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STUDY OF TEMPERATURE PROFILE ON VARIOUS LAND USE AND LAND COVER FOR EMERGING HEAT ISLAND

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Abstract: Hyderabad city, the fourth most populous city and sixth most populous urban agglomeration in India is emerging into a megacity with the population set to cross the 10 million mark by 2015. The city is currently in the midst of unprecedented urbanization as it has grown into a cyber-capital, and is now known as the tricity of Cyberabad- Hyderabad and Secunderabad. Commanding a massive area of 1905 km^2, the city suffers from a host of problems including heavy population growth, over-use of basic amenities and resources, sprawl, depletion of ground water and climatic changes attributed to enhanced greenhouse gases. This study evaluates the growth of the urban built up areas within the city using remote sensing and GIS, apart from analyzing the temperature profile across various land use and land cover. Landsat 5 TM data of 1989, 1999 and 2009 were used to understand the temperature changes over different land use and land cover. The study shows a 67% loss in water bodies while the urban built up areas have grown by 270%. The temperature profile also shows a dip in temperature while encountering water bodies, gardens and parks.

Keywords: Remote Sensing, urban growth, temperature profile, land use and land cover

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INTRODUCTION

Urbanization refers to accumulation of human population in discrete areas, resulting in transformation of land for industrial, commercial, residential and transportation purposes. The 21st century is experiencing unprecedented scales of urbanization as the urban population has risen dramatically from 30% in 1950 to 54% in 2014 and is expected to rise to 66% by 2030. Asia and Africa are urbanizing faster than other regions of the world and it is projected to be 64% and 56% urban by 2050 (World Urbanization Prospects, 2014). The city planners are facing serious challenges in the form of traffic congestion, development of infrastructure and provision of basic amenities such as water , sanitation and electricity (Kulkarni and Ramachandra, 2006).Other implications include loss of aquatic ecosystems and creation of heat islands due to discharge of heat from anthropogenic activities and reduction of water pervious surfaces and vegetation. The surroundings of built up areas in cities are cooler as compared to interiors of cities (Landsberg, 1981). There is a noteworthy difference of energy budgets of cities and its countryside called Urban Heat Island (UHI) (Crutzen, 2004).This phenomenon of UHI was studied using satellite derived land surface temperature (LST) measurements from various satellite data products acquired in thermal region of the electromagnetic spectrum. Global warming and urban heat island cause the increase of near surface ambient temperature in cities (Santamouris ,2001). For most of the major cities in the world UHI is well documented (Santamouris, 2007). LST plays a crucial role in monitoring surface heat islands (Voogt and Oke, 2003; Weng *et al*.2004). LST can also be used to monitor vegetation physiology (Karnieli *et al*. 2006). The high resolution data includes, the Landsat-5 Thematic Mapper (TM) which has a 30m resolution, and repeat cycle of 16 days (Li *et. al.* 2004; Ramachandra and Uttam Kumar, 2009) . The study of UHI remotely on global scales has been made possible due to the advent of satellite remote sensing technology (Streutker,2002). Stathopoulou and Cartalis (2007) identified daytime UHI using Landsat ETM+ data for major cities in Greece. Weng (2001, 2003) examined land cover (LC) and its influence on LST in the urban clusters in China's Zhujiang Delta and in Guangzhou. Ramachandra and Uttam Kumar (2010) studied the growth of Bangalore and its influence on the local climate using Landsat TM, Landsat ETM+, LISS (Linear Imaging Self Scanner)-III and MODIS (Moderate Resolution Imaging Spectroradiometer). Landsat TM data of 1989, 1999 and 2009 were used in the present study of Hyderabad City.

STUDY AREA

Hyderabad (78° 28' 27" E and 17° 22' 31" N) is the joint capital of the newly bifurcated state of Andhra Pradesh, India. It is one of the largest metropolitan city of India with an area of 1905 square kilometers (Fig.1).

