Green Infrastructure Measures to Mitigate Urban Heat Island Effect: a Case of Hyderabad City

V. Rama Krishna Sharma
Transaction Advisory Services
Ernst & Young LLP
New Delhi, India

Amanpreet Kaur
Urban & Regional Planning Department
Lea Associates South Asia Pvt Ltd
New Delhi, India

***Abstract*— Micro-climate changes due to urbanization are epitomized by the urban heat island (UHI), which is characterized by temperature differences between urban and rural areas. Unprecedented growth has resulted in the removal of vegetation, leading to loss of green land cover. It has also altered the change in land use and land cover which has aggravated the Urban Heat Island (UHI) phenomenon. Hyderabad city in southern India has been selected as a case study for the effect of urbanization on the local climate of the cities. The possible factors responsible for UHI effect in Hyderabad city was identified with an empirical support to this effect. This research paper tries to develop an original conceptual framework for the mapping of the formation of urban heat islands. First is to assess and analyze the UHI factors of the selected case study area where two types of data were used in this study: periodical air temperature data, and satellite image of Hyderabad city. Analysis of temperature data and land use showed significant changes in the micro climate of the city over the period. Second is the satellite image, used to generate a map of NDVI for the city, which in turn was used to generate the land surface temperature map of Hyderabad city. With the help of LST map it was found that, there were indications of temperature variations from the thermal reflections of each land use and land cover of the city. The greatest proliferation of hot spots is observed over some industrial development and mixed land use areas, where the UHI are expected to develop, while the cooler areas comprise green zones or water bodies. Based on population density and time series analysis of pollution for recent years showed intensification of UHI, in institutional, commercial, some parts of old city and industrial areas. A highly air polluted area, with moderate population density having mixed land use, and the scope for the future expansion, has been delineated for conducting the pilot study to propose measures to mitigate the UHI effect. The results demonstrate the possibility to reduce temperatures in residential and urban areas through judicious siting of green areas. As an outcome of the analysis, mitigating measures for UHI effect including green infrastructure and policy level guidelines are proposed. Since, Hyderabad city doesn't have any regulations for FSI.**

Keywords*— Air temperature, green infrastructure, urban heat island, urban planning, urbanization

I. INTRODUCTION

Urban Heat Island is a growing concern for a developing country like India, with the 2nd highest population in the world. Sustainable growth has become a prime mover while planning cities and government policies. Urban construction is the strongest human intervention on natural environment. It will make the biggest changes on natural environment, and these changes would be almost irreversible. The population and city area are growing with the development of urbanization.

An urban heat islands (UHI) phenomena means the temperature in a metropolitan area is significantly warmer than its surrounding rural areas. It was investigated and described firstly by Luke Howard in the 1810s, although he was not the one who names this phenomenon.

The "Urban Heat Island" (UHI) effect refers to an urban area a region, a city or an area within a city that is significantly warmer than its surroundings. It is the result of several factors, most notably a lack of tree cover and a built environment that uses materials that absorb rather than reflect solar radiation. The higher temperatures result in additional air conditioning load on buildings, which in turn leads to substantial additional waste heat, adding to the effect. Warmer temperatures induced by climate change will exacerbate the UHI effect and increase the resulting vulnerabilities.

There are several approaches to reducing the UHI effect. Tree canopy and vegetative surfaces have a cooling effect and do not significantly affect heating loads in the winter; in India, we can see this in the correlation between tree canopy and neighborhoods with higher heat indices. Similarly, use of lighter-color, more reflective materials in the built environment roofs, walls exposed to the sun, walks, roads and parking lots can play a positive role. And reduced use of air conditioning and greater efficiency can reduce the compounding effect of waste heat and the long-term impact of additional greenhouse gas emissions.

II. NEED FOR STUDY

A fair amount of research has been conducted in India on building energy demand, vehicular increase, as well as climate change related to urbanization. The Urban Heat Island has, however, remained among the less researched issues. Dedicated research on the heat island effect in India has primarily covered the observation and documentation of the effect city-wise in the country. In 1951, there were only 5 Indian cities with a population greater than 1 million and only 41 cities greater than 0.1 million population. Much of India effectively lived in 0.56 million villages. But in 2011, there are 3 cities with population greater than 10 million and 53 cities with population greater than 1 million. Further it is projected that there will be 6 cities with a population greater than 10 million including Hyderabad.

A. Study Area

Hyderabad (78° 28' 27" E and 17° 22' 31" N) is the joint capital of the newly bifurcated states of Andhra Pradesh and Telangana, India. The Hyderabad Urban Development Area (HUDA) is around 1907 sq.km. The HUDA area is divided into 29 planning zones (11 zones inside municipal limits and 18 zones in the non-municipal limits or peripheral areas). The city is located around 580m above Mean Sea Level (MSL). It experiences a minimum temperature of 11.6 ^{O}C and a maximum of 40.5 ^{O}C with an average annual rainfall of 73.55 cms. The city is situated centrally between the other metropolises of Mumbai, Chennai and Bangalore. Hyderabad, the administrative capital of Telangana.

The city is divided into seven sub-authorities Hyderabad Metropolitan Area (HMA) can be broadly defined as the jurisdiction covered presently under Hyderabad Urban Development Authority (HUDA) consisting of Greater Hyderabad Municipal Corporation (GHMC), Municipal Corporation of Hyderabad (MCH), Secunderabad Cantonment Board (SCB) and three Special Area Development Authorities (SADAs) namely Cyberabad Development Authority (CDA), Hyderabad Airport Development Authority (HADA) and the Buddha Purnima Project Authority (BPPA) with their respective jurisdictions to cater to the urban issues more efficiently supported with their guidelines to regulate the development of the whole city.

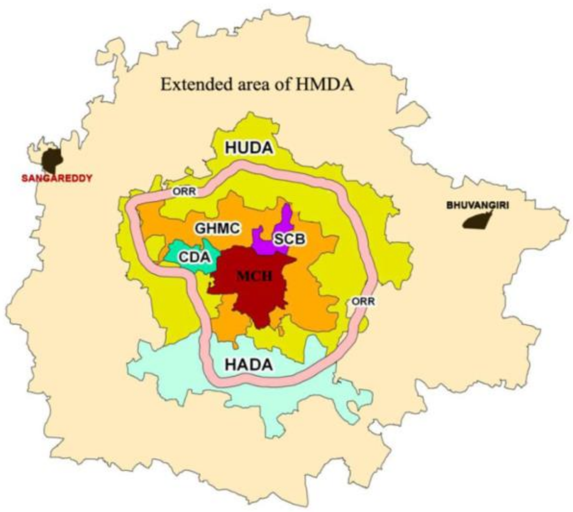


Figure I. Various jurisdiction in Hyderabad city

III. FACTORS CAUSING URBAN HEAT ISLAND IN HYDERABAD

A. Change in Land Use (Encroachment/ Shrinkage of water bodies)

As the city grown, Urban sprawl has encroached into vacant lands and water bodies due to the increasing pressure on land for housing and other activities. City of Hyderabad is bogged down by a slew of construction activity over the past few years, the once serene surroundings such as Banjara Hills, Jubilee Hills and Panjagutta have now turned into busy, congested urban centre’s. In place of sprawling bungalows and expansive green spaces stand rows of swank malls and top-end retail chains. At least half a dozen fresh commercial spaces are also seen rearing their heads in various parts of these neighborhoods’. This resulted into narrow roads, thickly polluted air and deadly traffic snarls. Urban planners charge the blame of this unfortunate transformation squarely on previous government activities that allowed developers to change the land use from residential to commercial.

"Many stretches in the city were declared commercial due to real estate pressures. Urbanization is a complicated issue and development projects have sprung up in a haphazard manner all over the city. This is only due to flexible laws for land conversion. All that a person has to do to set up a commercial establishment on a land parcel categorized as 'residential' for the conversion is pay an impact fee," (URDPFI, 2015) and implemented as said by the controlling authority of as major land parcel is under, Greater Hyderabad Municipal Corporation(GHMC).

All though the city has some identified residential land parcels still it’s now flooded with commercial ventures and allied activities. City areas where multiple land use is clearly demarcated along stretch of roads, and those categorized as 'residential' zones in municipal records, are now a hub of glass-facade-sporting commercial structures. For an instance: Road No 10 of Jubilee hills once had a scarce development that's dotted with a popular school, hotels, boutiques and parlors among other commercial establishments. Also, Road No 25 of Jubliee hills before 2001 still had some open land and even some agricultural land pockets that's currently one of the most sought-after hubs for real estate projects and commercial establishments. Going by earlier records, only Road Nos. 92 and 36 should have been used for commercial purposes. "Although there are a few stretches that continue to exist as residential pockets, City has lost its charm. Several buildings of more than five floors have come up along Road No 76 that used to be a quiet residential stretch till about five years ago. That's because it has become very easy to obtain a No Objection Certificate from the GHMC for such works," as said by local resident of the city for more than 30 years.

