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Research Article

ESTIMATING TEMPORAL LAND SURFACE TEMPERATURE USING REMOTE SENSING: A STUDY OF VADODARA URBAN AREA, GUJARAT

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ABSTRACT
The concentrated development, intensive human activities and urbanization have resulted in the increase in population pressure on infrastructure, natural resources, and in due course adding to burden of serious challenges. Amongst the perceived impacts, distinct difference of temperature between urban and peripheral area, which is, known as the urban heat island (UHI) effect. Such impacts affect not only the local environment, but also have consequences for more distant regions. Identification and characterization of UHI are typically based on land surface temperature (LST) that varies spatially, due to the complexity of land surface cover and other atmospheric factors. The knowledge of surface temperature is important to a range of issues and themes in earth sciences central to urban climatology, global environmental change, and human-environment interactions.
Urban land surface temperature (LST) pattern is a manifestation of surface energy balance and has been extensively studied using remote sensing technique. Moreover, satellite thermal infrared sensors provide different spatial resolution and temporal coverage data.
The present study aims to estimate the land surface temperature (LST) and its temporal change for the years 1990 and 2009 for the Vadodara Urban Area demarcated by VUDA incorporating Remote Sensing technique and LAND SAT data.

Key Words: *LST, LAND SAT, Remote Sensing, Temporal, Urbanization, UHI, VUDA*

INTRODUCTION
Worldwide urbanization has significantly modified the landscape, which has important climatic implications across all scales due to the simultaneous transformation of natural land cover and introduction of urban materials i.e. anthropogenic impervious surfaces. More than 50% of the world's population now lives in urban areas, and this number will continue to increase, particularly in developing countries (United Nations, 2008). Urbanization is mainly the result of a rapid population increase caused by a mass immigration and a flow of refugees. This unplanned and therefore uncontrolled urbanization results in the destruction of green areas and water resources (Rawashdeh and Saleh, 2006). This has changed the interaction of energy with the land cover resulting in the deviation from the normal condition. One of the major changes induced by the urbanization is a large amount of land cover transformed into the concrete and asphalted structures. Thus, there is a consequent change in the thermal characteristic of the impervious surface area. The use of heat-absorbing construction materials (e.g., stone, metal, and concrete) and building of roads, pavements, footpaths, parking lots, and terraces in urban areas and the corresponding reduction of natural vegetation and water bodies result in higher temperatures in urban areas which may seem to be localized effect but in long-term it may contribute to the global heat. The increased temperature not only leads to adverse climate, but also increases the energy use for air conditioning and the pollution level. The most important anthropogenic influences on climate are the emission of greenhouse gases and changes in land use, such as urbanization and agriculture. But it has been difficult to separate these two influences because both tend to increase the daily mean surface

temperature and changes in land use, (Pielke, 2002; Gallo and Owen, 1999). Evapo-transpiration also controls the surface temperature through the partitioning of incoming energy in latent and sensible heat. The latent heat flux is enhanced with increased vegetation due to the decrease in surface resistance to moisture flux (Stisen, 2007) Thus, the excess urban heat trap is having two faceted impacts that can hinder the sustainable growth and development, if not addressed with holistic approach.

Physical surface temperature (ST) is one of the most important environmental parameters used in determining the exchange of energy and matter between the surface of the earth and the lower layer of the atmosphere. A continuous measurement of this parameter is likely to yield information about suspected climate change. (Mohan, M., 2000)

Studies by Arnold and Gibbons (1996), Ji (1999), and Ward (2000) suggest that, the share of impervious surface varies with land use and zonation of the urban plan. Which in turn modulate the heat flux, and increases the land surface temperature. Surface and atmospheric modifications due to urbanization generally lead to a modified thermal climate that is warmer than the surrounding non-urbanized areas, particularly at night. This phenomenon is the Urban Heat Island (UHI). (Voogt and Oke, 2003a). The prevalence of heat island is not always necessary to be associated with every cities identified in the developing countries but the continuous monitoring of the variation in the land surface temperature may give us the probable zone of UHI at the early stage of MUHI (Micro Urban Heat Island).

