A Study of Changing Urban Landscape and Heat Island Phenomenon in Guwahati Metropolitan Area

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Abstract- Urbanization is undoubtedly the major transformation to land cover that profoundly influences biotic diversity. Changing urban landscape with high population growth and more demand for land is a major issue in Metropolitan Guwahati. The general pattern of urbanization in Guwahati is complex, diverse and fragmented which brings modification to natural land cover within the city. This complex urbanization process has altered the land surface characteristics within the city. An analysis of Landsat imageries has revealed subsequent decrease of land cover with a distinct spatial heterogeneity of land surface temperature from 1991 to 2008. To regulate the development, the proposed Master Plan for Guwahati 2025 has assigned some land use zoning. But the pressure of changing urban landscape has clearly seen over the eco-sensitive and Green belt areas, especially towards the periphery of the city. Due to scarcity of vegetation, some hotspots on surrounding hillocks were identified, the surface temperature of which is as high as the downtown. Thus, here an attempt has been made to correlate variation in temperature with land use type. The result of the present study is considered to be useful to develop countermeasure to thermal environmental problem in Guwahati metropolitan area.

I. INTRODUCTION

Spatial information on land use/land cover is a necessary prerequisite in planning, utilizing and management of natural resources. In the current context of development planning, information on land use/land cover and the changes over a period of time attain prominence because of its primary requirement in all the planning activities (NRSA, 2006). Land cover provides the interaction between the biotic and abiotic components of the ecosystem and thus changes to land cover also change biodiversity, evaporation, increase soil erosion and surface run off. Urbanization, characterized by a typical land use type of impervious surface area (ISA), and engineering structures has caused a major change to the land cover. The processes of urbanization govern the dynamics of global environmental degradation and thus draw attention to sustainable environment issues.

The ever increasing process of urbanization exerts pressure on natural vegetation cover and increase the atmospheric green house gases (GHG) through automobiles and industry. Because the heat storage capacity of ISA and engineering structures, as well as waste heat from automobile and industry, the temperature difference (ΔT_{u-r}) between urban and in a rural area outside the urban settlement is found to be higher. Thus most of the areas of human disturbance such as towns and cities are characterized with closed isotherms indicating an area of the surface that is relatively warm. This process is well known as Urban Heat Island (UHI). The magnitude of ΔT_{u-r} is greater at night, under clear skies and with little wind. The difference between urban and rural sites grows with time after sunset and reaches a maximum difference after about 4 hours (Mills 2004).

In India, many metropolitan cities have also experienced UHI in this decade (Deosthali, 2000; Amirtham et al. 2005; and Badrinath et al. 2005). Recently, estimation showed that Kolkata has experienced its warmest December 17 of this decade in 2009 with 19.4°C of minimum temperature (Bhattacharyya, 2009). Like Kolkata, Guwahati the major city of North-East India has also experienced its warmest year in 2009 ("Hottest year in city since 1950", 2009). Guwahati as a gateway to North-East India is characterized by a phenomenal change in urbanization in last few years. The population of Guwahati has increased from 809, 895 in 2001 to 963,429 in 2011 with an increase in population density from 3736 persons per sq. km. to 4445 persons per sq. km. respectively (Census of India, 2011). The rapid rate of urbanization has its effect on the vegetation cover and thus to the atmosphere in the city.

During the last decade, the economic activities within the city were speeded up. Industrial establishment and concentration of new companies had changed the economic scenario of the city in the beginning of the 21st century. The construction of new expressway from Jalukbari to Khanapara brought major land use change in the areas non adjacent to the traditional downtown centers. The high speed transportation system invited several industries, institution to set up their buildings alongside the expressway, most of which were earlier green belt or wetlands. Thus, the urbanization process within the city has accelerated at a high rate than ever before. The pressure of human settlement can be felt over the reserve forest, hills and the green belt areas of the city.

In this paper, an attempt has been made to investigate the impact of land use/land cover change on the thermal environment of Guwahati over the past 20 years. Quantitative remote sensing techniques have been adopted to investigate the change. The other objective of the paper is to relate the land use/land cover change study with the proposed Master Plan for Guwahati Metropolitan Area-2025, "Land Use Zoning and Development Control Regulation". This will portray the human intervention in eco sensitive zones of the city and its impact to the thermal environment of the city.

