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Research Article

Spatial and Temporal Change Assessment in Land Surface Temperature of Lahore using GIS and Remote Sensing Techniques

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Abstract: This study is an attempt to evaluate Land Surface Temperature (LST) variations of Lahore, a metropolitan city of Pakistan. LST have wide-ranging application viz; global climate change, urban climate, evapotranspiration, hydrological cycle and environmental studies. Therefore, Spatio-temporal assessment of LST variation is becoming vital to recognize the contributing factors and corresponding magnitude of contribution to the variation using GIS and remote sensing techniques. This study employed the radiative transfer method in assessing Spatio-temporal LST change using multi-temporal imagery acquired by Landsat 5 TM and Landsat 8 TIRS satellite data, for the year 1990 and 2015, respectively. Thermal infrared images of Landsat satellite revealed its suitability in monitoring temporal change in LST. The results indicated that high mean LST was recognized in the areas of Shalamar town, Gulberg town, Data Ganj Baksh town and Ravi town. On the other hand, the low mean LST was observed in the areas of Aziz Bhatti town, Samanabad town, Wagha town and Iqbal town in 1990.The results further showed that the areas of Gulbarg town, Wagha town, Shalamar town, Ravi town, Nishter town and Iqbal town, had been warmer in the year 2015 than the year 1990. It was assessed that in the areas of Aziz Bhatti town, Nishtar town and Wagha town, there were no urbanization and urban development. Therefore the lowest LST was measured in the year 1990. However the expansion and urban development of Lahore in these areas increased surface radiant temperature and they reflect highest LST assessed in 2015. The present study explores the suitability of employing GIS and satellite remote sensing techniques in finding out the spatial and temporal temperature change to achieve accuracy in terms of urban planning, decision and policy making for sustainable urban environment of Lahore.

Keywords: LST, Temporal change, Heat Island, Urban warming, Landsat, Town, Lahore.

1. INTRODUCTION

Radiative temperature of land, generally recognized as Land Surface Temperature (LST) [1,2], is a significant parameter in the physics of land surface processes from local to global scales [3-5]. LST is controlled by land-atmosphere heat exchange and solar radiation [6]. It plays an important role in water and energy transfers between land surface and atmosphere [7]. Therefore, Spatio-temporal distribution of LST not only reveals the variations of climate factors but also recognizes the characteristics of land surface. A comprehensive understanding of spatial and temporal change assessment of LST variations is significant for a range of studies, comprising climatology, meteorology, vegetation and hydrology etc. [8].

The land surface temperature in urban areas is increasing gradually as a consequence of massive land use changes taking place due to urban expansion [9]. It has led to reduction in agricultural land and loss of vegetation and green area in cities around the world [9]. A number of studies indicate that the land surface temperature of cities is generally (1-6°C) higher than those of the adjacent rural areas. This phenomenon is named Urban Heat Island (UHI) [10, 11]. Since 1800, studies concerning the recognition of rising temperature phenomenon in urban areas have increased and it has significantly [12]. Several scholars [10-14] documented that temperature in urban areas varied from those of the nearby countryside, in line with the greenhouse effects produced by use of carbon fuelled machinery. The cities, in this regard, consume 60 to 80% of energy produced globally and are contributing to CO_2 emission with equal share [15]. This comes as no surprise

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that cities signify areas with higher density of population and center of human activities. Several contributing factors include, automobile, industry, heat generating human activities, thermodynamic capacities of material, structural geometry and impervious surfaces are responsible for trapping and re-radiation of heat in the atmosphere. These factors in turn change the environmental conditions that alter the near-surface atmospheric temperature over the urban areas. Urban built-up area and bare land can have a particularly high impact on LST [16]. LST has a positive relationship with built-up area and shows negative relationship with blue and green spaces and forest cover [17]. Major decrease in green area affects the equilibrium of energy and heat exchange, leading towards intensification of surface temperature and declinein evapotranspiration and precipitation simultaneously [18-19]. Not only the high density areas, but also buildings and their structures matter and impervious surfaces of complicated shapes also tend to increase the land surface temperature.

