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# Urban Area Growth Monitoring in Sylhet City Using Remote Sensing and Geographic Information System from 2002 to 2017

**Sabrin Ara[1*] and Rabea Khatun[2]**

*[1,2]Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet, Bangladesh*

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**Abstract -** *Urbanization, a very striking phenomenon in this present world of development which inspires the dwellers to consume the resources regardless of brooding about the natural activities. Exploring the urban growth is another appellation of land use change detection which is essential to make any decision about the distribution of the limited properties as urban dynamics influence the environmental management. Change enquiry of landscapes is imperative for better thinking of the connections between human deeds and natural happenings. Sylhet city in Bangladesh is one of the speedy urbanized cities due to the public positive approach towards the city residence. This study is an effort to monitor the urban growth in Sylhet city from 2002 to 2017 by means of Remote Sensing (RS) and Geographic Information System (GIS). Landsat 7 ETM images for the year 2002, 2007, 2012 and 2017 were utilized to assess the urban area growth here. After applying various pre-processing techniques, image classification was performed using supervised classification-maximum likelihood algorithm. The results indicate that built up area of Sylhet increased from 11.95 km² to 18.51 km² from 2002 to 2017 losing 43.86% of its green cover startlingly. Correlation of population and built up area reveals a strong association.*

***Key Words*: Land use change, Landsat image, Remote Sensing, Geographic Information System, Maximum likelihood algorithm.**

## 1. INTRODUCTION

Currently, Bangladesh is undergoing an unplanned and rapid urbanization [1]. Increase in population with socio-economic advancement led to urbanization which consequently causes land use [2]. The pace and arrangement of urban growth monitored via Geospatial tools and techniques (Remote sensing and GIS) enables to report the overall landscape dynamics at a detailed level [3] This understanding is essential for the management of inadequate resources and building decision on various environmental issues [1]. Presentation of remotely sensed data helps to detect the changes in land use or land cover at low budget, in less time, and with better exactness in association with GIS while offering proper stage for data analysis [3-8].

Due to the forward-looking facilities in city area, people always have a preference for city abidance which is the key motivation behind shifting to the city-centered area in Sylhet. But there is no systematic endowment to provide accommodations this migrated folk here. The general intention of this research is to monitor the urban growth in SCC from 2002 to 2017 while specific objectives are to identify the changes in land use pattern and to explore the correlation between population and built up area alongside analyzing the trends with time.

Land use change detection is important to gather knowledge about the resources gained or lost in a particular land with time. Mainly, urban growth to accommodate the rapidly increasing population is liable for the land use alteration. In Sylhet city, migration from the rural part of the Sylhet district is one of the considerable issues for land use change. Previous study shows that GIS based land use change detection is time saving, reliable and cost effective.

### 1.1 Background Study

A little of the studies are emphasized here which have been conducted by various researchers for classifying Landsat images using supervised classification with the maximum likelihood algorithm.

#### 1.1.1 Outside Bangladesh

Weng [9] worked on investigating the land use conversion analysis in the Zhujiang Delta of China from 1989 to 1997. Another study on assessing urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing was done by Xiao et al. [10]. This study discovers the urban expansion from 1934 to 2001, and land use/cover change from 1987 to 2001. Wu et al. [11] conducted a study on monitoring the land use change in Beijing by means of remote sensing and GIS from 1986 to 2001. In this paper, land use change was also estimated for the succeeding 20 years. Belal and Moghanm [12] performed a study to assess the changes of agricultural lands, urban intrusion and water areas in another area of Egypt (Tanta and Quttour) during the period of 1972-2005 with integration using GIS. Abd El-Kawy et al. [13] detected the land use changes for the years 1984, 1999, 2005, and 2009 for the western Nile delta of Egypt using the same classification method. Again, from 1985 to 2010, urban growth was monitored and land use change was detected in Mansoura and Talkha (Daqahlia governorate Egypt) in a study by Hegazy and Kaloop [14]. In this study, the pre-managed images were also classified using unsupervised classification approaches. Bashir [15]conducted a research on the land use change in Edd Al-

