Study of Land Surface Temperature in Delhi City to Manage the Thermal Effect on Urban Developments

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STUDY OF LAND SURFACE TEMPERATURE IN DELHI CITY TO MANAGING THE THERMAL EFFECT ON URBAN DEVELOPMENTS

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Abstract:
Accelerated urban development effected Delhi city in last 10 years. This paper is mainly focusing the surface temperature changes in last 10 year in Delhi city as well as seasonal variation from that to understand the urban development effect on urban heat island. Here land use/land cover and land surface temperature and to access the thermal response pattern of land cover types studied through remote sensing techniques. The results shows that dominated importance of urban land cover expansion in the changes in heat island intensity and surface temperature patterns. Urban development was also related to continual population increases in Delhi city. For the planning application in Delhi city the combine use of satellite derived vegetation and land cover distribution with surface temperature maps provides a very useful tool. For the temperature control in Delhi city more green campaigns and landscaping designs is very important. And for that planners should focus on forest, green lawns and water bodies which make cooling effect in city.

Key Words: *Land surface temperature (LST), Surface emissivity, NDVI, Radiance, Land use /Land cover (LU/LC)*

1. Introduction

Rapid changes in land use land cover inside urban area have huge impact on urban environment. Faster urbanisation is one of the main causes of this LU/LC changes. Trees and vegetations are mostly affected due to this rapid process in urbanization. Trees are mainly replaced by the concrete buildings and roads. The open space inside city area is mainly converted in recreational or ornamental purposes. So that remaining parts of green area inside city is different ecosystem than countryside. The higher solar radiation, absorption and greater thermal capacity and conductivity are mainly found in urban area as most of the area is covered with buildings, roads and other impervious surfaces. By the nature of high heat store during day and realising in night in city area, it's found higher temperature than surrounding area. The heat released from urban houses, transportation and industry is the main causes of Urban Heat Island (UHI). Present day human- urban/rural contrast is mainly represent the UHI, which is due to effective changes in LU/LC like deforestation and the replacement of the land surface by anthropogenic influences. The result is reduced evapotranspiration and more rapid runoff of rain water (Carlson 1986). The ground level ozone production is increased due to the result of higher ozone level, which is caused due to higher urban temperature (DeWitt and Brennan, 2001). One of the most important resins of increasing urban temperature is due to increasing of air condition in city area which mainly increases energy consumption. Establishment of power plant and burning of fossils fuel is also having an effect on energy consumption and pollution both (Weng 2004).

Urban green campaigns are one of the best ways to reduce the urban heat. The ecological as well as economic and aesthetic benefits are the main cause of tree planting (Gatrell and Jensen, 2002). Green campaigns are the major issue in worldwide as many environmentally conscious planning authorities are focusing on urban trees (Nichol1994). For the urban and environmental planners relationship between urban growth and urban vegetation is valuable information to mitigate UHI. For mitigating the adverse thermal effect from buildings planners should use the knowledge on this relationship and make some policies which revised urban design and landscape as well as support more tree planting programs (Weng 2004).

To investigate the relationship between urban development and UHI in Delhi and to discuss the effectiveness that the city's greening campaigns have brought about to lessen urban temperatures and to reduce the heat island effect is the main objective of this study. This city Delhi has undergone an elementary change in land use and land cover due to accelerated rate of urban population. Due to the lack of proper land use planning and the measures for sustainable development, unplanned urban growth has created several environmental problems. The main question address in this paper is: (1) what are the changes in landuse land cover in last 10 years. (2)Need to investigate the relationship between urban growth and UHI effect with change surface temperature pattern. (3) To mitigate urban heat Island effect what are the green campaigns is need to adopt?

2. Study Area:

This studies were carried out over Delhi and surrounding areas situated between latitude $28^0$14'57" N to $28^0$52'18" N and longitude between 77^0 35' 34" E to 76^0 57' 38" E and altitude lies between 213 and 305 meters covering an area of 5160.18 km^2. One of the most characteristic features of Delhi climate is extreme low and high temperature. The ambient temperature rises to as high as 47^0 C while on other hand during winter is the temperature may reach as low as -0.6^0 C. January is the coldest month, while highest temperature is recorded in the month of May/June while the mean annual total rainfall is around 70 cm.