A number of techniques have been developed and adopted in the past to assess LST based on data obtained from meteorological stations [20]. Since the 1970s, satellite derived images and thermal infrared data have man advantages. Resultantly, most of the urban climate studies preferably utilized thermal data for regional LST analyses on different scales [21-24]. For instance, satellite remotely sensed data permits the acquisition of thermal data over a region and very large areas and also provides a lot of information. On the other hand, traditional method and direct measurements only provide point data. Another significant advantage of satellite remotely sensed data is that it is very economical and generally easy in acquiring thermal data, while direct measurement method is tremendously expensive and time consuming for the assessment of whole of the region where as thermal data from the satellite cover whole of the region and area of interest at same time. It is on this basis that GIS and remote sensing technology is adopted for the extraction of LST in the study area. This study aims at estimating spatial and temporal change assessment in land surface temperature of Lahore at town level. Therefore, there are two specific objectives of the present study. The first objective is to accomplish quantitative analysis to measure spatial and temporal change of land surface temperature of Lahore at town level for the year 1990 and 2015, using Landsat 5 (band 6) and Landsat 8 (band 10 and 11) thermal infrared data. The second objective is to make town wise LST map of Lahore for the year 1990 and 2015 using GIS and remote sensing techniques.

1.1. Study Area

The area selected for this study, Lahore, shown in Figure 1 is the capital city of punjab provice and second largest metroplitan city of Pakistan in term of population [25]. According to the provisional census report of 2017, Lahore population is about 11 million [26] and whole of the district Lahoreis declared an urbanized area [26]. Geographically the extent of Lahore is ranging from 31°-15' to 31°-43' N latitide and 74°-10' to 74°-39' E logitude (Figure 1) [25]. Lahore is surrounded by Sheikhupura district located in north and west, the two districts are separated by the river Ravi. It has Amritsar, a distrcit of India in the east while in the south, it has Kasur district of Pakistan [25]. Lahore covers an area of 1,772 km^2. The average elevation of district Lahore is about 217 m and characterized by a flate landscape [25]. Administratively, Lahore is divided into nine towns and Cantonment area [27]. Area wise, Iqbal town the largest town of Lahore, covers an area of 476.79km^2, while Shalamar town, the smallest town of Lahore, comprises an area of 26.88km^2 (Figure 1). Moreover, 80 percent of total area of Lahore district is occupied by 3 towns-Wagha town, Nishtar town and Iqbal town, while Shalamar town has the least area of about 15 Km^2 i.e. less than 1% of total area of the district. The area of the remaining five towns i.e. Samanabad town, Ravi town Gulberg town, Data Ganj Bukhsh town and Aziz Bhatti town occupies between 2 to 5 percent of the district area. Lahore has extreme climate with hotest weather in the months of May, June and July [25]. The mean minimum and maximum temperature for these months are 27.3 and 40.4 degree centigrades, respectively. The coldest months of the year are January and February. The minimum and maximum temperature for these months are 7.2 and 21.1degree centigrades, respectively [25].

