Urban land use change analysis using RS and GIS in Sulakbahar ward in Chittagong city, Bangladesh

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ABSTRACT

The main aim of the present study is to identify and detect the land use, land cover changes occurred in Chittagong city and to integration of Remote Sensing and GIS data for analyzing, evaluating and changing of land-use in study area. To conduct this study, Sulakbahar Ward of Chittagong City Corporation was selected as the study area. Based on remotely sensed data, the thematic maps and field records have been considered for detail investigation. Rapideye image of 2011 and Landsat TM image of 1989 of the study area were the two important bases of visual classification and change detection study. After making the images geometrically corrected, visual interpretation of the images has been done by generating thematic data layers with the help of ERDAS IMAGINE software. Change detection map is produced by overlaying the data layers of the two study years (1989 and 2011). Highest decrease (79 hectares) and highest increase (91 hectares) have occurred in the category of exposed land and settlement area respectively and about 27% of the total land has undergone changes into different land-uses between 1989 and 2011. Use of RS and GIS technologies are recommended for better planning and sustainable management of urban land use in study area.

Keywords: Urban, land Use, GIS, Remote Sensing, Chittagong city.

1. Introduction

Land is a very important asset and a means to sustain livelihood. It is the key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage. Land is a fundamental factor of production, and through much of the course of human history, it has been tightly linked to economic growth. It comprises biophysical qualities such as soil, topography, climate, geology, hydrology, biodiversity and political divisions. Land is also defined as consisting of such socioeconomic factors as technology and management. Land use has been defined as the way in which, and the purposes for which, humans employ the land and its resources (Meyer, 1995). Generally, land use change (LUC) is the modification of a piece of land. This change is based on the purposes of need, which is not necessarily only making the change in land cover but also change in intensity and management (Verburg et al., 2000).

In the face of a rapidly growing global population, increase in technological capacity and affluence, the Earth’s land cover has been transformed especially in developing countries (Codjoe, 2007). At the same time, social organization, attitudes, and values have also undergone profound changes. The history of urban growth indicates that urban areas are the
most dynamic places on the Earth’s surface. Despite their regional economic importance, urban growth has a considerable impact on the surrounding ecosystem (Yuan et al., 2005). In the last few decades, a tremendous urban growth has occurred in the world, and demographic growth is one of the major factors responsible for the changes. By 1900 only 14% of the world’s population was residing in urban areas and this figure had increased to 47% by 2000 (Long et al., 2007). 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, and 35 million in 2005 (BBS, 2011). Rapid urban growth leads to the transformation of rural lands to built-up areas, and it is estimated that each year more than 809 sq.km of agricultural land is being diverted to cities, roads and infrastructures in Bangladesh (BBS, 2005).

Urban growth is a common phenomenon in almost all countries over the world though the rate of growth varies. Currently, these are the major environmental concerns that have to be analyzed and monitored carefully for effective land use management. Land use / land cover inventories are assuming increasing importance in various sectors like agricultural planning, urban planning and infrastructural development (Imura et al., 1999). Recent years, urbanization is a major trend in big city all around the world (Weber, 2003). The main change of land use in these areas can be described as other type of land use converting into urban land. The land use change in large city area is a complicated process; several factors have influences on this process, including both physical and human aspects. On the one hand, accelerated urban expansion is usually associated with and driven by the social-economic factors; on the other hand, the process of urbanization has a considerable impact on the economics of the society in that area (Epstein et al., 2002 and He et al., 2006). So the detection of urban land change is important for officials and planners in the local government. A substantial amount of data from the Earth’s surface is collected using Remote Sensing (RS) and Geographic Information Systems (GIS) tools.

RS provides an excellent source of data from which updated land use/land cover (LULC) information and changes can be extracted, analyzed and simulated efficiently. Remote sensing is one source of information about urban areas, and it is becoming an important tool for understanding and solving many problems of cities and their suburbs. Remote Sensing (RS) is the science and art obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand et al., 1995). Geographic Information System (GIS) is a software aided system to solve some real world problems along with virtual planning processes. One may say that it deals only with geographic problems. However, it does not indicate a single type of task but integrating several aspects of collecting and storing data as well as to analyze, modeling and displaying the results (Al-Amin, 2012). In remote sensing, ‘Change Detection’ is defined as the process of determining and monitoring the changes in the land cover types in different time periods. It provides the quantitative analysis of the spatial distribution in the area of interest. 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 (Ahmed, 2011). With the advancement of technology, availability of historic spatio-temporal data and high satellite images, GIS and RS techniques are now very useful for conducting researches like land cover change detection analysis.
In this study an integrated approach of GIS and RS has been applied to identify and analyze the patterns of urban land use changes and provide quantitative and spatial information on changes of urban areas of the respective Ward of Chittagong city.