Furssan Locality, South Darfur State, Sudan from 1972-2008. Singh and Dubey [16] studied on land use plotting of year 2008 in Naina - Gorma basin (part of Rewa district, India). The work was done by visual image interpretation approach and unsupervised classification by ISODATA clustering method was used to classify the image. Changes over a period of two decades (1990 to 2010) in land use/cover of Uttarakhand (Ramnagar town area, Nainital district, India) was studied by Rawat et al. [17]. In another study, land use/land cover change was monitored over the same time period (20 years) in another area of Uttarakhand (Almora district, Hawalbagh block, India) by Rawat and Kumar [18]. Ramachandran et al. [19] classified satellite images from 1920 to 2015 in Eastern Ghats, India to detect the long-term land use and land cover changes. Butt et al. [20] worked to detect the land cover changes observed in Simly watershed, Pakistan for the years 1992 and 2012. Again Butt et al. [21] concentrated on analyzing of the change detection in Rawal watershed, Islamabad for the same duration. Hassan et al. [3] estimated the land use/cover changes in Islamabad from 1992 to 2012. Another study was done by Khan and Qasim [22] to investigate the land use change in Pishin district, Pakistan for the year 1992, 2003, 2013.Boori and Choudhary [23] worked to illustrate the urban growth and land use changes in Samara city, Russia from 1975 to 2015. Katyambo and Ngigi [24] monitored the change in urban land cover between 1995 and 2015 using GIS and Remote Sensing techniques in Nairobi metropolitan area, Kenya.

### 1.1.2 Within Bangladesh

Haque et al. [25] conducted a research on land use configuration change and its reasons in Sylhet city. The impacts of land use changes are also demonstrated in this study. This study includes both the digital image processing and field survey to detect changes from 1988 and 1997. A study on evaluation of land-use form change over a period of 18 years (1988–2006) in West Bhanugach Reserved Forest, (Moulavibazar district, Sylhet Forest Division, Bangladesh, was performed by Halim et al. [26] Both supervised and unsupervised approaches were applied in this study. Dewan and Yamaguch [27] conducted a study to monitor the land use and land cover change in Greater Dhaka, Bangladesh, using remote sensing to endorse supportable expansion. Land use/cover changes and urban expansion in Dhaka, between 1975 and 2003 were evaluated in this paper. Again, the authors worked in another paper to monitor and detect the changes in land use and land cover in Dhaka Metropolitan of Bangladesh during 1960-2005 [28]. To forecast and examine the forthcoming urban growth of Dhaka City, a research was conducted by Ahmed and Ahmed [29]. In this study, Landsat images of 1989, 1999 and 2009 were used to monitor the urban growth. Hassan and Nazem [1] documented the urban expansion of in Chittagong for the years 1977,1989, 1999 and 2013. Khan et al. [30] analyzed the satellite images of the southwest coastal area of Bangladesh over a period of 13 years (1999–2012) to detect variations in land cover. This study also inspected the shared effects of land-use changes and natural calamities. Sarwar et al. [31] worked on a paper to detect the changes in Sulakbahar ward in Chittagong city, Bangladesh from 1989 to 2011 using RS and GIS. In order to generate the change statistics, a cross summary procedure has been used in this study. Again, Islam et al. [32] detected the changes in land use from 2005 to 2015 in Chunati wildlife sanctuary, Chittagong, Bangladesh. Rai et al. [33] reviewed systematically the fluctuating status, forms, and arrangements of land use in Bangladesh on national, regional, and local scales from 1930 to 2015. Hassan [2] conducted his research on five cities (Rajshahi, Rangpur, Sylhet, Khulna, and Barisal) in Bangladesh which are urbanizing rapidly from 1973 to 2014. Masum and Hasan [34] studied on assessing the land cover changes of Satchari National Park in Bangladesh for the years 1993, 2006 and 2019. Authors also used NDVI classification method in their study. G.M. Munna et al. [35] made effort to assess the land use changes of Sylhet city from 2006 to 2019 using Normalized Difference Vegetation Index (NDVI).

