

# Chapter 10

## Investigation of Land Use and Landcover Changes and Its Relationship with Land Surface Temperature and Ground Water Temperature Over Bangalore City



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**Abstract** Urban heat redistribution is mainly result of surface energy process. Surface energy process is also contributed in urban environment. Urban heat island (UHI) is mainly defined when urban temperature is elevated compared to surrounding rural area. Both in above and below the ground UHI is observed. This is happened due to conductive heat transport. How the Land surface temperature and ground water temperature are affected by the urban land use in Bangalore is the primary plan of investigation. Landsat data of 1999 and 2009 are used to understand the LU/LC changes. In this present study we used satellite derived Land surface temperature and field collected Ground water temperature which was analyzed using interpolation method and Supervised Classification Change Detection technique applied for change analysis. Here investigation was done for a period of one decade (1999/2009) on LST changes over different land use. Moreover, relationship between NDVI and LST was also considered. To understand urban surface, we estimated Normalized Difference Built-Up Index (NDBI) and Built up Area Index (BUAI); with this we are trying to find relationship with ground water temperature. Changing land use pattern, mostly expansion of built-up area has effect over land surface temperature in Bangalore urban district. The correlation between LST and the Ground water temperature

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(GWT); has been studied on 2009 data and found 80% correlation between them. In result, it is showing that GWT is less than LST but wherever LST is high there GWT is also high. In city core area like residential, outside industrial and road, GWT and LST both show high but near to lake or park area both show low temperature. Results show that during years 1999 to 2009 that LST and GWT directly affected due to rapid urban growth which reflects over built-up area enlarged from 39 to 57%. We can understand that urbanization has an impact on both on LST and GWT. The study showed that land use land cover change has important role of increasing GWT which is a marker of the strength of urban heat island effect and can be utilized to evaluate the extent of the urban heat island effect.

**Keywords** Ground water temperature · Land surface temperature · Built up area index · Sub surface urban heat island · Remote sensing

## 10.1 Introduction

The urban heat island effect in core urban are like CBD and housing areas which increases strength of the heat waves. The large number of man-made urban structure is mainly made of tar and concrete which covers urban areas. The human urban–rural contrast and urban heat island represented by temperature gradient, the nonporous material such as asphalt and concrete replace land surface which is the main cause of deforestation. This increases rainwater runoff and reduces evaporation (Carlson 1986). The thermal characteristic of urban surface is a significant information for urban organizers and modelers for improving city site quality creation more eco-accommodating. In present time urban heat island (UHI) spectacle is occurring in all layers of present time urban areas, for example, environment, surface and subsurface. There are numerous issues identified related to this spectacle. UHI has a positive impact on regional atmospheric pollution and increased mortality rates because of heat waves. In case of SUHI which is directly responsible increases ground water temperature and it puts stress on underground ecosystem. From the study of Cheon et al. (2014), we found that mean air temperature is firmly identified with the yearly mean ground water temperature because of conductive heat transport measure. In another study (Menberg et al. 2014) clarify that surface air temperature affects subsurface ground water temperature (GWT). Yet it's still confusing of the connection process between air and ground water temperature.

At present time, satellite remote sensing is opening a new door to measure surface temperature. Air temperature, surface temperature and ground surface temperature are correlated with each other but it's not yet accurately resolute. From the study of Chakraborty et al. (2015), Pongracz et al. (2010), Peng et al. (2011), we understand that LST which is derived from satellite are easy to access spatial and temporal condition of UHI in different cities of India, Europe and worldwide. In other side, GWT measurement in existing ground water monitoring wells using interpolation

measurement process is costly and tedious method to study subsurface urban heat island (Ferguson and Woodbury 2007).

In the investigation of Osaka Japan by Huang et al. (2009), demonstrated that urban estimated well temperature was generously raised in contrast with those forecasted from meteorological time series. House, manure system and underground subway tunnels are the major anthropogenic sources of the causes of this irregularities. There are numerous investigations discovered which were attempted to appraise GWT from over the ground estimation, for example, LST.

