Journal of Bangladesh Institute of Planners ISSN 2075-9363
Vol. 8, 2015 (Printed in December 2016), pp. 187-194, © Bangladesh Institute of Planners

# Ecological Stress of Cities and its Impact on Urban Growth Management: A Study on Khulna City

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## Abstract

The study was conducted to present the development stress on surrounding natural environment associated with rapid urban growth. At the beginning of the study, physical situation of urban expansion of Khulna city is revealed. The urban growth scenario is derived through satellite image analysis of different years on land use land cover (LULC) changes around the city. Image analysis is comprised of supervised classification methods to derive the final results of LULC change. Hereafter, the climatic structure is assessed (changes in Built-up footprint) in relation with changing nature of LULC as well as urban microclimatic conditions. A popular method to detect changing urban microclimatic condition is analysing the changes in the urban microclimatic temperature generally known as Urban Heat Island (UHI) effect. The changing nature of LULC and UHI expresses the emergence of increasing stress of urban areas on the surrounding natural environment. As a result in the study LULC and UHI is assessed to examine the ongoing increasing stress. The result shows the overall increase in the built-up area from the year 1989 to 2014 is about 75.74% (1802.382 acres). The water body cover is reduced up to 153.209 acres and a variation in the fallow land cover is 48.43% in the temporal variation of 25 years. The zonal variation in surface temperature varies 29.64° – 40.71° in the city area and 28.77° – 40.16° outer skirts of the city area with in the time span of 1989 to 2014. Finally, it is seen that the ecological footprint due to built-up footprint is also increasing from the year 1989 to 2014.

## Introduction

Urbanization is the process through which cities and towns develop and grow. It includes the movement of people from rural areas as well as movements among towns and cities(Alberti M., 2003). Population growth and expansion of cities is the dynamic process of urbanization. Urbanised areas cover between approximately one and six per cent of Earth's surface, yet they have extraordinarily large ecological 'footprints' and complex, powerful, and often indirect effects on its surrounding nature (Rees & Wackernagel 1994; UNDP, 2009; Cooper, 2015). Similarly, from a biophysical perspective cities are dissipative structures that consume vast quantities of energy and material resources (Rees, 2003). Thus the humanity's ecological stress is therefore increasing simultaneously with worldwide urbanization (Rees, W.E., 2011).Bangladesh being a developing country is dilapidated with many climatic threats as well as from the process of haphazard urban growth. Bangladesh is a country with unique geophysical location hosting a rich variety of species to support the ecosystem of the country. However due to the various pressures of a growing population, development interventions, gaps in policy and legislation, and conflicting institutional obligations, 95% of Bangladesh's

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natural forest and 50% of its freshwater wetlands are lost or degraded in recent years(Alam, 2008). Bangladesh now has among the smallest areas of protected and intact forest in the world, consisting of 1.4% of its landmass. This situation is highly alarming because 70% of Bangladeshi inhabitants dependence on its natural resources (i.e. wetland and forests) for their livelihoods(Alam, 2008). The study focused on Khulna city area as being in the coastal region as well as an industry based linear city which is experiencing the similar dynamic trends of urban expansion. As the impact on the environment within the urban areas and surrounding the urban areas needs assessment with greater importance thus we might get a chance to reshape the development pattern towards a more sustainable one.

## Study Area Profile

Khulna city is the third largest industrial and second largest port city of Bangladesh. It is a divisional city and acts as regional hub of administrative, institutional, commercial and academic affairs. It is located on the banks of the Rupsha and the Bhairab Rivers. It lies between $22^{0}47'16''$ to $22^{0}52'$ north latitude and $89^{0}31'36''$ to $89^{0}34'35''$ east longitude shown in Figure 1. Total area of Khulna city corporation (KCC) is about 64.74 sq. km. comprising 31 wards with a total population of 751.23 thousands(BBS, 2011). The KCC area faced a reduction in overall population since the sudden shutdown of the industries but at present the population is again increasing. It is bounded by Dighalia Upazila and Khan Jahan Ali thana on the north, Batiaghata Upazila on the south, Rupsha and Dighalia Upazilas on the east and Dumuria Upazila on the west (Banglapedia, 2015).

