RESEARCH PAPER

Diurnal variations in land surface temperature of Metropolitan Lahore

Aisha Khan[*], Sheikh Saeed Ahmed

Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi, Punjab, Pakistan

Abstract

As natural and human induced changes to the earth surface causes the thermal heterogeneity to surface temperature of the earth surface, the remotely sensed thermal infrared (TIR) data obtained for the determination of Land Surface Temperature (LST) provides a continuous global coverage to determine and quantify these changes effectively. In this study, diurnal variations in the LST of Lahore were determined from the duration of 2000-2020 using MODIS data. MODIS Terra Satellite data of MOD11A1 and MOD11A2 was used to extract the daytime and nighttime LST variations respectively in the study area. The outcome indicated the spatial increase in the LST of Lahore leading to the increase in the urban heat island effect in the area as well.

*Corresponding Author: Aisha Khan ✉ aishahayat85@yahoo.com

Introduction

As natural and human induced changes to the earth surface causes the thermal heterogeneity to surface temperature of the earth surface, the remotely sensed thermal infrared (TIR) data obtained for the determination of LST provides a continuous and global coverage to determine and quantify these changes effectively (Khan *et al*., 2021, Liang, 2018). By controlling the effective radiating temperature of the surface of the earth, land surface temperature (LST) becomes the main determinant of overall terrestrial thermal behavior. Surface temperature is dependent on the surface conditions (Owen, Carlson & Gillies, 1998; Voogt & Oke, 2003; Nichol & Wong, 2005). Rapid change in the heating and cooling of the surfaces, comparatively to the air, causes higher surface temperatures during midday versus nighttime in comparison to the air temperature (Roth *et al*., 1989). Urban heat islands have many types and scales. To determine different UHIs at different scales many observational and modeling methods and technologies have been developed to obtain a qualitative and quantitative assessment of UHI. Using remote sensing and GIS technology is one such methodology, particularly for determination of spatiotemporal changes via determining LST. It is achieved by using the thermal sensors installed on air-crafts and satellites (Runnalls & Oke, 2000; Arnfield, 2003; Mirzai & Haghighat, 2010; Roth, 2013). It is one of the most pursued methodology especially due to the advancement in sensors resolutions and the access to data even for the remote areas due to the internet. With respect to UHI, the use of thermal sensors for quantification of its magnitude is mostly utilized. However, the images available are limited in its temporal patterns. Therefore, the data is obtained via multiple satellites and multiple sensors, for example MODIS images are used in order to understand the diurnal differences in UHI albeit the time stamp limitations (Sidiqui, Huete & Devadas, 2016). The research will help in comprehending the extent of variation existing in the day/night LST and subsequently day/night UHI of the urban areas of Lahore and will help in the development of the most appropriate policy interventions for the development of sustainable city in accordance with the requirements of global environment.

Materials and methods

Study Area and Method

The capital and the largest district of the province of Punjab is Lahore (Government of Punjab, 2018). Lahore city, the 2nd largest city of Pakistan in terms of population, is the 22nd largest city in the world on the basis of population (UNDES, 2022). It is the most developed district in the province and the census of 2017 showed that its population is entirely urban. Lahore is also the only megacity in Pakistan where the population has increased to more than double value in the (census) time span of 1998-2017 i.e., from 5.14 million to 11.13 million (Pakistan Bureau of Statistics, 2017; TBY, 2020).
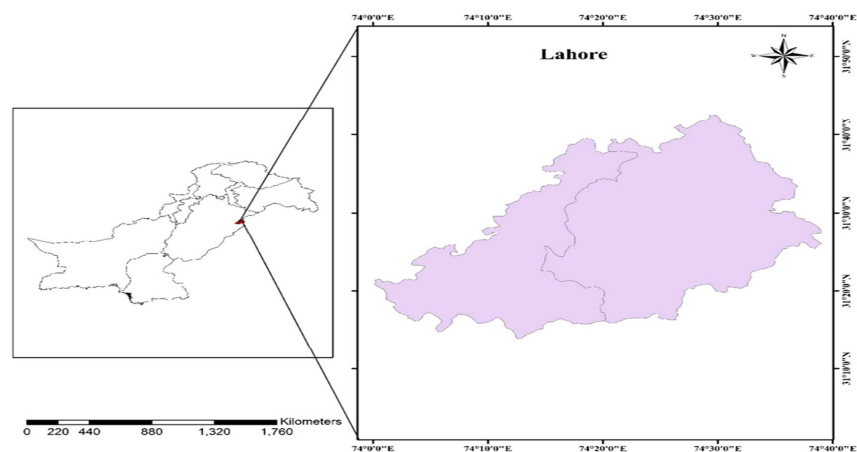

Fig. 1. Study Area Map-District Lahore.

