A Study of Urban Heat Island over Dehradun City: Impact of Land Use Land Cover changes

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4 Conclusion

Our study shows that the Dehradun city and its adjoining surrounding areas (particularly southern, eastern and south-eastern) have witnessed urban expansion over the last two decades. The LULC maps for the years 2000, 2010 and 2019 show that percentage of built-up area has increased significantly within the city as well as its surroundings, especially areas lying south and south east of the city. At the same time, the dense forest cover and the agriculture land in the study region have witnessed a decline. The LST trends over the study region show that areas which have undergone transition in LULC from agriculture/open forest to built-up have witnessed the greatest increase in LST. We have also seen diurnal asymmetry in LST trends over the study region which is best explained by the increase in cloud cover under global warming effect. Seasonal dynamics of LULC shows that major land cover of Dehradun's surrounding areas does not show much seasonal changes throughout the year as it lies in the open forest and the dense forest classes. Only the agricultural and fallow land classes show significant seasonal changes. After the harvest of Rabi crop in summer and Kharif crop in post-monsoon, agriculture land in the surrounding region of Dehradun becomes fallow land. We find that seasonal dynamics of agriculture land cover in the surrounding region of Dehradun does influence the urban-rural thermal contrast in the study region. Daytime LST maps show that Dehradun is warmer than the surrounding rural areas in all seasons. In spring and summer seasons, the night-time LST maps indicate that Dehradun is warmer than the surrounding rural areas. During the daytime, higher LST is observed over the built-up areas, agriculture and fallow land while lower LST could be seen over dense forest, open forest. During the night-time however, the agriculture and the fallow land cool much faster than the urban built-up because of their high sky view factors. The forest areas however remain comparatively warm during the nighttime because of their high thermal inertia. These patterns show that forests have a moderating effect on the local climate of the region.

Higher values of UHII were observed over the north and east strips in the surrounding region due to effect of high elevation of those strips with respect to the city. The SUHI formation over Dehradun is observed throughout the year. However, the magnitude of SUHI during the daytime (~2- 6°C for Terra and ~4-9°C for Aqua) is generally greater than that during the night-time (~1.5 - 3.5°C for Terra and ~0.5 - 2°C for Aqua), possibly because the thermal inertia of the surrounding vegetated area is greater than that of the urban built-up area. Further, the magnitude of SUHII is found to be the maximum during the rainy season (>6 °C) and the minimum during the winter (<2 °C) as the thermal inertia of the surrounding wet soil covered with vegetation is even more during the wet period as compared to dry winter. Our correlation and regression results show that ELEV along with LULC variables such as AGRI, FALO and BILT significantly affect the LST of a place in the study area. Further, ELEV is found to have a negative relationship with LST during the daytime. But in night, the relationship between ELEV and LST turns to be curvilinear because of the effect of local slope factor which allows the cold air to settle at lower altitudes of up to 1000m. Thus, night-time LST is found to increase with elevation up to 1000m and thereafter LST decreases with elevation as it does during the daytime.

The increasing LST trend over the study region during the last two decades is found to be consistent with the annual mean air temperature trend. There is also an increasing trend in the annual magnitude as well as annual frequency of CDDs over Dehradun city. However, the trend values from the satellite-based pixel data clearly show that increasing trend is very much prominent over the places showing transformation of land-cover from agriculture/open forest to built-up. The increasing trend in CDDs indicates that electricity demand for cooling requirements of indoor spaces should have increased over Dehradun city. We find that the annual electricity consumption trend over Dehradun is indeed increasing even after we normalize this trend by taking into consideration the increase in the population of Dehradun.

To summarize, our study shows warming trends over Dehradun city due to combined effect of urban heat island and global warming, particularly over areas which have undergone urbanization. These changes in the thermal climate of the city would require more energy consumption to ameliorate the human comfort levels, which will further provide positive feedback for urban heat island and global warming. Since Dehradun city comes under the ambit of the 'Indian Government Smart Cities Mission', it is necessary to provide a conceptual framework for future urban planning so as to achieve the mission goals. This may involve development of regulations which promote the increase in green spaces, cool roof tops, pervious surfaces, water bodies and green buildings in the city to mitigate the urban heating. In this regard, our study provides useful insights for the urban policy decision makers, especially in the context of cities with hilly terrain.