Physically Delhi can be divided into three segments: the Yamuna flood plain, the ridge and the plain. The Yamuna flood plain is somewhere low-lying and sandy. The ridge constitutes the most dominating physiographic features of this territory. It originated from the Aravali hills of Rajasthan and, entering Delhi from the south, extends in north-eastern direction and the rest of Delhi is categorized as a plain. Yamuna is the main river that passes through Delhi. Apart from the flood channels of Yamuna there are 3 canals, i.e. portion of Agra Canal, Hindu Canal and western Yamuna Canal.

The vegetation in the ridge (forest) is predominately of thorny scrub type, which is usually found in arid and semi-arid zone. Ridge Forest of Delhi falls in the category of 'Tropical thorn forest' as per the forest type classification of Champion and Seth (1968), and more especially as 'semi-arid open scrub'. Among trees that are dominant are Acacias.

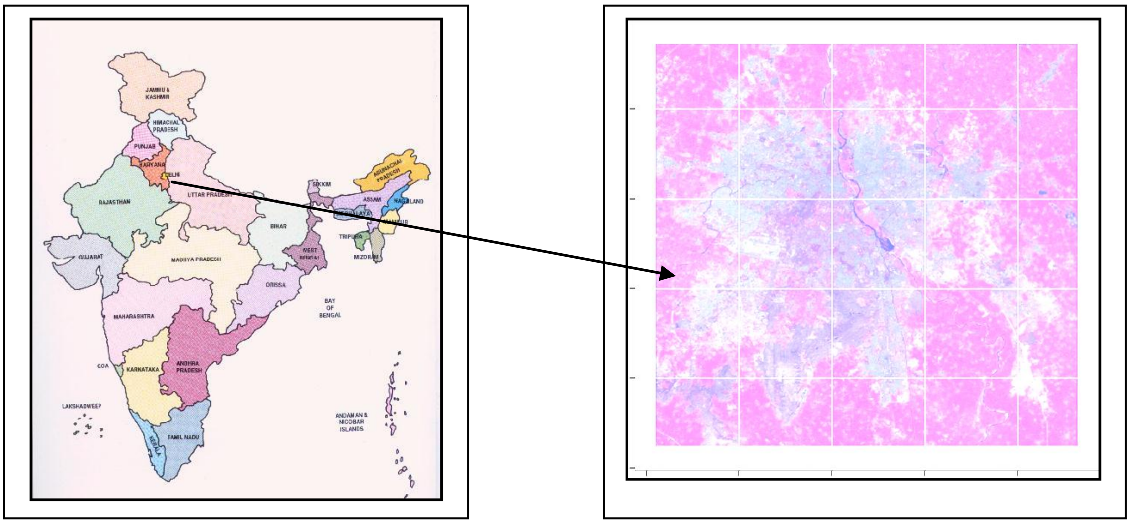


Figure 1: location of study area Delhi, India

As Delhi is the capital of India so development is going very fast this also increases the population growth. The population of New Delhi has increased rapidly in last 10 years. From a figure of 400000 in year 1901, the population of Delhi has increased to around 16,753,235 in the year 2011 according to the census of India. There has been tremendous development in transport, education and other facilities offered by the government and other agencies in Delhi. The population of Delhi is expected to rise 40% by the year 2020. Better roads and a good living standard in Delhi have attracted people from all over India.

3. Data and Material used

The surface temperature were estimated using satellite data over different Land use (LU)/Land Cover (LC) of Delhi over 10 year of time during summer and winter seasons. Landsat TM-5 datasets were used in this research. Landsat TM- 5 data are used for preparation of land use/land cover maps and estimation of surface temperature.

Table No.1: The following data were used to compare seasonal and temporal differences in surface temperature.

Dataset used	Summer		Winter	
	Year (2000)	Year (2010)	Year (2000)	Year (2010)
Landsat-TM5	May 9	May 5	February 14	February 3

All the satellite images were geometrically rectified. An atmospheric correction was used in all datasets of Landsat. These data are converted to emissivity, surface temperature, and the Normalized Difference Vegetation Index (NDVI). The land use/ land cover classifications were performed using Landsat image of February 2000 and 2010 datasets. Eventually, the land surface was classified into eight types of land cover classes: Agriculture, Settlement and water body, Open scrub, Open space with grass, Forest, Bare soil, Industries.

