Spatiotemporal Variation of Land Use and Land Cover and Associated Urban Heat Island Formation in Dhaka City Using Geoinformatics

Zaki Uddin Ahmed[1], Shamim Mohammad Murshid[2], Md. Tarikul Islam[3]

Abstract: ***This research paper aims to demonstrate the changes of land use and land cover of Dhaka city for the period between 1989 to 2010. This is accomplished by analyzing satellite images downloaded from website of USGS and temperature of Dhaka city from satellite imagery was also calculated to detect the changes of temperature. Analysis shows that heat island effects of Dhaka city are more noticeable in the present decades. Suggestions have been made to mitigate the effects of urban heat island as well as to attain promising benefits associated with the mitigation of urban heating.***

Keyword : Urban Heat Island (UHI), Land Use and land Cover (LULC), Dhaka, ILWIS.

1. Introduction

Environmental degradation has become a part of our life and it cannot be sequestered from human life till the end of human civilization. In the modern era, rapid urbanization and industrialization have not only improved our materialistic lives but also brought many devastating consequences such as global warming, air pollution and water pollution through the discharge of industrial waste. Apart from adverse global impacts, the local or regional effects of urbanization are rather more serious particularly in those areas where industrial activities have been flourishing or synthetic construction materials are being heavily used. As a result, the natural environment and ecological balances are tremendously affected in urban areas. About 3.63 billion of people (i.e. 52.1 % of world total population) living in urban areas are directly exposed to urban heating problems and more people will be vulnerable to these problems as the number of people living in urban areas are expected to grow to six billions by 2050 [1].

One major phenomena is observed in large city areas as compared to the surrounding rural areas, i.e. a higher temperature or heat content concentrated in urban areas called urban heat island (UHI). The Urban Heat Island (UHI) refers to the relative rise of surface and air temperature that predominantly occurs in urban areas as a consequence of land cover changes mostly due to anthropogenic

1 Lecturer, Department of Civil Engineering, University of Information Technology &Sciences (UITS), Bangladesh ,e-mail: zuahmadbuet05@gmail.com

2 Graduate Research Assistant, Department of Civil and Environmental Engineering, University of Delaware, e-mail: sm_murshid144@yahoo.com

3 Lecturer, Department of Civil Engineering, University of Information Technology &Sciences (UITS), Bangladesh,E-mail: tarikbuet9@gmail.com

activities [2]. Heat islands develop when a large fraction of the natural land cover in an area is replaced by built surfaces that trap incoming solar radiation during the day and then re-radiate it at night [3]. The key factors that contribute to the formation of urban heat islands include, but not limited to, reduced vegetation in urban areas, heat storing capacities of urban materials [4], urban geometry [5]and anthropogenic heat emission [6]. The adverse impacts of urban heating includes deterioration of living environment, increased energy consumption [7], elevation in ground level ozone [8] and even an increase in mortality rates [9]. Urban heat island contributes to the heating up of water in streams, lakes, ponds, and rivers which sequentially endanger aquatic flora and fauna, thereby disrupting natural environmental balances [10]. Increased daytime surface temperatures and higher air pollution levels associated with urban heat islands can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality [11]. The impacts of urban hear islands can also be exacerbated by heat waves, which are periods of abnormally hot, and often humid, weather. Sensitive populations, such as children, older adults, and those with existing health conditions, are at particular risk from these events. For example, in 1995, a mid-July heat wave in the Midwest caused more than 1,000 deaths [12]. While it is rare for a heat wave to be so destructive, heat-related mortality is not uncommon.

The field of urban heating has been a topic of extreme interest to both scientists and engineers due to its adverse environmental and economic impacts on the society. There are certain promising benefits associated with the mitigation of urban heating. Reductions in anthropogenic heat and planting vegetation on the sides of buildings can reduce air temperature by about 0.2-1.2°C both daily and spatially and temperature decrease can results into building's cooling energy savings by about 4-40% which indicates remarkable savings[13].