Urban planning experts, predictably, aren't surprised by this "incremental" pattern of development that's resulted in "urban chaos".

"Transforming a residential area into a commercial one has many implications. Residential areas must be modified to ensure that they can handle the extra energy consumption, waste generation and vehicular load that come with gradual commercialization thus giving rise to Urban Heat Island effect. The GHMC must also make sure that such commercial establishments don't alter the skyline of the area. Since this hasn't been done, the city is currently experiencing incremental development where the urban ecosystem has changed so much that nobody is aware of what is going on except the municipal administration. This will certainly result

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

in urban chaos," said by Anant Maringanti, Director of Hyderabad Urban Labs.

B. Shrinkage of Water bodies

Many water channels that used to carry flood waters from one lake to the next in a catchment area, have been encroached by private and government agencies. Mir Jumla Tank, Ma Sahab Tank, Batkamma Kunta are the water bodies that has been lost forever due to increase in urbanization since past decades.

TABLE I. NUMBER OF WATER BODIES PRESENT IN THE CITY

Year	Number of Water bodies
1980	932
1990	834
2010	400

TABLE II. NUMBER OF WATER BODIES PRESENT IN THE CITY

Year	Reduction of area of lakes (in %)
1980	2.51
1990	2.40
2010	1.57

Due to inefficient land management and the expansion of urban population has resulted into a rapid rise in the demand for housing, land for industry and commerce, public buildings and infrastructure. This is having a serious impact local climate and on the open space in the city that is shrinking with time. This chapter, as it is based on secondary data, indicates only broad trends at urban agglomeration level. For detailed land use study, primary data and high-resolution satellite data will provide useful insights for the city of Hyderabad.

C. Vehicular Ownership

Transport heralds the development of a region and has a vital role for to the economic development and social integration of the country. Road transport, with other modes of transport, provides indispensable mobility of people as well as goods and contributes to the economic prosperity of a nation. It is a key factor to social, regional and economic cohesion, including the development of rural areas. The transport sector in India consumes about 6.9%. Energy consumption also varies with the modes of transport and public transport system has least average energy consumption/ passenger/km (Singh, 2006). Various energy sources used in this sector are coal, diesel, petroleum (gasoline) and electricity. Road, rail and air modes of transport are responsible for emission of 80%, 13% and 6% respectively (TEDDY, 2007). Vehicular emissions account for about 60% of the GHG's from various activities in India (Patankar, 1991). It is seen that over 95% of total emissions pertaining to Carbon mono-oxide (CO) and hydrocarbons (HC) which are largely emitted by personalized modes of transport i.e. two wheelers and cars. Contribution of these personalized modes is as high as 84-91 % in total emissions in cities of various sizes. Buses contribute only around 2% in total emissions (Kandlikar, 2000). With deteriorating level of mass transport services and increasing use of personalized motor vehicles and same is the case in Hyderabad city. The exponential growth in the number of automobiles have serious implications for energy security, air pollution, road safety, equitable allocation of road space and will accentuate problems related to parking and congestion, which many of our cities have already started witnessing. The vehicular ownership has increased tremendously from 2003 to 2011.

Considering all the factors we have chosen the city of Hyderabad and the most urban agglomerated area of Greater Hyderabad Municipal Corporation area as case study area as shown in

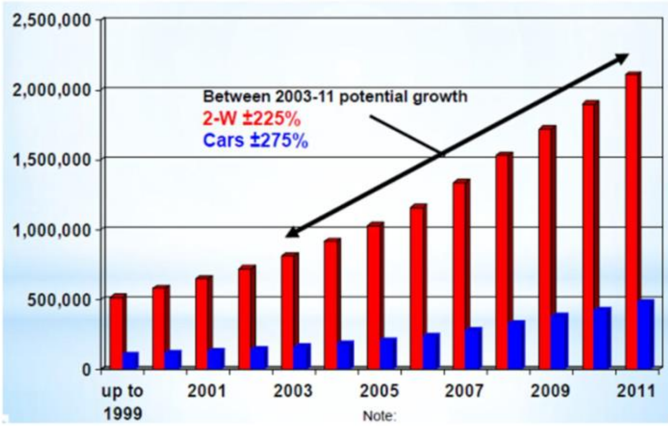


Figure II.

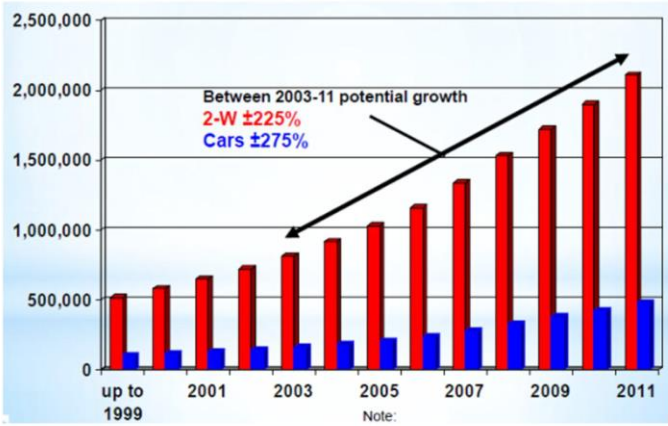


Figure II. Vehicular Ownership in Hyderabad city

D. Scope and Limitation

The study is limited to Greater Hyderabad Municipal Corporation boundary with references to the larger footprint.

IV. METHEDOLOGY

Early image of a city culture was to have more open spaces for social interaction, physical exercise along with this the major function of the open spaces are to act as a place for carbon sink which is one reason behind the fact that wherever there is more greenery the micro-climate is comparatively low as compared to a place with no open/green spaces. This brings me to study the impacts of upcoming built up & loss of vegetation due to perished away of green spaces for more profitable FSI. Therefore, my initial step is to classify the land use pattern over years through Remote Sensing Approach (i.e. satellite images) and mapping of UHI. Secondly the collected data for both the controllable factors (i.e. climate data such as temperature, precipitation, humidity, wind, sunlight, ground water potential) and Uncontrollable factors (i.e. Urban structure like geographical location of city, Population size and density, Air pollution, Built-up and Urban geometry, Thermal properties of fabric) as shown in the

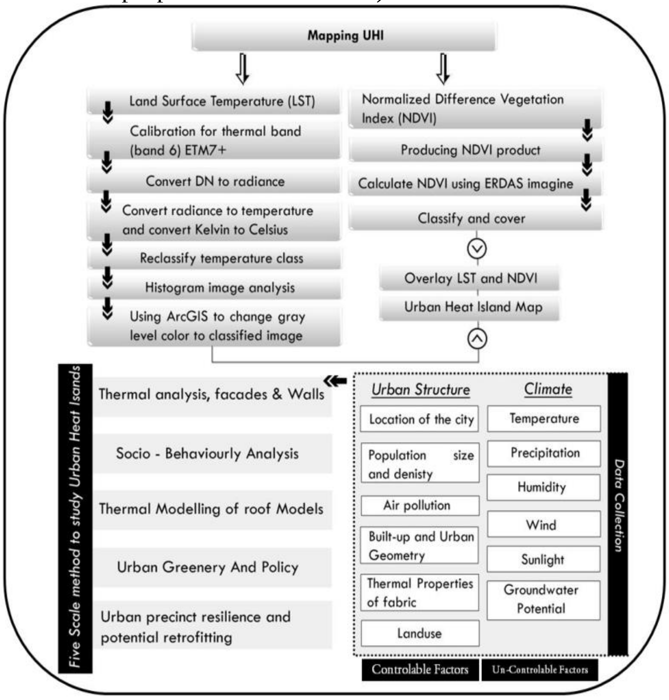


Figure III. Finally, a widely used Five Scale Method to study Urban Heat Island comprising the Thermal analysis of roof and wall material, (socio- behavioral analysis i.e. thermal comfort), Thermal modeling (i.e roof albedo calculations), Urban greenery and Policy and Urban prescient resilience.