4 Methodologies:

Estimation of surface temperature was made over eight types of land cover agriculture settlement, water body, open scrub, open space with grass, forest, bare soil, industries on several days of winter (February) and summer (May) seasons.

After applying the radiometric and geometric correction the subset images of radiance were created for the study area, both for visible and near infrared bands of Landsat TM-5.

For effective estimation of temperature, the emissivity values are to be derived at pixel level. The emissivity of vegetation in 8-14 µm remains more or less uniform. The proportion of vegetation cover in conjunction with NDVI has been taken to estimate pixel emissivity (Van de Griend & Owe M.1993).

Surface emissivity is calculated using:

$$\varepsilon = a + b * \ln(NDVI) \qquad (1)$$

Where a=1.0094 and b=0.047

$$NDVI = \frac{(\rho_{NIR} - \rho_{Red})}{(\rho_{NIR} + \rho_{Red})}$$

4.1 The surface temperature for Land sat is estimated as:

Landsat TM band 6 imagery can be converted from spectral radiance (as described above) to a more physically useful variable. This is the effective at-satellite temperatures of the viewed Earth-atmosphere system under an assumption of unity emissivity and using pre-launch calibration constants. The digital number (DN) of thermal infrared band is converted in to spectral radiance (Lλ) using Landsat user's hand book (Mansor & Cracknell, 1994). Radiance to convert to temperature as,

$$T = \frac{K_2}{\ln\left(\frac{\varepsilon K_1}{L_\lambda}\right) + 1} \qquad (2)$$

Where K_1= 607.76 $mWcm^{-2}sr^{-1}\mu m^{-1}$, K_2= 1260.56 K 2, L_λ = radiance, ε= emissivity

4.2 Urban growth in Delhi

The intensity of UHI is determined by the interaction of several factors, including the degree of urbanization (total built-up area, population size, industrial development and transportation), the geometry of a city, physical environment and human activities (Yang et al., 1984). Whether a city is a metropolis or a county seat, the UHI effect is linked to the composition of the underlying surface, i.e. the pattern and structure of land use and land cover. Urban development has often intensified the degree of UHI (Weng 2004). The following text reviews the history of urban development in Delhi.

Delhi city rapidly grow and changes since last hundred years. The city Delhi situated near the bank of Yamuna River. Indian capital was changed from Kolkata to Delhi long back in British period and it's almost century completed Delhi as a national capital of India. After rise of Delhi Sultanates Delhi became major hub for political, commercial and cultural context and it's also benefited due to its important geographical situation as it is situated main trade route between northwest India and the Gangetic plain. The old monuments inside this city are just a representative of that old history. Now Delhi became multicultural cosmopolitan metropolis, so people from different parts of country now migrated to Delhi to be a permanent resident.

The growth rate of Delhi population was increased due to enormous arrival of mass of population from Pakistan after partition during post independence era which affected the growth rate of trade and commerce and also helped in industrialisation. Delhi is a witness of several changes of political and administrative up and down since Independence. Delhi get its complete makeover from its past, It's started from a historical city to now present day biggest cosmopolitan in India. Most of all it's a capital of biggest democracy of the world.

The rapid increased in Delhi population is observed since last 10 years. Presently Delhi population was around 16,753,235 (source: census 2011) which observed 400000 in year 1901. People attracted to stay in Delhi because of good roads and high living standard which possible due to its extraordinary development in transportation, education and other facilities. Normal prediction on population did by census department shows that almost 40 % increases in population will found in 2020.