II. Significance of the Study

As stated earlier the city has experienced a phenomenal population growth in the last two decades. To regulate the uneven urban development, the Guwahati Metropolitan Development Authority (GMDA) has proposed the Master Plan for Guwahati Metropolitan Area (GMA)-2025. The land use zoning and development control regulation of the plan has assigned some land use zones within the metropolitan limit. However, the Master Plan is still in a draft mode due to several political issues. Nevertheless, the overall urban development in Guwahati is being planned by two main authorities' viz. GMDA and Guwahati Metropolitan Corporation (GMC). As there is no incentive or regulation for maintaining the Land use zoning, citizens are more or less reluctant in this regard. The Eco-sensitive zones (Hills and Wetlands) and the Green Belt of the city are continuously intervened with residential structures.

The relation among urban land use and heat island effect may provide some insight in the development plans of the metropolis. If the relation between urban land use and heat island phenomenon can be properly articulated, the authorities may implement some counter measures to minimize the effect of micro climate change in their development plans. This study may have significant impact to the land use policy of the upcoming satellites towns of Guwahati Metro.

III. Study Area

The proposed study incorporates the Greater Guwahati in Kamrup (Metro) district of Assam as the study area. The region is located between the latitude of 26°2´ N to 26°16´ N and 91°33´E to 91°52´E longitudes. The study area is situated on undulating plain with varying altitudes of 50 m to 55 m above mean sea level (MSL). To relate the study with the land use zoning of proposed Master Plan-2025, an extended boundary of Guwahati Metropolitan Area (GMA) with 328 sq. km is taken into consideration. The boundary of Greater Guwahati Area is coincided with the proposed modified boundary of Master Plan for Guwahati Metropolitan Area-2025. The region delineated under the proposed modified boundary constitutes of Guwahati Metropolitan Area, Sila-Matiya-Najirakhat-Bhulung area, Charmajulipam-Gandhmau-Ambari-BamunSoalkuchi area and Panchniyapara-Sajjanpara-Gariyapara-Alibari-Tarapatipa area.

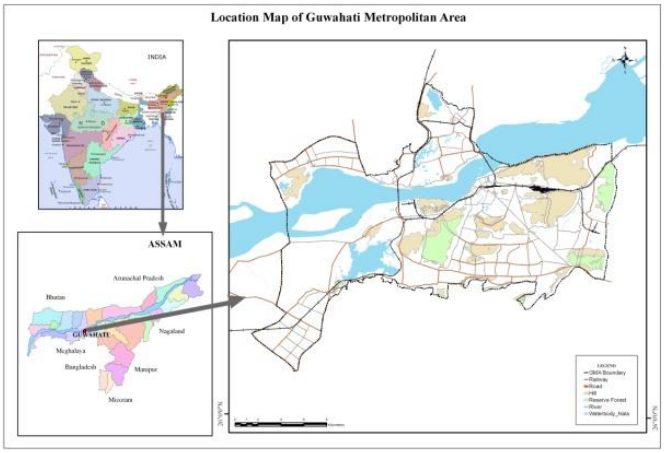

Fig 1: Location map of Guwahati Metropolitan area

Land Use and Land Cover Mapping

To explore the changes to the land use/land cover within the study area, this study has considered three time period viz 1991, 2000 and 2009 with an interval of 9 years. For this, the study has taken three Landsat images of the stated years; two of these are Landsat TM images of November 1991 and October 2009, while the other one is Landsat ETM+ image of August 2000. Before processing the land use/land cover maps, image geometric correction has been done using GCP derived from DGPS survey. As the Landsat TM and ETM+ images were taken by different sensors in different period, radiometric correction using relative radiometric normalization (Hall *et al*. 1991) has been carried out.