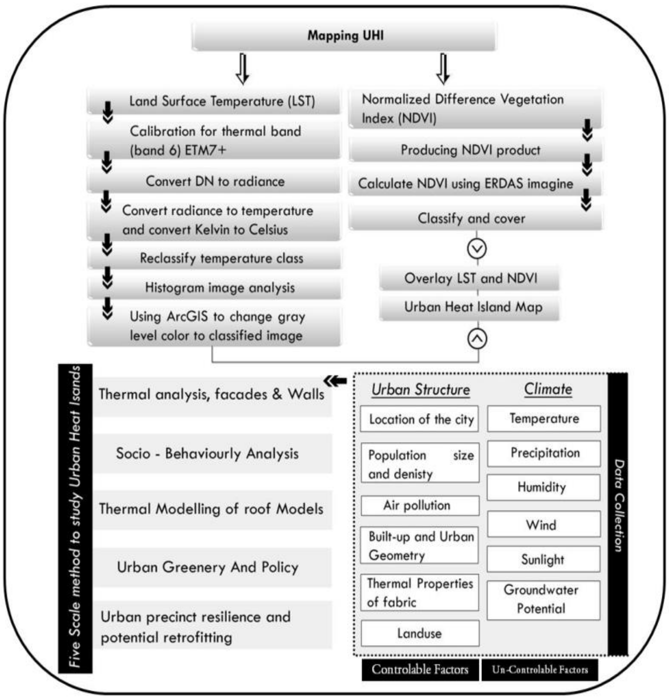


Figure III. Methodology

For conducting the study satellite data of LANDSAT-7TM (April. 21, 2001; April.01, 2011; April. 27, 2015) have been used. All images bands 1–5 and 7 have a spatial resolution of 30 m, and the thermal infrared band (band6) has a spatial resolution of 120m. Detail of the data given in TABLE III.

TABLE III. SATELLITE IMAGERY

Image Data	Sensor	Spatial Resolution
21-04-2001	Landsat 7 TM	30M
01-04-2011	Landsat 7 TM	30M
27-04-2015	Landsat 7 TM	30M

A. Image Processing

The LANDSAT-7 TM data was processed with layer stacking and the LST and other related parameters like NDVI and LULC were retrieved in order to study the spatio-temporal UHI effect over Hyderabad city. For calculating the LST values, the DN values of the imageries were converted into the Radiance values. As we had the Geo-TIFF format data we directly converted it into radiance data using ENVI software. Further Atmospheric correction was performed on the data by using the local values for meteorological parameters. USGS has a webpage that provides values for Transmittance, Upwelling Radiance, and down welling Radiance, for LANDSAT data.

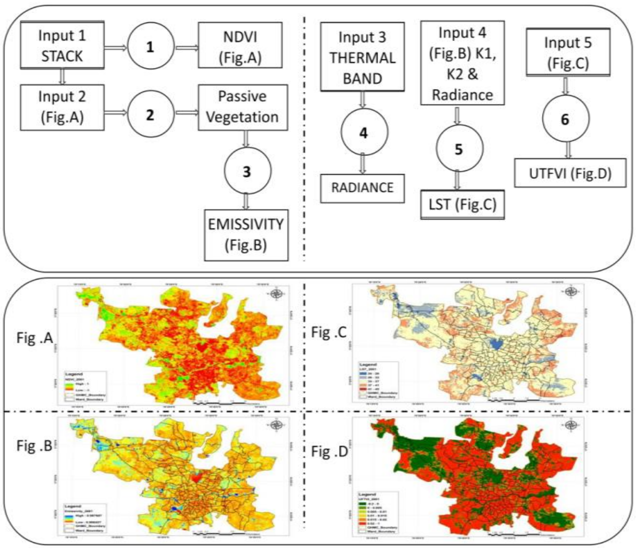


Figure IV. No.1-6 in the image processing are the equations given below respectively and Fig., (A) NDVI, (B) Emissivity, (C) LST, (D) UTFVI

B. Landsat – 7 TM Equations

- NDVI = (TM4 - TM3) / (TM4 + TM3)
- (NDVIOutput + 1) / (1 + 1)2
- Emissivity= 0.004 * Passive vegetation + 0.986
- Radiance = (Lmax - Lmin) * Qcal - Qcalmin) + Lmin

  Qcalmax - Qcalmin
- Land Surface Temperature (LST) T= K2/(ln[(ε K1)/Lλ]+ 1)- 273

  Constant values K1 = 607.76 and K2 = 1260.56

- Urban Thermal Field Variance Index (UTFVI) = (T – Tmean) / Tmean

Contribution of important individual factors such as the radiation from atmospheric pollutants to the urban area, the production of waste heat from air conditioning and refrigeration systems, as well anthropogenic heat, and the obstruction of rural air flows by the windward face of the built-up surfaces, has not been researched into substantially. An analysis of these factors would play a pivotal role in determining the causative factors of the UHI effect and lead to a better understanding of not only the phenomenon but also the mitigation strategies to overcome it.

V. ASSESSING THE LAND USE LAND COVER CHANGES ACROSS HYDERABAD DUE TO THE PROCESS OF URBANIZATION

The change in temperature at the Earth's surface due to a given heat flux is inversely related to the thermal inertia of the exposed material. Water bodies, having thermal inertia higher than dry soils and rocks, exhibit lower diurnal temperature fluctuations. As soil water content increases, thermal inertia also increases, reducing the diurnal temperature range. Present satellite remote sensing capabilities in measuring Earth surface temperature can be exploited to derive information on soil moisture, provided that the re-visitation time is adequate to follow the diurnal temperature cycle and the spectral resolution is sufficient to evaluate the net heat flux at the Earth surface. Land use / Land cover change in Hyderabad plays a prominent role in development of Urban Heat Island effect. Therefore, land use / land cover maps of Hyderabad are obtained from the satellite imagery from United States Geological Survey (USGS) are observed for three years i.e from 2001, 2011 and 2015.

A. Retrieval of land use/cover patterns

The Landsat-7 TM datasets were broadly classified into different classes of Built-up, Open land, Vegetation and Water body. The process was run using ERDAS IMAGINE 2011, unsupervised classification.

B. Spatio-temporal analysis of land use/cover patterns in Hyderabad city

Land use/ Landcover information for Hyderabad city within the (Greater Hyderabad Municipal Corporation) limit was retrieved from Landsat-7 TM data. This LULC classification was done for all datasets. The validation of the classification was done by the LULC file obtained from GHMC and checked. The classified data of April 2011 retrieved from Landsat-7-TM data was found to match with the former. Due to the seasonal change, the area under water body and vegetation was observed to be decreased in April for all the three respective years. It was also observed that the area under non- built up category increased. No major changes were observed in the class built-up. However, when considering the temporal pattern of LULC, the percentage area under considering the temporal pattern of LULC, the percentage area under vegetation, water body and the non-built up was observed to decrease from 2001 to 2015.