2. MATERIAL AND METHODS

2.1. Data

Landsat satellite imagery was the primary source of

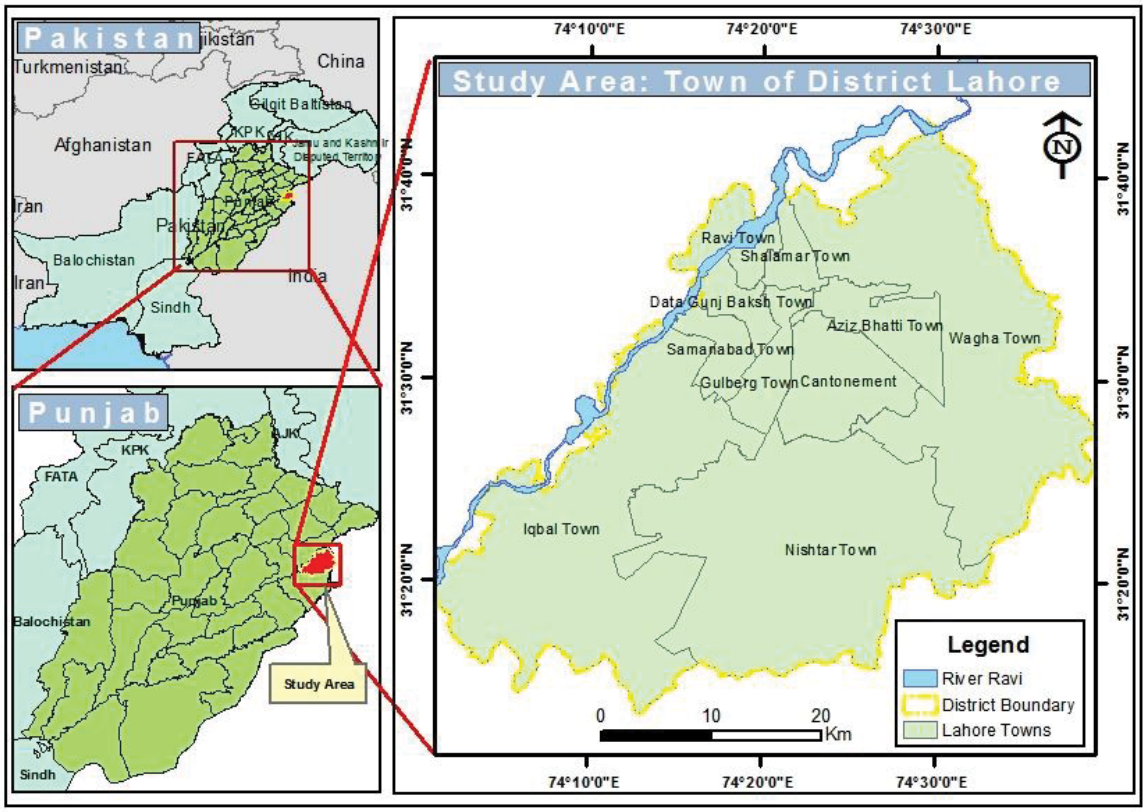


Fig. 1. Location Map of the study area (Lahore)

Table 1. Metadata of Landsat (5, and 8) Satellite Images

Date of Acquisition	Sensor	Bands	Spatial Resolution	Thermal Resolution	Path/Row
16 March 1990	TM	1-5 & 7	30m	-	149/38
		6	-	120m	
21 March 2015	OLI	1-8	30m	-	149/38
		Pan (9)	15m	-	
	TIRs	10 &11	-	100m	

data because of its temporal and spatial resolution and free availability. In total, two Landsat satellite images were collected for this research. Primary data was acquired through multi-source, multi-date and multi-sensor satellite images for the year 1990 and 2015 provided the data source for the Spatio-temporal change analysis of LST of the study area. Urban expansion and consequent change in temperature are assessed through Landsat 5/ TM, and Landsat 8/OLI_TIRs images for the year 1990 and 2015 respectively. These Landsat images were acquired and downloaded from U.S. Geological Survey database and from the site of http://landsat.usgs.gov/, according to the suitability and availability due to cloud cover (the acceptable cloud cover should not be more than 10%). The specifications and details of the acquired Landsat imagery are presented in Table 1. Global Land Cover Facility (GLCF) helps in understanding the environmental system deeply providing earth science data and its products. Satellite Remote Sensing (SRS) is, certainly, the most effective tool of monitoring, detection and estimation of temporal variation of temperature [28, 29].

2.2. Methodology

The overall research methodology of the present study is shown in Figure 2. Several studies have been accomplished on the relative hotness or "UHI effects" of metropolises to assess the air temperature using metrological data. Traditional