## Materials & Methods

Geographic Information System (GIS) and Remote Sensing (RS) techniques are proven to delineate such dynamic changes at the city scale. Landsat satellite images from United States Geological Survey (USGS) website covering the whole study area is collected for the year 1989, 2004 and 2014 (table 1). The band 6 of Landsat 5 image and band 10, 11 of Landsat 8 image contains the thermal signatures that are analyzed to derive the land surface temperature of the KCC and its surrounding area.

Table 1: Images and bands used and their characteristics

| Type | Properties |
|---|---|
| Landsat 5 TM (there are 7 bands) | Date: 5-03-1989, 19-03-2004 |
| Band 6 (Thermal Band)<br>Resolution | 10.40-12.50 μm<br>120× (30) |
| Other Bands Resolution | 30 × 30 m |
| Cloud cover | 0 |
| Landsat 8 (there are 11 bands) | Date:18-3-2014 |
| Band 10 and 11 (Thermal Band)<br>Resolution | 10.60 – 11.19, 11.50 – 12.51 μm<br>100 × (30) |
| Other Bands Resolution | 30 × 30 m |
| Cloud Cover | 0 |

Assessment of land use- land cover (LULC) change is an important method to assess global change at various spatial–temporal scales (Lambin, 1997). To detect the land use - land cover changes (LULC), a 'Supervised Classification' method has been used (Ahmed, 2011). The accuracy level of the classified land cover is assessed using different reference data and the resulted accuracy levels of the images are found more than the satisfactory level. The accuracy assessment of the classification result is done using accuracy assessment tool of ERDAS software. A total of 80 random points are selected and cross matched manually with the current land cover type. The result shows that the land cover classification has been about 85%, 88.7% and 93.67% accurate for 1989, 2004 and 2014 images respectively (Table 3). The usual accepted accuracy level is 75% (Ahmed, 2011) and accordingly the resulted accuracy level is more than the usual accepted accuracy levels of land cover classification methods.

## Analysis and Findings

The overall classification results and the temporal variations evidence the gradual increase in Built-up area within the period of 1989 to 2014. The overall increase in the built-up area from the year 1989 to 2014 is about 75.74% (1802.382 acres). The water body cover is reduced up to 153.209 acres and a variation in the fallow land cover is 48.43% in the temporal variation of 25 years (Table 5, Figure 2 & Figure 3).

Table 5: Temporal variation in the land-cover type

| Cover Type | Year | | |
|---|---|---|---|
| | 2014 (Area Acres) | 2004 (Area Acres) | 1989 (Area Acres) |
| Vegetation | 5228.754 | 3727.433 | 4979.599 |
| Built-Up Area | 4181.951 | 2640.9495 | 2379.569 |
| Water Body | 1197.818 | 1141.526 | 1344.027 |
| Fallow Land | 1996.810 | 5096.221 | 3902.529 |
| Total | 12606.1295 | 12606.1295 | 12606.1295 |

Source: Authors' Generated, 2015

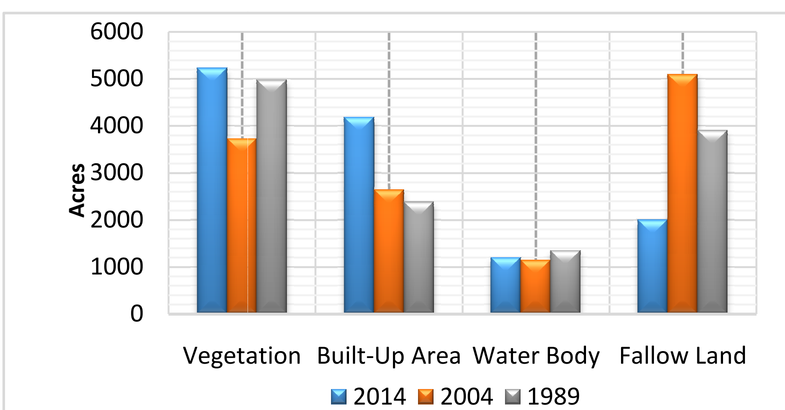


Fig. 2: Variation in Land Cover types

Such changes in the land cover types exerting pressure on the land resulting flimsy cohesion among the environmental variables (Pellikka, 2005). These rapid hovering demand on the lands, particularly in developing nations, are often ends up through urban sprawling, land degradation, or the transformation of agricultural land to shrimp farming land, build-up area etc (Ali, 2006) ensuing enormous cost to the natural environment (Nakagoshi, 2005).