No comprehensive study has been carried out on Urban Heat Island formation and its likely impact in Dhaka city. The followings are important objectives of our study:

- To create a LULC map of the study area for the time period between 1989 to 2010.
- To investigate the LULC changes in the study area during the time periods of 1989 to 2010.
- To analyze Urban Heat Island formation in Dhaka city.
- To prepare temperature variation map for the period of 1989 to 2010 for Dhaka city.

Remote Sensing (RI) and Geographical Information System (GIS) technologies were adapted to perform the desired analysis.

2. Methodology

In order to assess the land cover and land use change pattern in Dhaka city, three Landsat images containing multi-temporal satellite data of 1989, 2000 and 2010 were used in this research. Downloaded from USGS (http://www. earthexplorer. usgs. gov, date of last accessed: 17 December, 2013),these images are taken at two tiles: Path of 137 with Row of 43and Path of 137 with Row of 44, which cover the entire study area. The images representing dry season of Dhaka city have been captured for the month of November to January.

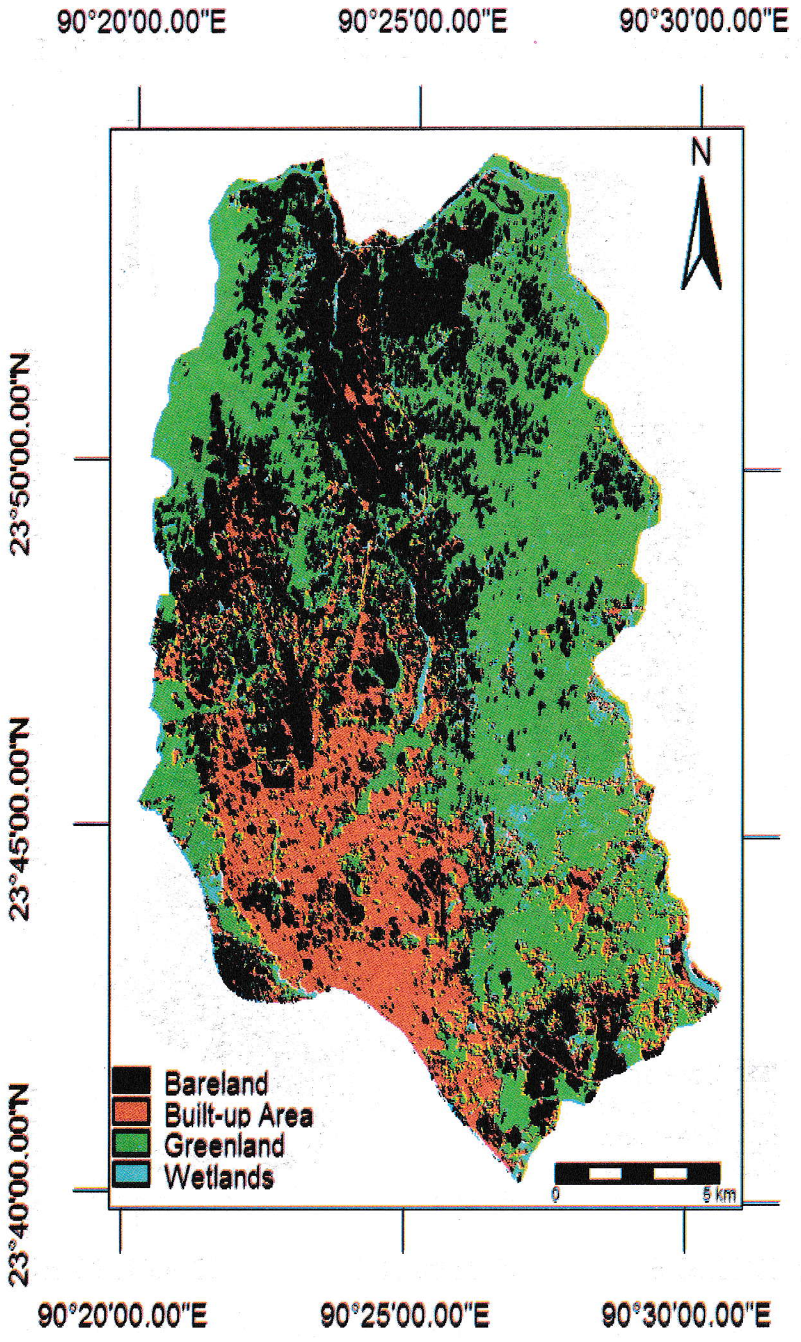
Integrated Land and Water Information System (ILWIS 2012) was used to process the Landsat images. Land cover and land use classification using satellite image analysis includes several steps, i.e. image importing, image gluing, sub setting, sample set preparation, supervised classification etc. While preparing the land use map for any particular year, firstly, the downloaded images of band 2, band 4 and band 7 from different tiles were imported individually. For each of these bands, images of the particular band at different tiles were glued to prepare a mosaic of the tiles. The combined image covered the entire study area. However, it also had portions beyond the study area. Thus, a sub-map was created which only contained the study area. In total three such maps (one for each of the bands 2, 4 and 7) were prepared. These images of band 2, 4 and 7 were used in the later part of land use mapping. The 7, 4, 2 combination was used for land use classification. Four types of land use were considered: (1) Build up area (2) Green land (3) Bare land and (4) Water bodies. A sample set was prepared using the same band combination and a reasonable number of pixels in the sample set were trained for each of the selected land use categories. The classification technique used was maximum likelihood classification algorithm. A land use map of the study area for the particular year was obtained in the process where the study area was classified into the four land use categories selected earlier. In the classification process, built up area included residential areas, road network and permanent settlement. Water bodies included ponds and lakes. Bare lands included all barren lands which are not currently in use. The raw images acquired had file formats as TIF. Pre-processing such as radiometric corrections which are a prerequisite for analysis of energy fluxes was done. All the operation from importing the data to analysis of the data was carried out in the GIS & RS software ILWIS.