Data collection

The Terra-Moderate Resolution Imaging Spectroradiometer (Terra-MODIS) Land Surface Temperature/Emissivity Daily (MOD11A1) and 8-Day (MOD11A2) Version 6.1 products were obtained for May 24, 2000 and May 27, 2020. The former provides daily per-pixel Land Surface Temperature and Emissivity (LST&E) and later provides an average 8-day per-pixel LST&E dataset. The images obtained have spatial resolution of 1 kilometer in a 1,200 x 1,200-kilometer grid.

Results and discussion

Day-Time Land Surface Temperature

The day time Land Surface Temperature for the years 2000 and 2020 for Lahore, Punjab is presented in Fig 2 (2000) and Fig 3 (2020).
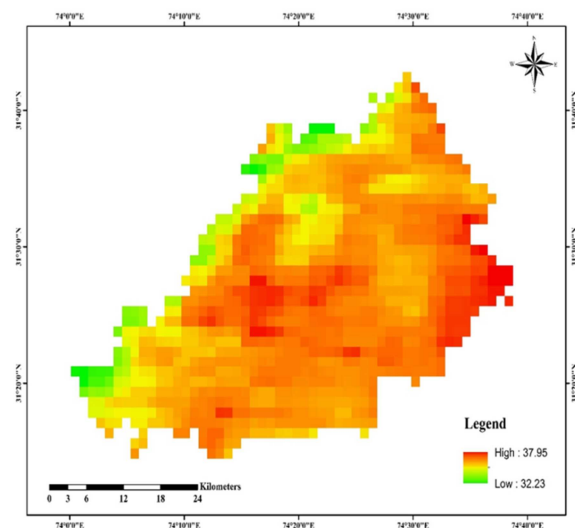

Fig. 2. Day time LST of Lahore, 2000.

The day time land surface temperature values for Lahore assessed from the RS image obtained from Terra MODIS is presented. The minimum LST is 32.23°C and the maximum LST is 37.95°C. The Day-time LST of District Lahore for the year 2020 is presented in the Fig. 3. The maximum temperature is 49.23°C and the minimum temperature is 38.45 ° C. The minimum temperature shows an increase of 6.22°C. The maximum temperature has increased by 11.28°C. The area in the medium to high temperature range has increased. The minimum LST of 2020 is higher than the maximum LST of 2000.
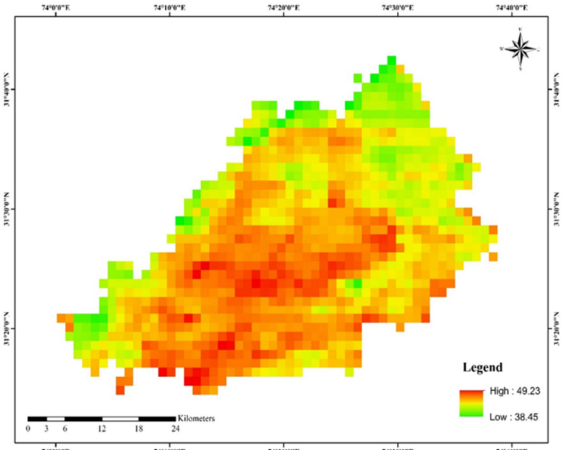

Fig. 3. Day time LST of Lahore, 2020.

Night-Time Land Surface Temperature

The night time Land Surface Temperature of Lahore for the years 2000 and 2020 is presented in the Fig. 4 and Fig. 5 respectively as follows. The minimum temperature for the year 2000 is recorded as 22.25°C and the maximum temperature during the night is recorded as 28.15°C. The minimum LST for 2020 during the night is 22.65°C and the maximum LST is 26.97°C. The maximum LST for 2000 and 2020 is 26.97°C and 31.57°C respectively. The minimum LST has shown an increase of 0.46°C and the maximum land surface temperature during the night has shown an increase of 4.6°C. The temperature range at night time has increased from 4.32°C (2000) to 8.46°C (2020) and also areas exhibiting the high LST has increased. Most of the area of Lahore exhibit a medium to high LST during the night in 2020.
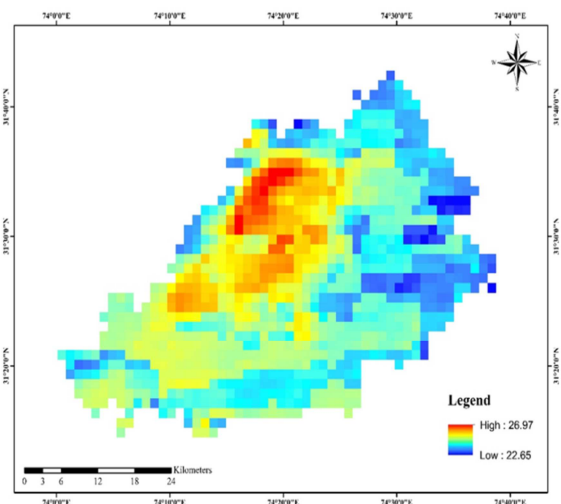

