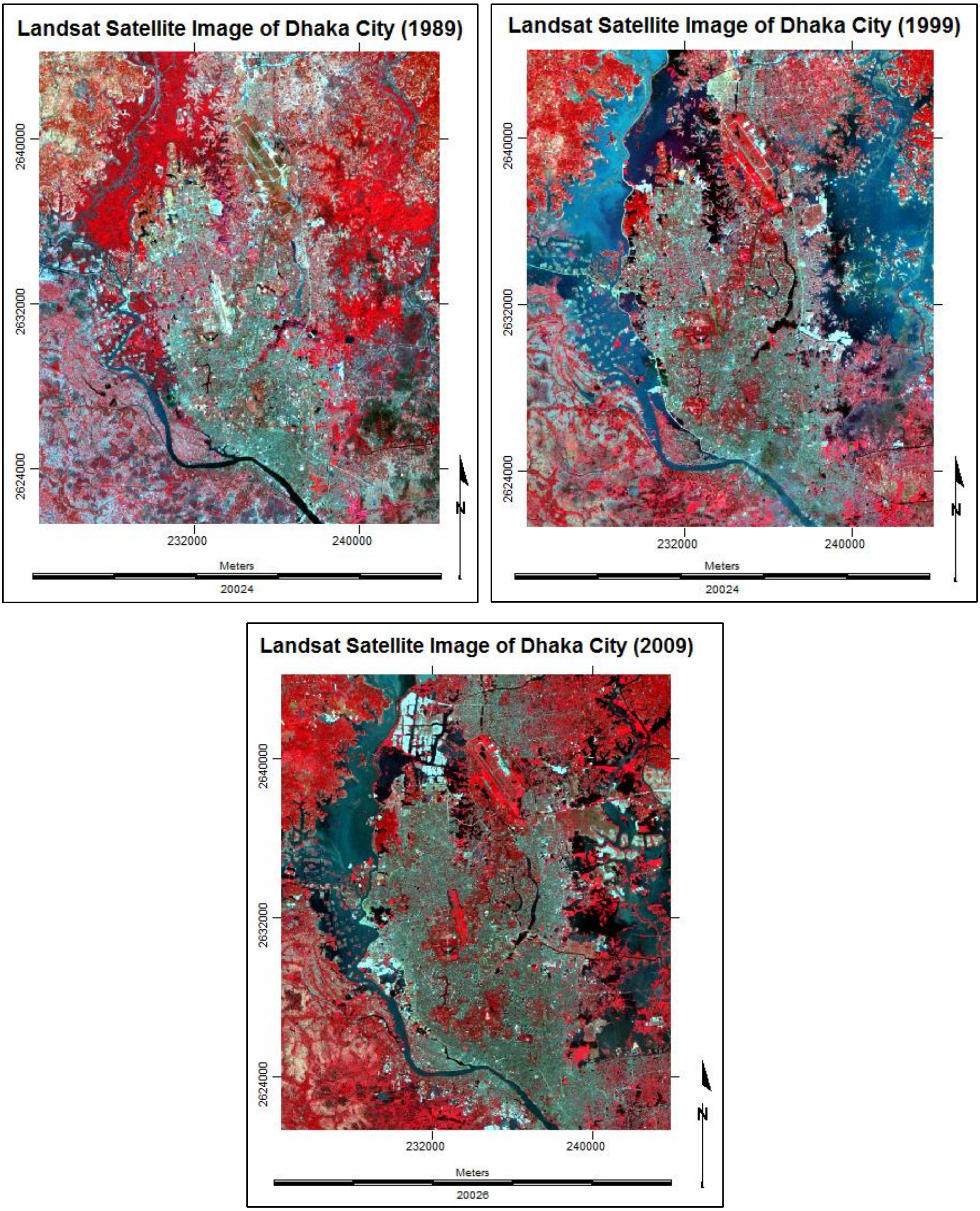

Figure 4: False color composite (RGB=4, 3 and 2) maps of the study area

3.3. Image classification

Image classification refers to grouping image pixels into categories or classes to produce a thematic representation (Canada Centre for Remote Sensing, 2010). Image classification comprehends various operations that can be applied to photographic or image data. There are two basic methods of image classification: supervised and unsupervised (Eastman, 2009). Supervised classification relies on the priori knowledge of the study area (Canada Centre for Remote Sensing, 2010). Therefore, for this research, a supervised classification method has been used.