3. Results and Discussion

3.1 Land Use and Land Cover (LULC) Changes

The LULC found for the year 1989, 2000and 2010 is summarized in Table 1 and LULC maps of Dhaka city for these three particular years have been shown in Figure 1 and Figure 2.

In 1989, about 26% area of Dhaka city was Bareland and 46% area was Greenland.Built up area and Wetland were approximately 23% and 5% respectively.In 2000, the percentage of Bareland was about 32% and 35% area was Greenland. Built up area and Wetlands were close to 29% and 4% respectively. In 2010, the Bareland in the city drastically decreased to only 8%. Among the others, 31% area was Greenland and 57% was built up area. The percentage of wetland slightly reduced to below 4%.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Bareland
Built-up Area
Greenland
Wetlands
0
5 km

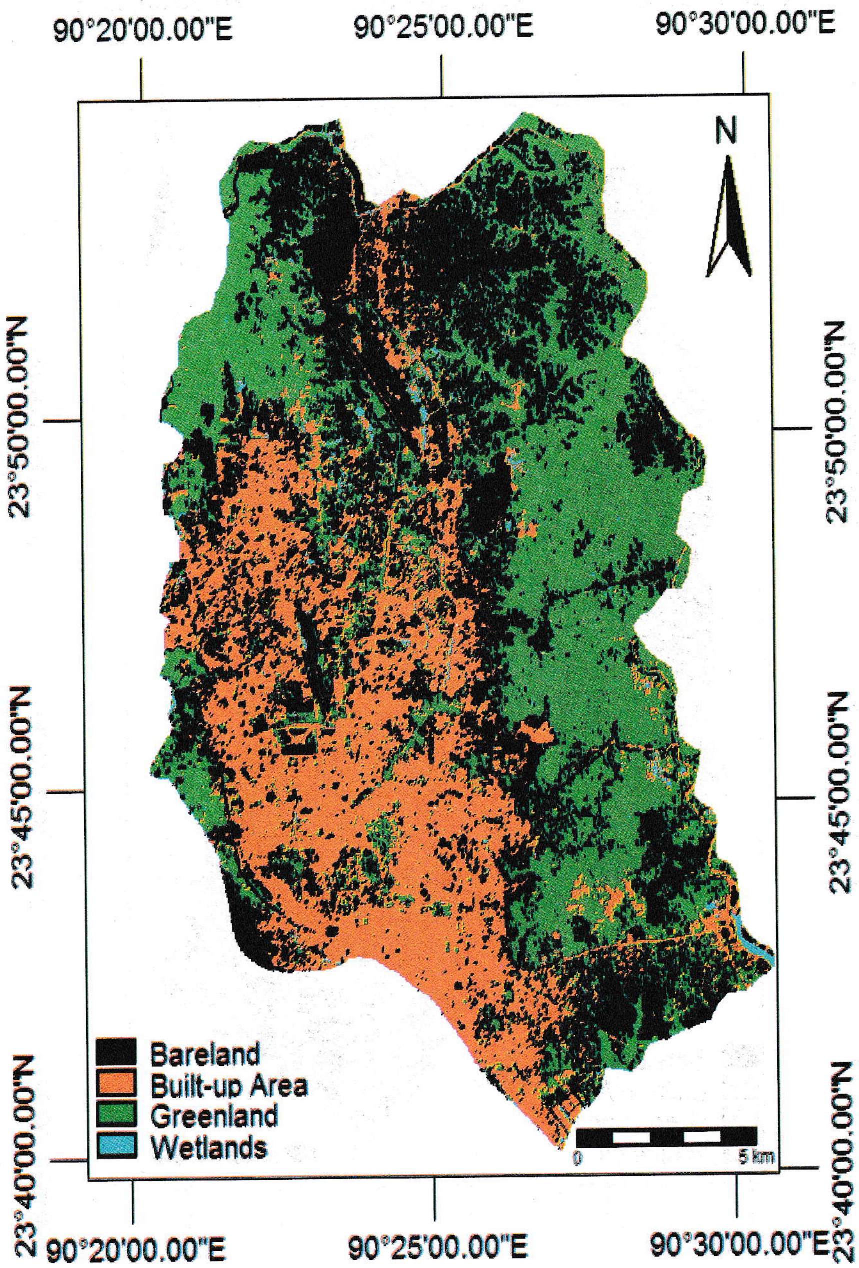

Figure 1: Land Use and Land Cover Map of Dhaka City for the year 1989 (left) and 2000 (right)