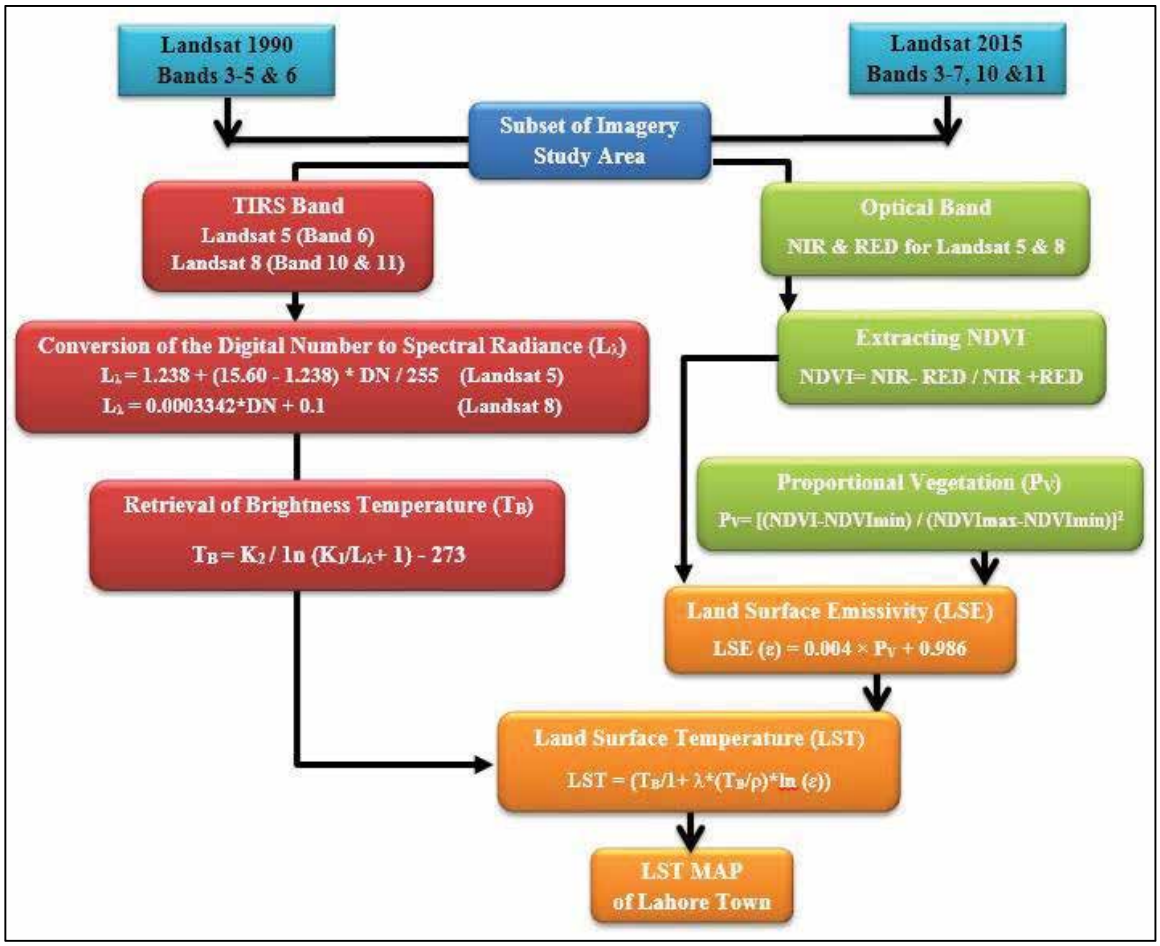


Fig. 2. Overall Methodology and Process of Land Surface Temperature Retrieval

techniques of obtaining data on temperature comprise direct observations using meteorological weather observatory. These measurements with high temporal resolution through weather observatory are expensive, time consuming and problematic for spatial interpolation as they have local and point coverage. Satellite sensors are capable of providing quantitative physical data at high temporal and spatial resolutions. A range of algorithms [30] has been established to estimate surface temperature from Landsat satellite 5/TM, 7/ETM+ and 8/TIRS imagery, such as single-channel method, mono-window algorithm [31] and radiative transfer method [32]. In the present study, the radiative transfer method is utilized to assess the spatiotemporal change in land surface temperature of Lahore. TIRS band 6 of Landsat 5/TM and TIRS band 10 and 11 of Landsat 8 were processed to retrieve the LST. Optical bands of Landsat-5 and 8 were analyzed to derive NDVI values to calculate land surface emissivity value to retrieve LST accurately. The detailed process and steps of retrieval of LST [33-36] are shown in Figure 2.

3. RESULTS AND DISCUSSION

The outcomes of this study reveal that the city of Lahore over the last few decades has experienced a rapid population and urban growth. The expansion of built-up areas in Lahore city has influenced the local climate. The urban climate of Lahore is affected not only by factors of global climate change in the South Asian region but indigenous factors also. The emission of CO_2 in particular, and greenhouse gases in general, contribute towards urban warming in Lahore. The significant variation in temperature trends of Lahore shows increase in temperature during various years. Moreover, land surface temperature is also progressively rising in Lahore. One of the leading causes is reduction in the vegetation and green area in the city. Lahore is undergoing rapid expansion of urban areas and it has caused formation of UHI. The UHI phenomenon