In case of supervised classification, the user develops statistical description for various known land cover types that is called signature development. Then a procedure is used to identify the similar pixels/signature for different land cover types for the whole image.

3.4. Training site development

Training sites are the areas defined for each land cover type within the image. The chosen colour composite is used for digitizing polygons around each training site for similar land cover. Then a unique identifier is assigned to each known land cover type. More than one training site for each type has been identified for making the land cover images. Five land cover types have been identified for this research (Table 2). The training sites developed for this research are based on the reference data and ancillary information collected from various sources as mentioned earlier. For developing training sites properly, all the satellite images have been analyzed with respect to spectral and spatial profiles. This is performed to make sure that the digital numbers (DNs) of different land cover types are acceptable prior to final classification (Eastman, 2009).

Table 2: Details of the land cover types

Land Cover Type	Description
Builtup Area	All residential, commercial and industrial areas, villages, settlements and transportation infrastructure.
Water Body	River, permanent open water, lakes, ponds, canals and reservoirs.
Vegetation	Trees, shrub lands and semi natural vegetation: deciduous, coniferous, and mixed forest, palms, orchard, herbs, climbers, gardens, inner-city recreational areas, parks and playgrounds, grassland and vegetable lands.
Low Land	Permanent and seasonal wetlands, low-lying areas, marshy land, rills and gully, swamps, mudflats, all cultivated areas including urban agriculture; crop fields and rice-paddies.
Fallow Land	Fallow land, earth and sand land in-fillings, construction sites, developed land, excavation sites, solid waste landfills, open space, bare and exposed soils.

3.5. Signature development

This is the stage of creating the spectral signature for each type of land cover. This is done by analyzing the pixels of the training sites. When the digitization of training sites is finished, the statistical characterizations of each land cover class are needed. These are called signatures. Signatures are developed incorporating the vector files containing training sites and the bands used for analysis. These signature files contain statistical information about the reflectance values of the pixels of the training sites for each land cover type (Eastman, 2009).

3.6. Classification

After developing signature files for all land cover classes the next step is to classify the images based on these signature files. This can be done by: hard or soft classifiers. These are kind of statistical techniques to classify the whole image pixel by pixel based on each known type particular signature (Eastman, 2009).

For this research, a hard classifier called ‘Fisher Classifier’ has been chosen. Fisher classifier uses the concept of the linear discrimination analysis (Eastman, 2009). Fisher Classifier performs well when there are very few areas of unknown classes and when the training sites are representative of their informational classes (Eastman, 2009). This is why fisher classifier is appropriate for this particular research, because most areas for the classes are known.

3.7. Generalization

After image classification, sometimes many isolated pixels may be found (Eastman, 2009). These isolated pixels may belong to one or more classes that differ from surrounding pixels. Therefore it is necessary to generalize the image and remove the isolated pixels.

Filtering is the solution for this type of problem. In RS analysis, filtering refers to the removal of certain spectral or spatial frequencies to highlight features in the remaining image. Mode filters are good for filling gaps between polygons after a vector-to-raster conversion (Eastman, 2009).

Therefore, a 3×3 mode filter has been applied to generalize the fisher classified land cover images. This post-processing operation replaces the isolated pixels to the most common neighbouring class. Finally the generalized image is reclassified to produce the final version of land cover maps for different years (Figure 5).