### 1.1.3 Image preprocessing, classification and accuracy assessment

Preprocessing of the satellite images before initiating classification and change detection, is highly needed and it aims at creating a more straight assemblage between the attained data and biophysical occurrences. Other studies that have also been acknowledged the importance of preprocessing the images are mentioned here. Without an operating Scan Line Corrector (SLC), the images after 2003 in Enhanced Thematic Mapper plus (ETM+) line of sight marks a zigzag pattern (stripping/gap). As a consequence, the width of the images increases toward the scene edge and imaged area is replicated. However, the Landsat & ETM+ still has the capability of taking useful images with the SLC turned off, specifically within the interior part of any desired area. Data obtained from Landsat 7 SLC-off have the similar radiometric and geometric quality as data obtained from Landsat 7 SLC-on. Focal analysis (an iterative process) is an essential tool which interpolates the missing data and resolves this phenomenon is to be used for gap filling/ destriping Due to solar radiance and scattering of sunlight the actual ground reflectance value gets changed. To extract the exact surface reflectance value, atmospheric correction along with haze reduction is to be performed. Also, radiometric correction need to be conducted. To classify the images, maximum likelihood algorithm is operated for classification of the images which generally gives satisfactory result. To perform classification, signature files need to be generated. A suitable signature is the one guaranteeing the presence of 'insignificant confusion' among the terrestrial covers to be diagrammed. To rise classification preciseness and decrease misclassifications, post-classification fine-tuning is consequently operated for straightforwardness and efficiency of the technique. After that, accuracy assessment of the classified image is to be done to propriety the classification and it is indispensable to execute accuracy assessment for every single classification [36-43].

### 1.2 Study Area

Sylhet, a major city of Bangladesh is positioned at 24.8917°N 91.8833°E, in the north-eastern section within the Sylhet Division, inside the Sylhet District. While Sylhet remains relatively small compared to other cities in the country, it is among the wealthiest with remittance income playing a dynamic role in supporting the growth of business and construction sectors [44]. The hills in the city, from north-south, are supposed to have influenced the particular location of the primary community foundation, but rapid urbanization makes these obstacles minor [2]. Sylhet City Corporation comprises of 27 wards and 210 mahallas, and has a total area of 27.36 $km^2$ (previously 26.50 $km^2$). **Figure 1** represents the study area.

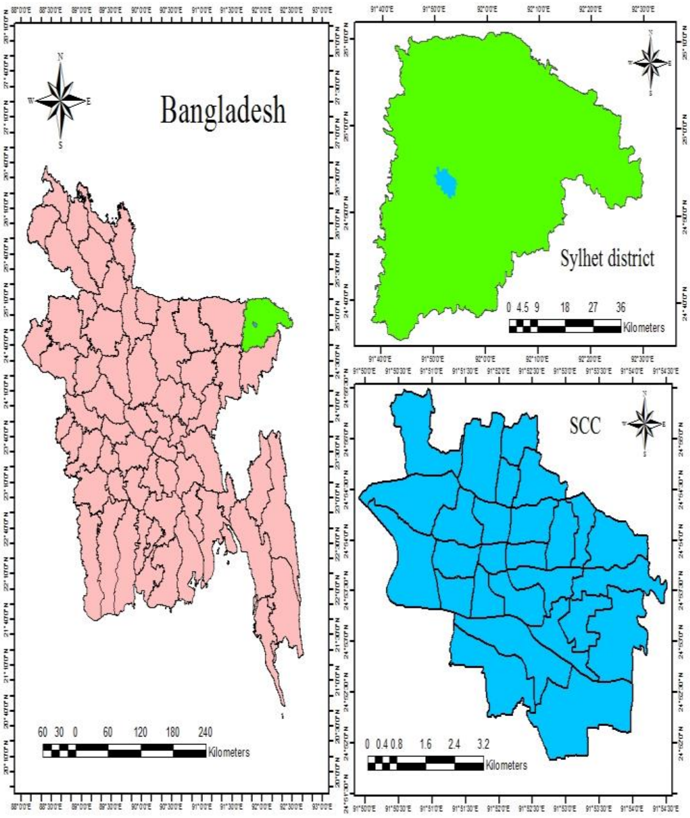


**Figure 1:** Study area of this research

## 2. Materials and Method

### 2.1 Data collected to develop land use pattern map

The required satellite images for this research have been taken out from the USGS Earth Explorer (http://earthexplorer.usgs.gov/). The images were extracted from Enhanced Thematic Mapper (ETM). The images were taken in dry season and cloud cover was specified as less than 10%. Data collected to develop the land use map is summarized in **Table 1.**