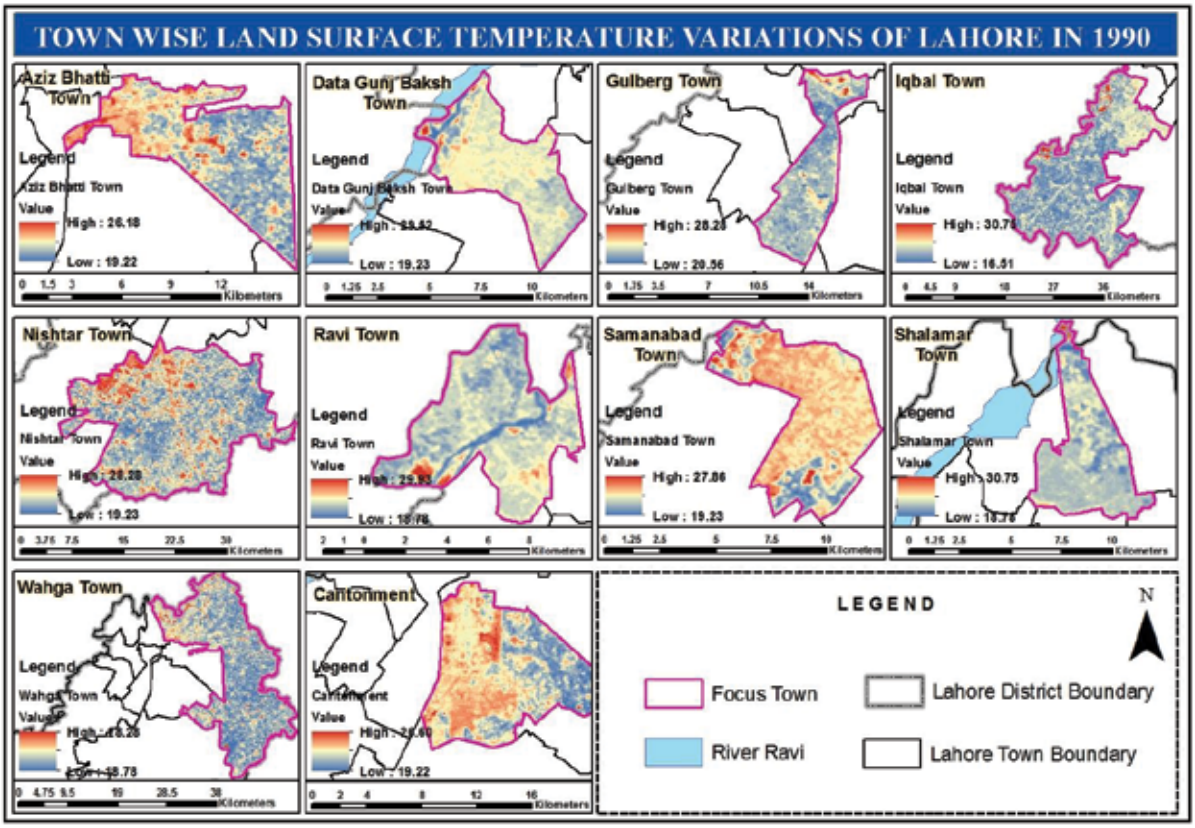


Fig. 3. Town wise comparison of land surface temperature of Lahore in 1990

requires the comprehensive analysis of LST spatial variations in order to investigate its mechanism and locate possible solution. Urban heat island effect in Lahore can be compared with the effects observed in the major cities on the globe like London [37], Beijing [38], Tokyo [39], Delhi [40] and Shanghai [41] and the contrast calls for modification in action plans to mitigate UHI effects.

The town wise comparative study of land surface temperature for the year 1990 and 2015 reflects the higher temperature with the extension of development going-on in the peri-urban regions. Some of the hot spots in the entire study region boast heat islands effects. The town wise LST mapof 1990, shows that high temperature areas were Shalamar town, Gulberg town, Data Ganj Baksh, Ravi, Nishtar and Iqbal town, as given in Figure 3. The mean LST variation between towns was 24.77°C to 23.63°C (Figure 5). Whereas, town wise LST map of March 1990, as shown in Figure 3, exhibits that low land surface temperature areas were Wagha town, Samanabad town, Aziz Bhatti town and Cantonment of Lahore. The mean land surface temperature variation of these towns was 22.71°C to 23.53°C (Figure 5).