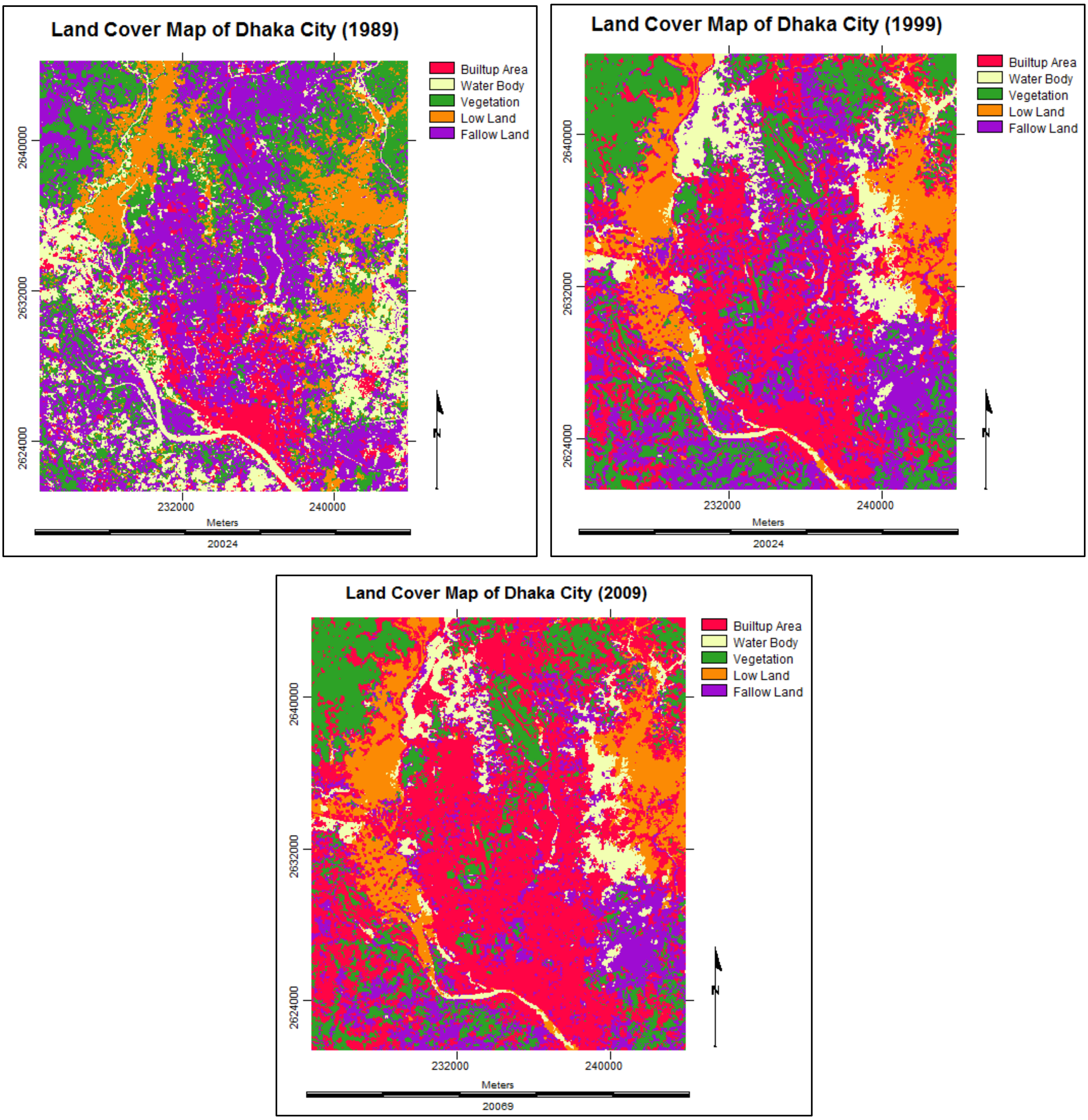

Figure 5: Land cover maps of Dhaka city

3.8. Accuracy assessment

The final stage of image classification process is accuracy assessment. Accuracy Assessment is a kind of process to compare the classification with ground truth or other data. It allows evaluating a classified image file (Eastman, 2009).

It is not typical to ground truth each and every pixel of the classified image. Therefore some reference pixels are generated. These are points on the classified image. Each point of reference pixels represents specific geographic coordinate of the image. These reference pixels are randomly selected (Congalton, 1991).

The randomly selected points within the classified image list two sets of class. The first set of class values represents the actual land cover type. The second set of class values are known as reference values. The ground truthing of reference values are possible through field visit, comparing base maps, aerial photos, previously tested maps or other data (ERDAS IMAGINE, 2006). The number of reference pixels is an important issue for accuracy assessment. It has been proved that more than 250 reference pixels (± 5%) are needed to estimate the mean accuracy of classification (Congalton, 1991). Therefore 250 reference pixels have been generated; using stratified random distribution process, for each classification image to perform accuracy assessment.