#### 2.1.1 Software used

- ERDAS Imagine 2015 (Hexagon)
- ArcGIS v10.3.1 (ESRI)

***Table 1:*** *Summary of the characteristics of the satellite images used*

| Data | Acquisition date | Projection | Sun elevation (°) |
|---|---|---|---|
| Landsat 7 ETM | 2002-02-26 | UTM (Zone 46N) | 46.14 |
| Landsat 7 ETM | 2007-02-24 | UTM (Zone 46N) | 45.67 |
| Landsat 7 ETM | 2012-02-22 | UTM (Zone 46N) | 45.59 |
| Landsat 7 ETM | 2017-02-19 | UTM (Zone 46N) | 46.09 |

*UTM=Universal Transverse Mercator

### 2.2 Method

The following flow diagram in **Figure 2** shows the method used in this study to attain the aim of this research.

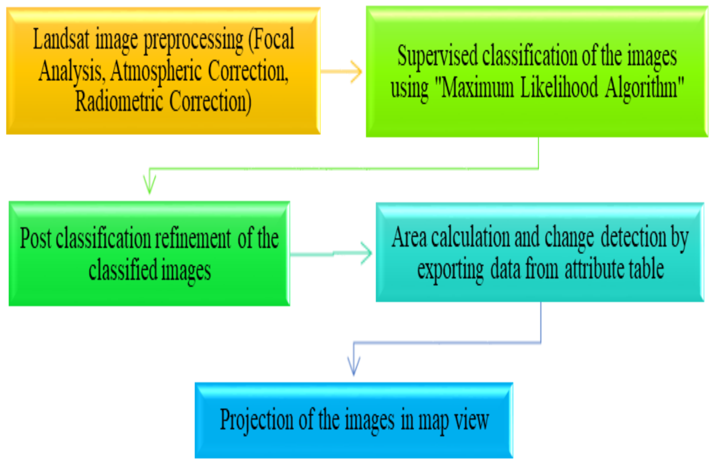


**Figure 2:** Work steps of this study

### Urban growth monitoring

According to Verburg [45] land-use conversion is the alternation in the intent of the land, which is not only the conversion in land cover but also modifications in concentration and management of resources. Attempt has been taken to evaluate the land use transformation from 2002 to 2017 (taking 5 years interval) in Sylhet city using remote sensing and GIS techniques. For this to do, the following steps have been followed.

### 2.2.1 Image Preprocessing

All the bands without thermal (Band 6) and panchromatic (Band 8) were stacked using the layer stack tool in ERDAS imagine. Raw images obtained from Landsat satellite contains effect of solar radiance, reflectance, dust, haze, smoke which eventually can lead to error in classification results. To resolve these issues, some corrections are needed to be done before attempting to classification. In this study, images were corrected in ERDAS imagine by using focal analysis tool to fill the gap of Landsat 7 images recurrently. Then atmospheric correction was done prior to haze reduction. After that, the subsetting was done based on the area of interest (AOI). The shapefile of Sylhet district and Sylhet City Corporation (SCC) was projected into WGS 1984 UTM Zone 46N before subsetting.

### 2.2.2 Image Classification

False color composite (FCC) (Band 2,3,4) was used in this study. Bands were called (Red, Green, Blue) according to the requirement of FCC from the stacked image. The images were classified using ArcGIS v10.3.1. The area was categorized into five major classes, viz. waterbodies, vegetation and forest, built up area, sand fill and crop land with seasonal fallow land. **Table 2** represents the classes. For every single preset land use category, training sections were designated by demarcating polygons around symbolic sites and a total of 500 training samples were taken. Then signature file was created by means of the pixels bounded by these polygons. Later, maximum likelihood algorithm was applied for supervised classification of the images. It is one of the most popular supervised classification method. It is a method which takes for a particular pixel for a certain class. This theory adopts that the probability of a specific class to be in a specific pixel is always equal.