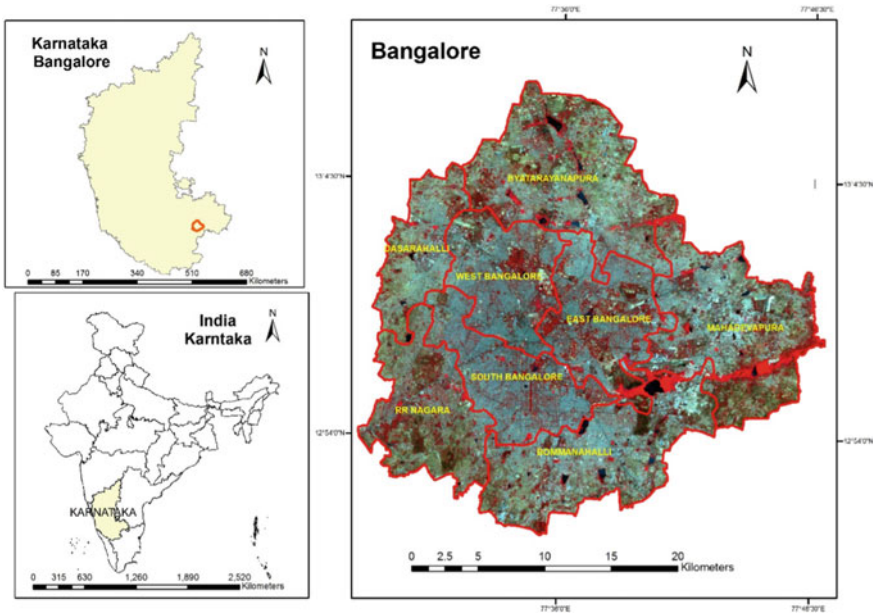
Without satellite information, because of time delay among above and subterranean temperature, more profound GWT was hard to quantify. Anthropogenic heat fluxes effect into subsurface is not preferred by Zhan et al. (2014). In numerous investigations it appeared that building, underground tunnel, sewage system elevated thermal temperature in underground. Therefore, need to improve the estimation of urban GWT urban bodies and buildings is under observation.

The principle goal of the examination is to understand how land use and land cover change put an impact over GWT and LST over Bangalore city. The extraordinary change in land use/land cover related with human exercises is viewed as an incredible main impetus in nearby atmosphere and climate changes. Urban Heat Island (UHI) intensity is closely related to LU/LC patterns over time. Therefore, accurate detection of LU/LC changes associated with urbanization and LST, GWT distribution is critical to environmental monitoring, management and planning. Therefore, for this research, much emphasis is placed on determining the urban LU/LC changes and their impact on GWT and LST patterns. The current examination targets identifying the effect of Land Use/Land Cover Changes of Bangalore Urban District on its Land Surface Temperature and Ground water temperature. For this purpose multi-temporal LANDSAT TM Images of 1999 and 2009 are used for post classification (supervised classification) change detection. This emphasizes the change in Built-up, Water bodies of other land use classes. The LST retrieved from multitemporal LANDSAT TM Images of 1999 and 2009, GWT data was collected from field which is available for the year 2009.

## 10.2 Study Area

### 10.2.1 Location of the Study Area

The population density of Bangalore is almost 20,000 people per km<sup>2</sup> and more than 8 million people staying under the greater Bangalore corporation. The geographical span area of Bangalore city is almost 713 m<sup>2</sup> which is situated at an altitude of 894 m (MSL). 12° 39' N and 13° 18' N latitude and 77° 22' E and 77° 52' E longitude (Fig. 10.1) where Bangalore is situated in between. Presently the city is facing water scarcity because of rapid increase of population due to industrialization and migration from rural Karnataka and rest of the country relatively in short time span.



**Fig. 10.1** Showing study area Bangalore, India

### ***10.2.2 Rainfall in the Study Area***

Bangalore city experiences both SW and NE monsoon rainfall. However SW monsoons are prominent. The average rainfall is around 800–900 mm per year. As per meteorological department data (residual mass curve analysis of rainfall data) from 1901, the average rain tend to be rising in the first two decades and fell in the consequent years up to 1950, thereafter a rise occurred in 1980s and, presently it is on rise.

### ***10.2.3 Geological and Hydrological Settings of the Study Area***

The aquifer setup, geography and chronological behavior of groundwater level are the major points to understand the hydrological setup. The essential for the peninsular granitic complex pattern which is mainly Precambrian Granite and Gneiss of the Indian Precambrian Shield are founded surrounding terrains of Bangalore district. Migmatite and gneiss are prevailing, however there is a zone of granite and granodiorite exactly 20 km wide moving in a north–north-west bearing over the far western part of the area.

Minor regions of charnockite happen in the far south western aspect of the area, and there are some little extended assemblages of amphibolite's. Central part we mostly found the trend of schist aligned along a north south. Several dolerite dykes to the north, west and southwest are observed in Bangalore city according to the Geological and Mineral map of Karnataka and Goa. The dominant strike direction we found in northeast and smaller structure of strike we found in easterly side. The dimensions of the dykes are indicated by Hunse and Farooqi (1995) in a report on groundwater of Bangalore Urban District. They additionally allude to lineaments, obviously connected with cracking (or potentially the dolerite dykes), with a grouping of strike in a north-upper east arrangement, and with a length going from 5 to 30 km.

### 10.3 Material and Method

The surface temperature was assessed utilizing Landsat TM-5 datasets over various Land use (LU)/Land Cover (LC) of Bangalore territory more than 10 years of time span. On other side Ground water temperature data was collected from field work in 2009 (Table 10.1, Fig. 10.2).