C. Change Dynamics of LU/LC vis-à-vis Urban growth parameters

Figure V Land Use/ Land Cover for 2015, 2011 & 2001 respectively

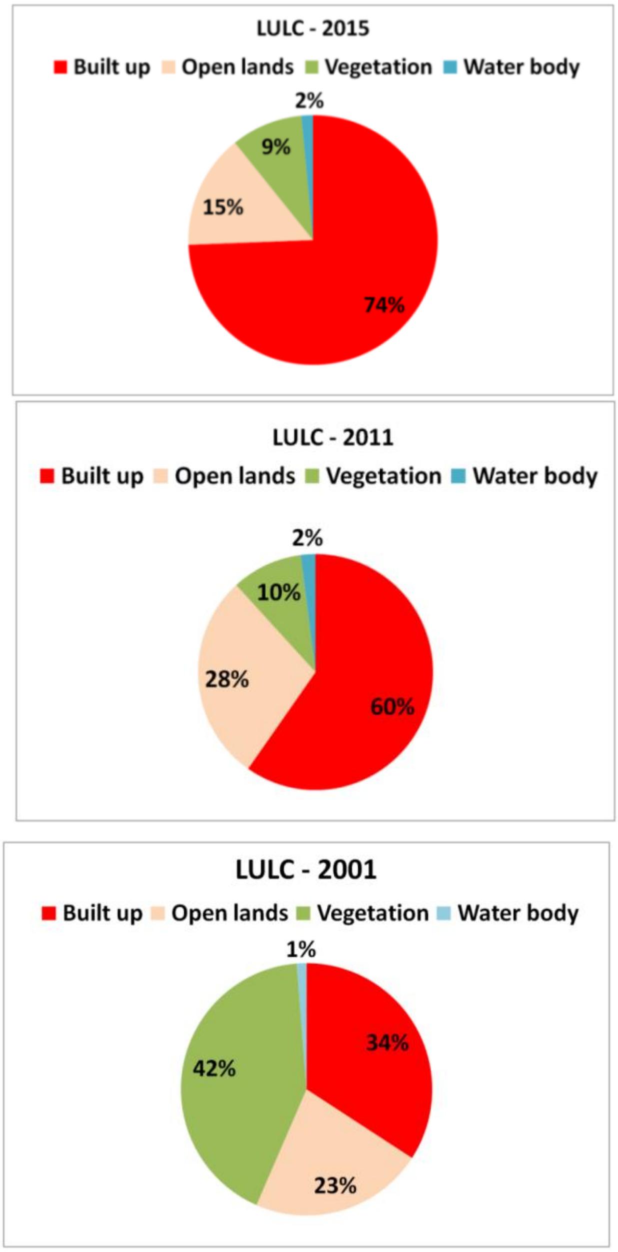
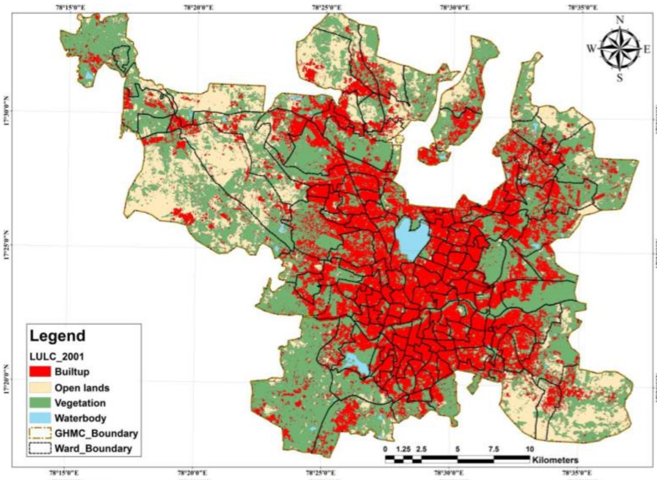
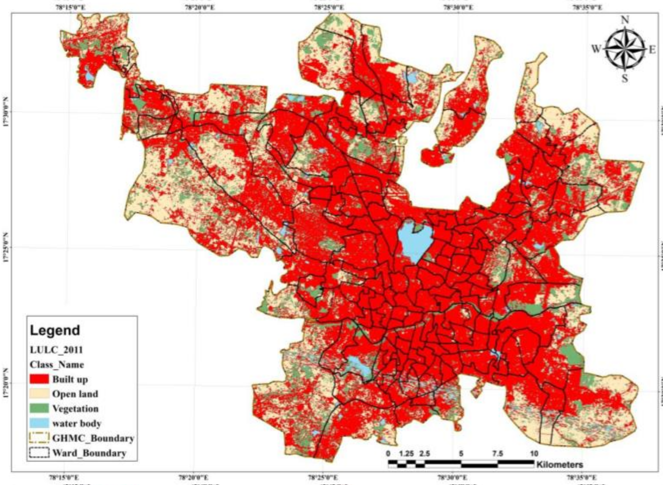
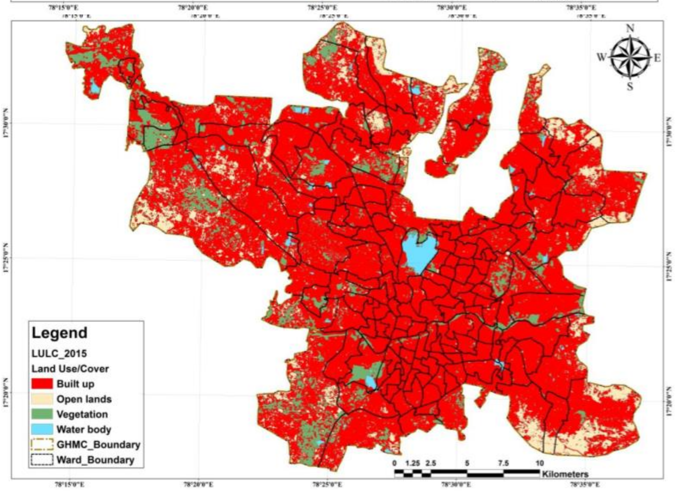


Figure VI Land Use/ Land Cover for 2001, 2011 & 2015 respectively







D. Results & Discussions

Decrease in agricultural land suggested both conversion of land to urban land use or discontinuation of agricultural activities in anticipation of conversion to urban areas. This is resulting in such lands being left undeveloped as vacant land or converted into layouts for considerable period to speculate higher land values. The urban growth not only explains the increase in urban built-up area and population but also the continuity of trend with much more accelerated pace since Hyderabad qualified as Mega City. After 2001, due to clearance of scrub land, open land increased by 26 percent. Further due to utilization for non-agricultural open land declined to 17 percent. Because of utilization of land for non-agricultural purposes (residential and commercial), percentage of mixed built-up land has increased. Area under parks and gardens in GHMC it increased more than twice in 2011 and got stabilized thereafter. This is mainly due to Green Hyderabad Programme. It is noticed that the residential development has taken place on all directions in a contiguous pattern due to availability of land and no proper guidelines, in all directions in case of Hyderabad. Urban growth and increase haphazardly in built-up area have resulted into loss of productive agricultural land, green areas, loss in surface water bodies.

TABLE IV . STATISTICS OF LULC FOR APRIL OF DIFFERENT YEARS

Year	Area	Built-up	Open Lands	Vegetation	Water Body	Total
2001	Km.sq	212.54	139.40	262.80	7.6	622.50
	(%)	34.14	22.39	42.22	1.25	
2011	Km.sq	372.28	177.35	60.98	12.57	623.18
	(%)	59.74	28.46	9.79	2.02	
2015	Km.sq	459.27	94.50	58.77	9.27	621.81
	(%)	73.86	15.20	9.45	1.49	

Statistics of LULC for April of years vegetation, water body and the non-built up was observed to decrease from 2001 to 2011 and 2015, while the percentage of urban area (i.e. built up) showed a great rise and decrease in agricultural land suggested both conversion of land to urban land use or discontinuation of agricultural activities in anticipation of conversion to urban areas. this is resulting in such lands being left undeveloped as vacant land or converted into layouts for considerable period to speculate higher land values. the urban growth not only explains the increase in urban built-up area and population but also the continuity of trend with much more accelerated pace since Hyderabad qualified as mega city. After 2001 clearance of scrub land, open land increased by 26 percent. Further due to utilization for non- agricultural open land declined to 17 percent. As a result of utilization of land for non- agricultural purposes (residential and commercial), percentage of mixed built-up land has increased. Area under parks and gardens in GHMC it increased more than twice in 2011 and got stabilized thereafter. this is mainly due to Green Hyderabad Programme. It is noticed that the residential development has taken place on all directions in a contagious pattern due to availability of land and no proper guidelines, in all directions in case of Hyderabad. Urban growth and increase haphazardly in built up area have resulted into loss of productive agricultural land, green areas, loss in surface water bodies as shown in Table 9. The area under built up had increased from as low as 35% to 74% from 2001 to 2015, while vegetated areas, open lands and water bodies were observed to decrease in percentage from 42% to 9%, 22% to 15% and 1.25% to 1.49% respectively. Spatially, an increasing urban growth was observed in the western and south-eastern parts of the city, with a decrease in vegetation in the same patch. The reasons for urban growth in both areas are mainly due to increased commercial and residential development in western areas of Hyderabad, and industrial area development/expansion in the south-eastern patch.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

VI. MICRO-MAPPING THE URBAN HEAT ISLANDS OF HYDERABAD CITY BASED ON REMOTE SENSING AND IN-SITU OBSERVATIONS

Derivation of Normalized Differential Vegetation Index (NDVI) from Landsat-7 TM imagery. NDVI from Landsat-7 TM is calculated from reflectance measurements in the red and near infrared (NIR) portion of the spectrum. The formula for NDVI is given by: NDVI=NIR–Red / NIR+Red (4).