Supplementary data

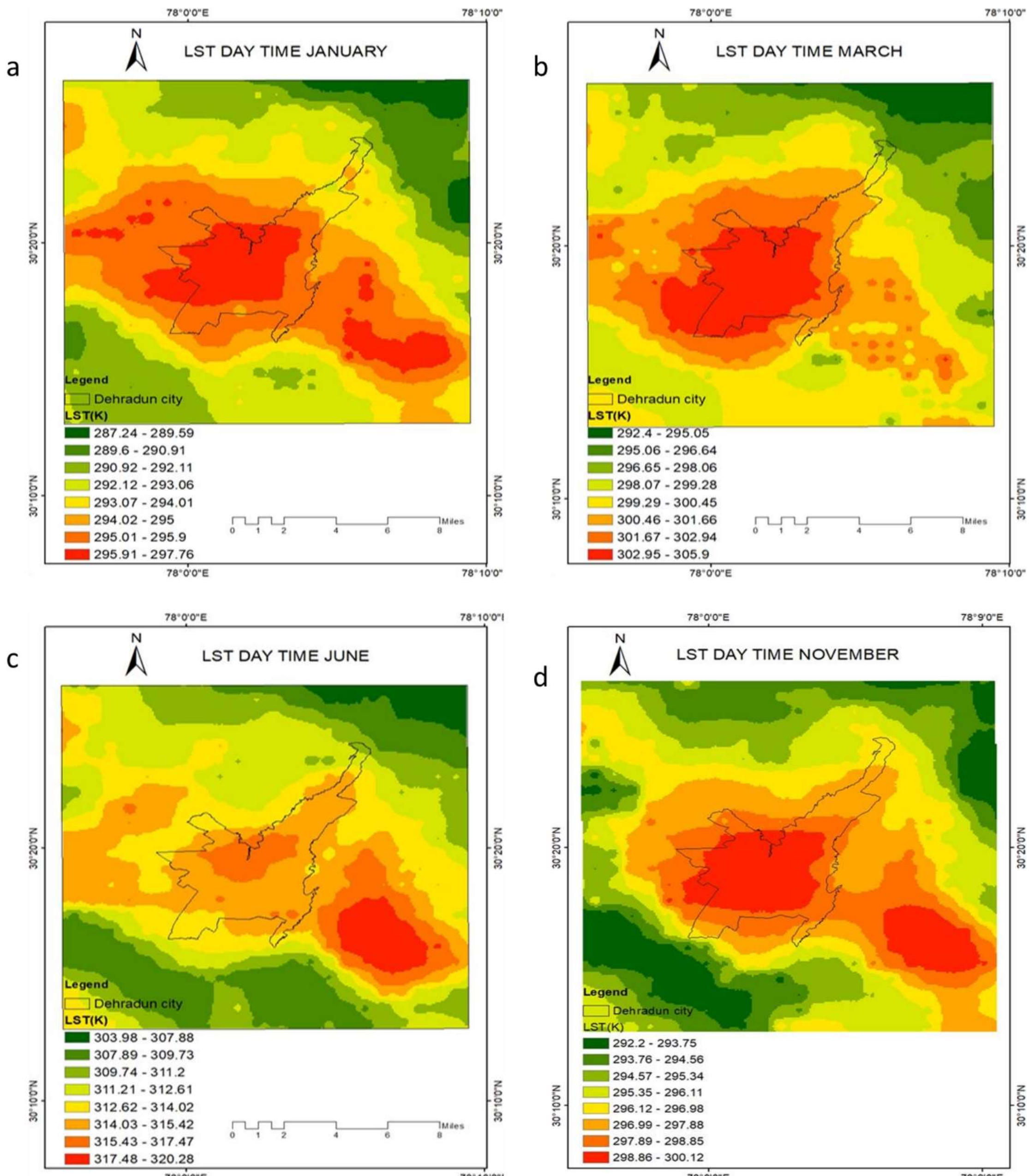

Fig. 1Terra Daytime LST maps of different seasons of 2019, over the study area.