***Table 2:*** *Classes depicted on the basis of classification*

| Class name | Description |
|---|---|
| Built up area | Residential, commercial, industrial, transportation, streets, mixed urban, farmstead/rural residence. |
| Vegetation and forest | Varied forest lands, green leaves |
| Waterbodies | River, open water in low lying land, lakes, ponds and reservoirs |
| Crop land and seasonal fallow land | Crop fields and fallow lands (used by people for different purpose), exposed soil, excavated soil. |
| Sand fill | Sand bar (natural or manmade) |

In this study, false color composite images of the study area have been used instead of the true color composite images, because in true color composite image, the features cannot be identified clearly. Example of false color composite image is shown in **Figure 3.**

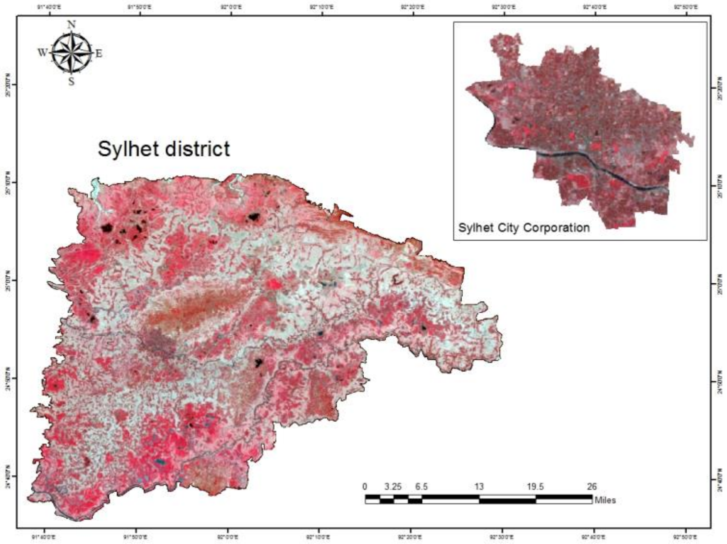


**Figure 3:** False color composite image of study area

### 2.2.3 Post Classification Smoothing

Post classification refinement of the images was done using the Majority Filter and Boundary Clean tool of ArcGIS before assessment of classification accuracy. This made the classified images more smooth and clean.

### 2.2.4 Area Calculation and Finding Change

To detect the changes in the last 15 years, areas of the representative classes have been calculated in attribute table of the classified images. The resolution of the pixels was 30m*30m.

Then, data was exported from the attribute table for the four maps to measure the percentage of changes. Microsoft Excel (2016) was used to calculate the changes.

### 2.2.5 Accuracy Assessment

Assessment of accuracy of the classified images has been executed to justify the validity of facts revealed from the classified image. A total of 80 users value were created using the stratified random sampling method (a minimum number of observations are randomly placed in each category) for each image. Ground truth data obtained from Google Earth for 2017 was used after converting the layer of user value to KML file. For 2002, 2007 and 2012, ground truth data was obtained from the Landsat images of the respective years as reference.

KAPPA coefficient measures the agreement between predefined producer values and user defined values. The KAPPA coefficient (COHEN 1960) for classified image of 2002, 2007, 2012 and 2017 are 0.98, 0.91, 0.92 and 0.89 with overall accuracy 98.75%, 92.5%, 93.75% and 91.25% respectively.

### 2.2.6 Map Presentation

After completing the accuracy assessment, map layout has been made in ArcGIS for the four classified maps of year 2002, 2007, 2012 and 2017 respectively. Then the maps have been exported for presentation.

## 3 Result and Discussion

### 3.1 Urban growth monitoring

It is audited from the classified images for the years 2002, 2007, 2012 and 2017 that, land use in Sylhet City Corporation has changed a lot with a large urban growth. Again, the decrease in vegetative area has been observed. The classified images are shown in map view from **Figure 5-8.**