The earlier studies used the in-situ measurement using the data procured by the meteorological data which ground-based observations taken from are fixed thermometer networks with the limitation that it cannot give the continuous information of the surface for the regional study. With the advent of thermal remote sensing technology, remote observation of UHIs became possible using satellite and aircraft platforms that have provided new avenues for the observation of UHIs and the study of their causation through the combination of thermal remote sensing and urban micrometeorology. (Voogt and Oke, 2003b) At regional scale, the only way to determine Surface Temperature is by using satellite data (Gupta et al., 1997). To identify the change over the period at regional level is one of the main requirements to analyze the climate change. Falahatkar et al., (2011) used the technique of image differencing to produce a radiant temperature change image using the normalization of the surface radiant temperature order to understand the impacts of land cover change on surface radiant temperature. The temporal study by Rajasekar (2009) used contour to visualize the change in the concentration of heat with respect to time.

Rao (1972) reported the first SUHI observations (from satellite-based sensors).The archived land sat imagery is evidently showing the expansion of the urban category over the time. Thus, the remote sensing is extremely useful for understanding the spatio-temporal land cover change in relation to the basic physical property in terms of the surface radiance and emissivity data. Since the 1970s, satellite-derived surface temperature data have been utilized for urban climate analyses on different scale Landsat Thematic Mapper (TM) data, Enhanced Landsat Thematic Mapper plus (ETM+)data, and Moderate Resolution Imaging Spectroadiometer (MODIS) data have been widely utilized (Carlson,1977; Carnahan and Larson,1990; Hung, 2006).

In recent studies, quantitative approaches for urban thermal environment and related factors are widely seen. Li et al., (2011) has studied Relationship of LST to NDVI and vegetation fraction. The study of Ferguson G., and A. D. Woodbury (2007), indicated that subsurface temperatures are linked to land-use and supports previous work indicating that the urban heat island effect has significant and complex spatial variability.

Objective

The present study aims to evaluate the applicability of remote sensing satellite data, the process for estimating and demarcating the heat island effect. As the satellite sensor measures radiance, this study focused on the estimation of the land surface temperature. In addition, to identify the temporal trend of land surface temperature and its change from 1990 to 2009.The study delineates the thermal zones, calculates temperature within these zones, and compares the thermal variation for two-time period.

Study area

The study area is limited to the boundary marked by the planning agency, Vadodara Urban Development Area (VUDA) region, in the Vadodara district of Gujarat; Situated in the Central Gujarat, VUDA extends between 21º and 23º North latitudes and 73º and 74º.10' East longitude over an area of 714sq.km. The region has witnessed a rapid growth and developmental changes induced by rapid industrialization from 1980 with center of growth and expansion is the Vadodara city.

MATERIALS AND METHODS

The two set of data are used in this study were

a). Remote Sensing Data: Landsat Thematic Mapper 5 TM image , year 1990-2009 .

Landsat 5 TM data set has seven spectral bands, of which the seventh band records emitted energy in the thermal infrared portion of the spectrum and gives information about the thermal characteristics. So, Landsat Thematic Mapper (TM) images, for the month of October are used for generating the Thermal map.

b). Collateral information: Survey of India Toposheet for Georegistration.

Methodology

The thermal band is used to convert the raw value in to the black body temperature in Degree Celsius using Arc GIS Software.

1) Thermal map generation.

i). Conversion of the Digital Number (DN) to Spectral Radiance (L)

- $L_\lambda = L_{MIN} + (L_{MAX} - L_{MIN}) * DN / 255$

  Where, L = Spectral radiance,
  L_{MIN} = 1.238 (Spectral radiance of DN value 1),
  L_{MAX} = 15.600 (Spectral radiance of DN value 255),
  DN = Digital Number

ii) Conversion of Spectral Radiance to Temperature in Kelvin.

- $T_b = K_2 / \ln((K_1/L_\lambda) + 1)$

  Where,
  K_1= Calibration Constant 1 (607.76)
  K_2 = Calibration Constant 2 (1260.56)
  T_b = Surface Temperature

iii) Conversion of Kelvin to Celsius.

- $T_b = T_b - 273$

2) Thermal Image differencing technique is used to identify the magnitude of the change during 1990-2009

RESULTS AND DISCUSSION

On the basis of the result derived it is seen that the land surface temperature of the study area has shown a significant increase all over during(Fig.1) 1990 and 2009(Fig.2), which may be attributed to the higher amount of insolation or the other atmospheric factors which needs to be studied. The comparing the two times LST scenario, it suggests that the transformation of the land cover to the built-up do bear its role in the accumulation of the heat. This in time contributes in the formation of the heat island. It is also observed that the vegetation and water body patches are having relatively low temperature, which acts as heat sink. This reveals that such study is important aspect while planning for the sustainable development of the city. In addition, the densification of the vegetation lowers the temperature as it enhances the evapotranspiration that maintains the heat flux.