2. Aim & objectives of the study

The principal aim of this study was to apply remotely sensed data to detect and analyze urban land use changes of the corresponding Ward of Chittagong City Corporation, Bangladesh. The specific objectives of the study are:

1. To identify and detect the land use and land cover changes occurred in the Sulakbahar Ward of Metropolitan Chittagong; and
2. To Integrate Remote Sensing data into GIS for analyzing, evaluating and mapping of the changes of land-use and land cover of the last two decades in the study area.

3. Study Area

In recent times, Chittagong has been challenging numerous difficulties like unplanned urbanization, hill cutting, land slide, water-logging, growth of urban slums and squatters, traffic jam, environmental pollution and other socio-economic problems. In this regard, it is much needed to track the land use changes over time and predict the future scenario of Chittagong city. Chittagong City Corporation area possesses an area of 171 sq. km. with 41 Wards and 4.5 million of population (BBS, 2011). Among the 41 Wards, Sulakbahar (Ward No-8) has been considered for the present study. This Ward lies in the heart of Chittagong city and it has a variety of land uses e.g. industrial, residential, educational, vacant, hilly etc. According to the census of 2001 of Bangladesh, Sulakbahar Ward has an area of 502 hectare with the population of 119370 (BBS, 2001). The Ward is located between 22°21’ N latitude to 22°23’ N latitude and 91°21’ E longitude to 91°52’ E longitude (Figure 1).

3.1 Methodology

In order to conduct the study, a great deal of information was needed which was fulfilled through the primary and secondary sources. Before conducting the study, a reconnaissance survey was carried out to have a good idea about the study area and its land use. First of all, two remote sensing images of the study area named Rapideye (2011) and Landsat TM (1989) were collected from SPARRSO. The Rapideye image was geometrically corrected.
using UTM projection. The Landsat image was corrected geometrically with reference to this image by generating ground control points (GCP). The boundary of the Sulakbahar Ward has been digitized from the base map prepared by Chittagong City Corporation and converted to UTM projection from geographic projection to extract the image of Sulakbahar Ward. While conducting this study, a number of ground truth visits were done. Visual interpretation for the image of 2011 was carried out coupling the field collected (GPS Survey) data on the feature types with the image. Visual interpretation for the image of 1989 was carried out based on standard technique of color and texture analysis for particular false color composite of the image and interviewing of the local people.

The vector data layers were managed to make them suitable for GIS analysis to render statistics on land use and land use changes as well as to generate the relevant map products. In order to generate the change statistics, a cross summary procedure has been used through ERDAS Imagine software. Overlay (through ‘Union’ operation) of the composite data layers of the two study years has done to generate a multi-temporal composite data layer. The attribute table of this composite data layer was rebuilt to generate multi-temporal change-classes with appropriate identification of each change-class which helped to generate area statistics on the change of land use classes and assigning unique color for a particular feature on the map. The land use maps pertaining of two different periods were used for post classification comparison, which facilitated the estimation of changes in the land use category and dynamism with the changes. Post classification comparison is the most commonly used quantitative method of change detection with fairly good results. Finally, analysis of results is done to represent the findings of this study.

4. Result and discussion

4.1 Land Use Classes

By using of RS and GIS technique a large area can be mapped rapidly at low cost. It is a very important tool for studying land use and land cover analysis. In this study, six major land-use (Table-1) categories are identified considering the nature and diversity of land-uses in the study area, which are:

<table>
<thead>
<tr>
<th>Land use/Land cover Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Settlement Area</td>
<td>Residential (High, Middle and Low class), Commercial, Socio-economic infrastructure etc.</td>
</tr>
<tr>
<td>2. Educational Institutional Area</td>
<td>Govt/private: School, Polytechnic Institute, College, University etc.</td>
</tr>
<tr>
<td>3. Hill Area</td>
<td>Hills with mixed forest land, vegetable land and others</td>
</tr>
<tr>
<td>4. Industrial Area</td>
<td>Different types of heavy and light industry etc.</td>
</tr>
<tr>
<td>5. Water Bodies and</td>
<td>Permanent open water, lake, ponds, canals etc.</td>
</tr>
<tr>
<td>6. Exposed land</td>
<td>Exposed soils, landfill sites, vacant, vegetable land etc.</td>
</tr>
</tbody>
</table>
4.2 Interpretation of Landsat TM Image of 1989

For the interpretation of this image two methods are followed (e.g. False Color Composite and interviewing). Because of low image resolution, cross reference with the Google Earth image and recent remote sensing image have helped to determine the land-use of 1989 in the study area. From the image of Landsat TM 1989 (Figure 2) six major land use types have been identified and each of the land-use classes will get brief description in the following table-2.

