



Changes in Land Use and Land Surface Temperature Over Nashik City, MS, India

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Abstract

Rapid transformation of land use in and around major urban centers of the world has triggered a definitive change in the urban built environment. One of the consequences of this transformation is the increase in land surface temperatures (LST) in the urban areas. Nashik city also presents a peculiar case of growth in its built-up area. The present study aims at assessing the changes in land use land cover (LULC) and LST over Nashik city. This study was carried out for a period of nine years (2010–2018). Landsat ETM+ and OLI/TIRS data sets were employed to extract LULC, NDVI and LST. Changes in normalized difference vegetation index (NDVI) have also been investigated since the vegetation affects temperature. It has been observed that during the period of nine years, the built-up area increased 1.7 times and the LST increased by 2–3 °C in the city core, particularly during summer. This indicates the intensification of LST in the city core. The adjoining areas also present, more or less, a similar pattern due to the increase in the built-up area. Vegetation in the eastern part of the city has discernibly reduced to a considerable extent, which has also altered the thermal pattern of the city. A strong negative correlation is observed between the built-up areas and the LST over Nashik.

Keywords

Land use • Land surface temperature • NDVI • Nashik

1 Introduction

In the present era, urban sprawl and related changes in urban built environment have led to different environmental problems in the urban sector. One of the factors that contribute in the modification of microclimate in the cities is the increase in the built-up surfaces. Concrete and tar laid surfaces are characteristic of the modern cultural landscape. These surfaces are capable of absorbing higher amounts of incident radiation and result in increasing surface temperatures, thus causing significant changes in urban thermal environments (Li et al. 2010). These changes in urban thermal environment often lead to the formation and sprawl of urban heat island (UHI), wherein higher land surface temperatures (LST) are observed at the city core as compared to that of its immediate surroundings (Landsberg 1981). Advances in remote sensing techniques and availability of thermal satellite data have enhanced the scope of urban climate studies. Considerable work has been carried out to understand the urban thermal characteristics using remote sensing data (Streutker 2002; Weng 2001). Correlation of vegetation indexes (NDVI) and built-up areas with LST are studied by a number of researchers in order to understand the impact of changing land use land cover on urban surface temperatures (Carlson et al. 1995; Barbeiri et al. 2018). Yuan and Bauer (2007), compared percentage imperviousness along with NDVI as indicators of LST, while Xiao et al. (2008) employed multiple regression and principal component analysis to establish correlation of LST with the population's density, land use and vegetation.

In India, cities are growing at faster rates due to increased demand in housing and infrastructural facilities. It has been observed in some of the Indian cities that land surface temperatures (LST) have swiftly increased with the growing urbanization. Some of these cities are Pune, Ahmedabad, Guwahati, Delhi, etc. It is therefore essential to investigate whether medium-sized cities such as Nashik are also experiencing similar phenomena. Nashik city (Fig. 1) is situated