Table 2: Population Growth of Delhi, India (source: census 2011)

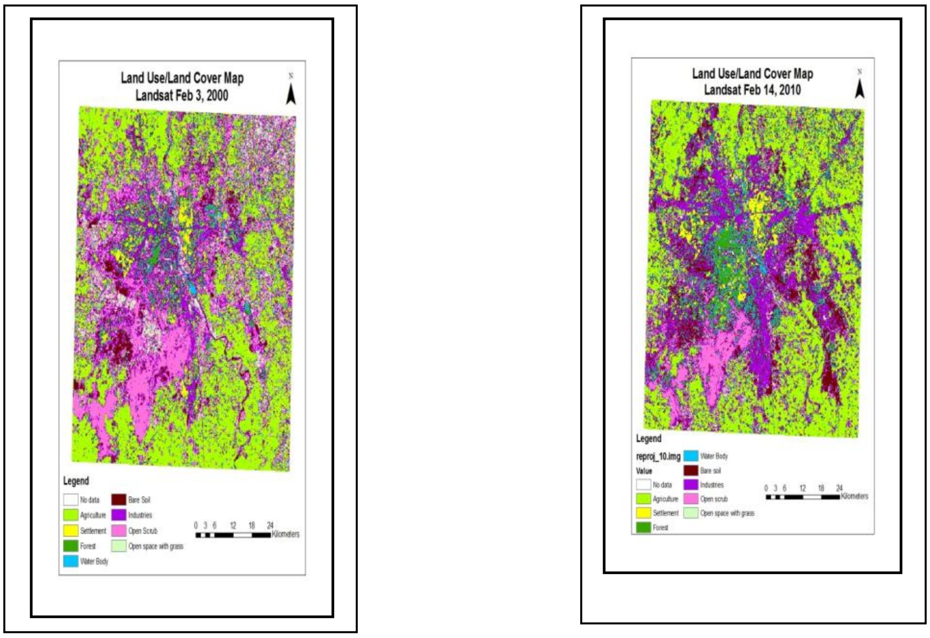
Census year	Population (in millions)	Decennial growth Rate (%)
1901	405819	-
1911	413851	2.0%
1921	488452	18.0%
1931	636246	30.3%
1941	917939	44.3%
1951	1744072	90.0%
1961	2658612	52.4%
1971	4065698	52.9%
1981	6220406	53.0%
1991	9420644	51.4%
2001	13782976	46.3%
2011	16,753,235	21.6%

The population of Delhi was almost 13,782,976 in the year 2001 but it increased to 15,279,000 in the year 2004 (source: census 2011). The large opportunity for employment and education influenced people from other state to come in Delhi. Approximately estimated figures tell that almost 2 lack to 3 lack people yearly migrated from others state to became permanent resident in Delhi. Huge number of Delhi population is mainly covered by the people migrated from other state.

5. Results and Discussion

5.1 LU/LC analysis using Land sat data

The change in LU/LC over the last 10 year period was studied using Landsat-TM5 datasets of February 2, 2000 and February 14, 2010 (figure 1a and 1b). The population of Delhi soared to 16.7 million according to census of India 2011. The population density is 11,297 person per sq. km which is highest in the country. This increase in population is causing change in the LU/LC.



(a) *(b)*

Figure 2: LU/LC map of Landsat (a) February 3, 2000 and (b) February14, 2010

From the figure it is evident that most of the changes/development is observed in and around south eastern part of Delhi. Noida and Greater Nioda have come up with urban structures like multinational office buildings, multiplexes, shopping malls, apartments and residential areas. New developments like shopping malls, apartments and industrial area have been developed in and around north eastern part near Gaziabad and the same increase in urban structures are also observed in southern part Faridabad and north eastern part of Delhi. Table 3 shows the percentage increases in particular LU/LC in the last 10 years.

Table 3: Area statistics of different LU/LC from year 2000 to 2010

Landsat Feb 3, 2000

LU/LC	Area (Km²)	Area (%)
Agriculture	1954.91	37.75
Settlement	291.93	5.63
Water body	44.53	0.86
Open scrub	1149.15	22.19
Open space with grass	849.68	16.40
Forest	147.70	2.85
Bare soil	486.18	9.38

