ANALYSIS OF LAND SURFACE TEMPERATURE AND LAND USE / LAND COVER TYPES USING REMOTE SENSING IMAGERY - A CASE IN CHENNAI CITY, INDIA.

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Abstract

Cities often experience a distinguished climate termed the “Urban Climate”. Urban climates are characterized by differences in climatic variables (air temperature, humidity, wind speed and direction, and amount of precipitation) from those of less built-up areas. The major factors contributing to these differences are the land use and land cover transformations. These land use changes often includes replacements of natural surfaces with highly reflective parking lots, concrete masses, asphalt roads etc affecting the thermal environment in cities. Researches show that urban places are warmer than surrounding rural environments and are generally termed as "urban heat island". The aim of this study is to analyze the variations in the thermal environment that exists throughout the city due to different land cover conditions. This study analyzes the land surface temperature differences in the city of Chennai and compares with the land use and land cover types using TM and ETM+ data of 1991 and 2000. The data indicated the increase in urban built up areas and the reduction of vegetated areas. The thermal band of Landsat TM is used in identifying the specific locations of micro urban heat islands with in the city. From the study it is evident that the heat island pockets are obviously going up, not only increased in area but also in intensity. The various land cover types such as high density built up spaces, medium density built up spaces, low density built up spaces, sparse vegetation, dense vegetation, barren land, marshy lands, water bodies etc and the land use types such as the commercial, residential, industrial, institutional and open spaces contributes to the variation in temperatures leading to the formation of urban micro heat islands. With the increasing energy demand in cities, it is possible to reduce the energy needs by mitigating the effects of these micro urban heat islands. Thus it is essential to study the heat environment (heat island effect) of the city to facilitate in planning green lands, altering the surface cover and formulating urban design guidelines.

Key words: Urban Climate, Thermal infrared imagery, land use and land cover changes; land surface temperature, urban heat island.

1. INTRODUCTION

Urbanization changes the land cover types in an urban area and results in distinguished climatic conditions termed the “Urban climate”. Urban climates are distinguished from those of less built-up areas by differences of air temperature, humidity, wind speed and direction, and amount of precipitation. These differences are mainly due to the alteration of natural surfaces with highly reflective parking lots, concrete masses, asphalt roads etc resulting in the higher absorption of solar radiation, and a greater thermal capacity and conductivity, thereby affecting the thermal environment in cities. This leads to the heat storage during the day and is released during the night. These alterations owing to urbanization lead to “Urban Heat Island” (UHI). The urban heat island refers to the increase in urban air temperatures over those in surrounding rural areas and the difference generally being greater at night than during the day. The main cause of this phenomenon is the faster rate of cooling of the open areas around cities when compared with the rate of nocturnal cooling of densely built-up centre (Baruch Givoni, 1998). The causes of the UHI includes, blocking the view to the night sky by buildings, the thermal properties of surface materials and lack of evapotranspiration in urban areas, geometric effects called the "canyon effect” and the anthropogenic heat (Oke 1982, Santamouris 2002).

2. BACKGROUND LITERATURE ON THERMAL REMOTE SENSING

Urban Heat Island studies were traditionally performed with in situ measurements of air temperatures in isolated locations, mobile traverse (thermometers fixed on moving vehicles) and ground meteorological data (Streutker 2002, Weng 2004). It is difficult to analyze the spatial distribution of temperature through these methods. With the development of remote sensing technology, which collects multi-spectral, multi-resolution and multi-temporal data spatial distribution of temperature can be analyzed with ease. Remote sensing and GIS is an effective tool in detecting urban land use and land cover change (Ehlers et al. 1990, Treitz et al. 1992, Harris and Ventura 1995). Voogt and Oke (2003) assessed the use of thermal remote sensing in urban climate studies and revealed the distinction between the atmospheric UHI and the surface UHI. According to them, Atmospheric UHI is detected by ground-based air temperature measurements taken from standard meteorological stations, whereas surface UHI is observed from thermal remote sensors. Atmospheric UHIs are best expressed under calm and clear conditions at night whereas surface UHI intensities are greater during daytimes (Roth et al. 1989). Streutker (2003), Weng (2003), Boegh et al, (1998), Carson et al. (1994), Lo et al. (1997), Freindl (2002), Kalnay and Cai

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(2003), Voogt and Oke (2003), Balling and Brazell (1988), Roth et al. (1989), Gallo et al. (1993) have conducted researches using thermal remote sensing technology. The higher resolution of 120m and 60m of Landsat TM and Landsat ETM+ thermal infrared data enables the study of surface temperatures at city levels. In this study, the relationship between land cover and surface temperature in the city of Chennai was analyzed and examined using satellite data from Landsat 5 TM and Landsat 7 ETM+. Band 6 and Band 61 from TM and ETM+ respectively were used for brightness temperature which intersected with land cover types from other bands of TM and ETM+. The spatial structure of the thermal environment in the city was analyzed and the hottest surfaces within the city were identified and compared with urban land use types.