For comparison, LST was also assessed for March 2015, as shown in Figure 4. According to the estimation, 1.98°C LST has increased in last 25 years. According to the town wise LST map of 2015, high temperature areas were Gulbarg town, Wahga town and Cantonment as shown in Figure 4. It is observed as per Figure 4 that Gulbarg town, Wahga town, Ravi town, Nishtar town, Iqbal town, Shalamar town and Cantonment were warmer in the year March 2015 than the year March 1990. LST observed in these towns ranged from 25.17°C to 27.85°C (Figure. 5). It is worth mentioning that in the area of Aziz Bhatti town, Nishtar town and Wagha town, there were no urbanization and development. Therefore the lower temperature was experienced in the year 1990, it ranged from 22.71°C to 23.76°C. However the expansion and urbanization of Lahore in these areas increased temperature in 2015, it ranged from 25.41°C to 26.14°C as compared to 1990 (Figure 5).

In the conclusion of the present research, the LST variations are examined and it is showed that there is a significant change in the land use

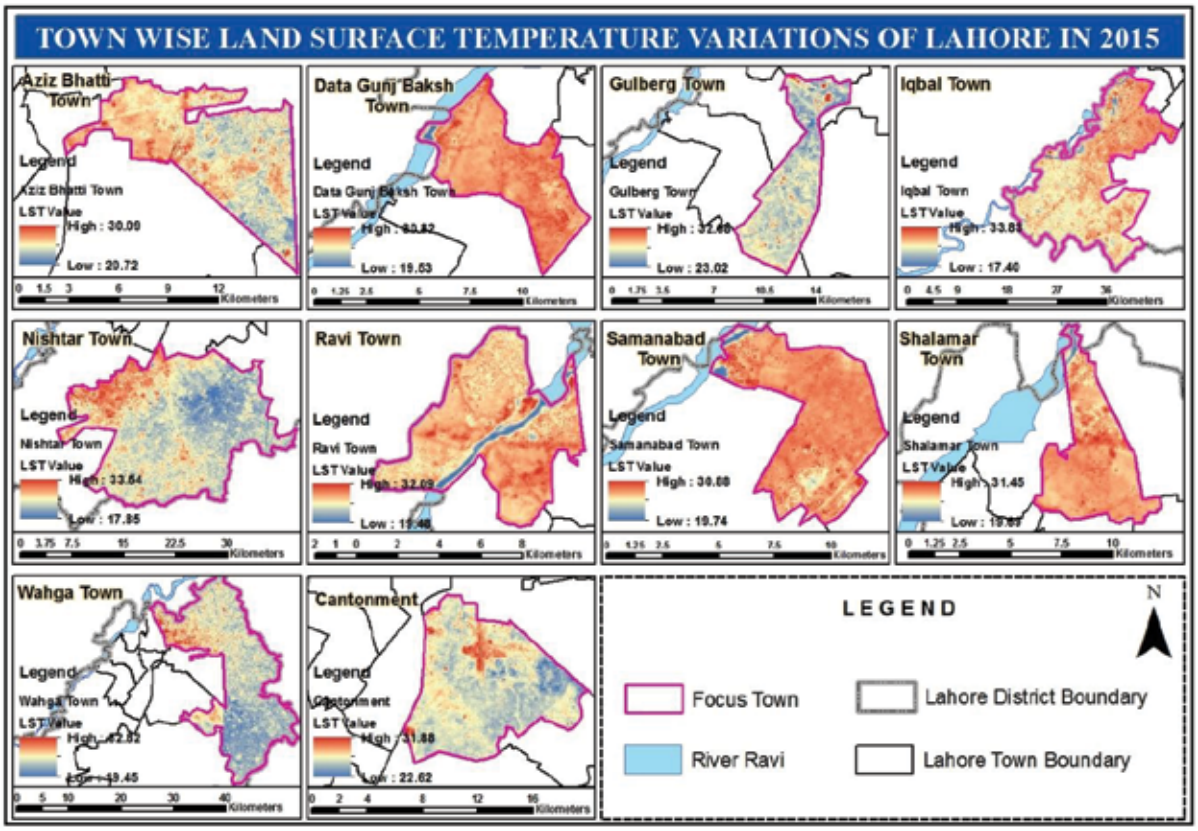
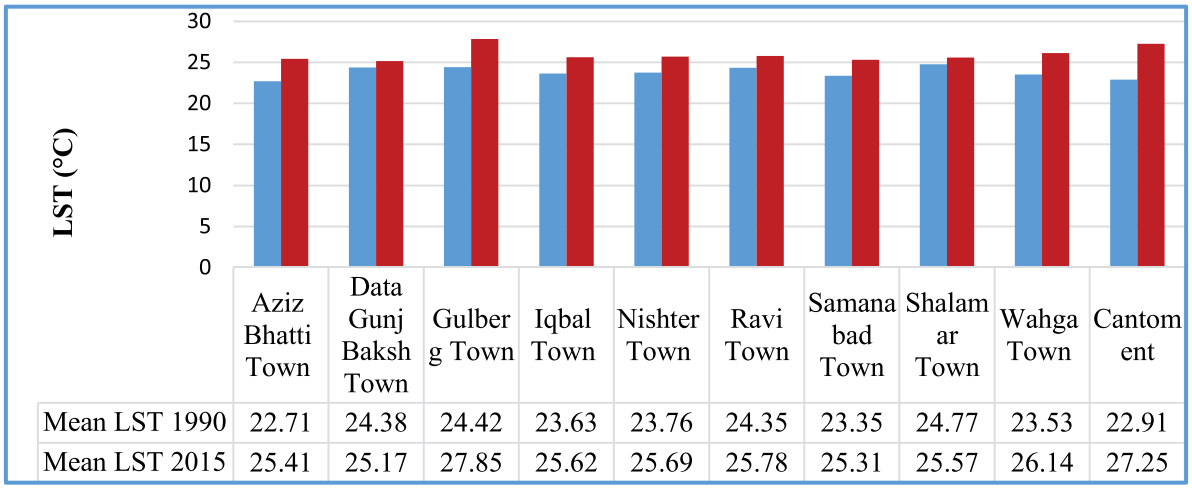