This kind of little 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, rise in the temperature, $CO_2$ emissions etc(Hegazy, 2015).

On the other hand, Weng (2001) in his studies has highlighted that the best way to understand the impact of land cover changes on surrounding environment is to investigate the links between the thermal signatures and land cover types. Figure 4 visualizes the average Land Surface Temperature (LST) values in the three periods. Clearly, the built-up land exhibited the highest LST, followed by fallow land or bare soil, water body, and vegetation in all three periods. These findings are similar to that reported by Weng, 2001, Weng & Yang, 2004. The findings signify that built-up areas increase surface temperature by replacing natural vegetation with non-evaporating, non-transpiring surfaces. In addition, from Figure 4 it is noticeable that the LST increased for all land cover types over the periods (e.g., even for vegetation). This situation indicating the urban warming effect-otherwise temperature would not have been increased in vegetative area. However, temperature increasing rate (e.g., 1.17 °C/10 year), of outside ofurban area is lower in comparison with the rate of temperature increasing rate (e.g. 1.14°C/10 year ) in the KCC area as shown in Figure 4. This is probably due to the fact that the KCC area experienced a rapid growth.

Table 6: Temperature variation with time in and around the KCC Area

| **Year** | **Inside KCC Boundary (Degree Celcious)** | | | **Outside KCC Boundary (Degree Celcious)** | | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| 1989 | 23.892 | 29.64 | 26.07 | 23.44 | 28.77 | 25.87 |
| 2014 | 27.64 | 40.71 | 33.12 | 27.40 | 40.16 | 33.09 |

Source: Author Derived, 2015

The resulted temperature map of the year 1989 represents the KCC boundary area and its surroundings. The result expresses that the temperature variation remains between the minimum temperature 23.89°C and maximum temperature 29.64°C. On the other hand, in the 2004 and 2014 the temperature variation is extending most due to urban expansion. It is evident that within this period though the expansions of urban areas took place mostly within the boundary of KCC, the impacts of temperature variation is also visible in the surrounding areas. In the year 2004 the minimum temperature was about 27.64°C and maximum temperature extended towards 41°C while in the year of 2014 the temperature map shows that the maximum temperature rises up-to 41°C and this variation extends beyond the boundary of the Khulna city corporation with the temporal variation (Figure 5, 6 and 7).

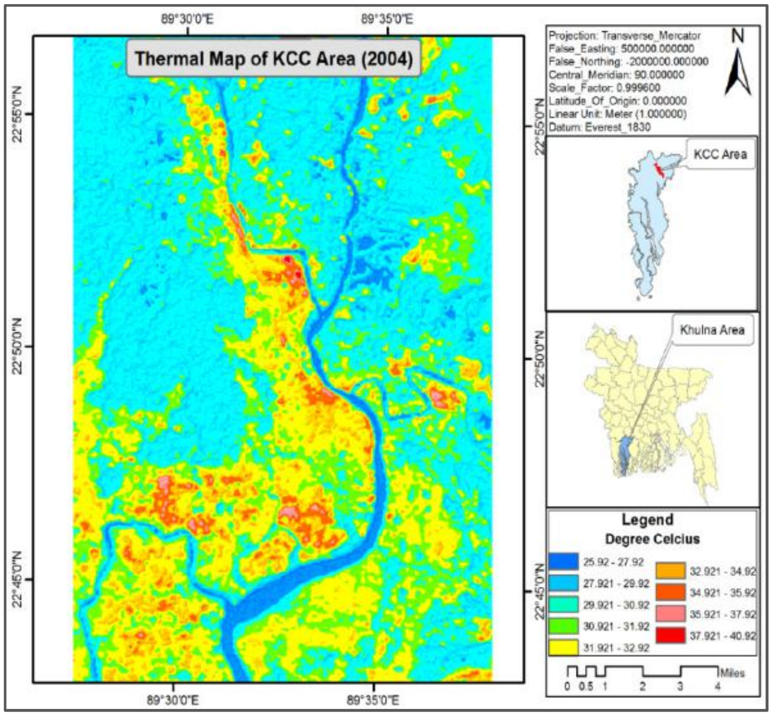


Fig. 6: Temperature Variation in KCC area and its surroundings (Year 2004)