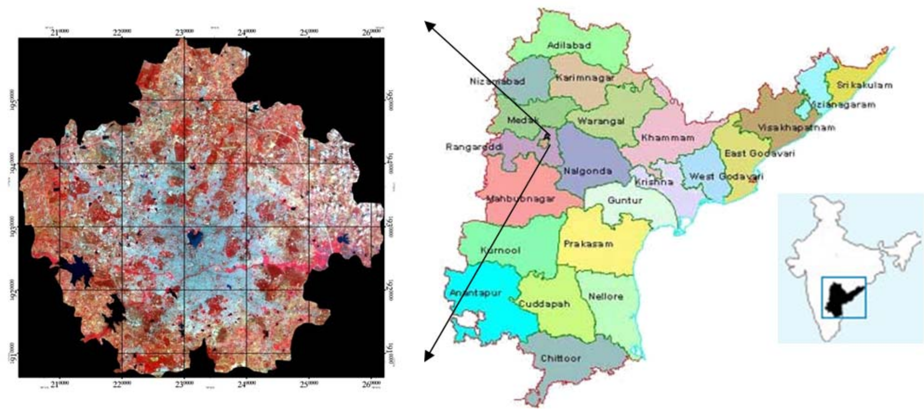


Fig.1 Study Area location Map

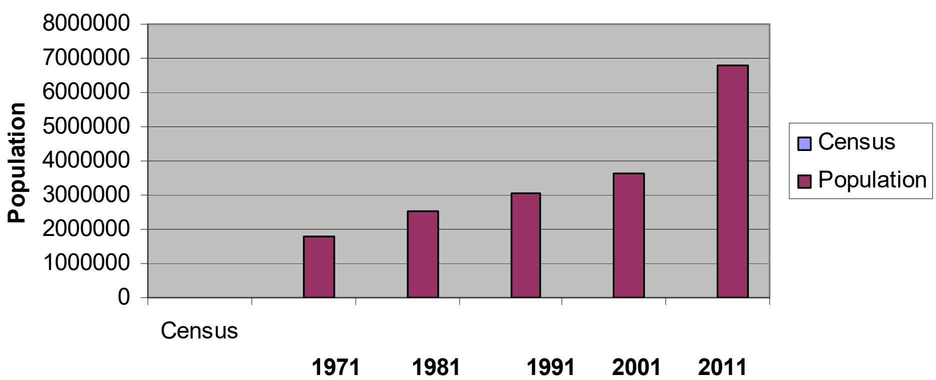


Fig.2 Population growth in study area from 1971 to 2011

The city has 6,809,970 residents and the metropolitan area comprise of 7,749,334 residents making it the fourth most populous city and the sixth most populous urban agglomeration in India (Fig.2). Hyderabad is

$$L_{TM6} = \frac{DN_6}{255}(Lmax - Lmin) + Lmin$$

situated on Deccan plateau, located in North West of Andhra Pradesh. It has an average elevation of about 536 metres above sea level (1,607 ft). Most of the area has a gently sloping terrain and some areas are hilly. Crops are commonly grown in the surrounding paddy fields. The historic Old City of Hyderabad was founded on the banks of river Musi. The New City is an extension of the city to the north of the river, with the construction of many government buildings and landmark structures, especially towards the south of the Hussain Sagar lake. Hyderabad Metropolitan Area (HMA) can be broadly defined as the jurisdiction covered presently under Hyderabad Urban Development Authority (HUDA) and three Special Area Development Authorities (SADAs) namely Cyberabad Development Authority (CDA), Hyderabad Airport Development Authority (HADA) and the Buddha Purnima Project Authority (BPPA). Many big tanks were built by the Qutub Shahi rulers (1534-1724 A.D.) and later by the Asaf Jahi rulers (1724-1948) in and around Hyderabad city. It is estimated that there were 932 tanks in 1973 in and around Hyderabad which came down to 834 in 1996 (169 of which are above 10 hectares). Consequently the area under water bodies got reduced from 118 to 110sq.km (EPTRI, 1996).