Then the 'Supervised Classification' method with 'Maximum likelihood' has been adopted to define land use classes. The images are classified to nine land use classes viz. high dense Settlement, low dense Settlement, trees and shrubs, dense vegetation, Open land, water, river sand, agriculture and agricultural current fallow land. The Settlement class encompasses roads, buildings, and other build landscapes. Vegetation represents live growth that has a green color. The open land class can conflict with some built up areas as it contains some bright cyan values. Water represents water bodies including river, swamp and "nala" (drain).

Land use and land cover change in Guwahati, 1991-2009

The Land use and land cover change statistics have been derived for six major land use classes. From table1 it is clear that the highest change has occurred to high dense Settlement. In the year 2000, it was increased by 56 percent from 1991.

Table 1: Percentage of Major Land Use and Land Cover Change in the Guwahati Metropolitan Area (1991 to 2009)

	2000	2009
	p.c. of change over '91	p.c. of change over '00
Trees & shrubs	-22.53	-1.72
Dense Vegetation	-4.88	-26.23
High dense Settlement	56.15	23.85
Low dense Settlement	-5.83	2.65
Open Space	-0.70	-16.71
Water	-9.44	-4.97

However, the low dense Settlement area decreased by 5.83 percent in 2000, as most of the low density areas were converted to high dense Settlement areas. A most noticeable phenomenon that has arisen during 2000 is that the growth of new settlement areas along the national highway 37 from Jalukbari to Khanapara. The high dense Settlement has further increased by 23.8 percent during 2009. The low dense Settlement areas along the national highway have changed to high dense Settlement areas till 2009. The modernization of LGBN International Airport at Borjhar has also caused major change to land cover in 2009.

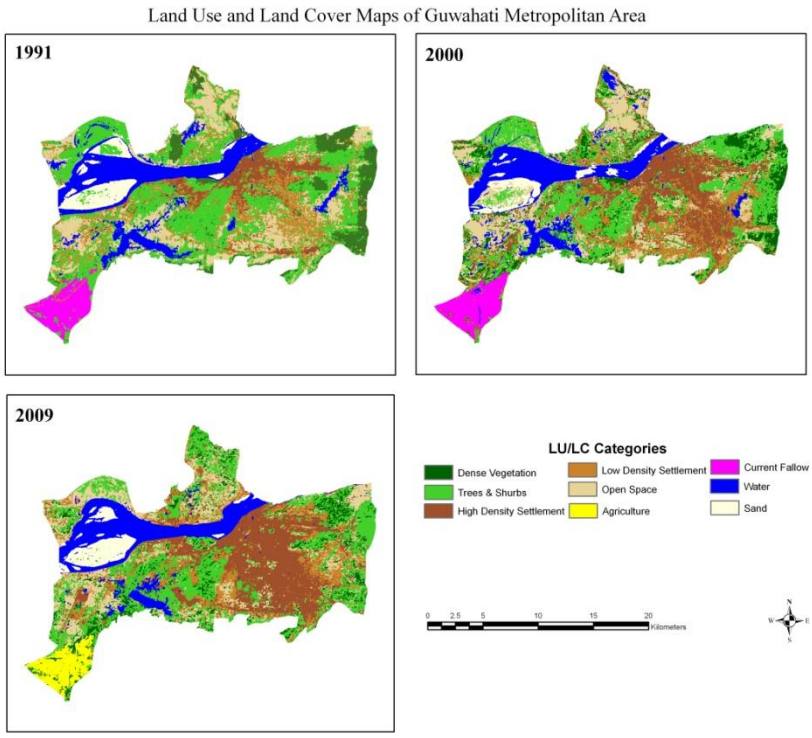

Figure 2: Land use and land cover maps of Guwahati Metropolitan Area

The pressure of increased urban built up land with high and low settlement over the vegetation cover can clearly been seen in the lad use/ land cover maps in figure 2. The dense vegetative cover shows a declining rate with 4.8 percent in 2000 to 26.3 percent in 2009. Most these areas are under the eco sensitive zone (Hills and Reserve Forest) of the proposed Master Plan-2025.