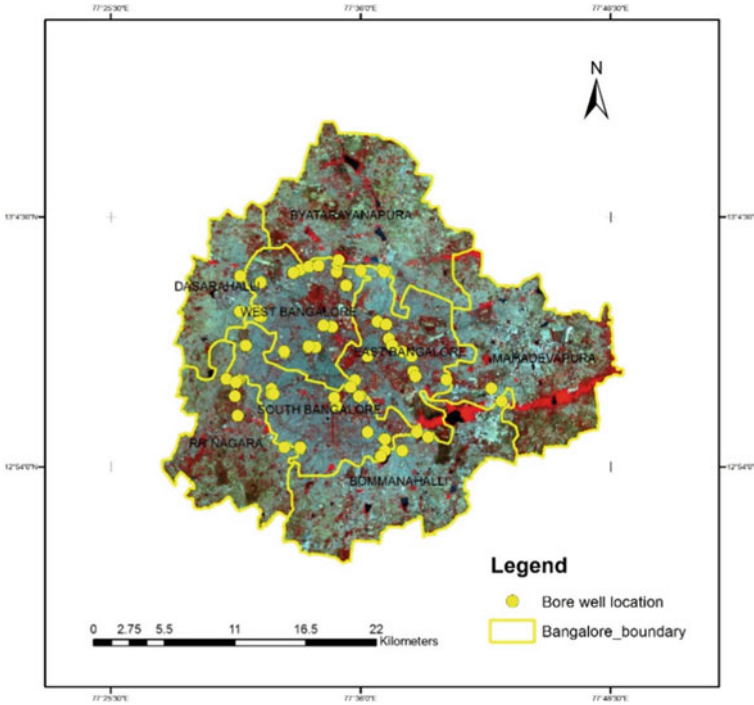
#### 10.3.1 Methodology

To remove geometric and atmospheric error geometric correction and atmospheric FLAASH correction was applied over all Landsat satellite images. Landsat image of 1999 and 2009 datasets are used to achieve land use (LU) and landcover (LC) classification. LU/LC are classified in four classes like vegetation, built-up, waterbody and others. NDVI, surface emissivity and surface temperature all these biophysical parameters are retrieved from these data sets. On the other hand ground water temperatures are collected from different wells. 77 wells GWT data are collected from field which was collected during field visit. GWT and LST, considering in same scale for that we use geostatistical tool in ArcGIS. GWT are interpolated using IDW technique under Geostatistical tool in Arc GIS.

Here 1999 and 2009 summer (March) (April) data is used to estimate surface temperature over various land use/land cover. Radiance was calculated over visible and near infrared bands after pre-processing and subsets over Landsat-5 images. Value is needed to derive at pixel level to get effective results in surface temperature and surface emissivity. Emissivity was mostly observed uniform in the spectral range

**Table 10.1** Data used for GWT and LST

Dataset used	Year (1999)	Year (2009)
	Landsat TM-5	Landsat TM-5
		Ground water temperature



**Fig. 10.2** Showing borehole location GWT collected in area of Bangalore, India

between 8 and 14  $\mu\text{m}$ . To estimate pixel base emissivity the proportion of vegetation cover in conjunction with NDVI was taken care.

$$\varepsilon = a + b * \ln (\text{NDVI}) \tag{10.1}$$

where  $a = 1.0094$  and  $b = 0.047$  where,  $\text{NDVI} = \frac{(\rho_{NIR} - \rho_{Red})}{(\rho_{NIR} + \rho_{Red})}$   $\rho$  = reflectance

Thermal band 6 in Landsat TM imagery is used to estimate spectral radiance which is mentioned above (NASA 2004). This is the viable at-satellite temperatures of the saw Earth-atmosphere framework under a suspicion of solidarity emissivity and utilizing pre-launch alignment constants (Mansor and Cracknell 1994). The conversion of digital number of thermal bands into spectral radiance are mainly followed by Landsat user’s handbook (Mansor and Cracknell 1994). Temperature is estimated as,

$$T = \frac{K_2}{\ln\left(\frac{\varepsilon K_1}{L_\lambda}\right) + 1} \tag{10.2}$$

where  $K_1 = 607.76 \text{ mWcm}^{-2}\text{sr}^{-1} \mu\text{m}^{-1}$ ,  $K_2 = 1260.56 \text{ K}$ ,  $L_\lambda = \text{radiance}$ ,  $\varepsilon = \text{emissivity}$ .

After estimated LST we use Arc GIS to extract same place LST value where GWT data is available. Then we use geostatistical tool in ArcGIS to interpolate LST using IDW Geostatistical tool.

Increased job opportunity in cities is the main cause of increase in population density which effected on the expansion of building area. The impermeable land in urban area increases like roads, buildings, sewer tunnels. This change has an impact on physical geographic environment of cities which is main cause of the Urban Heat Island Effect.

To understand the urban built-up land use class, Normalized Difference Built-Up Index is a good indicator. Unique spectral response of built-up lands that have higher reflectance in MIR wavelength range than in NIR wavelength range based on this principle this index developed. Using reflectance value from MIR and NIR bands of the satellite image NDBI was calculated. NDBI is given as

$$\text{NDBI} = (\text{MIR} - \text{NIR}) / (\text{MIR} + \text{NIR}) \quad (10.3)$$

where MIR is represented as middle infra-red band and NIR is represented as near infra-red band.