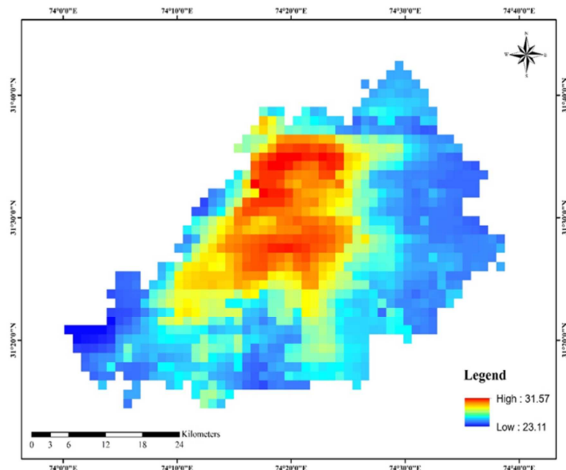**Fig. 4.** Night time LST of Lahore, 2000.

Fig. 5. Night time LST of Lahore, 2020.

Therefore, the Maximum day-time LST of Lahore has increased by 0.564°C year. The night-time LST for Lahore has increased by 0.023°C year for the minimum night-time LST and for maximum night-time LST, the increase is by 0.23°C year. The spatial coverage for maximum night-time LST had also increased in 2020 for urban core area of Lahore.

Conclusion

The overall increase in the diurnal land surface temperature of Lahore metropolitan for maximum and minimum values and for day and night indicates the increase of urban heat island effect in the area particularly for the duration of 2000-2020. Lahore is a completely urban area and any is developing continuously. The increase in LST of Lahore is not limited to the increase in the increase in the numerical value of temperature. The LST increase in Lahore is also spatial increase i.e., the area with high LST has also increased leading to the overall increase in urban heat island of the study area. In order to prevent the resulting degradation of the built-environment due to the continuous increase in diurnal LST, cooperative efforts and contribution of all the stakeholders is required. These include policy makers, the governmental and non-governmental sectors, the residents, the urban developmental planners and the researchers. The study further recommends the urgency in identification and implementation of the tailored mitigation efforts suited for the area for the curbing of the increasing

LST as soon as possible as any further delay will result in further increase in renumeration required to compensate for even the minimum of the negative impacts on the environment.

References

Arnfield AJ. 2003. Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. International Journal of Climatology **23**, 1-26.

Khan A, Chatterjee S, Weng Y. 2021. Characterizing thermal fields and evaluating UHI effects. Urban Heat Island Modeling for Tropical Climates 37-67. Elsevier.

Liang S. 2018. Recent progress in Remote Sensing of Earth's Energy Budget. Comprehensive Remote Sensing **5**, 1-31. Elsevier.

Mirzaei AP, Haghighat F. 2010. Approaches to study Urban Heat Island- Abilities and limitations. Building and Environment **45(10),** 2192-2201.

Nichol J, Wong WS. 2005. Modeling urban environmental quality in a tropical city. Landscape and Urban Planning, **73(1),** 49-58.

Owen TW, Carlson TN, Gillies RR. 1998. An assessment of satellite remotely-sensed land cover parameters in quantitatively describing the climatic effect of urbanization. International Journal of Remote Sensing **19(9),** 1663-1681.

Roth M, Oke TR, Emery WJ. 1989. Satellite-derived urban heat islands from three coastal cities and the utilization of such data in urban climatology. International Journal of Remote Sensing, **10,** 1699-1720.

Roth M. 2013. Urban heat islands, in: H.J.S. Fernando (Ed.), Handbook of Environmental Fluid Dynamics, Systems, Pollution, Modeling, and Measurements, Vol. **2,** CRC Press, New York (US).

Runnals KE, Oke TR. 2000. Dynamics and Control of the Near-Surface Heat Island of Vancouver, British Columbia. Physical Geography **21,** 283-304.

Sidiqui P, Huete A, Devadas A. 2016. "Spatio-temporal mapping and monitoring of Urban Heat Island patterns over Sydney, Australia using MODIS and Landsat-8,". 4th International Workshop on Earth Observation and Remote Sensing Applications (EORSA) 217-221.

The Business Year. 2020. From Karachi to Lahore: Pakistan: 4- Top cities. United Nations Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3.

Voogt JA, Oke TR. 2003. Thermal remote sensing of urban climates. Remote Sensing Environment **86,** 370-384.