DATA USED AND METHODOLOGY

Base layers were generated using Survey of India (SOI) toposheets of 1:50000 and 1: 250000 scales.The Landsats 4 and 5, carried onboard the Thematic Mapper sensor from July 1982 to May 2012 and the satellite had a repeat cycle of 16 days.

The satellite was decommissioned in January 2013. The data files contain 7 spectral bands with a resolution of 30m while the thermal band 6, having a 120m resolution was resampled to 30m. Collection of field data was done using a hand held GPS. Remote Sensing data used for the study are Landsat TM (1989, 1999, 2009) as given in **Table 1**, apart from Google Earth data (http://earth.google.com) which helped in pre and post classification as well as for validation of results. The analysis was done as follows:

1. The acquired remotely sensed data was georeferenced , masked and cropped to suit the study area.

2. Accuracy assessment was done with knowledge of the field, visual interpretation as well as referring to Google Earth (http://earth.google.com).

Table 1. Landsat image details

Image Date	Sensor	Spatial Resolution
21-11-1989	Landsat 5 TM	30m
01-01-1999	Landsat 5 TM	30m
27-10-2009	Landsat 5 TM	30m

3. Supervised classification was done using Support Vector Machine Classifier by specifying LC types present in a scene.

Calculation of reflectance and temperature using LANDSAT data

The Landsat-5 TM, TIR band 6 was used to calculate the surface temperature of the area. The TIR sensors can measure radiances at the top of the atmosphere (TOA) from which brightness or black body temperatures can be derived using Planck's Law (Dash *et al.* 2002).As only a relatively small region is considered, the water vapour content in the atmosphere is assumed to be constant and hence the atmospheric condition may be considered as uniform and its influence on temperature radiance can be ignored. The at- satellite brightness temperatures can thus be used to reflect the distribution of surface temperature . Brightness temperature can be derived in two steps (Chen *et al*.2002). The digital number (DN) was first converted into radiance L_{TM} using Eq. (1)

(1)

where DN_6 is the DN for band 6 and L_{max} = 1.896 (mW * cm^{-2} * sr^{-1}), and L_{min} = 0.1534 (mW * cm^{-2} * sr^{-1}). The radiance was then converted to at sensor brightness temperature in kelvin, T_{TMS} (at satellite) using Eq. (2):

$$T_{TMS} = \frac{K_2}{\ln\left[\frac{K_1}{\frac{L_{TMs}}{b}} + 1\right]} \quad (2)$$

where the coefficients K_1 and K_2 are prelaunch calibration constants, K_1 = 60.766 (mW *cm^{-2}* sr^{-1} µm) and K_2 = 1260.56 K and b is effective spectral range and b = 1.239 µm (when the response of the sensor is much higher than 50% (Xiao- Ling *et al.* 2006), T_{TMS} (in degree Celsius) = T_{TMS} (in degree Kelvin) - 273

RESULTS AND DISCUSSION

The images of 1989, 1999 and 2009 were classified using Support Vector Machine classification and is displayed in Fig.3. An earlier study on accuracy assessment of the study area shows that Support Vector Machine classifier gives higher overall accuracy of 96.39% (Sainu & Mandla, 2012). The class statistics is given in Table 2 .Detailed analysis of all the above

Table 2. Greater Hyderabad LU/LC classification statistics

Year	Area	Urban Built -Up	Water	Vegetation	Barren Land
1989	km^2	158.7	193.48	255.82	1353.36
	%	8.09	9.87	13.05	69
1999	km^2	342.51	82.75	324.66	1211.49
	%	17.46	4.22	16.55	61.73
2009	km^2	429.68	64.34	679.6	787.8
	%	21.91	3.28	34.65	40.16