For the LANDSAT TM Imagery the TM5 (MIR) and TM4 (NIR) bands are used for estimating the NDBI.

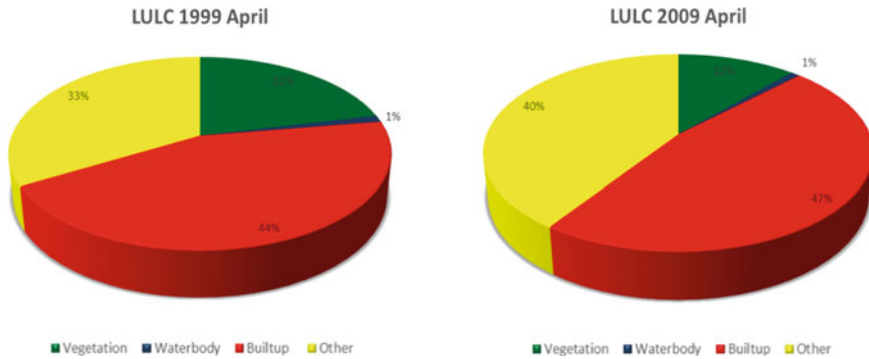
But NDBI has some disadvantages. Barren land and low-density vegetation area, both of these two kinds of land also reflect as an urban built-up area in results. So as to upgrade the consequence of urban built-up areas extraction (Liu et al. 2018) BUAI was assessed.

$$\text{BUAI (Built Up Area Index)} = \text{NDBI} - \text{NDVI} \quad (10.4)$$

In NDVI non-vegetated area is mainly occupied with built-up land, barren land and waterbodies. Here in this methodology we used BUAI to enhance our results over urban built-up area.

### ***10.3.2 Results and Discussion***

The LU/LC classification for LANDSAT TM Datasets for 1999 and 2009 was carried out by taking four classes namely Built-Up, Vegetation, Water bodies and others. The datasets was classifying using the supervised Classification-maximum likelihood method. In first steps training sets are created on the basis of ground truth and spectral signature then classified it into four classes. An overall accuracy of 88.74% (Kappa Coefficient: 0.8480) for Feb 1999 datasets and 87.15% (Kappa Coefficient: 0.8275) for Jan 2009 datasets was obtained during the accuracy assessment. The



**Fig. 10.3** Showing LU/LC statistic of 1999 and 2009

classified map of LU/LC of Bangalore Urban District for 1999 and for 2009 is shown in (Fig. 10.4). The LU/LC maps show different LU/LC classes such as Built-up, Vegetation, Water bodies' agriculture and dry/other open lands. The maps also delineate the greater Bangalore region from the outskirts.

We can observe from the (Fig. 10.3) that the built class are increasing in last 10 years from 44 to 47%. Due to emerging electronics city in the Anekal taluk south eastern region of Bangalore showing more expansion in built-up. In northern part built-up expansion is toward the New International Airport at Dvanahalli in Bangalore Rural district which is very near to Bangalore North Taluk. The built-up extension toward Bangalore East is credited due to the development of the ITPL in Whitefield in the Bangalore East Taluk. The built-up extension toward Bangalore West is because of the settlements coming near the Peenya Industrial Area and also the increase in the number of industries in that region. According to census urban population in Bangalore has increased by 46.86% and population density to have increased from 2985 per km<sup>2</sup> in 2001 to 4378 per km<sup>2</sup> in 2011 are the major causes behind urban expansion.

The increase in the Built-up and other land use class but a decrease in the Vegetation and Water body's classes can be clearly appreciated in the Fig. 10.3. These figures show the percentage wise distribution of the area of different LU/LC classes of Feb 1999 and Jan 2009 respectively. The increasing urbanization and industrialization may be attributed as the reasons for the loss of vegetation and water bodies. Figure 10.4 shows the LU/LC classification of the year 1999 and 2009.

Here LST values were retrieved from the emissivity and radiance value for both the Landsat TM datasets of April 1999 and 2009. The LST maps of April 1999 and 2009 have been shown in Fig. 10.5. In both the images of LST 1999 and 2009 showing significant increase in surface temperature of over Bangalore urban district, the LST maps indicate a surprising higher Land Surface Temperature in the outskirts compared to the Greater Bangalore Region for both the temporal data. This is a fact that there are more urban green space and water bodies and wetlands in the heart of the city which keeps the city cooler compared to the outskirts.