Table 2: Proportion of Land-uses in 1989 & 2011

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Landsat TM 1989</th>
<th>Rapideye 2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (Hectares)</td>
<td>Area (Hectares)</td>
<td>%</td>
</tr>
<tr>
<td>1. Settlement</td>
<td>169</td>
<td>260</td>
<td>36.74</td>
</tr>
<tr>
<td>2. Educational</td>
<td>27</td>
<td>43</td>
<td>05.87</td>
</tr>
<tr>
<td>Institution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Hills</td>
<td>53</td>
<td>29</td>
<td>11.52</td>
</tr>
</tbody>
</table>
Out of 460 hectares of total land (Table-2), 169 hectares was occupied as settlement area. Among the land-use classes, settlement area posed the highest proportion of the land which was 36.74% in 1989 (Table-2). Since the location of the Sulakbahar Ward is geometrically around the center of the city, it achieved a great proportion of settlement two decades back also. Educational institutions were another land use type. Chittagong Polytechnic Institute and Nasirabad Government Women’s College are the two famous educational institutes were available in the year of 1989 within the study area. They contributed 27 hectares of total land which is 5.87% of total land use.

Hills are more common in the northern part of Chittagong city than the southern part. Sulakbahar Ward is one of the Wards of the northern part of Chittagong city. 53 hectares of land was under hill category which was 11.52% of the total land. Industrial use was another land use type. Because of the location of the major sea port of the country in the shore of Chittagong city, various industries were developed and are also developing within the territory of the city. Both sides of the Baizid Bostami road were furnished with the industries since 1989 and land area covered 46 hectares (10%) of the area of Sulakbahar Ward. The image of 1989 is not so helpful to find out the water bodies in the study area. It is established that the water bodies of the urban areas are decreasing day by day. So the water bodies are available today, must be available in the past. By assuming this conception, 2 hectares of water bodies is depicted in the land-use class of 1989 with the verification from the recent image. It is observed from the image that one third of the land of 1989 was exposed. In table-1, 35.43% of the total land, which was 163 hectares, was remained as the exposed land.

4.3 Interpretation of Rapideye Image of 2011

Rapideye image is furnished with the 5m resolution which provides a good idea to conduct the visual interpretation. Besides, ground truth information has helped to detect the classes more precisely. From the Rapideye Image 2011 (Figure 3) six major land use types have been identified which is presented (Table-2) and description of the land-use classes are enlisted below. The greatest proportion of the land which is 260 hecates is used as the settlement area in 2011 as per the Rapideye image. Since the increasing of urban population is occurring for several factors (e.g. natural increase of population, rural-urban migration, areal expansion) which demands more settlement facilities for the surplus population and which ultimately makes this major share (56.52%) in the land-use in the Sulakbahar Ward of Chittagong city. Along with the two major educational institutions of 1989, Chittagong Veterinary and Animal Sciences University has assimilated to educational institute area of this Ward between the two study years. It is noteworthy that this is the only veterinary university of the country. The educational institute area has increased from 05.87% to 09.35% between 1989 and 2011 (Table-2).

Although, hills and Chittagong are the two closely related words, the total amount of hills has decreased because of several factors. This study has revealed that there is a significant decrease of 5% (24 hectares) of the hills between the last two decades. There is only 29%
hectares of hills available in 2011. The present industrial land is 59 hectares which was 46 hectares in 1989. Somewhat 2% of industrial land has increased from 1989 to 2011. But there might have been occurred a huge vertical increase within the industrial area, which in not the matter of concern of this study.

A substantial 21% of the exposed land has declined between the last two decades in the study area. Exposed land category had provided its major share of land to other land-use categories such as settlement, educational institute and industrial infrastructure of the study area. In other words, most of the exposed land has been converted to other land use categories, particularly in the form of settlement. GPS reading, image texture has helped to detect the water bodies in the study area. This image is more sophisticated to locate the water bodies in the study area. There is only 2 hectares of land in this category and it contributed the lowest proportion of the land-use which is only 0.44% of the total land (Table-2).