3.9. Assessment procedure

The collected base maps have been used to find the land cover types of the reference points. Figure 6 shows the randomly selected 250 points for each base year. From the accuracy assessment cell array, three types of reports are generated (ERDAS IMAGINE, 2006). These are:

- **a)** Error Matrix: it compares the reference points to the classified points in a $c \times c$ matrix, where c is the number of land cover classes.
- **b)** Accuracy Totals: it calculates statistics of the percentages of accuracy that is based on the error matrix and
- **c)** Kappa Coefficient.

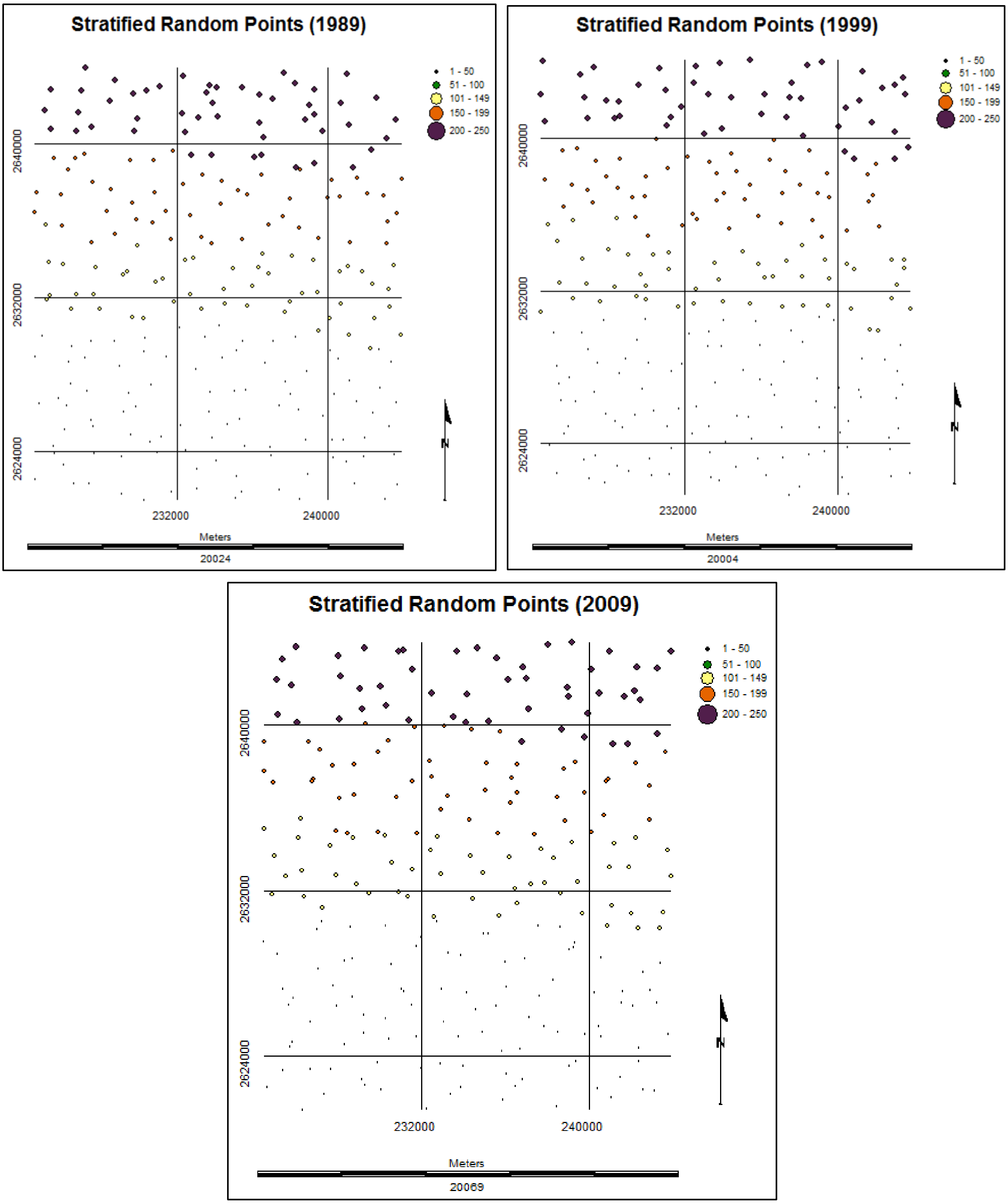

Figure 6: Selected stratified random points for ground truthing

3.10. Accuracy results

User's accuracy measures the proportion of each land cover class which is correct. On the other hand, producer's accuracy measures the proportion of the land base which is correctly classified (ERDAS IMAGINE, 2006). Producer's and User's accuracy are also found consistently high ranging from 71%-100% (Table 3, 4 and 5) for all the years. Therefore, higher values of producer's and user's accuracy indicate that the prepared base maps are quite good enough for further analysis.

The overall accuracies for 1989, 1999 and 2009 are found 85.20%, 86.80% and 91.60% respectively, with Kappa statistics of 0.8054, 0.8294 and 0.8592.

It means few misclassifications have been observed in the classified land cover maps of Dhaka city. This may be because of the same spectral characteristics of some land cover types. For example, in case of 1989 base map, certain built-up areas were misclassified as fallow land. Again, in most cases it was really difficult to separate water bodies and low/cultivable lands categories. The reasons may be the seasonal variations of the satellite images for different years and the similar spectral properties of land