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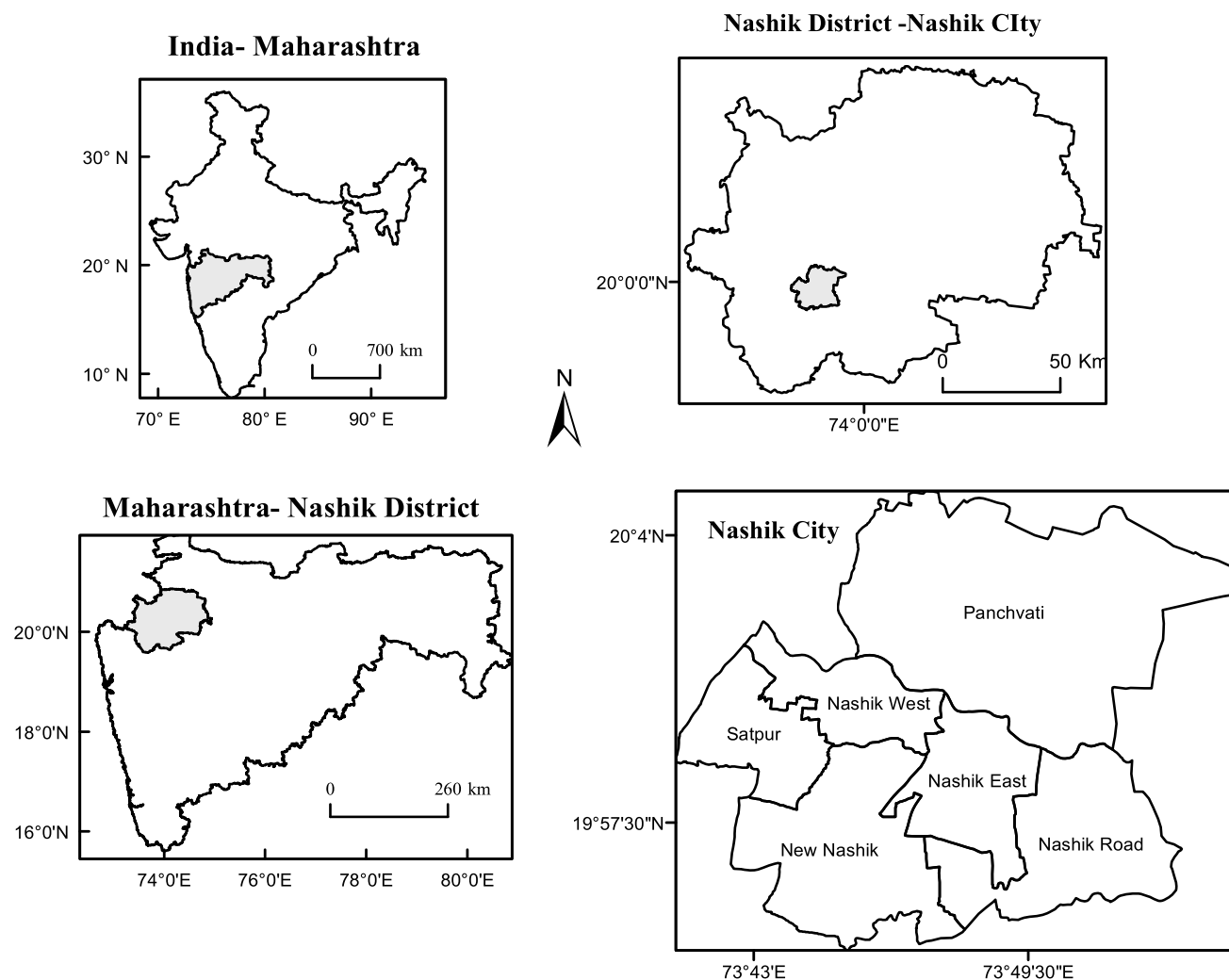


Fig. 1 Location of the study area

on the banks of River Godavari at an elevation of 584 m ASL on the western edge of the Deccan plateau. It enjoys a tropical wet and dry climate.

The main aim of the study is to bring about spatiotemporal variations in the land use and land surface temperature of the Nashik city, during the period 2010–2018.

2 Data and Methods

The details of the data set used for the present work are given in Table 1. ETM+ and OLI/TIRS data were downloaded from the global land cover facility's site. The downloaded data sets were subjected to the preprocessing procedure which included radiometric and atmospheric correction. These data were further employed for the land use land cover classification and retrieval of LST.

The satellite images obtained were primarily subjected to the basic preprocessing steps. This included the radiometric and atmospheric corrections, reprojection and enhancement of the images. In order to obtain the thematic maps for different land use types, the images were subjected to supervised classification. Eight land use classes were identified (hillsc, barren land, water bodies, roads, fallow land, built-up, vegetation and agricultural land) and processed for accuracy assessment after the classification. LST is commonly retrieved using a different set of algorithms like split window (Becker and Li 1995), mono-window (Qin et al. 2001) and single-channel technique (Jimenez-Munoz and Sobrino 2003). For the present work, LST was extracted by the single-channel algorithm. Standard procedure depicted in the Landsat 8 user handbook (2018) was adopted for the retrieval of LST. In all, LST was retrieved by the following four steps: conversion of DN (QCAL) to top of the