3. AREA OF STUDY

Chennai-Madras, a metropolitan city of India, is located on the Coromandel Coast of the Bay of Bengal. Chennai located at 13.04° N latitude and 80.17° E longitude, has a flat coastal plain with an average elevation of 6m. To define the relationship between the urban factors and the UHI intensity it is essential to study the various land uses of Chennai. The major green areas in Chennai include the Guindy National Park, Anna University, RajBhavan, IIT Madras and the forest reserve near Sembakkam in the southern part of Chennai. Northern Chennai is primarily an industrial area and the central Chennai is the commercial heart of the city with the downtown area. Southern and Western Chennai, which were predominantly residential areas are currently turning into commercial areas, hosting a large number of IT and financial companies.

4. METHODOLOGY

Two Scenes of landsat TM and ETM+ image, dated 25th August 1991 and 28th October 2000 were used effectively to identify the spatial distribution characteristics of land use/ land cover classes and surface temperature in the city of Chennai. Band 6 and Band 61 of TM and ETM+ respectively, were analyzed with respect to the surface temperatures, whereas the other bands were used for land cover classifications. The land cover classification image and the surface temperature images were then compared to understand the relationship between the land cover types and the temperature patterns in the city.

4.1. Preparation of image data

The image data for Chennai city has been downloaded from the website http://glcf.umiacs.umd.edu/index.shtml. The thermal bands, band 6 of TM and band 61 of ETM+ have been rescaled using MultiSpec©, to increase the thermal band area and file size to match the other bands, thus preserving the 30-meter resolution of the data. The study area from the full scene has been subsetted in both TM and ETM+, using ENVI software so that they have same spatial resolution and cover the same area to facilitate comparison of images.

4.1.1. Land Cover Classification

By using ENVI software, land use / cover pattern were mapped by Supervised Classification with the maximum likelihood algorithm. Eight land cover classes were classified in both the TM (1991) and ETM+ (2000) images by using bands 1-5 and 7. The classes include: high density built up spaces, medium density built up spaces, low density built up spaces, dense vegetation, sparse vegetation, water, sandy area and the barren land. Fig. 1a and 1 b shows the supervised classification image of TM (1991) and ETM+ (2000) data.

4.1.2. Retrieval of Land Surface Temperature

The thermal band images of TM and ETM+ images were used in order to map the thermal urban environment of Chennai city. The TM thermal band 6 and ETM+ band 61(10.4 – 12.5 μm) has a spatial resolution of 120m and 60m respectively and are considered suitable for capturing the complex intra-urban temperature differences allowing thus an effective analysis of the urban climate. In this study, the LST was retrieved using a LST software tool developed by (J.Zhang et al. 2006), which includes three major steps: (i) NDVI Calculation, (ii) Emmisivity preparation and the (iii) LST calculation. In the LST software two method of calculating the surface temperature has been programmed namely the Qin et al's Mono window Algorithm and Jimenez Munoz and Sobrino's algorithm. In this study the Qin et al's mono window algorithm has been used to retrieve LST. Fig. 2a and 2b shows the calculated land surface temperature of Chennai using the LST software tool in 1991 TM image (band6) and 2000 ETM+ image (band61).

5. RESULTS AND DISCUSSIONS

Based on the supervised classification of the 1991 image and the 2000 image, the areas of the high density built up spaces and the medium density built up spaces have increased drastically and a marginal increase has been evident in the dense vegetated areas. The effects of urbanization were clearly evident through the decrease in the area of low density built up spaces and sparse vegetation. The urban growth statistics of the two years 1991 and

2000 are given in Table 1. The land surface temperature calculated based on the Qin et al's mono window algorithm using the LST software tool developed by J. Zhang et al. 2006, clearly indicates the increase in Urban Heat Island pockets which were indicated by the red colour in the image. The reduction in the blue colour indicates the water bodies. The area of green space has also been reduced to a greater extent and the increase in urban sprawl is shown by the yellow spots.

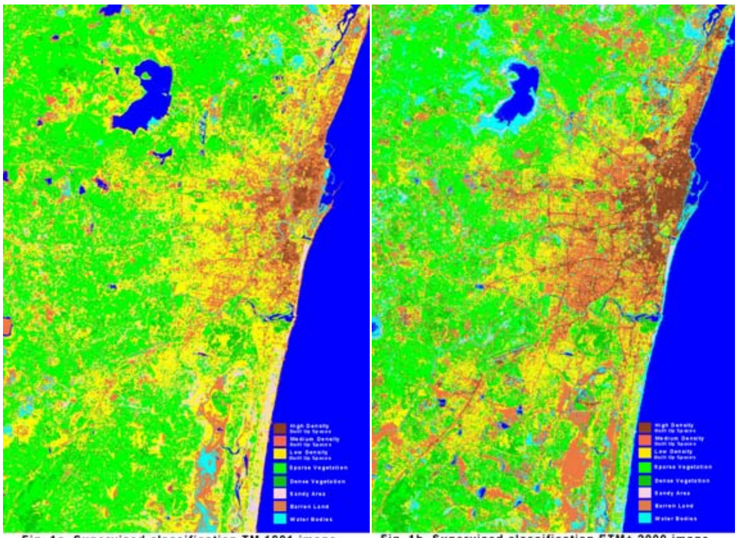

Fig. 1a. Supervised classification TM 1991 image   Fig. 1b. Supervised classification ETM+ 2000 image