The image of thermal change has been derived by image differencing technique (Fig.3.). It is seen that the land use change has higher impact on the temperature regime of the area, as also the density of the land use can affect the temperature. The temperature for several observation points of heat sinks and urban heat source show that the temperature has increased, throughout the area

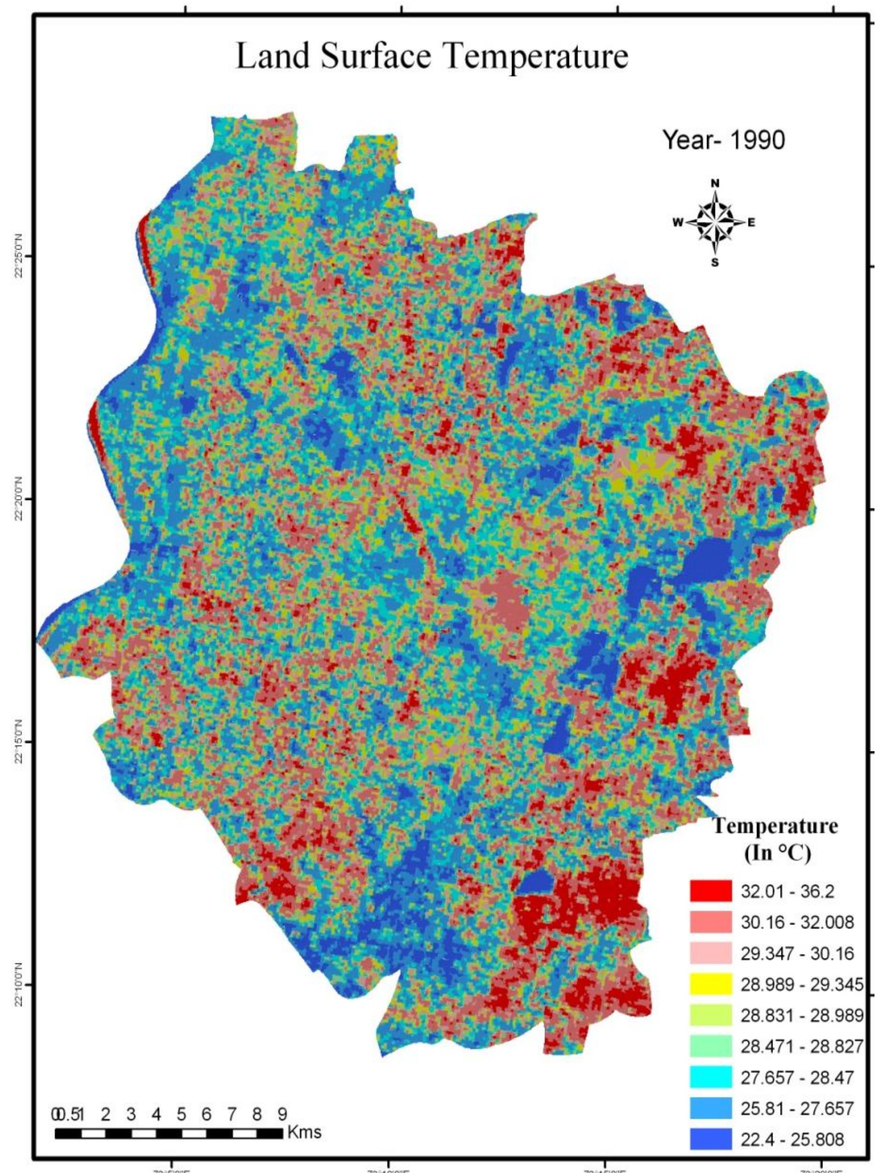

Figure 1: Land Surface Temperaturen(Year 1990)

in 2009. However, the vegetation and water body had lower temperature as compared to the built-up; also interestingly, it was seen for lakes which are relatively dried and encroached showed higher temperature. The role of Eutrophication and temperature in lakes needs to be investigated further.