Table 1 Satellite data used for the study

Satellite	Sensor	Bands (spatial resolution in meters)	Date
Landsat 7	ETM+	Blue(30), Green(30), Red (30), NIR(30), MIR1(30), TIR(60), MIR2(30), PAN(15)	April 26, 2010
Landsat 8	OLI/TIRS	Blue(30), Green(30), Red (30), NIR(30), SWIR1(30), SWIR2(30), PAN(15), Cirrus(30), TIR 1(100), TIR 2(100)	April 5, 2013
			April 21, 2014
			April 10, 2016
			April 16, 2018

atmosphere (TOA) radiance values, conversion of spectral radiance to black body temperature (BBT), emissivity correction and LST retrieval. For the last step, LST was retrieved using Eq. 1.

$$S_t = \frac{T_B}{1 + (\lambda * T_B / \rho) \ln \varepsilon} \quad (1)$$

3 Results

3.1 Changes in LULC Over Nashik City

The output of the classified images was obtained as thematic maps, wherein the classes defined earlier were displayed using various colors (Fig. 2). The overall accuracy obtained for all the images was above 80%, and the kappa statistic was above 75%. During the last nine years, it is observed that the percentage of built-up area has increased almost by 1.7 times. In 2010, the built-up area was 26.76% which is recorded at 44.85% by 2018. This rapid increase in built-up area is mainly observed in the southern parts of the city. In the recent time, northern parts of the city also have started experiencing rise in built-up areas (Fig. 2). The vegetation (inclusive of natural, agricultural and fallow) has decreased by 7% (from 2010, (42.09%) to 2010 (35.04%)). Overall, it appears that the vegetation has not decreased much in these 9 years. A decrease by almost 5% of barren land in the last nine years' time is recorded. Most of this decrease in barren land can be attributed to the growth in settlements in these areas. Considerable decrease in hills is also noticed during the study period. 10% of the city area was covered with hills in 2010; however, by 2018, hills are attributed to a mere 4.84% of the total city area.

3.2 Changes in LST Over Nashik City (2010–2018)

Figure 3 depicts the spatiotemporal changes in LST from 2010 to 2018. Mean LSTs obtained for all these images indicated an increasing trend in LST over Nashik city (36.3 °C in 2010 to

39.41 °C in 2018). Even though LST values ranged up to 45 °C in 2010, the areas reporting this value were relatively rare. The city core region had higher LST (36–40 °C) while the immediate surroundings had lower LST (32–36 °C) in 2010. By 2013 and subsequent period, a gradual spread of higher LST values was observed moving out from the city core toward the suburbs. In all the images, lower LSTs were noted over the major water body (River Godawari) that drains through the city. The northern and southern hill spurs (reported as barren land parcels in most of the images (Fig. 2)) and the areas devoid of vegetation have recorded very high LST (>40 °C). As compared to the 2010 condition, most of the suburbs have recorded an increase in the LST values by 1–2 °C in 2018. However, most of the barren patches, hills and intermittent barren land between agricultural patches have recorded an increase in LST by almost 4 °C or even more in the last 9 years. Isolated barren patches, airport and the bare hill tops have recorded an increase by almost 6 °C or higher than that. LST for the city core appears to have increased by 2–3 °C during these nine years.

As compared to the condition of 2010, certain areas in 2016 show a decreasing trend in temperature. However, the net areas that are represented by the decreasing LST are relatively lower than the areas where the increasing trend is observed. In some localities in western parts of the city, temperatures have dropped down by 0–2 °C. There are very few patches along the river which have decreased LST values (0–2 °C).

3.3 Changes in LST Over Nashik City (2010–2018)

NDVI versus LST values were plotted for all the years; but here, they are represented for only 2010 and 2018. These plots obtained to understand the relationship between NDVI and LST (Fig. 4) indicated that there is a definite negative relationship between them, thus, indicating that a decrease in NDVI will lead to an increase in LST and vice versa. All the years recorded a negative trend and were found to be significant at the 0.05 level of significance, thus establishing the fact with 95% of confidence level.