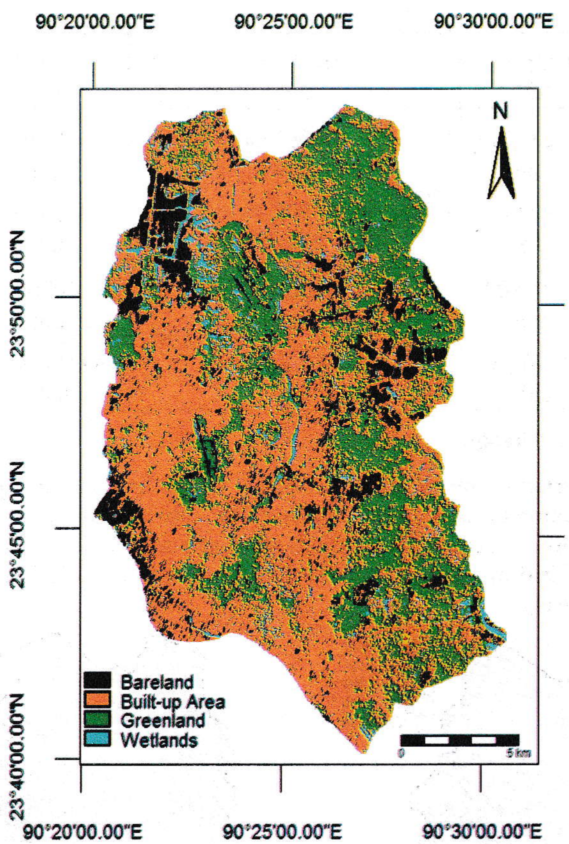

Figure 2: Land Use and Land Cover Map of Dhaka City for the year 2010

Table 1: Land Cover and Land Use (LULC) of Dhaka City

Land Cover Type	Year 1989		Year 2000		Year 2010	
	Area	% of Total Area	Area	% of Total Area	Area	% of Total Area
Bareland	78943500 sqm (7894.35 ha)	26.39	95877000 sqm (9587.7 ha)	32.05	24169500 sqm (2416.95 ha)	8.07
Built up area	67255200 sqm	22.48	86579100 sqm	28.94	170400600 sqm	56.96

	(6725.52 ha)		(8657.91 ha)		(17040.06 ha)	
Greenland	138230100 sqm (13823.01 ha)	46.21	103787900 sqm (10378.79 ha)	34.69	93259800 sqm (9325.98 ha)	31.17
Wetlands	14707800 sqm (1470.78 ha)	4.92	12887400 sqm (1288.74 ha)	4.30	11307600 sqm (1130.76 ha)	3.78

3.2 Temperature Changes

Temperature variation maps were produced based on the analysis. The temperature variation maps of Dhaka city have been represented for the year 1989 and 2010 in Figure 3. Temperature for different land use and land cover for the year 1989 and 2010 in Dhaka city have been represented in the Figure 4 and Figure 5 respectively.

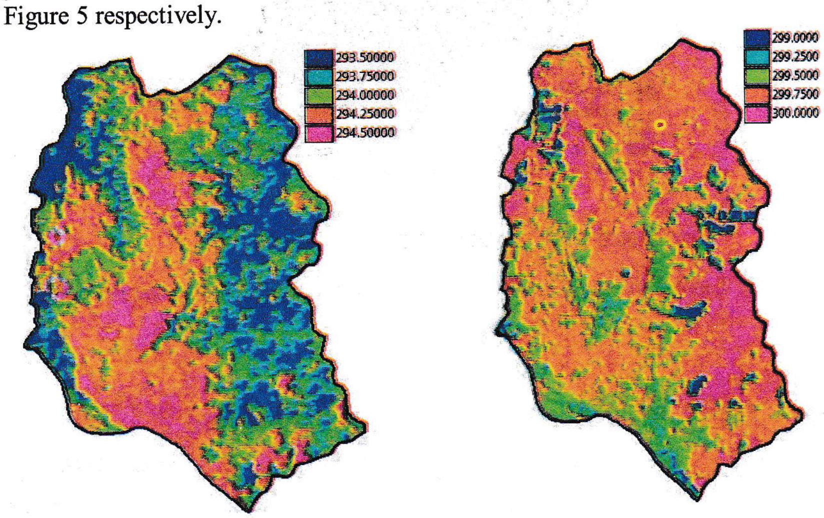

Figure 3: Temperature Variation Map of Dhaka city for the year 1989 (left) and for the year 2010 (right)