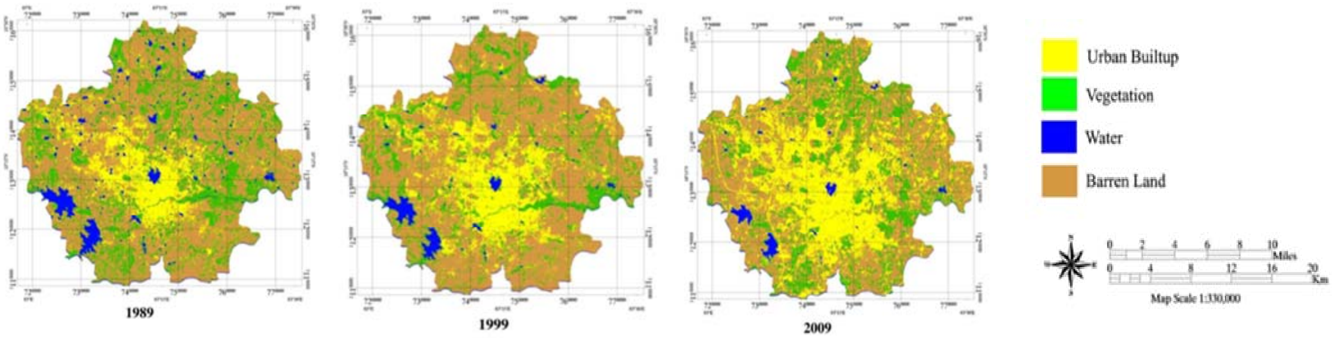


Fig. 3 Land use maps of 1989, 1999, 2009

classified images was performed and there is evidence of sprawl in all the images. The analysis was corroborated by field visits in 2010 and Google Earth image. It is also observed that urban areas have increased from 158.7 km^2 in 1989 to 429 km^2 in 2009, an increase of 270% whereas the water bodies have decreased from 193.48 km^2 to 64.34 km^2 a decline of 67%. Urban sprawl along with a decline in natural resources is observed in this study. The fast growth of urban sprawl has resulted in loss of water bodies, increase in consumption of energy and green house gas emissions due to increase in usage of private vehicles.

Anthropogenic heat discharge due to increased energy consumption, artificial materials having high heat capacities and conductivities occupying most of the land surface, and the consequent decrease in water pervious surfaces and vegetation, contribute to increase in surface and atmospheric temperatures. A key parameter to evaluate the thermal behavior of a variety of terrestrial processes at differing spatio- temporal scales, is land surface temperature (LST) (Aniruddha and Joshi ,2014). The landscape of Hyderabad city is dotted with hills and massive rocks which presents a higher temperature than the city centre. However a rise in temperature at a local level results in higher energy consumption to overcome the heat and this implies rise in emission of green house gases which in turn influences global climatic changes. The LST map derived from the thermal band 6 using the method described in 3.1 is shown here (Fig. 4) .The mean temperatures observed over different land cover features in the LST maps of 1989, 1999 and 2009 are given in Table 3.