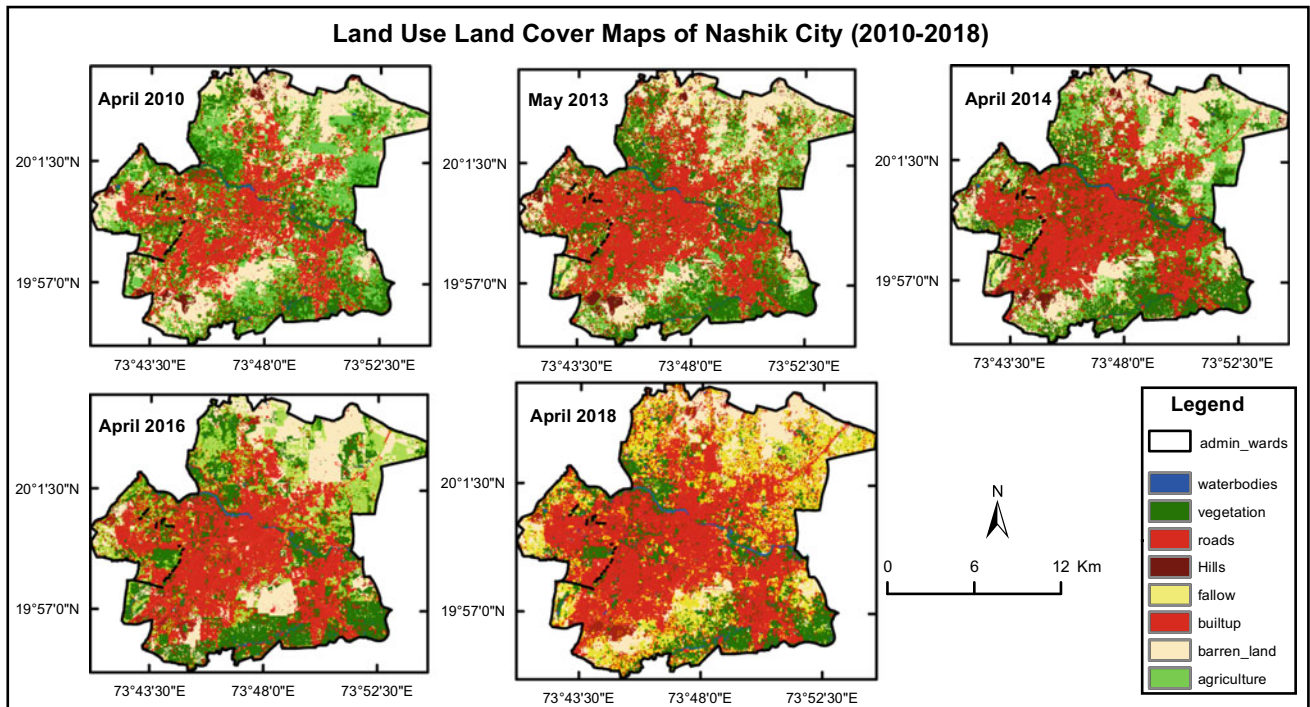


Fig. 2 Land use land cover maps of Nashik city (2010–2018)