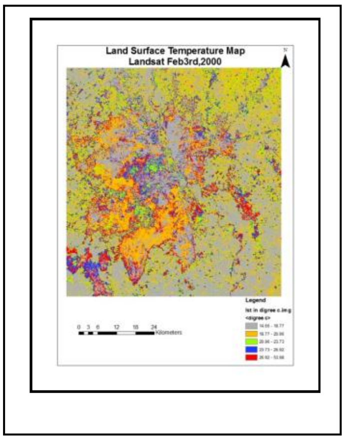
Landsat Feb 14, 2010

LU/LC	Area (Km²)	Area (%)
Agriculture	1884.23	39.43
Settlement	390.05	8.16
Water body	24.95	0.52
Open scrub	538.08	11.26
Open space with grass	610.50	12.78
Forest	268.51	5.62
Bare soil	449.54	9.41

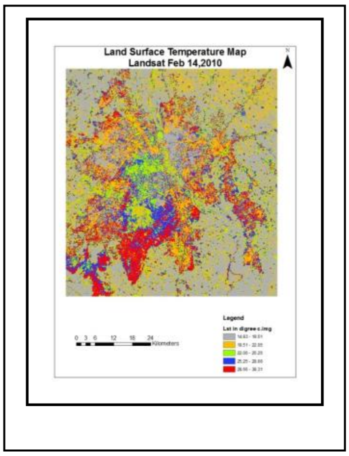
The LU/LC change statistics in the 10 years period is mentioned in table 3. The analysis shows that during the 10 years, there is marginal change in the agricultural, forest & bare soil while large change in open scrub settlement & industrial in the past 10 years.

5.2 Analysis of Land surface temperature

Land surface temperature analysis is one of important parameter of urban heat island analysis. The LST analysis was performed for summer and winter season over the last 10 year period using Landsat. Figure 3 and figure 4 shows the LST map for the years 2000 and 2010 of different season. The images clearly show that the surface temperature is higher in 2010 than 2000 which is due to land use change attributing mainly to increase in urban built-up area.



(a)



(b)

Figure 3: Land surface temperature images of Landsat data (a) February 3, 2000 (b) February 14,2010

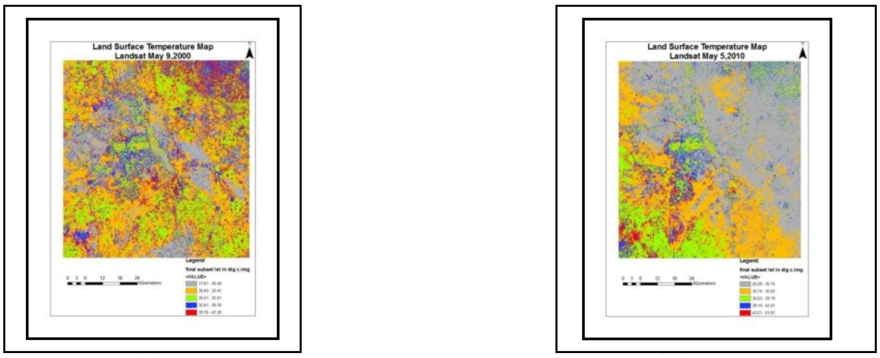


Figure 4: LST images of Landsat data of (a) Landsat May 9, 2000, (b) Landsat May 5, 2010

Figure 3 and 4 shows the land surface temperature (LST) maps for the years 2000 and 2010 for summer and winter session of Landsat image. Landsat showing both are high LST in summer than winter season. These four images are mainly shows the temperature change is summer and winter as well as changes of surface temperature in last 10 years.

During summer both data of landsat value observed high over built-up, industrial, bare soil and fellow land and comparatively low values observed over water body, forest and open space with grass. If we concentrate on urban built-up area which is mainly combine of residential area and industrial area and season variations is showing much higher. In (2000) LST on industrial area is showing 22.3^{0}C in winter, but in summer it is showing 32.5^{0}C almost 10^{0}C increases in temperature. This same trend we also found in 2010 images of landsat where LST on industrial area is showing 24.2^{0}C in winter but in summer it is showing 34.5^{0}C almost 10^{0}C increases in temperature. It is observed that the increase is around ±2^{0}C during the last 10 years over the urban areas.