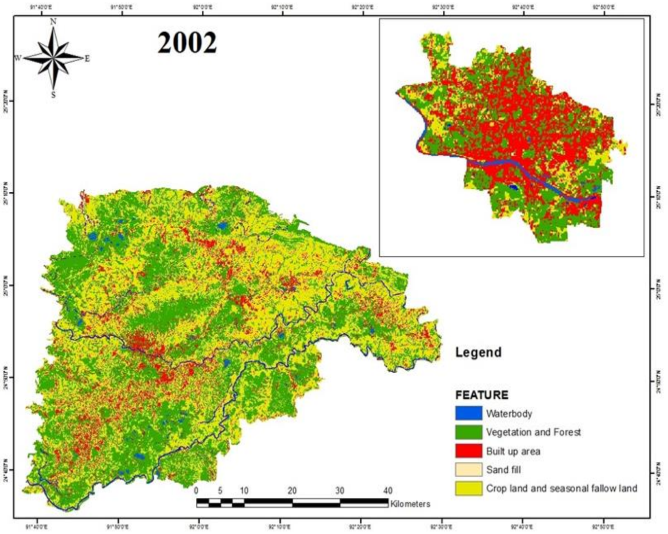


**Figure 4:** Land use map of year 2002

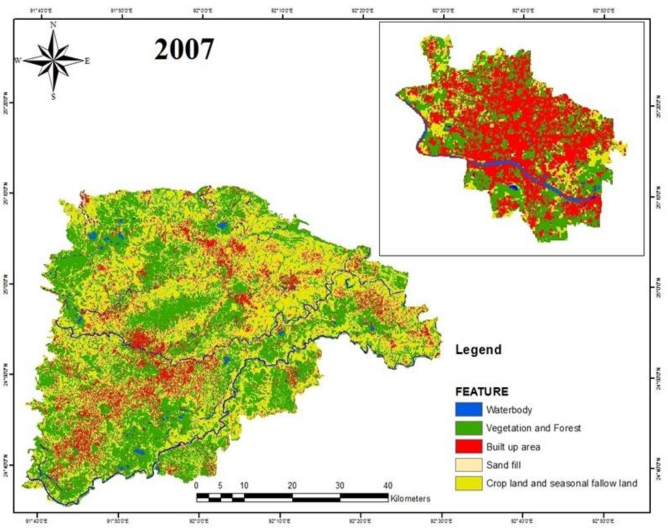


**Figure 5:** Land use map of year 2007

### 3.2 Accuracy of classification

To investigate the exactness of the findings exported from the images, classification accuracy has been assessed for the images of 2002, 2007, 2012 and 2017. A total of 80 users value were created using the stratified random sampling method for the four images based on visual interpretation. Again, 80 producers value were obtained from reference images based on ground truth data. For the year 2017, ground truth data have been obtained from the Google Earth. Using error matrices the overall accuracy, user accuracy, producer accuracy and Kappa coefficient have been carried out which are presented in **Table 3.**

***Table 3:*** *User and Producer Accuracy of classification*

| Year | Overall accuracy | Kappa coefficient |
|---|---|---|
| 2002 | 98.75 | 0.98 |
| 2007 | 92.5 | 0.91 |
| 2012 | 93.75 | 0.92 |
| 2017 | 91.25 | 0.89 |