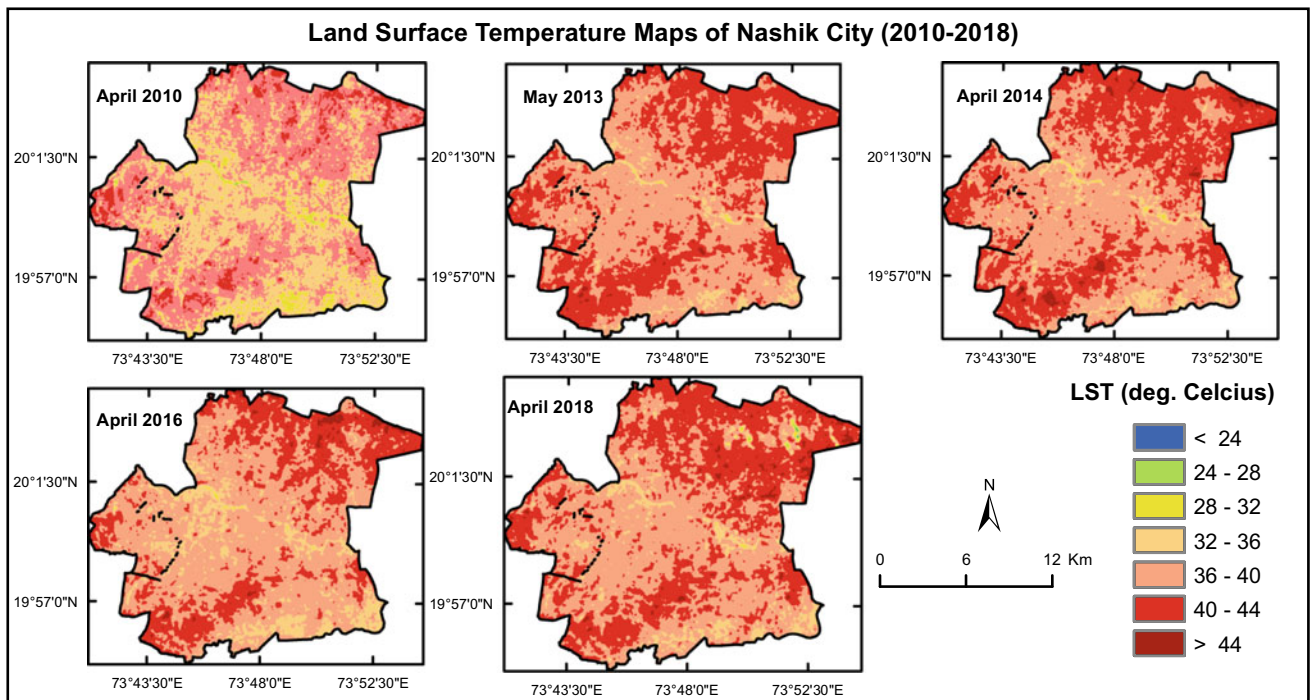
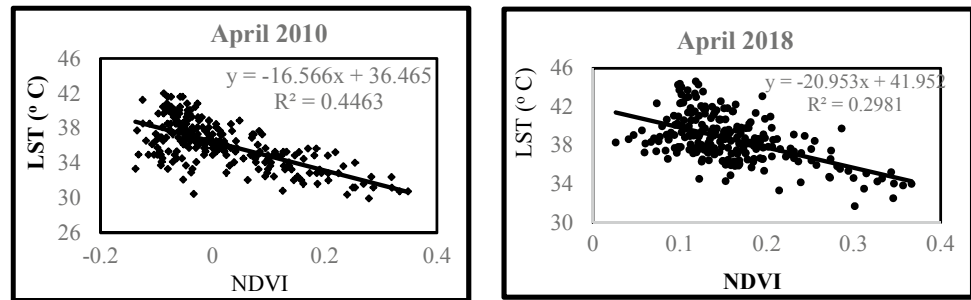


Fig. 3 Land surface temperature maps of Nashik city (2010–2018)

Fig. 4 NDVI–LST relationship (2010–2018)



4 Discussion

Over the period of nine years, the built-up area of Nashik city has increased from 26.7 to 44.85%. This clearly indicates that Nashik is growing at a fast rate. Overall, it is observed that for the entire city, the LST values (mean) have increased. A major increase is noted in 2013 from that of 2010 condition. In 2010, the mean LST for Nashik city was recorded as 36 °C which increased to 39.45 °C by 2013. 2014 imaging recorded a slight increase in LST (39.49 °C). While by 2016, it was noticed that the mean LST values for the city dropped down slightly by 0.78 °C and reached a value of 38.67 °C. However, again by 2018, there is an increase noticed in the mean LST of the city, where the mean LST recorded was 39.41 °C. The NDVI–LST relationship study indicated a negative relationship between NDVI and LST. While studying the LST of 2018 over 2010, it was revealed that the areas where vegetation is relatively dense recorded lower values of LST. However, areas dominated by barren land and industries recorded maximum LST. This again highlights the role of vegetation in mitigating the intensification of LST.

5 Conclusions

During a brief period of nine years, it was observed that the built-up area has gone up by almost 1.7 times in the city and the land surface temperature has increased by 2–3 °C in the city core, particularly during summer, thus, indicating an intensification of city core LST. Thermal field in the suburbs (western part of the city) has been modified, and LST has increased by 5 °C in the last 9 years due to the change in land use. Western and southwestern parts of the city show LST values as that of the city core indicating expansion of built-up area. The research also reveals higher temperatures near the city's boundary due to the barren land and hill slopes. Vegetation covers certain areas such as the eastern part of the city which has discernibly reduced to a considerable extent, which has also influenced the thermal pattern

of the city. The present study has clearly brought out the spatiotemporal variations in the LST and also proved that the LST is highly (negatively) correlated to the vegetation and built-up areas. In the process of development, the city planners have to give considerable thought to maintaining the green character of the city and see to it that the brown agenda does not overwhelm the green agenda.

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