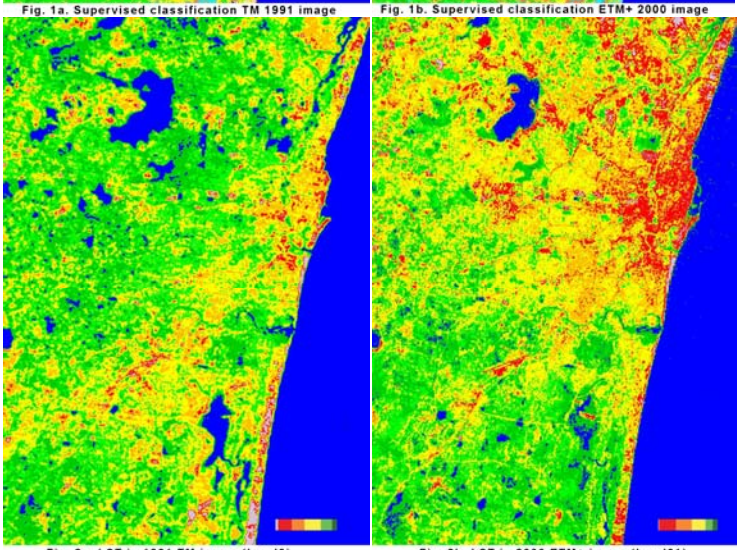

Fig. 2a. LST in 1991 TM image (band6)   Fig. 2b. LST in 2000 ETM+ image (band61)

Comparing the surface temperature images and the land cover classification images, the relationship between the land cover classification and the surface temperature can be clearly understood. The hot spots in the 1991 image are mainly concentrated in the old towns of George Town and Triplicane, industrial areas of Guindy transportation nodes such as the Harbour area and at the Airport and the commercial hub of Purasawalkkam. The increase of blue colour in the LST image when compared to that of the land cover image is due to presence of marshy lands whose temperature is also combined with that of the water bodies. The heat pockets are indicated by the red colour in the LST and are predominantly in the dense built up spaces indicated by the dark brown spots in the land cover classification.

The hot spots in the 2000 image are found at the high density residential neighbourhoods of Adayar, Mylapore and in most parts of Northern Chennai, commercial hubs of T-nagar, barren lands in North Chennai and in the industrial area of Ambattur Industrial Estates. In addition to the harbour and the airport, the transportation nodes the Koyambedu Bus Terminus and the Koyambedu market area also show hot spots. The increase in water bodies in the 2000 image when compared to that of 1991 is due to the month of data acquisition. The 2000 image was acquired in the month of October a rainy month in Chennai, when compared to that of 1991 which was acquired in the month of August.

Table 1. Urban growth statistics of Landsat 5 TM and the Landsat 7 ETM+ images

S.No	Class Type	% Area (1991)	% Area (2000)	Difference
1.	High density built up	0.746%	4.185%	3.44%
2.	Medium density built up	9.951%	16.945%	6.99%
3.	Low density built up	27.201%	19.981%	- 7.22%
4.	Sparse Vegetation	30.509%	23.606%	- 6.90%
5.	Dense Vegetation	7.277%	8.779%	1.50%
6.	Barren lands	2.220%	6.798%	4.58%
7.	Water Bodies	18.968%	18.296%	- 0.67%
8.	Sandy Area	3.127%	1.409%	- 1.72%

The combination of dense built up areas and reduced "vegetation" has resulted in the increased urban temperatures. The increasing urbanization with replacement of the natural soil and vegetation cover of the area by artificial features like roads, buildings, etc. is a significant factor in the increase of heat pockets. It has been observed that micro urban heat islands have a significant impact on the land use and land cover characteristics of an area. The heat islands are mostly formed because of the reduced landscape, dark coloured surfaces, built up spaces, heat generating vehicles and industries.

6. CONCLUSION

Increase in density, reduction in open spaces and green cover, increase in built up spaces have proved to increase the heat island phenomenon. These thermal changes deteriorate the urban environment causing health problems. Therefore Urban planners, designers, architects need to consider the urban climate while designing and planning cities. Further studies using onsite measurements with remote sensing data can equip in assessing the nature of UHI at a micro level which can be a source for urban planning strategies. Satellite-based studies can aid urban planners in providing recommendations for building design and landscaping of urban developments that are useful in minimizing the heat accumulation and retention by urban surfaces.

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