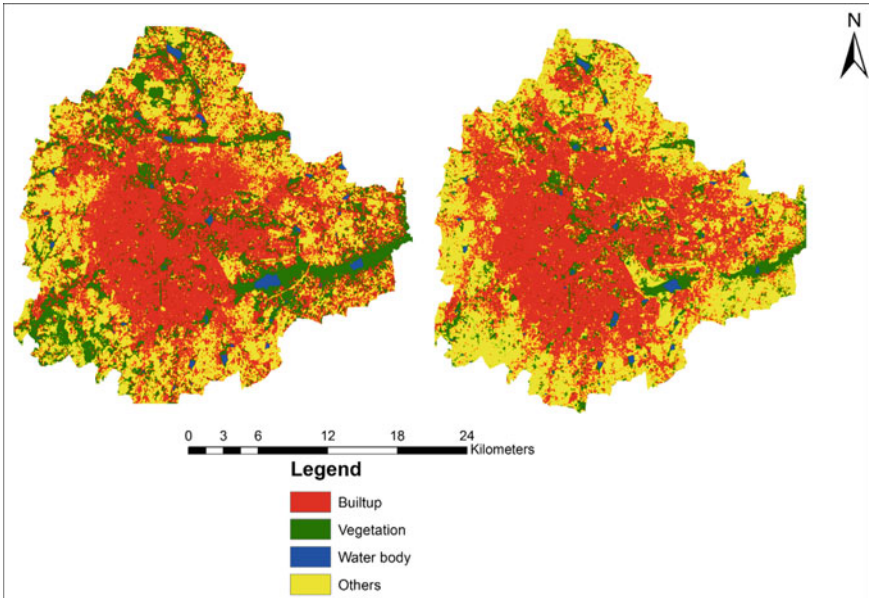


Fig. 10.4 Showing LU/LC of Bangalore 1999 and 2009

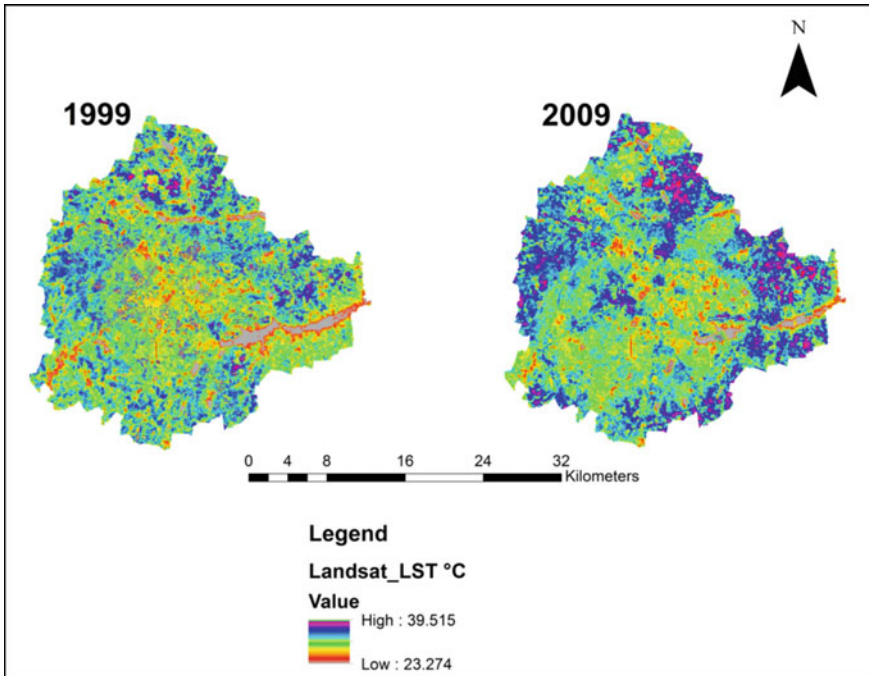


Fig. 10.5 Showing Land surface Temperature of Bangalore 1999 and 2009

Outskirts have more vacant lands, mining activities and urban agglomeration affecting on the loss of vegetation. From the study of Abinakudige (2011) we observed similar condition of lower LST value in the heart of the city compared to the outskirts.

Ground Water Temperature (GWT) and Land Surface Temperature (LST) over Bangalore city affected by LU/LC change are also focused in this study. A map of GWT and LST are created using ArcGIS Geostatistical tool for fair comparison. To understand the relationship between GWT and LST, Correlation coefficient are performed. Even relationship between GWT and LST of the different land use land cover has been studied here.

From the Fig. 10.6 we observed that in the 2009 showing that wherever LST is high in the same place GWT is also showing high. We observed that north western part of western Bangalore and southern part of Bayataranpura showing high LST and high GWT in 2009 images. As in this area urbanization is higher than city inside because inside city parks and gardens makes city cooler than outside. In 2009 southern part of Bangalore which is the near boundary of Bomanahalli and Mahadevapura temperature is showing high in both LST and GWT because of rapid urbanization effect.