4.4 Change detection analysis

Satellite images of 1989 and 2011 are used to prepare land use and land cover change maps for the study area. Land-use change in the Sulakbahar Ward is indebted to hills and exposed land categories for providing their lands to rest of the land-use categories to ensure their changes. This study is to locate the horizontal changes only; there are some vertical changes which are not considered here. Thus, 73.04% of land has remained in the same category like 1989 in the sense of horizontal change of the land-use. The major category based land-use changes of Sulakbahar Ward are demonstrated in table 3 and figure 4.

<table>
<thead>
<tr>
<th>Change Class</th>
<th>Area (Hec)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill to Settlement Area</td>
<td>12</td>
<td>2.61</td>
</tr>
<tr>
<td>Hill to Educational Institutional Area</td>
<td>6</td>
<td>1.31</td>
</tr>
<tr>
<td>Hill to Industrial Area</td>
<td>2</td>
<td>0.44</td>
</tr>
<tr>
<td>Hill to Exposed Land Area</td>
<td>4</td>
<td>0.87</td>
</tr>
<tr>
<td>Exposed land to Settlement Area</td>
<td>79</td>
<td>17.17</td>
</tr>
<tr>
<td>Exposed Land to Educational Institute</td>
<td>10</td>
<td>2.17</td>
</tr>
<tr>
<td>Exposed Land to Industrial Area</td>
<td>11</td>
<td>2.39</td>
</tr>
<tr>
<td>No Change</td>
<td>336</td>
<td>73.04</td>
</tr>
<tr>
<td>Total</td>
<td>460</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Based on Landsat TM 1989, Rapideye 2011 and field survey 2014

Figure 4: Land-use change map of the study area
Source: Based on Landsat TM 1989, Rapideye 2011 and field survey 2014
4.5 Change of hill to Other Land-uses

In 1989, 53 hectares of hills was available in the study area whereas it is 31 hectares in 2011. However, the largest proportion 12% (12 hectares) of the hill has turned into settlement area between the two concerned years. Educational institutional area has earned the second most area (1.31%) of the hill which is 6 hectares. The exposed land of 2011 has earned 4 hectares of the hills of 1989. The least proportion (2 hectares) of the hill has moved in to industrial area (Table 3 and Figure 4).

4.6 Change of exposed land to other Land-uses

Like the change of hill to settlement area, settlement area has captured the highest proportion (79 hectares) of the exposed land between 1989 and 2011, which is 17.17% of the total land. Educational institutional area and industrial area have earned 10 hectares (2.17%) and 11 hectares (2.39%) respectively of exposed land from 1989 to 2011 (Table 3 and Figure 4). One fourth of the land has totally changed to different land-use categories just between the period of 1989-2011. There might have some changes within the same categories of land-uses which are not the focuses of this study. Whenever only the visual changes are one fourth of the total land in between the two decades, the rate of change could be termed as alarming. If the changes are going on as per the urban land-use planning, there is no significant question to be raised, but if everything is going without any planning then it is high time checked back to ensure a sustainable urban land-use model.

5. Conclusion

The land use pattern and land cover change can be easily identified by using geoinformation technique. Remote sensing technique is the most effective way to monitor the gradual land cover and land use changes of different years. The study clearly indicates that, GIS and RS have successfully been applied as modern tools of land use and land use change detection. About 27% of the total land has undergone changes into totally different land-use categories. A total amount of 96 hectares of exposed land is turned into different urban land uses. Highest rate of change has occurred from exposed land to settlement land that is 79 hectares (17.17%) of the total area.

This study recommends that remotely sensed high resolution image along with GIS technology is very essential for the land-use change in general and for the urban land-use change detection in particular. Urban land-use database can be formulated by RS image along with the GIS techniques. To decrease the pressure on the limited urban land, more vertical use (e.g. high rise building) of the land is suggested for the increasing population. As the increasing population is directly involved with this rapid change of land-uses, high growth rate of population should be checked. As most of the hills are the habitat of different flora and fauna which are essential for the ecological balance, on an urgent basis, this downward trend of the hill cutting should be checked for the sustainable environment. Urban land-use planning should be done in the light of such land-use map which is formulated through maintaining both the RS and GIS techniques.

So, appropriate measure and planning approach should be taken to promote the systematic development of urban area to reduce its negative impact on society and environment. The concerned authorities should immediately take appropriate measures for environment friendly sustainable urban land management in Bangladesh. Chittagong is one of the fastest growing
and commercial capital city in Bangladesh. Many parts of this city are unplanned. This kind of research will contribute shaping the urban form of the city in a planned manner. The decision makers as well the city planners can initiate appropriate plans based on the outcome of this research. This kind of analytic study would be helpful tool for further research and planning of land-use of the Shulakbahar Ward in particular and of the Chittagong city in general.

6. References