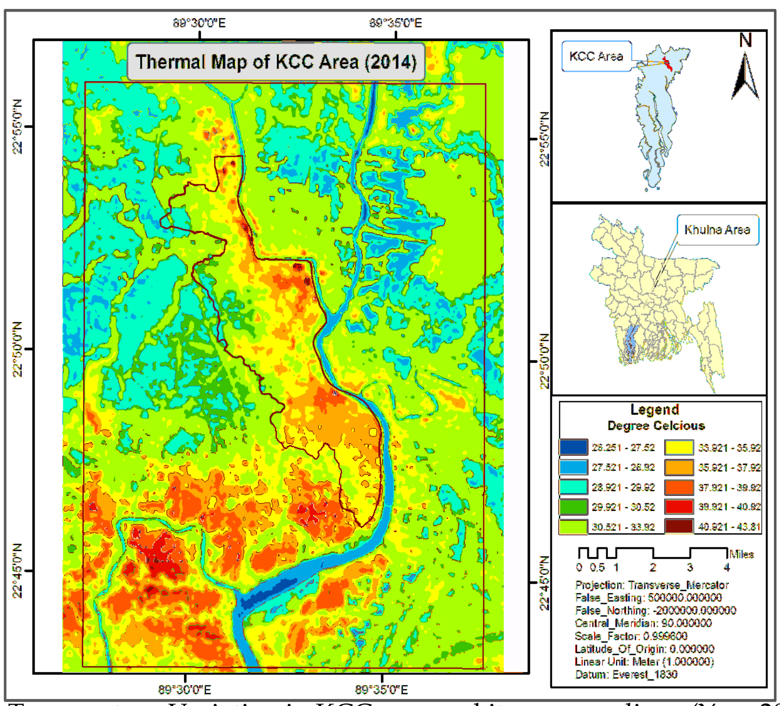


Fig. 7: Temperature Variation in KCC area and its surroundings (Year 2014)

Finally, in the table 7 the built-up footprint is calculated based on equivalency factor and the resulted data from image analysis. The built-up footprint expresses the amount of global hectares land required to sequester the amount of stress (i.e. $CO_2$ etc.) by the built-up formations. The equivalency factor for is attained from the global footprint network (GFN) website. It is used to weight different land areas in terms of their capacity to produce resources useful for humans. The weighting criterion is therefore not just the quantity of biomass produced, but also the quality of such biomass, meaning how valuable this biomass is for humans. This factor equalizes any difference in bio-productivity of different land types, thus creating a homogenous scale of land quantity that can be compared across nations, cities, or individuals. The factor converts land area, in hectares, to global hectares (Xu & Martin, 2010). The table 7 shows that with the increase in the built-up formation the built-up footprint thus the ecological footprint is also increasing from the year 1989 to 2014 (2417.09 gha to 4247.91 gha) shows the exerting pressure on the natural environment due to rapid urban expansion.

Table 7: Temporal Variation in Built-Up Footprint of KCC Area

| **Cover Type** | **[1]Area (Acres)** | | **Hectare** | | **[2]Equivalency Factor (gha/hectare)** | | **Built-Up Footprint (gha)** |
|---|---|---|---|---|---|---|---|
| Built-Up Area 1989 | 2379.569 | × | | | | = | 2417.09 |
| Built-Up Area 2004 | 2640.95 | × | 0.40469 | × | 2.51 | = | 2682.603 |
| Built-Up Area 2014 | 4181.951 | × | | | | = | 4247.91 |

[1]*Imageanalysis of KCC area 1989, 2004 and 2014*

[2]*Ewing, Moore, Goldfinger, Oursler, Reed, & Wackernagel (2010)*

## Conclusion

As a developing country Bangladesh is experiencing rapid urbanization. The associated development and conversion of land cover is an inevitable part in this process of urbanization. This dynamic conversion process of land cover should be addressed in land use planning process. Particularly, the conversions of natural land cover to artificial land covers demand knowledgeable attention and scientific analysis. This is because of the associated stress enforcing to the natural environment from this conversion process. Throughout, the study it is tried to depict this kind of development stress by analyzing the LULC and Micro Climatic parameters. This type of analysis should be included in land use planning for a city at large scale. The analysis will give a clear path of to conserve the environmentally significant area as well as to protect the particular natural area from the development to ensure the balance consumption and development. The incorporation of bio-capacity and ecological footprint calculation within the development context can improve the land use planning decision. This study has just given an orientation to consider the ecological stress in development as well as in land use planning process.

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