covers in some cases. Moreover, less image spectral resolution has directed to spectral mixing of different land cover types. This has caused spectral confusions among the cover types. It is also important to mention that the images of 1999 and 2009 represent winter season while the image of 1989 represents spring season.

It is typical that most land cover classification images are 85% accurate (Eastman, 2009). Therefore, it can be stated that the classification accuracy achieved for this research is above satisfactory level.

Table 3: Accuracy totals (1989)

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
1	18	21	18	100.00%	85.71%
2	46	38	35	76.09%	92.11%
3	66	61	54	81.82%	88.52%
4	43	35	31	72.09%	88.57%
5	77	95	75	97.40%	78.95%
Totals	**250**	**250**	**213**		

Table 4: Accuracy totals (1999)

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
1	62	72	60	96.77%	83.33%
2	28	24	20	71.43%	83.33%
3	56	53	47	83.93%	88.68%
4	33	30	29	87.88%	96.67%
5	250	250	217	85.92%	85.92%
Totals	**250**	**250**	**217**		

Table 5: Accuracy totals (2009)

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
1	112	115	108	96.43%	93.91%
2	22	19	17	77.27%	89.47%
3	43	45	41	95.35%	91.11%
4	28	28	24	85.71%	85.71%
5	45	43	39	86.67%	90.70%
Totals	**250**	**250**	**229**		

4. Change detection analysis

Change detection is important because it helps the researcher to understand and monitor the land cover change pattern (e.g. urbanization, deforestation, agricultural land management) within the study area.

4.1. Change in area

It is clear that over the years (1989 to 2009) builtup area has increased in huge percentage (from 8.4% to 46%). It is also noteworthy that fallow has decreased in good rate (from 38% to 17%). Other land cover types have decreased in a very small amount (Figure 7).

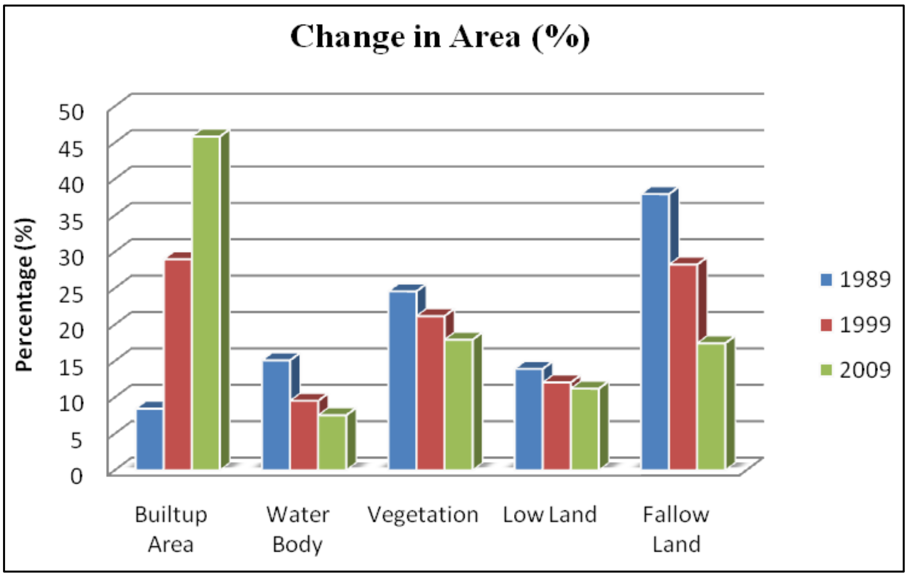

Figure 7: Land cover change in area (%)