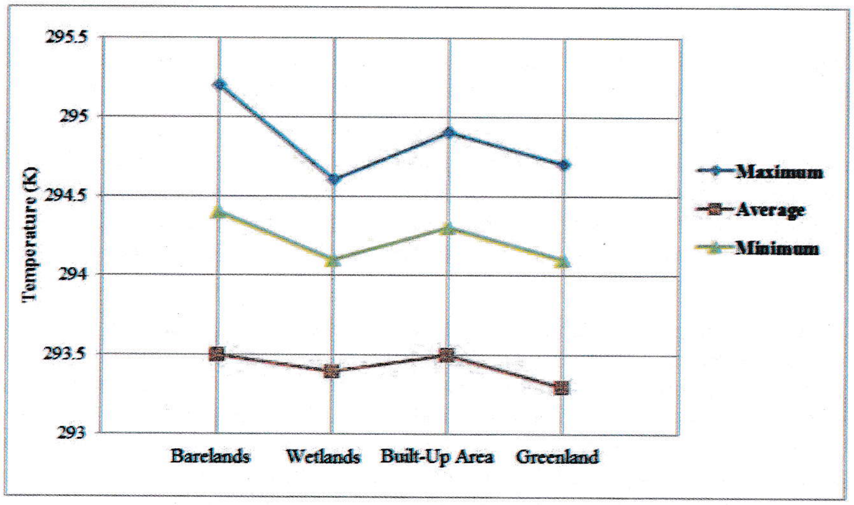

Figure 4: Temperature for Different Land Use and Land Cover in Dhaka City for the year 1989

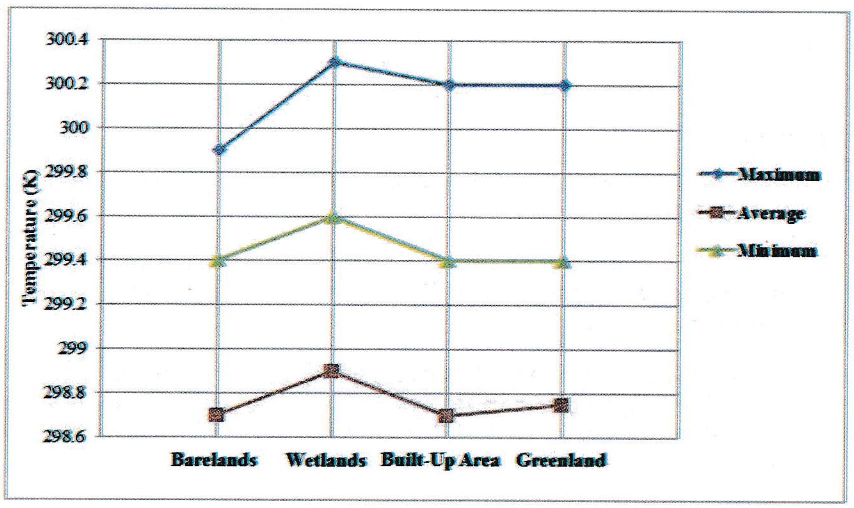

Figure 5: Temperature for Different Land Use and Land Cover in Dhaka City for the year 2010

4. Conclusion and Recommendations

Total vegetation cover of Dhaka city is gradually decreasing from the time period of 1989 to 2010. With the reduction of vegetation cover in Dhaka city, built up area goes on increasing and along with the rapid advancement of urbanization; the temperature of Dhaka city shows an average overall increase of about 5±0.5 degree Celsius. Someone who has experienced the perspiration summer days of Dhaka city will agree that average temperature of Dhaka city shows an increasing trend over the few last decades. The urban city dwellers are tormented by the blistering summer days coupled with the unwanted load shedding any time.

Poor urban design in Dhaka city is the biggest cause of formation of heat island in Dhaka city. When the growth of city alters the urban fabric by man made paved surfaces of concrete and asphalt, tar roofs and other features substituting forest growth, urban heat island is created. Their surfaces mostly absorb rather than reflecting the sun's heat, causes surface temperatures and overall ambient temperatures to rise.

Plausible strategies like urban tree plantation, green roof approach etc. should be adapted to reduce the urban heat island problem of Dhaka city. Trees and other plants help to cool the surrounding environment, making vegetation a simple and effective way to reduce urban heat island effects. Trees and vegetation can lower surface and air temperature by providing shade through evapotranspiration. Shaded surfaces may be 20-45°F (11-25°C) cooler than the peak temperatures of unshaded materials. Evapotranspiration, alone or in combination with shading, can help to reduce peak summer temperatures by 2-9°F (1-5°C). Researchers have found that planting deciduous trees or vines to the west is typically most effective for cooling a building, especially if they shade windows and part of the building's roof [14].

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