Land Cover change with reference to proposed Master Plan-2025

For the Guwahati metropolitan area the GMDA (Guwahati Metropolitan Development Authority) has proposed a plan as "Master plan for Guwahati Metropolitan Area-2025". The vision of the master plan 2025 is, "Guwahati city to be one of the most admired State capitals of India as Gateway to the North-East, with a unique image of its own". Within the aspects of land use planning the master plan has the provision of green belt and eco sensitive zone as major land use types. Green belt characterized by open space, gardens and other recreational areas in the master plan. The hills and reserve forest of the city are considered as eco-sensitive areas.

Table 2: Proposed land use break-up in GMA

Sl. No	Land Use Categories	Area in Ha.(excluding new towns)	% of Developed areas	Area in Ha.(including new towns)	% of Developed areas
1	Residential	8646	31.9	10383	31.7
2	Retail Commercial	360	1.3	447	1.4
3	Wholesale Commercial	81	0.3	417	1.3
4	Industrial	518	1.9	918	2.8
5	Public and Semi-Public	3270	12.1	3606	11.0
6	Composite use I	814	3.0	814	2.5
7	Composite use II	300	1.1	841	2.6
8	**Recreation & Open Space (Green Belt)**	3324	12.3	3728	11.0
9	Transportation	2853	10.5	3407	10.4
10	**Eco-Sensitive Zone**	6919	25.5	8245	26.0
	Total	27085	100.0	32806	100.0

Source: Master Plan for Guwahati Metropolitan Area-2025, Land Use Zoning and Development Control Regulation

To understand the land use zoning of Guwahati, the settlement data derived from the land use and land cover maps (1991 to 2009) are compared with the Land use zoning plan of GMDA. The data thus derived has clearly shown the pressure of changing urban landscape over the Green Belt and Eco-sensitive areas (Table 3). Many built up areas with high and low settlement categories are identified over the two land cover classes. The built up areas considered here are the combination of low and high dense settlement type of the classified land use maps.

Out of the total 3728 hectare of green belt area in the comprehensive master plan, 721.8 hectare (19.36%) of area can be traced as built-up zone during 1991. The percentage of eco-sensitive zone which has been traced as built up area during that period was about 11% (900.83ha.).

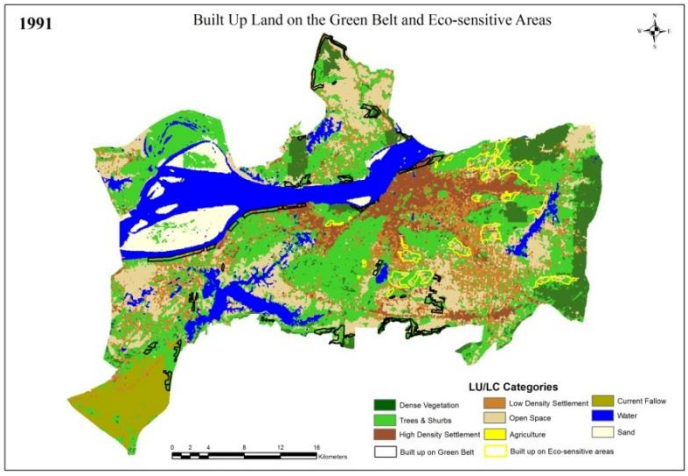

Figure 3: Built up areas on Green Belt and Eco-sensitive Area (1991)

Table 3: Built Up areas on Green Belt and Eco-Sensitive Areas

Year	Built-up area on Green belt (hectare)	% of the total proposed green belt area	Built-up area on Eco-sensitive zone (hectare)	% of the total proposed Eco-sensitive zone
1991	721.79	19.36	900.83	10.9
2000	886.62	23.78	2128.73	25.82
2009	1028.5	29.03	2227.5	27.01

While analyzing the land use patter of 2000 (figure 3), the built-up zone on the green belt has found to be further increased to 886.6 hectare (23.78%). The eco-sensitive zone has also changed significantly from 900.8 hectare to 2128.7 hectare. The pressure of increasing settlement has brought further changes to the green belt and eco-sensitive areas in 2009. In that year, the built up land on green belt and eco-sensitive zone increases to 29 percent and 27 percent respectively.