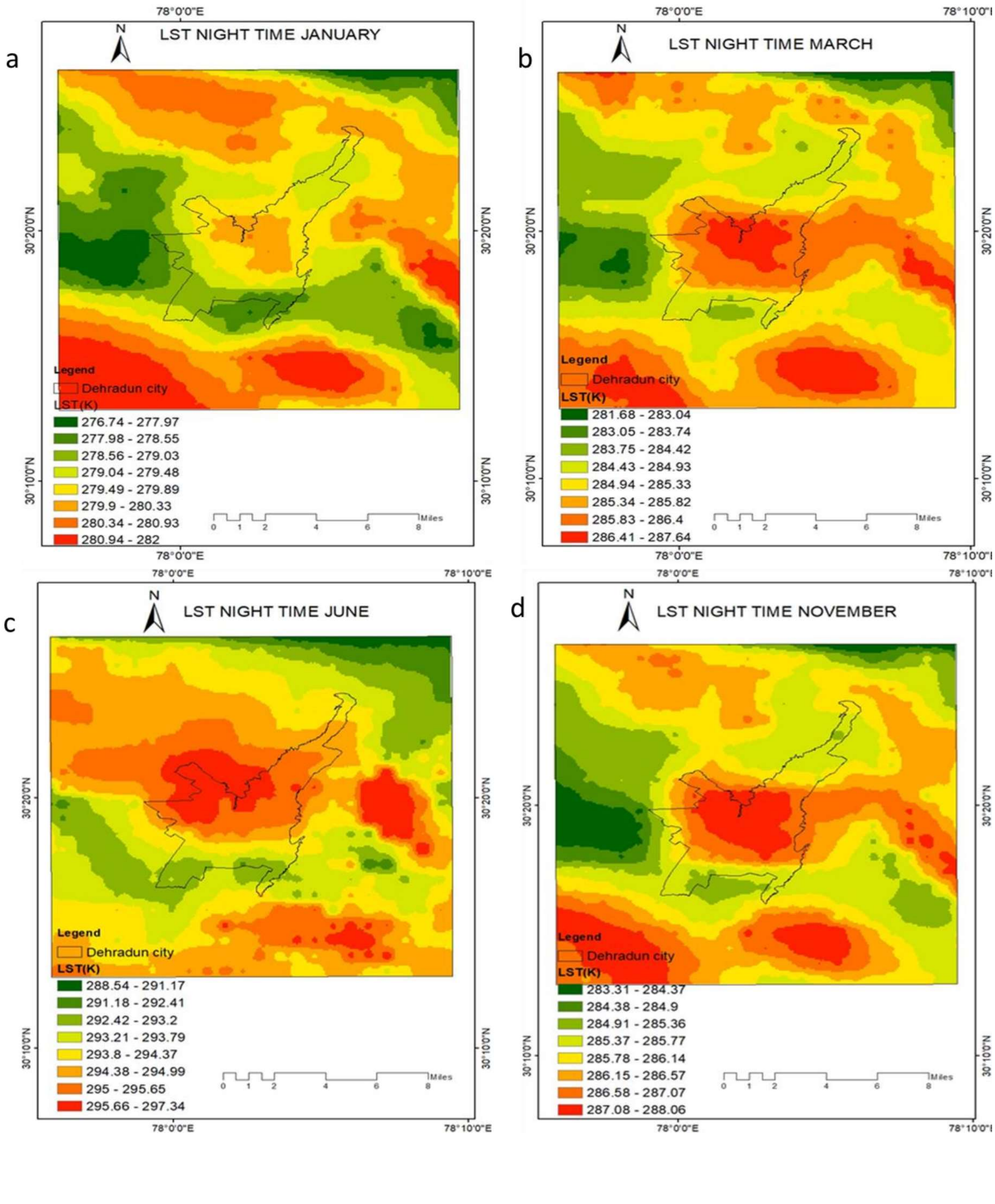

Fig. 2 Terra Nighttime LST maps of different seasons of 2019, over the study area.

Fig. 3 Temporal monthly variations of daytime UHII over east, west, north and south strip.

Fig. 4 Temporal monthly variations of nighttime UHII over east, west, north and south strip.

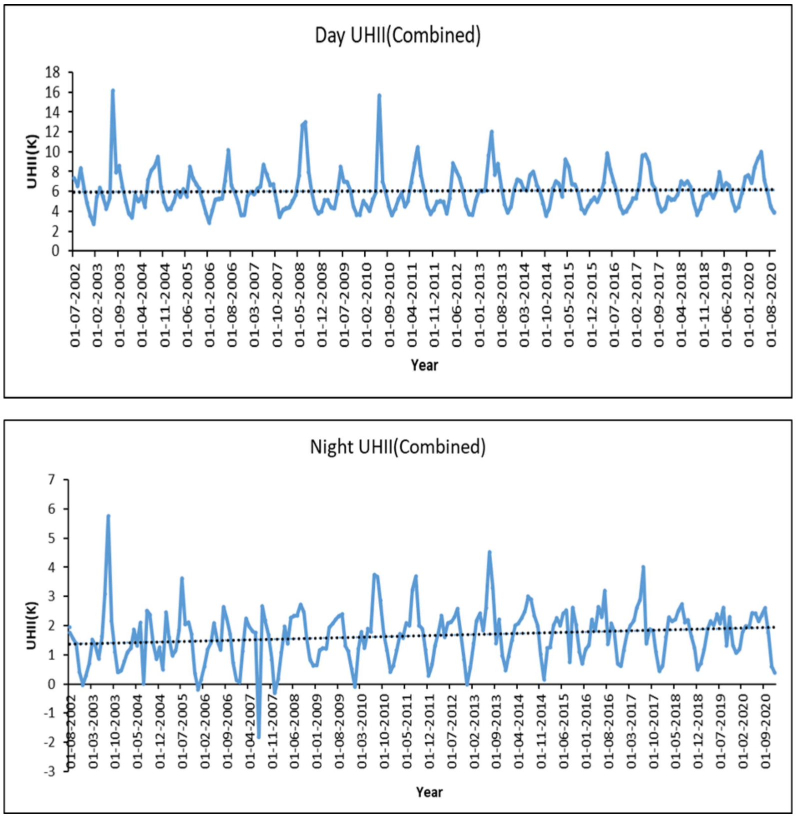

Fig.5 Temporal monthly variations of UHII over the combined strip.