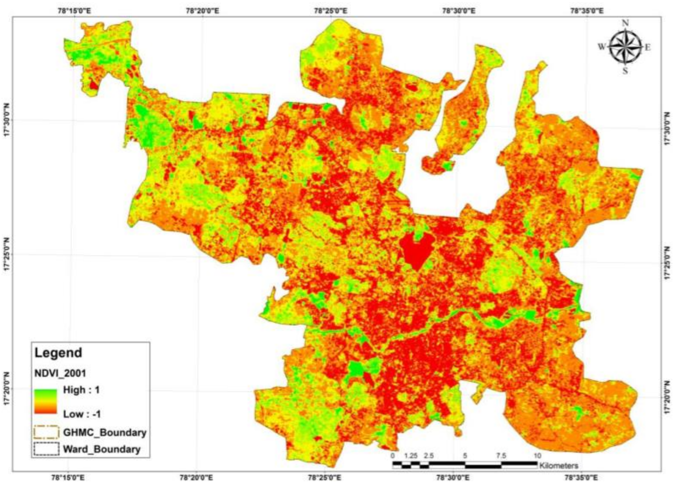
A. Spatio- temporal analysis of NDVI

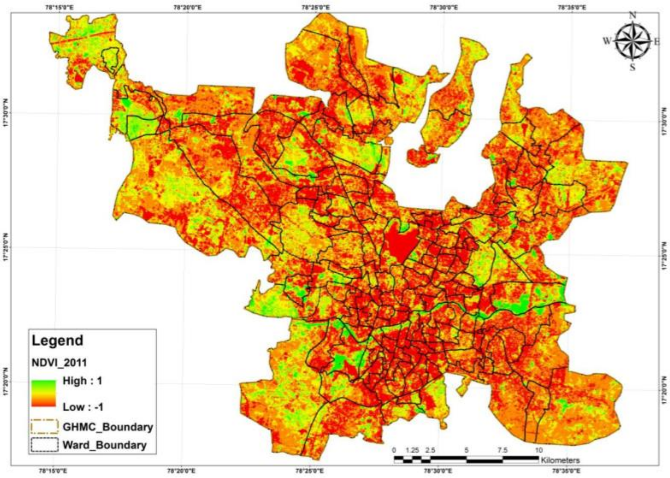
The Normalized Difference Vegetation Index (NDVI) is one of the most widely applied vegetation indices. Normalized difference vegetation index [NDVI] is used to measure and monitor plant growth, vegetation cover and biomass production. Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1. A dense vegetation canopy (0.3 to 0.8), Soils (0.1 to 0.2) Reflects near-infrared spectral somewhat larger than the red spectral, Clear Water (very low positive or even slightly negative) low reflectance in both spectral bands.

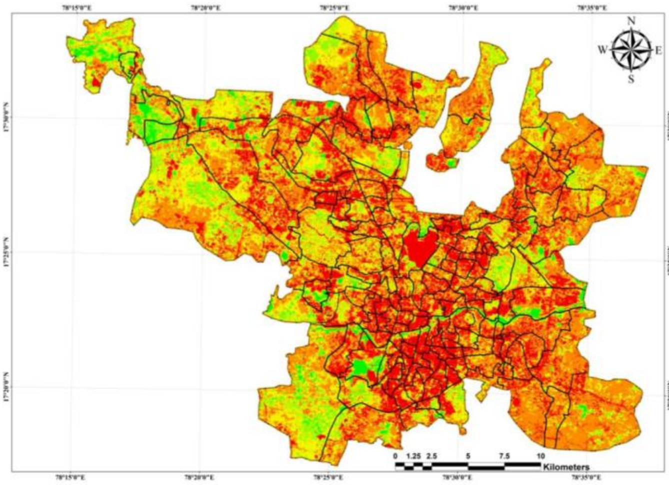
B. Spatio-temporal analysis of NDVI calculated for the Hyderabad city

To study the spatio-temporal changes in LST and the UHI effect, study of NDVI parameter becomes important. It allows determining the density of green on a patch of land based on observation of the distinct colors (wavelengths) of visible and near infrared sunlight reflected by the plants. As seen in case of land use, the percentage of area under vegetation was found to decrease over time from 2001 to 2011.

Figure VII Normalized Differential Vegetation Index (NDVI) 2001, 2011 & 2015 respectively







C. Results and Discussions

On observing the NDVI parameter, a gradual decrease from 2001, 2009 to 2011 was observed in its value, from 0.24, 0.26 and 0.25 respectively. Spatially observing, higher NDVI values of about 0.4 to 1 were observed in the south-western part and east northern parts of Hyderabad. While the central areas, with dense urban areas, eastern and southern parts with high industrialization were observed to have very low NDVI values.

D. Emissivity

Emissivity is the measure of an object's ability to emit infrared energy. Emitted energy indicates the temperature of the object. Emissivity can have a value from 0 (shiny mirror) to 1.0 (blackbody). Most organic, painted, or oxidized surfaces have emissivity values close to 0.95.

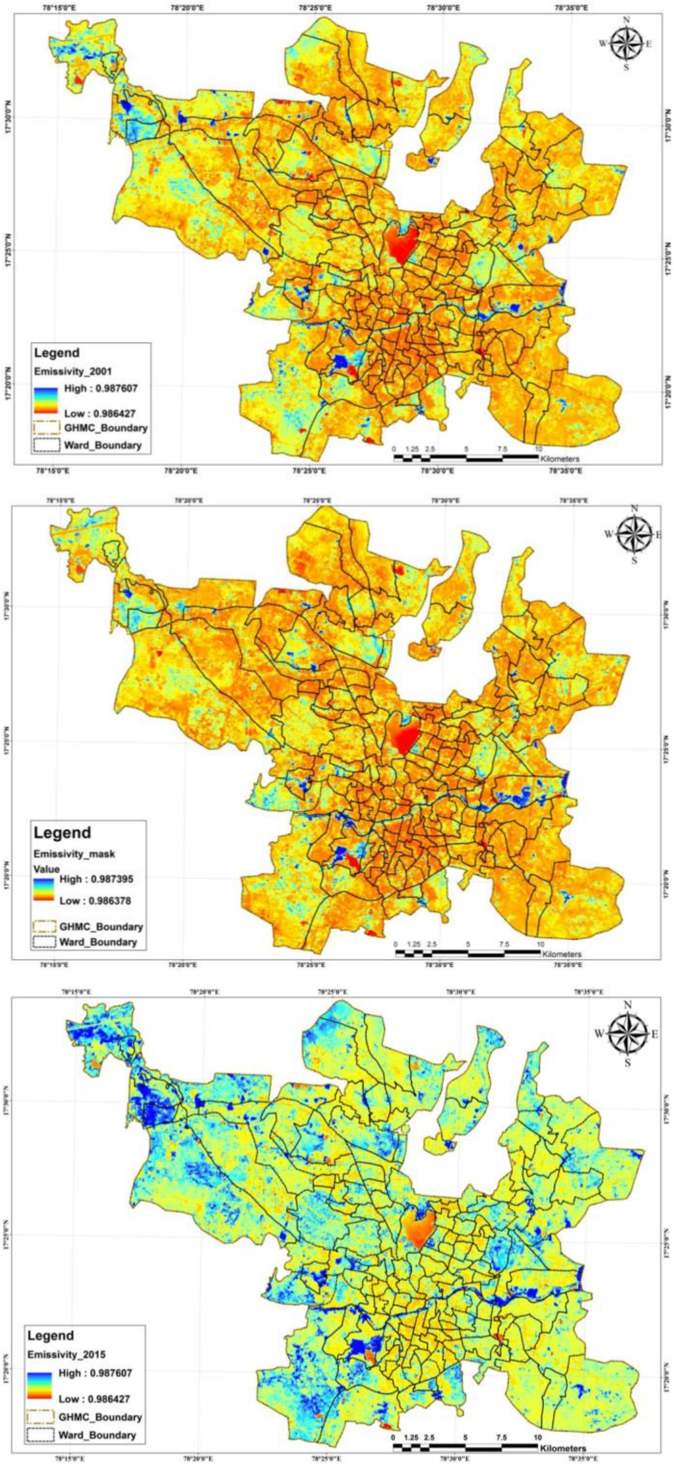
E. Relation between NDVI and Emissivity

The spatial variation of both the thermal emissivity (8–14/mu;m) and Normalized Difference Vegetation Index (NDVI) was measured for a series of natural surfaces within the city limits of Hyderabad i.e GHMC limits. The measurements were performed with an emissivity-box and with a combined red and near-infrared radiometer, with spectral bands corresponding to Landsat-7(TM). The empirical relationship is of potential use for energy balance

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

studies using thermal infrared remote sensing. The relationship was used in combination with AVHRR (GAC), AVHRR (LAC), and Landsat (TM) data to demonstrate and compare the spatial variability of various spatial scales.