From the Fig. 10.7 it was proved that there is very strong correlation between LST and GWT. In the year 2009 we observed positive correlation between GWT and LST.  $R^2$  value is 0.8338 in 2009 which is showing very high. As we have already seen that in (Chakraborty et al. 2015) paper on Delhi that urbanization has impact on LST. We

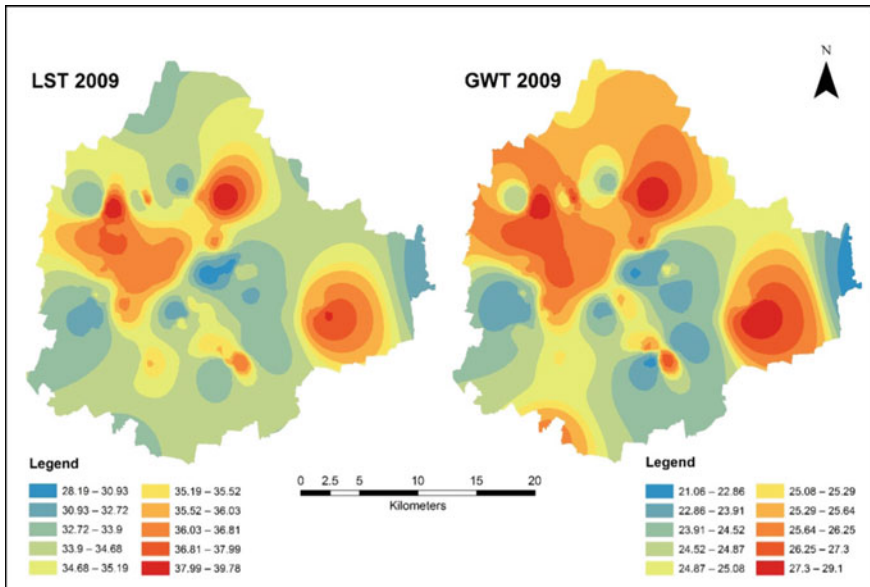
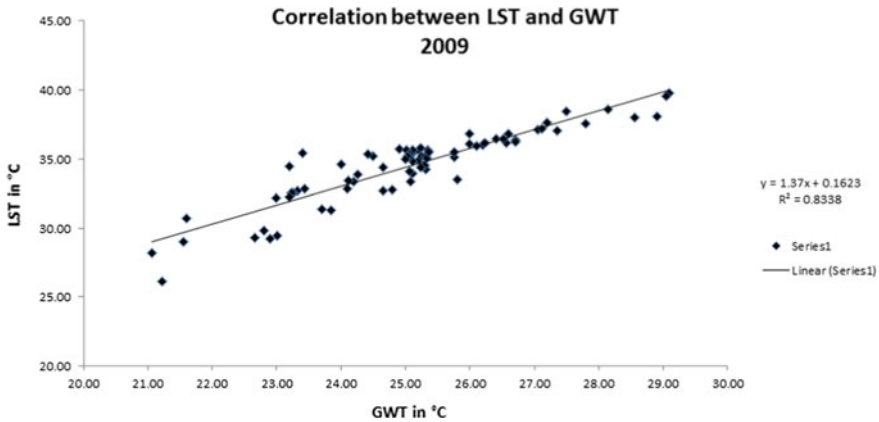


Fig. 10.6 Showing LST and GWT of Bangalore 2009



**Fig. 10.7** Showing correlation between LST and GWT of Bangalore 2009

**Table 10.2** LU/LC comparison with GWT and LST 2009

Land use/Land cover	Ground water temperature 2009	Land surface temperature 2009
Built up	27.20	37.61
Open land	29.05	39.57
Fallow land	23.20	34.44
Shrub land/parks/forest	21.20	29.37
Water body	21.06	28.19

can establish relationship with LST and GWT which proved that urbanization has also effect on GWT (Table 10.2).

Here we try to find out how built-up area is affecting over LST and GWT. For that we calculate NDBI to focus on built-up area. Here we observed that last 10 years huge population boom inside Bangalore city which was going to effect on LU/LC change. This increased population density is the main cause of increasing built-up area in Bangalore. We found strong indication increasing built-up from satellite derive LU/LC and NDBI from both 1999 and 2009 images. NDBI has some disadvantages if we purely are using it. Our idea is to focus on urban built-up areas extraction and for that to enhance our result we used BUAI. We found very positive correlation between BUAI with LST and GWT.

Last 10 years Bangalore showed huge change in built-up area which mainly affected over LST and GWT. From the Figs. 10.8 and 10.9 we mainly estimated NDBI and BUAI (Built-up area index) of the year 1999 and 2009. We consider BUAI is better indicator than NDBI. Here we observed south eastern part of Bangalore near Bellendur, Kadabeesanahalli and Marathahalli village (red marked in Figs. 10.8 and 10.9), this area near to HAL airport we found huge changes in BUAI due to high