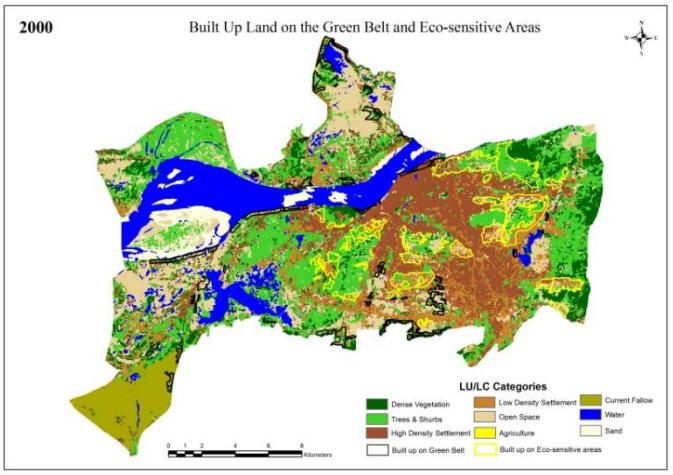

Figure 4: Built up areas on Green Belt and Eco-sensitive Area (2000)

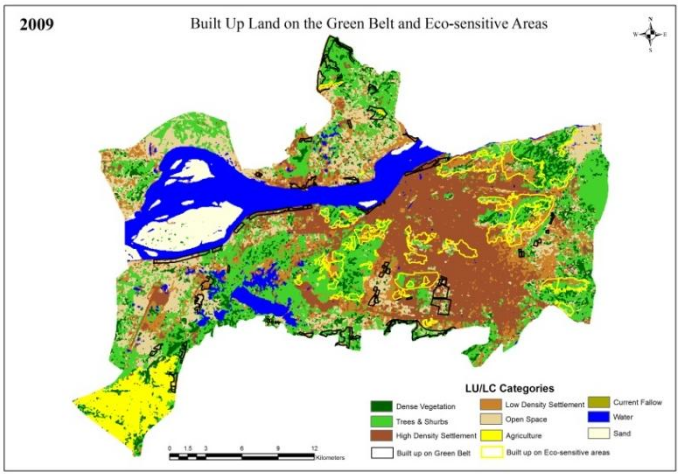

Figure 5: Built up areas on Green Belt and Eco-sensitive Area (2009)

A survey has been conducted during 2011 in some selected points of Guwahati metropolitan area to verify the continuous intervention of built up land over the green belt and eco-sensitive areas. The survey has revealed that more than half (56%) of the landowners have their legal ownership of these lands. The overall urban development in Guwahati is being planned by two main authorities' viz. GMDA and Guwahati Metropolitan Corporation (GMC). Thus the failure to land use zoning regulation indicates lack of coordination between these two authorities.

As there is no incentive or regulation for maintaining the Land use zoning, citizens are more or less reluctant in this regard. The Eco-sensitive zones (Hills and Wetlands) and the Green Belt of the city are continuously intervened with residential structures.

Land Surface Temperature Mapping

To calculate the surface temperature, Band 6 (10.4 to 12.5 µm) of Landsat TM and ETM+ images was used. The first step

was to process the data by converting the DN to radiance. The radiance is calculated using the equation:

L_λ = Gain × DN + offset …..(1) (Landsat 7 Science User Data Handbook Chap.11, 2002)

The gain and offset are embedded in the header file associated with the image.

Using the software the DN is converted to radiance (1), radiance to brightness temperature (2), and finally brightness temperature to surface temperature (3) in Kelvin:

$$T_B = \frac{K_2}{\ln(\frac{K_1}{L_\lambda}+1)} \quad (2)$$

$$S_t = \frac{T_B}{1+(\lambda \times \frac{T_B}{\rho})\ln\varepsilon} \quad (3)$$

Here,

Lλ= radiance
T_B = brightness temperature
S_t= land surface temperature

ε= emissivity $\{\varepsilon = 0.004R_V + 0.986$ and $R_V = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2\}$

NDVI= Band4-Band3/Band4+Band3

The surface temperature data as derived from equation (3) is converted from Kelvin to Celcius. As the thermal imageries were taken at different period, the minimum and the maximum temperature in the land surface temperature maps vary significantly. For simplicity and to make the interpretation comparable among the study periods, the surface temperature difference has taken into consideration. Each pixel values of surface temperature has been subtracted from the minimum temperature found in the data and then categorized accordingly.
From the surface temperature map of **1991** (Figure 4), it can be seen that the high temperature zones are lying in the central urban area and along the major roads in the city. Some industrial areas in the period have shown a temperature difference up to 5°C. As the eco-sensitive zones in that period were less affected by urbanization, all these are within a temperature difference of 1°C.