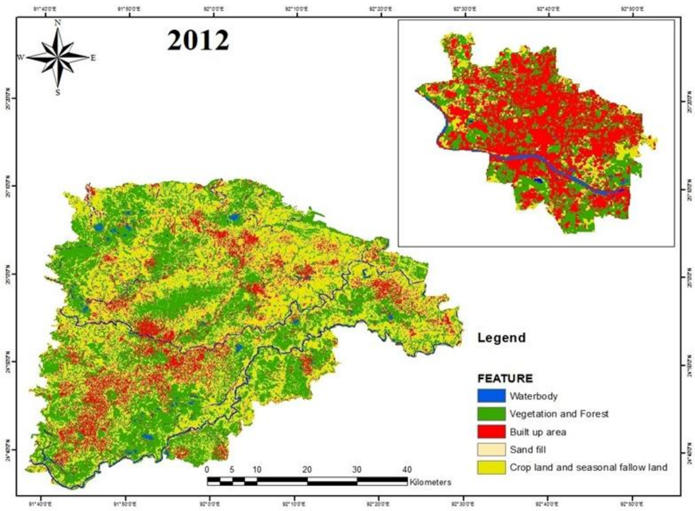


**Figure 6:** Land use map of year 2012

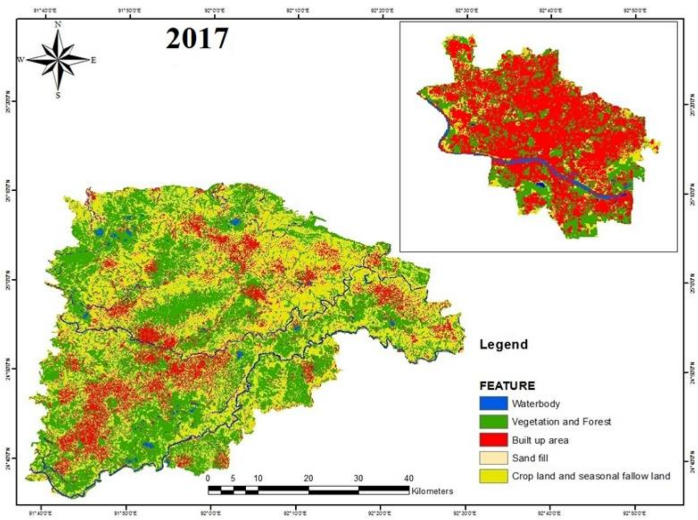


**Figure 7:** Land use map of year 2017

Accuracy obtained from the results is acceptable. Due to the malfunction in Landsat 7 after 2003, accuracy for the image of year 2002 is more than the others. The value of user and producer accuracy was also calculated.

### 3.3 Area Calculation

The areas of the respective features have been calculated in the attribute table and exported then. **Table 4** shows the area of the features .Here, though the city boundary of SCC did not remain same from 2002 to 2017, area for 2017 has been used for detecting the changes within that area of 27.36 $km^2$ in this study.

**Table 4:** Calculated area of SCC from 2002 to 2017

| Feature | 2002 ($km^2$) | 2007 ($km^2$) | 2012 ($km^2$) | 2017 ($km^2$) |
|---|---|---|---|---|
| Waterbody | 1.121 | 1.0546 | 1.002 | 0.9783 |
| Vegetation and forest | 9.9453 | 8.4347 | 6.6932 | 5.6828 |
| Built up area | 11.9514 | 13.8342 | 16.6283 | 18.509 |
| Sand fill | 0.0742 | 0.0983 | 0.0856 | 0.0923 |
| Crop land and seasonal fallow land | 4.2681 | 3.9382 | 2.9509 | 2.0978 |
| Total | 27.36 | 27.36 | 27.36 | 27.36 |

The result shows that the city area's green cover (vegetation and forest) was 9.9453 $km^2$ in 2002, which declined to 5.6828 $km^2$ in 2017 i.e. in the last 15 years the city has lost 4.2625 $km^2$ (43.86%) of it's green cover startlingly. The study reveals that among five different land use or cover types, crop land and seasonal fallow land contributed to 15.6% of the total city area in 2002, which has reduced to 7.7% in 2017.

The key causes of this reduction in verdancy, indicated by the study, point to the built-up area of Sylhet City Corporation which has increased from 11.9514 $km^2$ in 2002 to 18.5088 $km^2$ in 2017. In fact, in 2002 the city already became overburdened with buildings and covered 43.68% of the total area and in 2017 the percentage has become 67.65% which is staggering. Therefore, built up area of Sylhet city has shown an expansion of 54.87% in 2017 from 2002. In addition, the sand bars, have seen to be increased and the rate of increase was more within 2002 and 2007. From the ground truth observation, it has been observed that sand bars were created cutting the trees to build new infrastructures.

As the images were taken in dry season (month February), the area of the waterbody already showed to be less in 2002 i.e. 4.09% of the total area. Even so, 12.73 % in waterbody has reduced from 2002 to 2017.

### 3.4 Change detection

After exporting the data from the attribute table of the classified images, changes have been detected using MS Excel. **Figure 8** represents the changes in area of the features from 2002-2017. It is evident from this figure that built up area increased causing decrease in the green cover i.e. vegetation and forest as well as crop land and seasonal fallow land. The rate of increase in built area is higher for the interval 2007-2012 than other time intervals.