As seen for 1990 there was the formation of distinct UHI owing to the central city location. However, in due course of growth and development, it is seen that the city has expanded, but the expansion is not continuous but inter mixed with open space. This forms several micro urban heat islands (MUHIs) instead of UHI, which can be monitored and can be prevented for expanding the heat regime by proper sectoral plan.

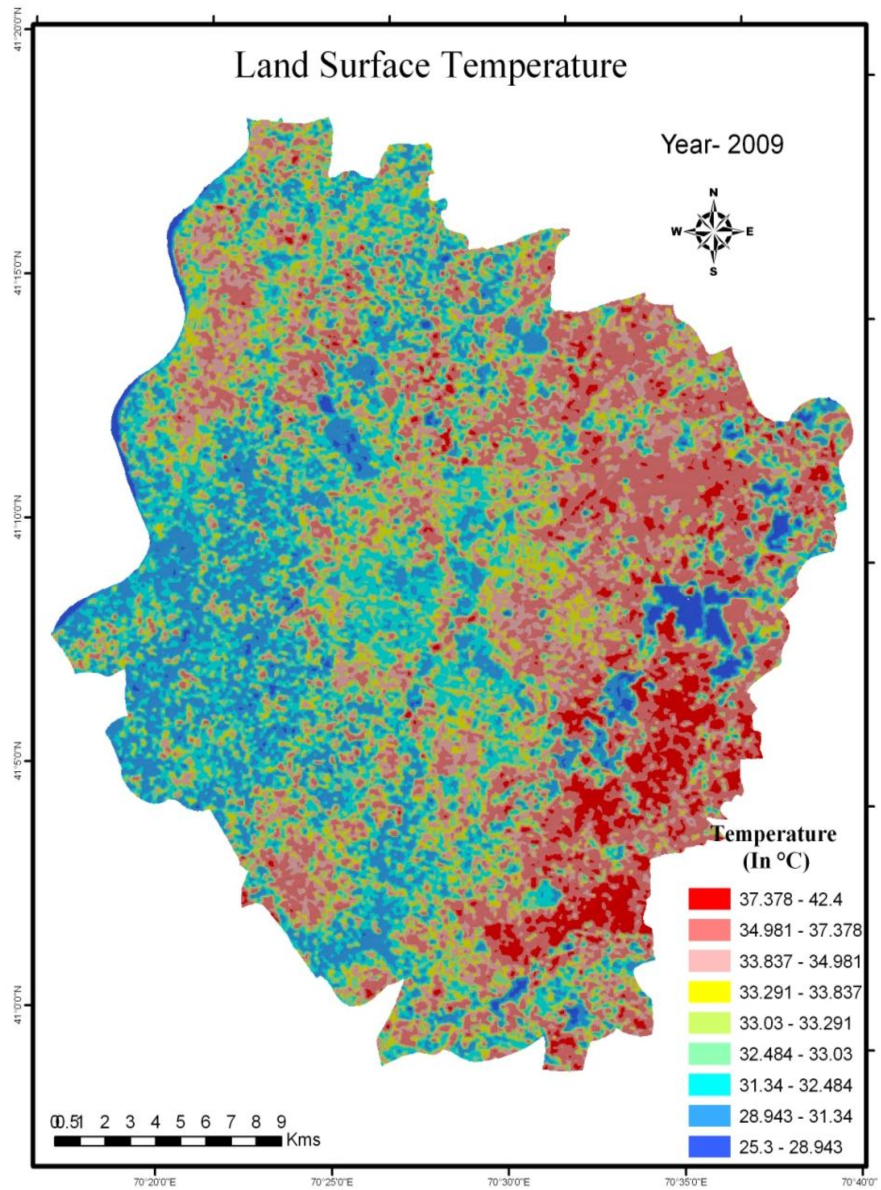

Figure 2: Land Surface Temperature, Year 2009

The effect of agricultural development, increasing evaporation during the day, would also tend to decrease the maximum temperature. Irrigation would increase the heat capacity of the soil, thus increasing the minimum temperature. Here, it is seen that the eastern part, which comprises of patches of the current fallow, records the highest thermal characteristic, which may be due to its dryness as the crops are harvested at this time of the year.