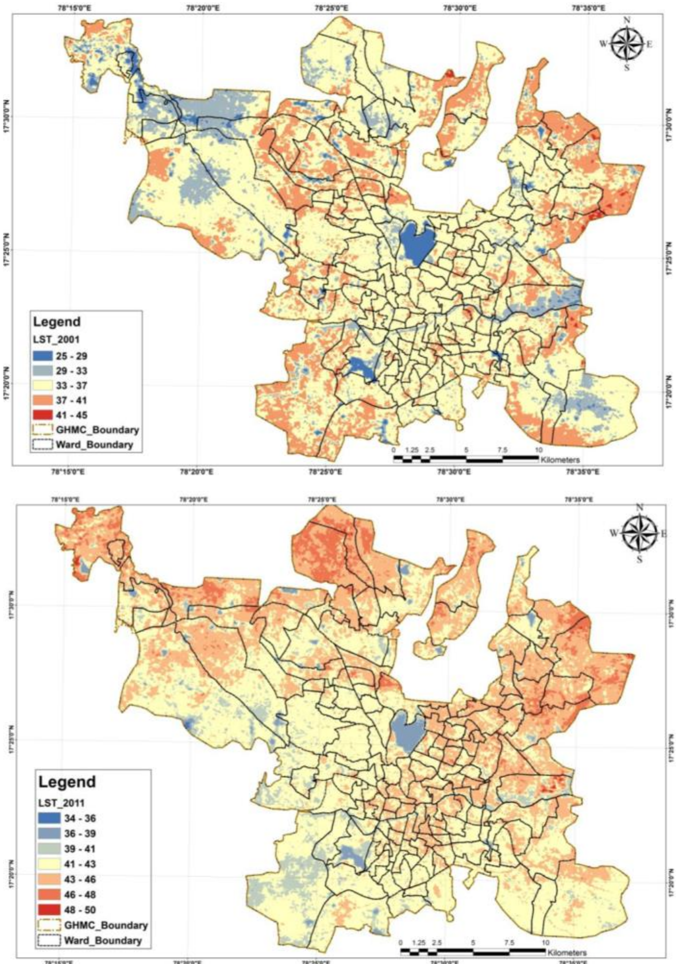
Figure VIII Emissivity 2001, 2011 & 2015 respectively

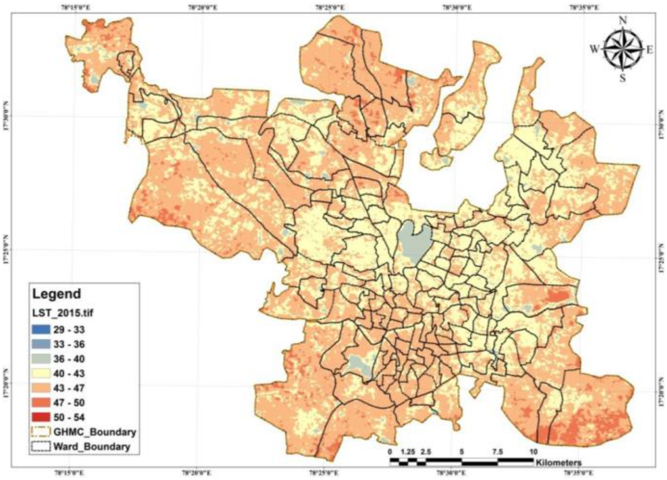


F. Spatio- temporal analysis of LST

Spatio-temporal analysis of Land Surface Temperature patterns for Hyderabad city Land Surface Temperature can provide important information about the surface physical properties and climate which plays a role in many environmental processes (Dousset.et.al, 2003). Land Surface Temperature is the radiative skin temperature of land surface. LST is determined by the land surface energy balance and varies rapidly because of the low thermal inertia of the land surface. LST may relate to the uppermost vegetation canopy or be a mixture of canopy and ground surface temperatures. It is how hot the “surface” of the Earth would feel to the touch in a particular location. From a satellite’s point of view, the “surface” is whatever it sees when it looks through the atmosphere to the ground. It could be snow and ice, the grass on a lawn, the roof of a building, or the leaves in the canopy of a forest. Thus, land surface temperature is not the same as the air temperature that is included in the daily weather report.

Figure IX Land Surface Temperature 2001, 2011 & 2015 respectively





G. *Results and Discussions*

Land Surface Temperature was computed using the Mono window algorithm for both winter and summer months of 2001, 2009 and 2011. Temporally, the mean surface temperature was observed to increase by about 1.5^{o} to 2^{o}C, from about 28.5^{o}C in 2001, to 30.7^{o}C in 2009 and 31.6^{o}C in 2011. Also, the range of minimum and maximum temperature showed an increase over time, thus indicating increased temperatures and an onset of Urban Heat Island effect. Spatially, the mean LST changes over time were found to be directly related to change in the LULC and NDVI.

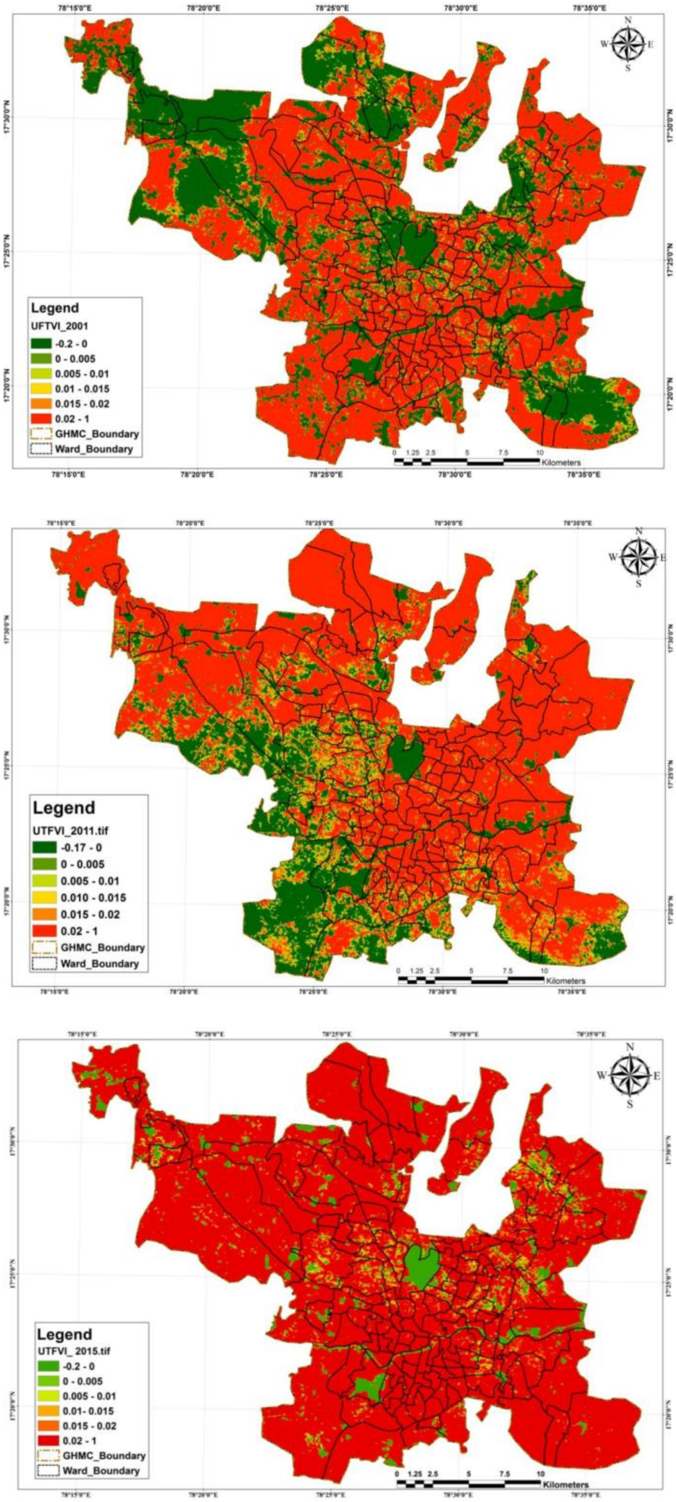
H. *Urban Thermal Field Variance Index*

Urban thermal field variance index (UTFVI) was used to quantitatively describe the urban heat island effect. To reflect the changes of urban thermal field directly, UTFVI can be further divided into six levels in accordance with six different ecological evaluation indices. TABLE V gives the specific;

TABLE V. INTER-RELATIONSHIP BETWEEN UTFVI, UHI AND ECOLOGICAL EVALUATION INDEX URBAN THERMAL FIELD

Urban thermal Field Variance Index	Urban Heat Island phenomenon	Ecological Evaluation Index
<0	None	Excellent
0.000 – 0.005	Weak	Good
0.005 – 0.010	Middle	Normal
0.010 – 0.015	Strong	Bad
0.015 – 0.020	Stronger	Worse
>0.020	Strongest	Worst

Figure X Urban Thermal Field Variance Index (UTFVI) 2001, 2011 & 2015 respectively



I. *Results and Conclusion*

As shown in the Figure X above shows the UHI threat is wide spread and got intensified in the GHMC limits in the city of Hyderabad over years from 2001 to 2011 and 2015.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

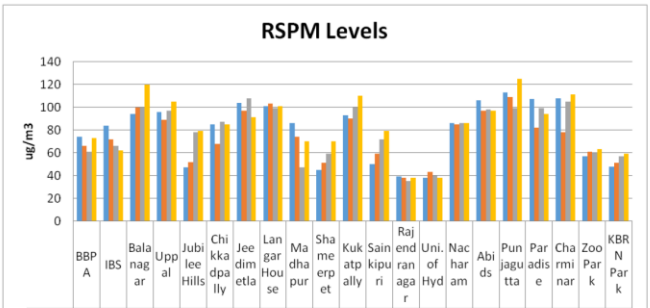
VII. SIMULATING AND ASSESSING THE FACTORS AT SELECTED CASE STUDY AREA

The study area is selected based on the factors like core area, population density and the pollution levels which are considered as the major factors for the contribution of UHI effect.