Table 4: Comparison of derived LST using satellite data for different months of year 2000 & 2010

Land use/land cover	Landsat 2000 Feb(°c)	Landsat 2010 Feb(°c)	Landsat 2000 May(°c)	Landsat 2010 May(°c)
Industrial Area	22.3	24.2	32.5	34.5
Agriculture	17.7	17.6	33.2	38.1
Open space with grass	21.7	21.4	30.1	34.4
Residential area	22.2	22.2	31.1	33.6
Forest	18.6	18.2	31.1	29.8
Water body	15.3	16.7	23.4	24.1

From the table 4 we understand that industrial and residential temperature is high in both the months of 2000 and 2010. Surface temperature over agricultural land (fallow land) as observed in May month temperature is always higher than February in all years. In the month of May agricultural land have no crops in field so it behaves like a bare land. Open space with grass also shows high temperature in May due to same reason.

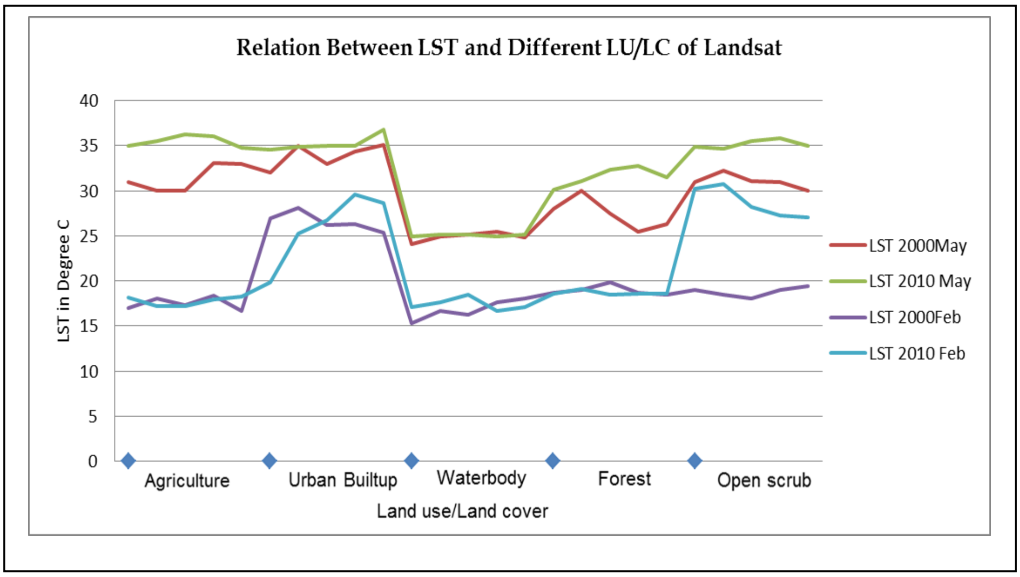


Figure 5 Relationships between LST with LU/LC on Landsat of February and May, 2000&2010

Form the figure 5 we compared different satellite LST data of different season with different LU/LC of 2000 and 2010. From that we can understand that LST of May is more than the LST of February. And it's also very clear that 2010 LST is showing higher value than 2000 LST. LST is showing higher value on urban built-up and open scrub but in others LU/LC it will show relatively low value. Agricultural land is also showing high LST in May months due to fallow land. Water body is also showing low LST in all images. This graph gives good idea about changes of LST in different season in 10 years gap.

The ground data collection and field measurements were possible during the year 2010. Hence, the comparison of satellite and ground based measured was analyzed. Table 4 shows the comparison of satellite derived LST with that of ground measured values. It is observed that Landsat estimated values are in close agreement with that of ground measured data within error of $\pm$ 2^0C. Inter-normalization of landsat was not done. The ground measured point were averaged values of several points in the Kernal of 100m*100m. For the validation of ground data with the GPS points were refer on landsat & compared the value. For ground data collection Thermal Infrared thermometer was used.