The study suggests that built-up classification in urban areas with diverse structures and interspersed vegetation and water body in varying percentage can well be employed to identify the heat sinks and islands using thermal data. This would also be greatly useful for monitoring

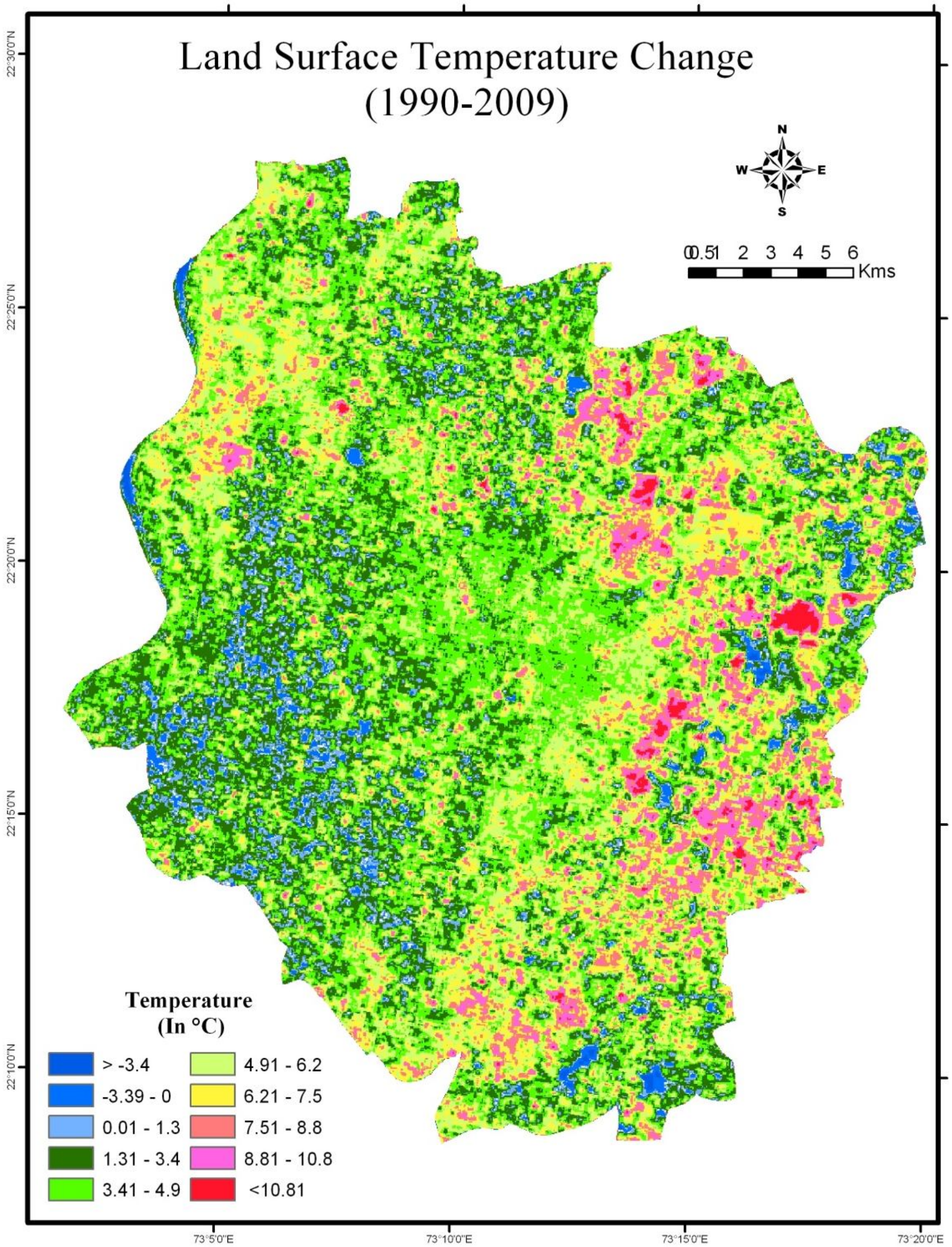

Figure 3: Land Surface Temperature change for 1990-2009

the temperature changes within the urban areas showing degradation of vegetation and added built-up area. The higher temperature zone identified and correlated to the centers of urbanization through the present study, can be managed using suitable measures to maintain the heat flux in the environment. The patches of vegetated area and the network of water bodies play a critical role in regulating the temperatures within the Vadodara urban environment. This assumes that a planned growth of vegetation, intermixed with the concrete structures, can play a part in controlling the formation of heat islands within the urban areas. A proper ecofriendly urban settlement design is the need of quickly developing new built up areas.

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