A. RSPM level variation

There are 21 air pollution monitoring stations in Hyderabad. Therefore, air pollution levels are monitored at various pollution monitoring stations in Hyderabad city are studied annually from 2009 to 2012 yearly average of RSPM (Respirable suspended particulate matter) also known as (PM10) levels is considered as pollution levels in the area.

Figure XI Yearly Average RSPM Levels in Hyderabad city



	BBPA	IBS	Balanagar	Uppal	Jubilee Hills	Chikkadpally	Jeedimetla	Langar House	Madhapur	Shamerpet	Kukatpally	Sainikpuri	Rajendranagar	Uni. of Hyd	Nacharam	Abids	Punjagutta	Paradise	Charminar	Zoo Park	KBR N Park
2009	74	84	94	96	47	85	104	101	86	45	93	50	39	38	86	106	113	107	108	57	48
2010	66	72	100	89	52	68	97	103	74	51	90	59	38	43	85	97	109	82	78	61	51
2011	61	66	100	97	78	87	108	99	47	59	100	72	35	40	86	98	99	99	105	60	57
2012	73	62	120	105	79	85	91	101	70	70	110	79	38	38	86	97	125	94	111	63	59

Figure XII Level of Air Pollution (SO2, NOx and PM10)

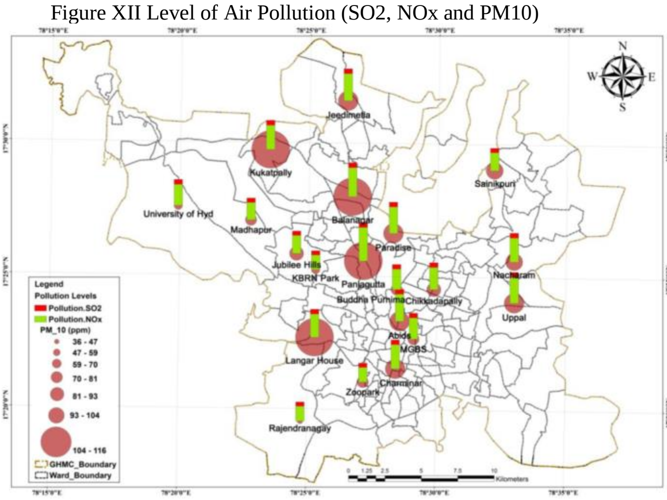
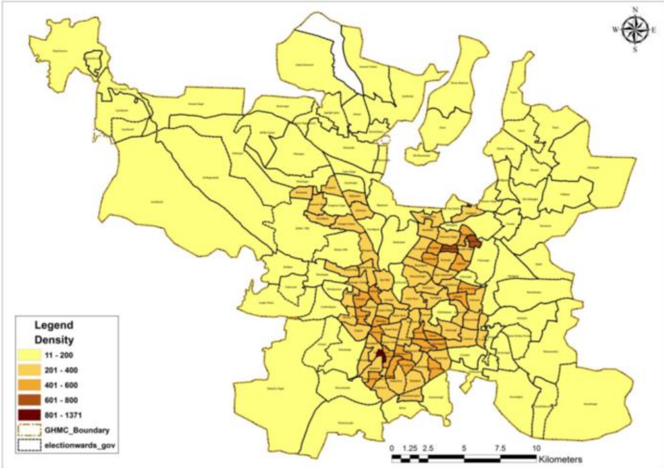


Figure XIII Population Density

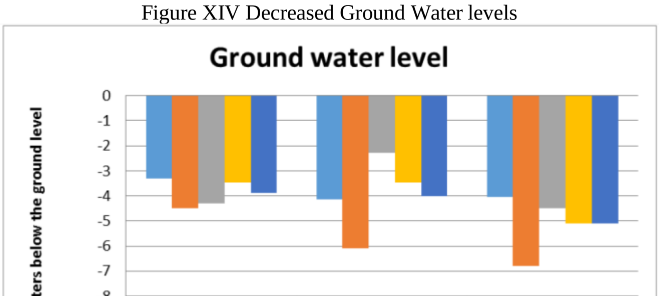


Inference: Panjagutta has highest average of pollution in the city and balanagar stands next. The study area is chosen as Panjagutta, as Panjagutta ward is taken to study based on air pollution levels as levels are very high contributing for UHI in that area. Panjagutta is a ward under circle X in central zone of Hyderabad. Panjagutta is considered as one of the core areas of Hyderabad city which is a partly residential and commercial area.

B. Ground water level variation

Degradation of water is another important indicator of heat island effect. Therefore, ground water levels of different years are studied in the months of January, May, August and November to analyze the scenario. The level of water is considered below the ground level (0) for which it is depicted in reverse chart in which the values are negative.

Figure XIV Decreased Ground Water levels



	2009	2010	2011
January	-3.3	-4.15	-4.05
May	-4.5	-6.1	-6.8
August	-4.3	-2.28	-4.5
November	-3.48	-3.46	-5.1
Average	-3.9	-4	-5.11

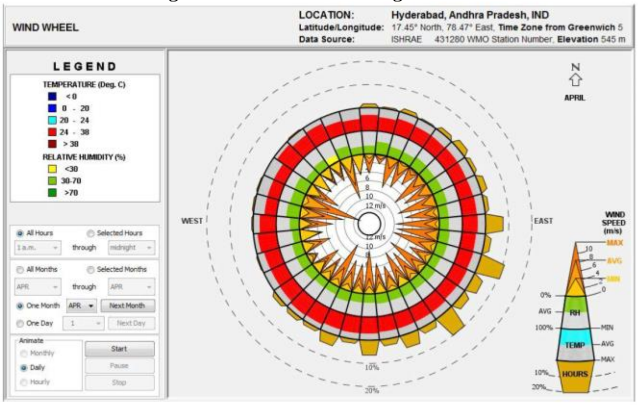
Inference: The level of ground water has decreased gradually in the month of May i.e. summer and showed a gradual decline from 2009-2011.

C. Wind level

Figure XV showing all Four (Temperature, Precipitation, Relative Humidity and Wind Direction) and it's generated from California Energy Code model. As we have studied satellite images only for the month of April so even the Wind Wheel has been generated only for the month of April.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

Figure XV Wind Wheel Diagram



VIII. PROBABLE GREEN INFRASTRUCTURE MEASURES TO MITIGATE UHI IN THE STUDY AREA

Green Infrastructure is associated with a variety of environmental, economic, and human health benefits, many of which go together with one another. The benefits of green infrastructure are particularly accentuated in urban and suburban areas where green space is limited and environmental damage is more extensive. Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. Green infrastructure benefits include:

A. Urban Heat Island Mitigation and Reduced Energy Demands

Urban heat islands form as cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. The displacement of trees and vegetation minimizes their natural cooling effects. Additionally, tall buildings and narrow streets trap and concentrate waste heat from vehicles, factories, and air conditioners. By providing increased amounts of urban green space and vegetation, green infrastructure can help mitigate the effects of urban heat islands and reduce energy demands. Trees, green roofs and other green infrastructure can also lower the demand for air conditioning energy, thereby decreasing emissions from power plants.

B. Improved Air Quality

Green infrastructure facilitates the incorporation of trees and vegetation in urban landscapes, which can contribute to improved air quality. Trees and vegetation absorb certain pollutants from the air through leaf uptake and contact removal. If widely planted throughout a community, trees and plants can even cool the air and slow the temperature-dependent reaction that forms ground-level ozone pollution (smog).