4.2. Gains and losses by category

Figure 8 illustrates that builtup area has increased over the years while there is slight loss in this category. It means some parts of the previously existed builtup areas have converted to some other land cover classes, while vast new area has transformed into builtup area from other classes.

Gains in builtup area are evident in all three combinations. Again fallow land cover type is decreasing in large percentage in all the years. The changes (in terms of gains and losses) in other land cover types are almost the same or not influencing. Therefore an abrupt increase in builtup area and decrease in fallow land cover type is quite clear from this kind of analysis (Figure 8).

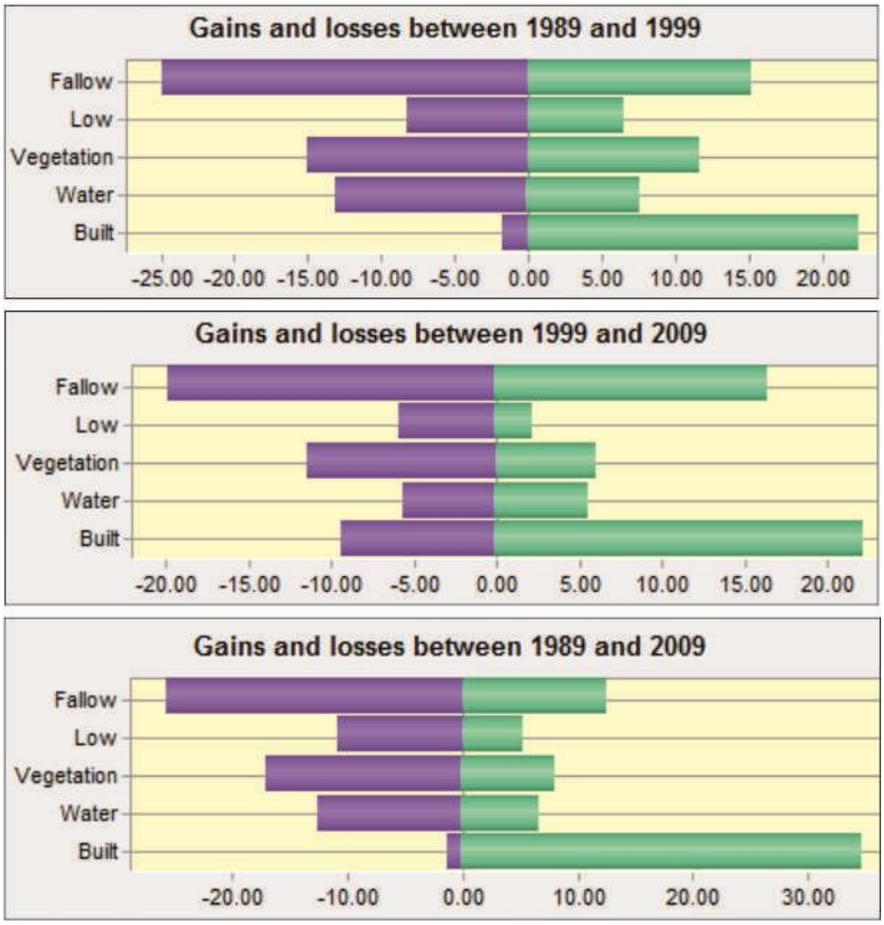

Figure 8: Gains and losses of land covers by category (unit: % of area)

4.3. Contributors to net change experienced by builtup area

Figure 9 illustrates which land cover type is contributing more to net change in built-up area. It is found that fallow land is contributing most converting towards builtup area followed by water body and vegetation.