Table 5: Comparison of LST derived using different satellite & ground measured data

Land use/land cover	Date & Time	Ground Data	Landsat 2010 May
Industrial Area	22/5/2010 10:47 am	39.9°c	38.0°c
Residential Area	22/5/2010 12:45pm	34.1°c	32.7°c
Agriculture	23/5/2010 4:30am	35.1°c	31.8°c
Open space with grass	23/5/2010 10:18am	36.1°c	35.4°c
Residential area	24/5/2010 12.15pm	34.2^{0}c	33.2^{0}c
Industrial area	24/5/2010 10.30am	34.5^{0}c	37.0^{0}c
Road side Built up	25/5/2010 12.30pm	36.2^{0}c	39.1^{0}c
Open space with grass	25/5/2010 12.45pm	36.7^{0}c	35.4^{0}c

6. Implications on planning—managing the urban heat?

An examination of the linkage between urban development, the ground base measurements and satellite-derived land surface temperatures provides a theoretical model of the dynamics of an urban thermal environment, which is very useful for urban planning and decision making. Based on the results of this study, the following planning implications can be derived:

a) Urban heat island (UHI) effect is increased due to continuous increasing of urban buildings. LST in last 10 years is increase is around ±2^{0}C over the urban built-up areas. This continuous heat increase is due to increases of urban area mainly south eastern part of Delhi. Noida and Greater Nioda have come up with urban structures like multinational office buildings, multiplexes, shopping malls, apartments and residential areas.

b) For the understanding of thermal response of each land use (LU)/land cover (LC) type and the thermal effect of spatial arrangement of different LU/LC type's satellite imagery can be used to derive information on LU/LC types and surface temperature at high spatial and temporal resolutions.

c) Vegetation plays major role to reduce the amount of thermal radiation from results it's indicate very clearly. So maintaining and enhancing urban forest give a hopeful solution of maintaining urban heat. City planners and government should concentrate more on green campaigns.

d) Inputting and mitigating upwelling thermal energy into the atmosphere is varies in different types of vegetation. The area with trees is showing cooler than grass lawns. For city annual tree plant camping planners should concentrate on this point.

e) It is easily understandable from satellite imagery that tree lines roads, water bodies, parks and garden showing cool temperature. So it is very important to increases trees side of roads and also increases garden in the city. As well as Jamuna river need to clear as its effected due to human influence which is the cause of water pollution and indirectly increases the temperature.

f) Another important thing observed that industrial area is much higher land surface temperature than residential area. It makes us understand that it will be better to make industrial area outside the city area or relocating the industries from city area.

Green buildings technology across all its major construction agencies through a circular issued in 2003 Delhi has decided to adopt that. The green building concept emphasizes sustainable site planning, design and construction of buildings to achieve maximum harmony with nature and at the same time reduce negative environmental effects

Along railway lines, railway stations, along the drains, village community lands and villages, bunds of agricultural lands, farm lands etc were also selected for plantation in coordinated efforts with the concerned agencies. Initiatives such as free distribution of saplings through 13 Departmental nurseries and through the nurseries of other greening agencies were also taken. Novel approach such as free distribution through petrol pumps and Mother Diary milk vending booths during monsoon season yielded productive results. Due to this resin forest area is increased 2.85 to 5.62 %. But still it's not enough with the increasing rate of urbanization. For controlling this heat Delhi need more plantations.

7. Conclusion:

Remote sensing and GIS is useful tools for deriving information regarding of land use and land cover land surface temperatures and for examining the thermal effect of urban development. The urban built up area of Delhi is increased 5.63% to 8.16% in last 10 years. The urban development has altered the magnitude and pattern of UHI. Application of Landsat TM thermal infrared data to the study of land surface temperatures suggests that different land cover types have distinctive thermal responses. The spatial variability and land surface temperature is increased due to the conversion of natural and vegetated surface into urban uses. Effective city's Green campaign planning is possible by combining Satellite-derived land use/cover maps showing the vegetation distribution with land surface temperature maps. Forest, water body, green lawns showing cooling effect, so urban planners can use this knowledge to managing the temperature. City planning department of Delhi should focus on afforestation policies and green building concepts and parks and garden introduce more in city area. This research has demonstrated that whatever pollicises taken by Delhi planning authority to make Delhi green it's not so effective to reduced adverse thermal effect of urban development. It is also suggested that trees are more effective to reduced temperature than green lawns.

But we can suggest high resolution thermal data will give more information for this type study. Then we can study differentiate more categories of vegetation type, so that the effect of vegetation's biophysical properties on the urban thermal environment. Multi-sensor remote sensing data is very useful to study the changing pattern of UHI and their interaction with vegetation dynamic and urban development.

8. Acknowledgements

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