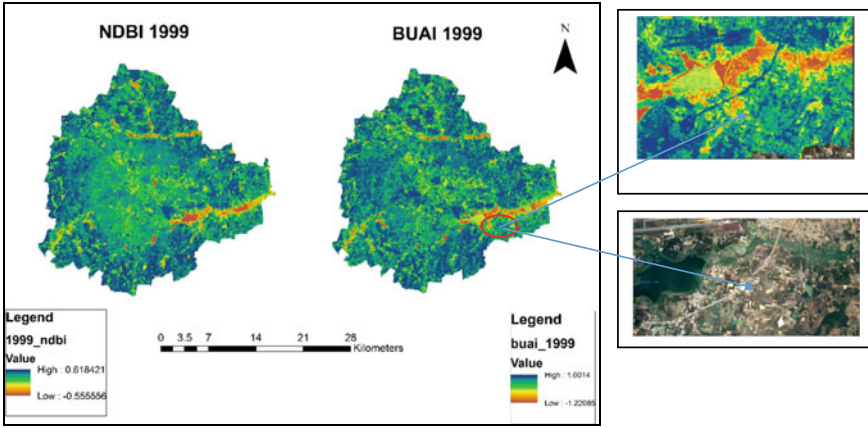


Fig. 10.8 Showing NDBI and BUAI of Bangalore 1999

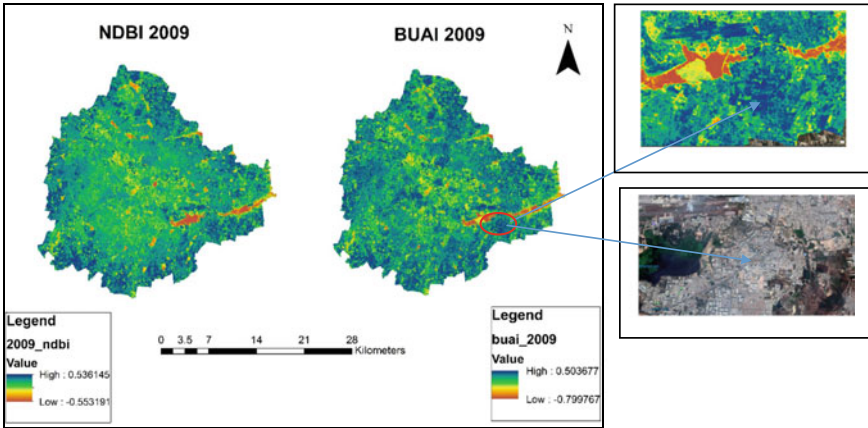
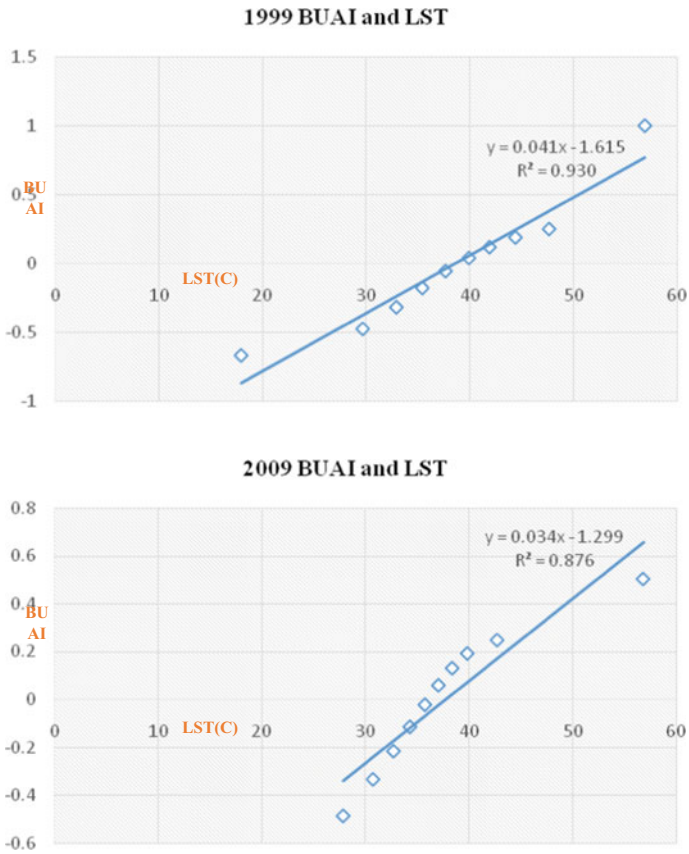


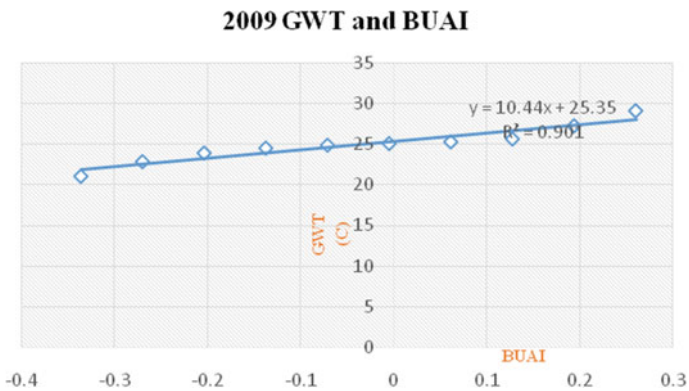
Fig. 10.9 Showing NDBI and BUAI of Bangalore 2009

construction of built-up area. Due to high construction of built-up area in last 10 years also affected in high LST and GWT value.