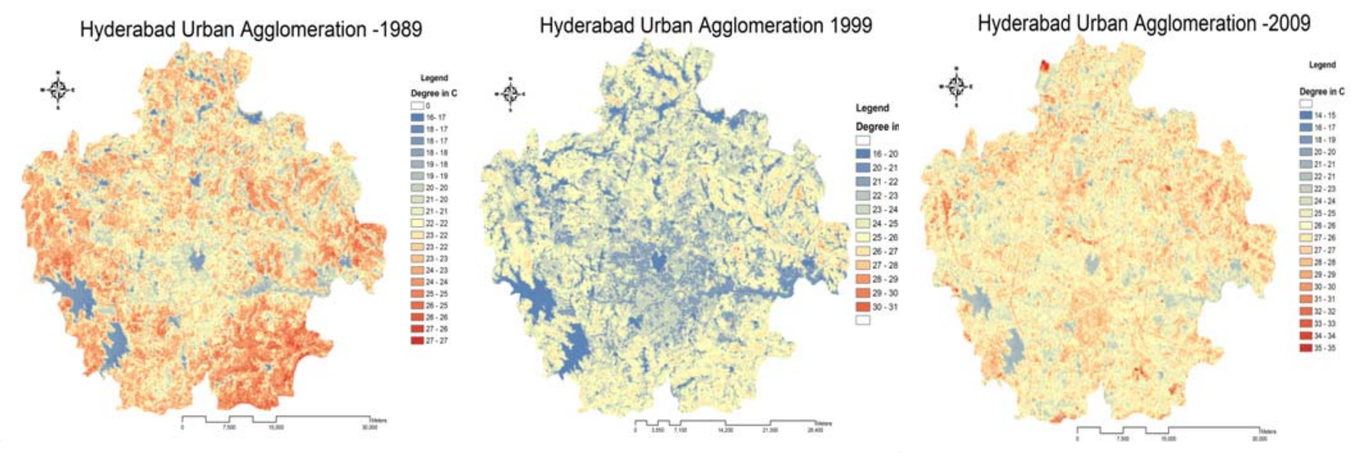
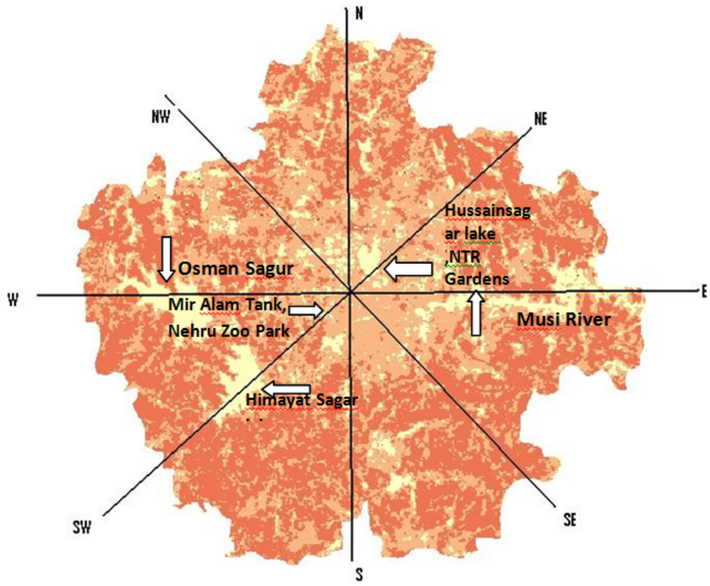


Fig. 4 Land Surface Temperature for the year 1989, 1999 and 2009

Table 3. Greater Hyderabad LST statistics

	Mean Temperature +/- STD Devn		
	1989	1999	2009
Urban	24.44 +/- 0.23	26.08 +/-0.68	28.31 +/- 1.24
Vegetation	22.05 +/- 0.72	23.32 +/- 0.78	24.00 +/- 1.14
Water	20.43 +/- 0.47	21.00 +/- 0.82	21.06 +/- 0.30
Barren	26.36 +/- 0.54	28.96 +/- 1.36	29.85 +/- 1.12



Direction	Mean LST
N	24.12
NE	23.3
E	22.89
SE	24.59
S	24.75
SW	23.29
W	23.00
NW	24.03

Fig. 5 Transect lines superimposed over classified map of Hyderabad and LST in different directions (Centre $17^0$23'4.99"N, $78^0$27'12.13"E)

Transects were drawn across the city in various directions north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W), northwest (NW) and the LST was analyzed as shown in Figure 5.

The temperature profile was analyzed in different directions by overlaying the land surface temperature (LST) map over the classified map of Hyderabad in order to envision the effect of built-up areas, water bodies, vegetation, open ground and rocky areas on temperature. The profile plot fell below mean while encountering water bodies or green patches of vegetation on the transect starting at the centre of the city and moving along the transect in different directions. The corresponding profile plots are shown in Figure 6. The major water bodies and parks causing decline in temperature have been encircled and marked. The spatial location of these water bodies can be observed in Figures 5.