C. Additional Wildlife and Recreational Space

Greenways, parks, urban forests, wetlands, and vegetated swales are all forms of green infrastructure that provide increased access to recreational space and wildlife habitat.

D. Improved Human Health

An increasing number of studies suggest that vegetation and green space - two key components of green infrastructure - can have a positive impact on human health. Recent research has linked the presence of trees, plants, and green space to reduced levels of inner-city crime and violence, a stronger sense of community, improved academic performance, and even reductions in the symptoms associated with attention deficit and hyperactivity disorders.

E. Reduced and Delayed Stormwater Runoff Volumes

Green infrastructure reduces storm water runoff volumes and reduces peak flows by utilizing the natural retention and absorption capabilities of vegetation and soils. By increasing the amount of pervious ground cover, green infrastructure techniques increase storm water infiltration rates, thereby reducing the volume of runoff entering our combined or separate sewer systems, and ultimately our lakes, rivers, and streams.

When rain falls in natural, undeveloped areas, the water is absorbed and filtered by soil and plants. Storm water runoff is cleaner and less of a problem. Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments. At the city or county scale, green infrastructure is a patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the neighborhood or site scale, storm water management systems that mimic nature soak up and store water.

F. Enhanced Groundwater Recharge

The natural infiltration capabilities of green infrastructure technologies can improve the rate at which groundwater aquifers are 'recharged' or replenished. This is significant because groundwater provides about 40% of the water needed to maintain normal base flow rates in our rivers and streams. Enhanced groundwater recharge can also boost the supply of drinking water for private and public uses.

G. Stormwater Pollutant Reductions

Green Infrastructure techniques infiltrate runoff close to its source and help prevent pollutants from being transported to nearby surface waters. Once runoff is infiltrated into soils, plants and microbes can naturally filter and break down many common pollutants found in storm water. Storm water runoff is a major cause of water pollution in urban areas. When rain falls on our roofs, streets, and parking lots in cities and their suburbs, the water cannot soak into the ground as it should. Storm water drains through gutters, storm sewers, and other engineered collection systems and is discharged into nearby water bodies. The storm water runoff carries trash, bacteria, heavy metals, and other pollutants from the urban landscape. Higher flows resulting from heavy rains also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure. While single-purpose gray storm water infrastructure is conventional piped drainage and water treatment systems and is designed to move urban storm water

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 04, April-2019

away from the built environment, green infrastructure reduces and treats storm water at its source while delivering environmental, social, and economic benefits.

H. Reduced Sewer Overflow Events

Utilizing the natural retention and infiltration capabilities of plants and soils, green infrastructure limits the frequency of sewer overflow events by reducing runoff volumes and by delaying storm water discharges.

I. Increased Carbon Sequestration

The plants and soils that are part of the green infrastructure approach serve as sources of carbon sequestration, where carbon dioxide is captured and removed from the atmosphere via photosynthesis and other natural processes.

J. Increased Land Values

Several case studies suggest that green infrastructure can increase surrounding property values. A green retrofit program can convert unsightly abandoned lots into "clean & green" landscapes resulted in economic impacts that exceeded expectations. Vacant land improvements led to an increase in surrounding housing values by as much as 30%.

K. Typical components and Interfaces of Green Infrastructure

Buildings

- Green Roofs
- Vertical Greening

Hardscape

- Pervious Pavement

Landscape

- Bioretention
- Rain Gardens

Water

- Rain water Harvesting
- Gray Water Harvesting

Recognizing the importance of the natural environment in decisions about land-use planning and Emphasizing the “life support” function provided by a network of natural ecosystem, which are interconnected to target at achieving a sustainable urban environment of clean air and water, healthy soil, providing shade and shelter, and other social benefits in a community as goals.

There are some general sectoral issues of Hyderabad city basing on those below TABLE VI has some physical planning recommendations.

TABLE VI. Issues identified in study area & recommendations

Urban Sector with Issues	**Recommendations**
Urban planning	Physical-conversion of impervious pavements to porous pavements
Albedo factor	Cool roofs by use of high albedo materials, white concrete and topping of roads
Anthropogenic heat	Promotion of low power consumption strategies
Urban vegetation and forestry	Increase in vegetation through plantation initiatives
Surface heat reduction	Rain water harvesting, storm water management through rain gardens, to recharge the decreasing ground water levels.

IX. CONCLUSION

FSI is a common variable in cities and results in varying pattern of development of the urban form and space. FSI is a tool for planners to control the extent of built-up area on a given plot and an instrument to check the real estate market. Building rules and regulations form a vital link to achieve a city’s urban form. Urban form refers to the pattern of development of the city, considering aspects like density, land use, transportation and degree of development. The form of the contemporary city has been perceived as a source of environmental problems as the city of Hyderabad has haphazard growth.

FSI is the ratio between total built-up areas to the plot area available. In India (except for few cities) it is known as Floor Area Ratio (FAR) (National Building Code, 2005). Currently, the Greater Hyderabad Municipal Corporation’s (GHMC) development plan does not have specific FSI rules for buildings in Hyderabad. Specifically, high rises have a free FSI (no limit on FSI), to encourage real estate growth in the city. However, as per the Telangana building rules, the built-up area in some cases such as stepped type, podium and tower buildings was being done at higher FSI of up to 5.

Land disposition of six Indian cities show that the land available in the corporation limit is the maximum in the city of Delhi with and extent of 1397 sq.km and the population density is highest in the corporation limits of Mumbai having a density of 24, 882 persons per sq.km., with 480 sq.km. Extent of land available in the corporation limits.

At the sector or neighborhood level, throughout the study area is planned for green spaces are provided in the form of neighborhood parks/tot-lots. These should be properly maintained in terms of irrigating the plants /trees and making the provision of pruning at regular intervals.

Green infrastructure is to be promoted and incentives should be paid by the government to encourage.

- Heat action plan to be implemented in the Master planning process.
- Adaptation of FSI guidelines will play a vital role in UHI mitigation.

ACKNOWLEDGMENT

We are indebted to the faculty members of Planning Department, School of Planning and Architecrue, Bhopal. Heartfelt thanks to the officials of the Telangana State Pollution Control Board. We are thankful to our friends who were associated since long and their ever-encouraging attitude and support has significantly contributed in my pursuit for this research work.

REFERENCES

[1] Dousset.et.al. (2003). Satellite multi-sensor data analysis of urban surface temperatures and landcover. Journal of Photogrammetry and Remote Sensing , 43-54.

[2] Ganda, S. C. (2012). Comparision of long term rainfall trends in urban and nonurban regions of Indian land mass and its probable implication. Journal of Indian Geophysical Union , 37-40.

[3] Joshi.P.K. (2009, October 19-22). Assessment of night-time urban surface-temperature land use/cover relationship for thermal urban environment studies using optical and thermal satellite data. (7. F. Serving, Ed.) Remote Sensing for Sustainable Development .

[4] Kandlikar. (2000). The causes and consequnces of particulate air pollution in Urban India: a synthesis of the science. Annual Review of Energy and the Environment , 629-684.

[5] Kiran Chand.et.al. (2005). Studies on Urban Heat Islands using ENVISAT. Journal of the Indian Society of Remote Sensing , 4.

[6] Oke, T. R. (1987). Boundary Layer Climates. London & New York: Routledge.

[7] Oke.T.R. (1982). “The energetic basis of the urban heat island",. Quarterly Journal of the Royal Meteorological Society , 455.

[8] Oke.T.R. (2006). Initial guidance to obtain representative meteorological observations at urban sites. Canada: Wold Meteorological Organization.

[9] Patankar, P. (1991). Urban transport in India in Distress. Pune: Central Institute of Road Transport.

[10] Rizwan, A. M. (2008). A review on the generation, determination and mitigation of Urban Heat Island. Journal of Envrionmental Sciences , 120-128.

[11] Rosenzweig, C. a. (2001). Climate Change and a Global City: The Potential Consequences of Climate Variability and Change — Metro East Coast. Columbia University: Columbia Earth Institute.

[12] S.Sundersingh. (1990-1991). Effect of heat islands over urban madras and measures for its mitigation. In Energy and Buildings (pp. 245-252).

[13] Singh, S. K. (2006). Future mobility in India: Implications for energy demand and CO2 emission. Transport Policy , 398-412.

[14] TEDDY. (2007). Teri Energy data Directory and Yearbook. New Delhi: Tata Energy Research Institute.