Fig. 4. Town wise comparison of land surface temperature of Lahore in 2015



	Aziz Bhatti Town	Data Gunj Baksh Town	Gulberg Town	Iqbal Town	Nishter Town	Ravi Town	Samanabad Town	Shalamar Town	Wahga Town	Cantonment
Mean LST 1990	22.71	24.38	24.42	23.63	23.76	24.35	23.35	24.77	23.53	22.91
Mean LST 2015	25.41	25.17	27.85	25.62	25.69	25.78	25.31	25.57	26.14	27.25

Fig. 5. Town wise trends of land surface temperature of Lahore in 1990 and 2015

in terms of temperature comparisons as displayed in Figure 3 and 4. The reduction of the diversity of species and damage to the eco-system can be attributed to the conversion of natural vegetation and consumption of the cultivated land into built-up area. The built-up areas comprise buildings, pavements, parking lots, roads and respective infrastructure. All these building materials and concrete contribute towards the increase in land surface temperature of Lahore. In built up land, the highest temperature is recorded, followed closely by the vacant land, while the temperature is less

in the areas with water bodies and vegetation as shown in Figure 3 and 4. Similarly, transportation and the combustion of the vehicles add to more air pollution, creating health issues and contributing towards smog problem. The growing number of industries in Lahore has also been a contributing factor in increasing land surface temperature. The process of intensification of land surface temperature of Lahore is gradual, but persistent. One of the major issues in intensification is the reduction in green area in the city. It is significant to note that the consumption of the cultivated land and green spaces has been transformed into built-up areas and impervious surfaces, resulting in increased temperature in Lahore. The assessment of environmental conditions and measures for the policy making for the protection of the environment can be carried out by considering the above mentioned factors.

4. CONCLUSION

The study has shown the usefulness of GIS techniques and remote sensing data in assessing spatiotemporal LST variation in different towns of Lahore between 1990 and 2015. The land surface temperature of Lahore is increasing gradually as a consequence of massive land use changes taking place due to urban expansion. The study also confirmed that the urban development had increased LST in study area by 1.98°C within 25 years. The expansion of built-up areas in Lahore has influenced the local climate. In most of the densely populated and industrial areas of Lahore has high temperature is being experienced. It is significant to note that the cultivated land and green spaces had been transformed into built-up areas and eventually in impervious surfaces, resulting in increase in temperature of Lahore. One of the leading causes is reduction in the agricultural land and greenarea in the city. Finally, the combination of RS and GIS techniques has demonstrated that it is an effective and efficient methodology for analyzing and monitoring patterns of land use change and its effect on land surface temperature. Moreover, the present research shows that the integration of proportionate urban built-up area and greenery spaces can provide a significant measure to reduce urban heat island effect in Lahore. The conclusions drawn from the study signify that the development and the maintenance of green spaces are critical in sustainable urban environment and reduction of adverse effects of increased LST on the urban dwellers. These measures can reduce the urban warming and related effects of the climate change.

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