### 3.5 Correlation test and trend analysis

To measure the strength of association in between the variables (population and built up area) correlation test has been worked out and Pearson Correlation Coefficient (PCC) has been determined. **Table 5** shows the numerical value of the variables. The trends in population and built up area with time are shown in **Figure 9.**

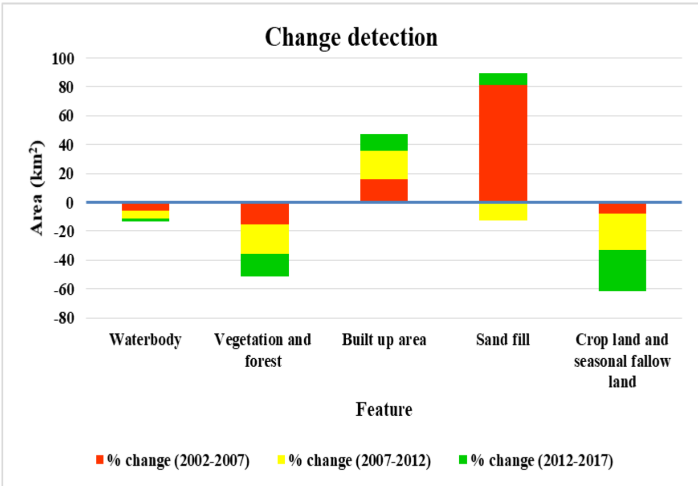


**Figure 8:** Changes in area of the features in Sylhet city in the last 15 years.

**Table 5:** Variables to be correlated

| Year | Population* | Built up area |
|---|---|---|
| 2002 | 299679 | 12.1514 |
| 2007 | 427265 | 14.7842 |
| 2012 | 552828 | 16.3983 |
| 2017 | 782646 | 18.4771 |

*Sylhet City Corporation

Correlation (significant at the 0.05 level of 2 tailed), PCC = .988 (a very strong correlation).

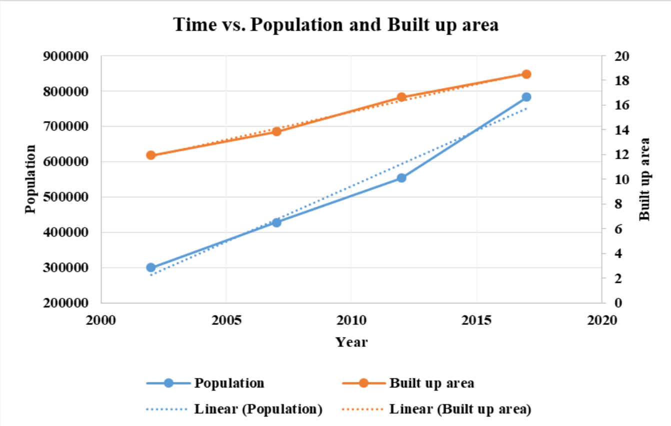


**Figure 9:** Trend in population and built up area with time.

## 4. CONCLUSION

The study was directed in Sylhet city with an aim to detecting the land use change from 2002 to 2017 correlating the built up area with population. The study reports that Sylhet City Corporation (SCC) is losing its green cover remarkably and facing a massive urban growth. In other words, SCC is fetching a concrete bush day by day. As per analysis, it is found that land use in Sylhet City Corporation has changed a lot and the built-up area has amplified from 11.9514 $km^2$ to 18.5088 $km^2$ in the mentioned 15 years causing loss in green cover of 43.86%. This study suggests that, proper planning for land use should be schemed. There are some limitation of this study-

- Due to the malfunction in scan line corrector of Landsat 7 (after 2003), it causes striping on the images and creates data gaps. The missing DN values had been interpolated using the focal analysis tool in ERDAS imagine. But it is a fact that, interpolated data are not dependable as real data to the same degree.
- The classification of the images has been done using the maximum likelihood algorithm-supervised classification. This method is based on visual inspection which may not always be correct. Again, the method takes huge time for calculation, counts severely on a regular distribution of the records in every single input band and tends to classify over the signatures.

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## BIOGRAPHIES

Sabrin Ara is a Faculty member (Lecturer) of Civil and Environmental Engineering department of Shahjalal University of Science and Technology, Sylhet. Her areas of interest and research are in the Geotechnical Engineering, Land Use-Land Cover change detection (GIS & RS), Recycling resources and Waste management.

Rabea Khatun holds a B.Sc. degree in Civil and Environmental Engineering from Shahjalal University of Science and Technology. Her areas of interest and research are in Structural Engineering and Environmental Engineering