In the year **2000**, as most of the low density areas were converted to high dense Settlement areas the inner urban settlements has shown a temperature difference of 6°C. Due to densely built urban landscape, the surface temperature of some settlement areas is found to be as high as the industrial area in that period. Due to massive decrease of vegetation cover the hills and reserve forest areas have shown a temperature difference of 3°C and more. However the lower temperatures still occurred in the peripheral areas of the city.

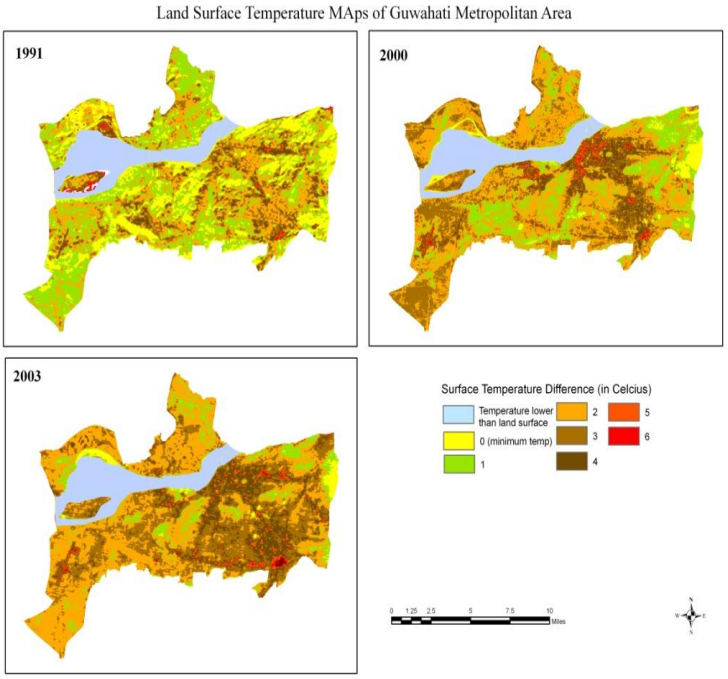

Figure 6: Surface temperature maps of Guwahati Metropolitan Area

The Guwahati metropolitan area has shown a prominent heat island in the year **2009**. The high dense Settlement areas have a significant effect in the heat island formation. New industrial set up along the National Highway 37 has also increased the surface temperature in the periphery of the city. A patch of high surface temperature zone can also been traced around the newly modernized LGNB International airport. The most significant change to urban heat island phenomenon in that year is the spread of high temperature zones from inner to outer areas of the city. Moreover, due to scarcity of vegetation, some hotspots on surrounding hillocks were identified, the surface temperature of which is as high as the downtown.

IV. Conclusions

During the last 20 years, the Guwahati metropolitan area has undergone phenomenal change in urban landscape that resulted in the loss of natural land cover. As a result, the surface temperature of the city has increased and a prominent urban heat island is formed in and around the settlement areas. All these have severe environmental and health consequences. The land use regulation plan of GMDA's Mater plan can be a tool for sustainability of natural land cover. But the continuous intervention of human settlement to natural land covers in Guwahati metropolitan area has revealed the failure of land use zoning and regulatory action. The metropolitan development authorities should have strict regulation in the green belt and eco sensitive areas of the city. Social forestry in the green belt areas, light color surfaces in residential units, plantation in the roof of buildings and trees along by the roads, may be some countermeasures of the heat island effect in Guwahati

metropolitan area. Solution of such problem is an urgent need to sustain the quality of urban life.

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