CONCLUSION

Urbanization has resulted in drastic change of land cover. Decrease in number and size of existing water bodies with increasing population and related infrastructure including residences and industries has left its impact upon the catchment yield, water retaining capacity of soil, ground water table apart from affecting the flora and fauna present in the region. Higher level of anthropogenic activities leads to higher LST. A 2^0C rise in temperature can be observed over the decades. Urban sprawl has almost tripled the urban built up area during the same period and is observed mainly in the southern and western directions. Newly built up areas comprise of IT hubs , high rise residential buildings, small and large scale industries, private houses apart from roads connecting the same. The growth in the southern direction can be attributed to the new international airport at Shamshabad which replaced the former airport at Begumpet, thereby encouraging commercial and residential hubs. The IT hub of HITEC city encouraged the growth in the western direction. It is spread across the suburbs of Madhapur, Gachibowli, Nanakramguda, Manikonda and Kondapur.This type of urbanization wherein the surrounding suburbs get converted to urban areas, is reminiscent of the Asian form of urbanization, also known as 'Desakota', which is very different from western form of urbanization wherein rural to urban migration predominates. The expressway also called as the Outer Ring Road (ORR) connected to the Inner Ring Road through 33 radial roads enhances connectivity and contributed in a large way to the development of the region.

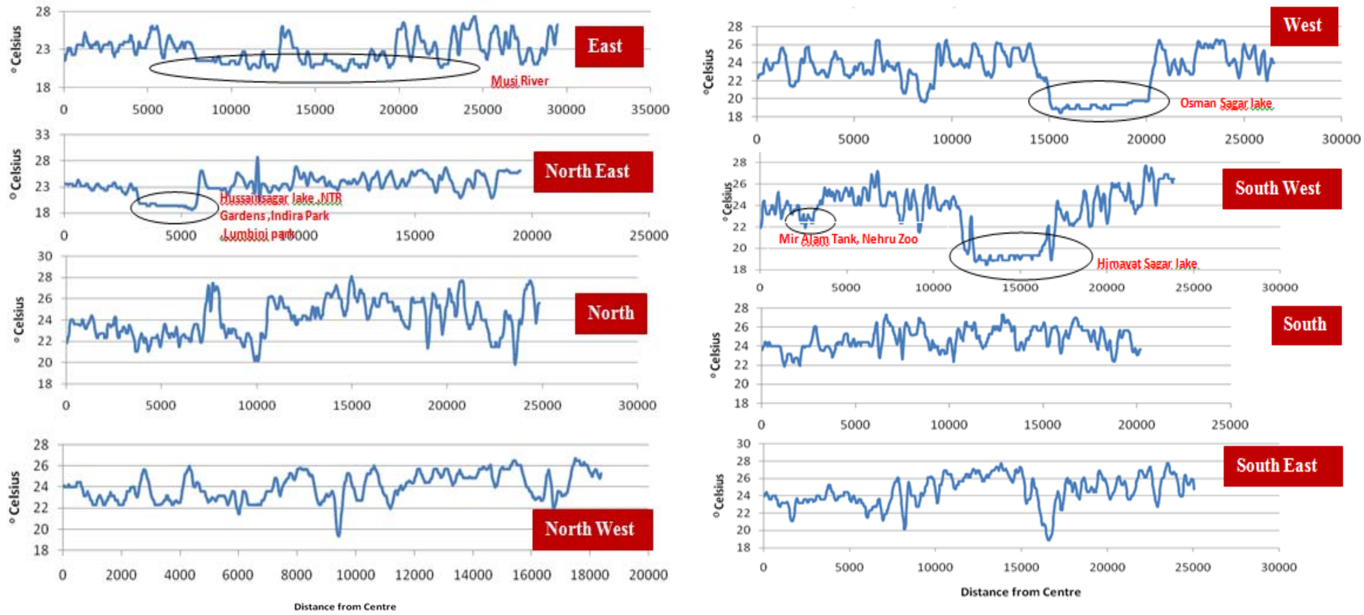


Fig. 6 Temperature profile over different land use / land covers along different directions

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