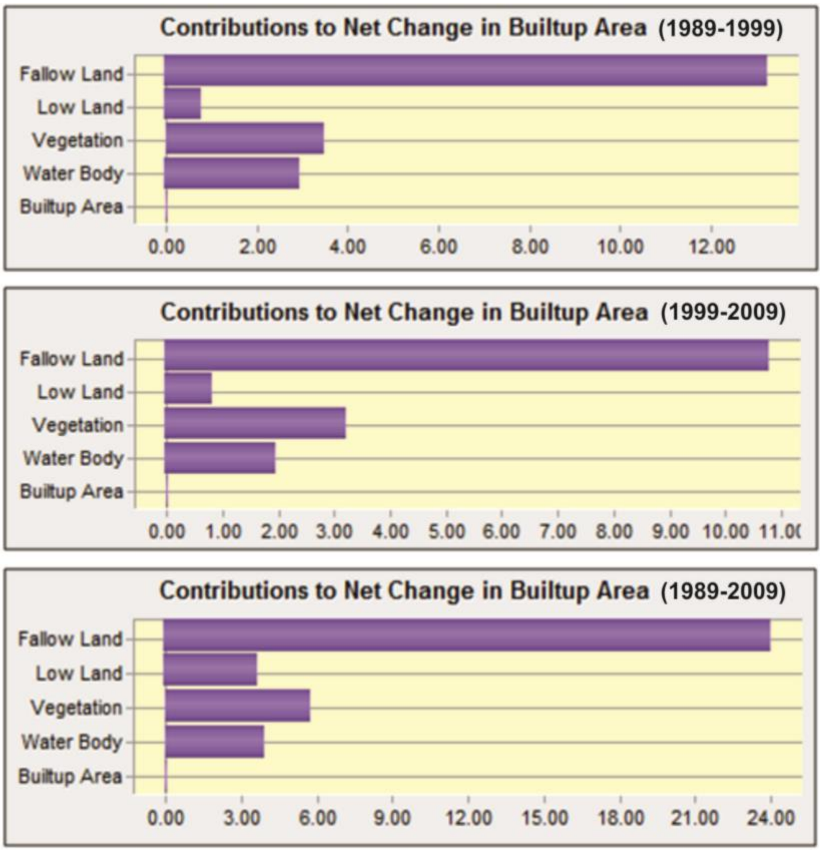

Figure 9: Contributors to net change experienced by builtup area (Unit: % of area)

4.4. Gains and losses in land cover types

In case of builtup area, the core southern part of Dhaka city has remained the same. While the north-east and south-west parts have converted to builtup areas. The northern part of Dhaka city has gained water body followed by a massive decrease in the south-east and south-west parts (Figure 10).

No particular pattern on gains or losses is found for vegetation. In cases of low land the changes are evident in eastern and western parts. Fallow land has decreased markedly and the losses are clear in north-western and mid parts (Figure 10).