A sample point method using 50 randomly selected points were used to understand the connection between LST and GWT to NDBI and BUAI derived from Landsat TM-5 1999, 2009 respectively. Here GWT is only concentrated over year 2009 as availability of data sets, which was collected by ground survey. Good positive correlation found between LST, GWT and BUAI is clearly understood from the three transect lines in Figs. 10.10 and 10.11. It was observed from results that BUAI detected high same scenario were found over LST and GWT. The correlation



**Fig. 10.10** Showing correlation between BUAI and LST of Bangalore 1999 and 2009



**Fig. 10.11** Showing correlation between GWT and BUAI of Bangalore 1999 and 2009

coefficient of  $R^2 = 0.9305$ ,  $R^2 = 0.8765$ , between BUAI (Built-up area index) and LST (land surface temperature) over the year 1999 and 2009 showed very positive relationship. Correlation coefficient of  $R^2 = 0.9018$  over 2009 found between BUAI and GWT which detected as positive correlation in results.

## 10.4 Conclusions

In this study multi-temporal remote sensing data are used to understand land/use and land cover changes as well as surface temperature changes and investigate the relationship with GWT in Bangalore city. Rapid changes in land use classes like built-up has an impact over LST and GWT, this study was attempted to understand that. This study is considering four classes, those are built-up, vegetation, water body and others. If we see the result, then we observed that built-up area is increased by 44–47% in last 10 years. Here we found there is strong relationship between NBDI and BUAI with LST which proved that this increased built-up has affected on increasing LST value. The similar trend we found over GWT. We can take that GWT is a good indicator for urban heat island study. We observed that built-up area is showing higher LST in both the years 1999 and 2009. We also observed that under built-up area GWT is showing higher value than non-built up area. We also observed that Bangalore city expanding its boundary mainly outskirts area of the city removing the vegetation area and converting in built-up area less vegetated area mostly concrete area found with higher LST and GWT value. Even we found very strong positive relationship between NDBI, BUAI and LST. So, this study gives us a basic understanding how huge construction in Bangalore city is affecting on LST and GWT value. In the last 10 years Bangalore city lost its parks, gardens and lakes. It is understandable from this study that for mitigating Urban Heat Island effect city parks and lakes are taking major role. So, it is important to protect existing country parks and lakes to mitigate urban heat gradually in a long term. Bangalore city authority should focus more to protect its parks and lakes which will mitigate its temperature. City also take adoption of green building project more. Instead of using thermal power city should move toward sustainable energy consumption like sun energy. It's also focused to clean its lake from pollution. Electric vehicles should be encouraged more inside the city.

## References

- Carlson TN (1986) Regional-scale estimates of surface moisture availability and thermal inertia using remote thermal measurements. *Remote Sens Rev* 1:197–247
- Cheon JY, Ham BS, Lee JY, Park Y, Lee KK (2014) Soil temperatures in four metropolitan cities of Korea from 1960 to 2010: implications for climate change and urban heat. *Environ Earth Sci* 71(12):5215–5230

- Chakraborty SD, Kant Y, Mitra D (2015) Assessment of land surface temperature and heat fluxes over Delhi using remote sensing data. *J Environ Manage* 143–152
- Ferguson G, Woodbury AD (2007) Urban heat island in the subsurface. *Geophys Res Lett* 34(23):L23713
- Huang S, Taniguchi M, Yamano M, Wang CH (2009) Detecting urbanization effects on surface and subsurface thermal environment—a case study of Osaka. *Sci Total Environ* 407(9):3142–3152
- Hunse TM, Farooqi MA (1995) Groundwater development perspective in Bangalore District, Karnataka. Central Groundwater Board, South west Region Technical Report, Series D
- Mansor SB, Cracknell AP (1994) Monitoring of coal fire using thermal infrared data. *Int J Remote Sens* 15(8):1675–1685
- Menberg K, Blum P, Kurylyk BL, Bayer P (2014) Observed groundwater temperature response to recent climate change. *Hydrol Earth Syst Sci* 18(11):4453–4466
- NASA, Landsat Project Science Office (2004) Landsat 7 Science data users hand book, Chapter: 11, Data products. [http://www.gsfc.nasa.gov/IAS/handbook/handbook\\_htmls](http://www.gsfc.nasa.gov/IAS/handbook/handbook_htmls)
- Peng S, Piao S, Ciais P, Friedlingstein P, Ottle C, Bréon F-M, Nan H, Zhou L, Myneni RB (2012) Surface urban heat island across 419 global big cities. *Environ Sci Technol* 46(2):696–703
- Pongracz R, Bartholy J, Dezso Z (2010) Application of remotely sensed thermal information to urban climatology of Central European cities. *Phys Chem Earth* 35(1–2):95–99
- Zhan W, Ju W, Hai S, Ferguson G, Quan J, Tang C, Guo Z, Kong F (2014) Satellite-derived subsurface urban heat island. *Environ Sci Technol* 48(20):12134–12140