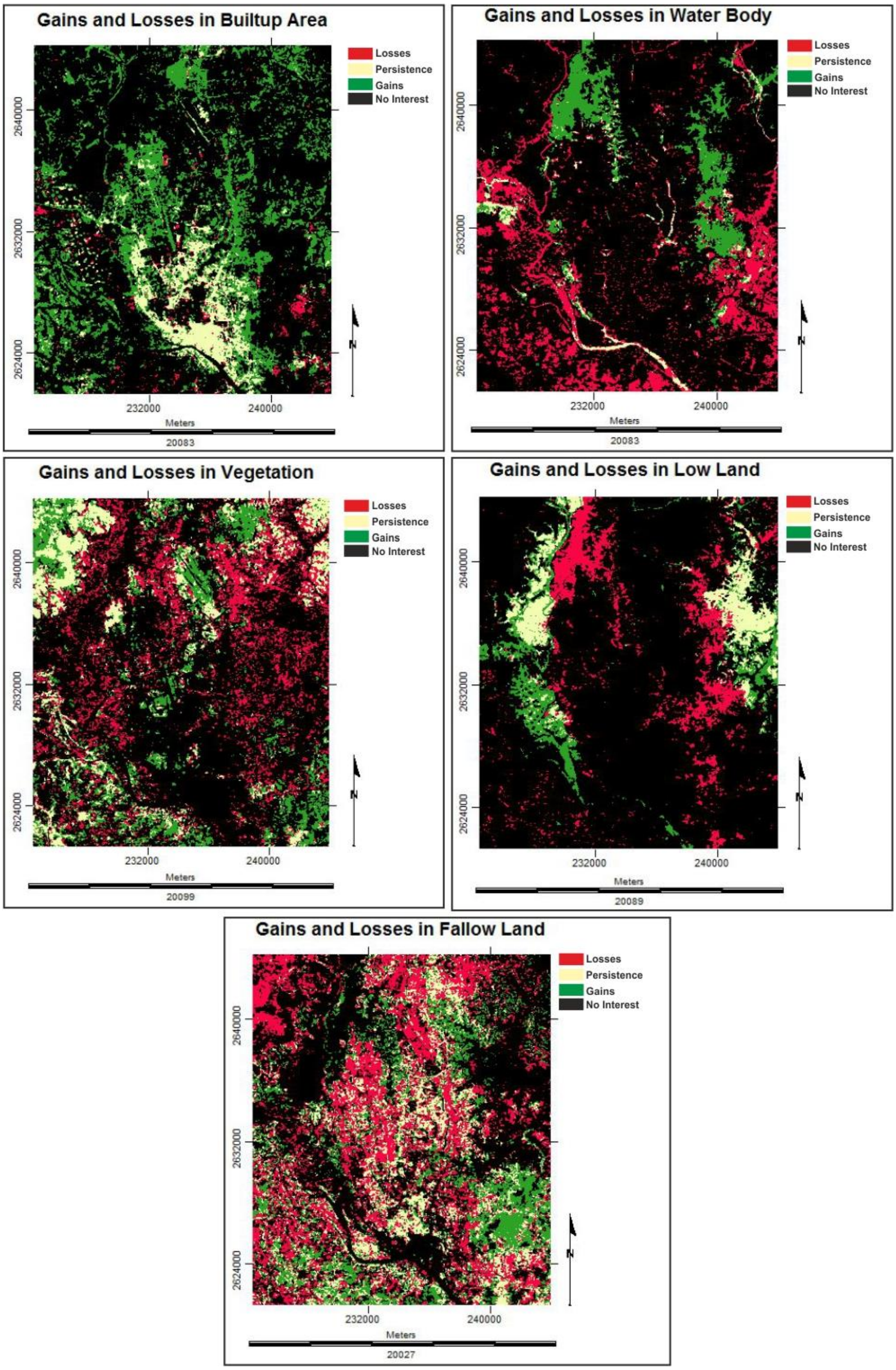

Figure 10: Gains and losses in land cover types (1989-2009)

4.5. Summary of land cover change detection analysis

In summary, it can be stated that in any combinations of time periods (1989-1999 or 1999-2009 or 1989-2009) some similarities have been found. Those are as follows:

- **i.** The increase in builtup area is prominent.
- **ii.** The net contribution to builtup area is mainly from fallow land followed by water body.
- **iii.** The expansion of urban area is following the northern and western portions of Dhaka city.
- **iv.** The growth of urbanization is haphazard indicating the absence of proper planning.

Moreover, fallow land and water body types are basically converting into builtup areas over the years. This is the general trend of land cover change pattern for Dhaka city from 1989-2009.

5. Conclusion

Dhaka, as the capital city of Bangladesh, encounters a host of problems perpetuating for decades. With the growing importance of the city and mounting up pressure of population, the problems are getting more and more precarious every year. Amid all the problems, uncontrolled urban growth/ development is perhaps the most irritating one particularly for the planning and development control authorities like DCC and RAJUK.

The unwanted urban growth originates not only due to ineffective development control but also due to failure of the equilibrium between demand and supply of buildable and liveable urban land. Therefore, regular monitoring of the plan implementation is necessary together with the urban development trend in new areas. An early measure in tackling problems can not only save huge public money but also reduce the miseries of the city dwellers. In this regard, performing this kind of change detection analysis, using Remote Sensing Techniques, to monitor the urban growth is highly recommended.

The interpretation of depicting the future scenario in quantitative accounts, as demonstrated in this research, will be of great value to the urban planners and decision makers, for the future planning of the modern and much liveable Dhaka City.

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