Temporal Analysis of Land Surface Temperature (LST) Dynamics (2003-2023) Using Geospatial Techniques

Rokovotso Nagi[1], Kedovikho Yhoshu[2]

[1] Research Scholar, Department of Geography; Nagaland University, Lumami. 79862, India
Email: *rokonagi7[at]gmail.com*

[2]Assistant Professor, Department of Geography; Nagaland University, Lumami. 798627, India
Email: *kedovikho[at]nagalanduniversity.ac.in*

Abstract: ***The study examines the spatio-temporal fluctuations in Land Surface Temperature (LST) throughout five significant years-2003, 2008, 2013, 2018, and 2023-in the West Kohima district. Satellite-derived thermal imagery was employed to produce land surface temperature maps for evaluating temperature distribution and temporal variations. The analysis indicates a persistent increase in surface temperatures, accompanied by a notable expansion of high-temperature regions (exceeding 31°C), especially in the northern and eastern sectors of the study area. These findings highlight the consequences of urbanization, vegetation depletion, and alterations in land use/land cover on thermal dynamics, leading to localized warming and possible urban heat island phenomena. The research underscores the necessity for sustainable urban planning and vegetation preservation to alleviate the detrimental effects of increasing temperatures on the local climate and community health.***

Keywords: Geospatial, Landsat, Land Surface Temperature (LST), West Kohima District

1. Introduction

Land Surface Temperature (LST) is a critical metric for assessing the energy equilibrium between the Earth's surface and the atmosphere. It is affected by land utilization, vegetative cover, urban development, and climatic alterations. The extraction of Land Surface Temperature (LST) from remote sensing data has become an essential instrument in analyzing and comprehending the dynamics of Urban Heat Islands (UHI) [7,8]. Increasing land surface temperature can result in significant environmental and socio-economic consequences, such as heat stress, modified hydrological cycles, and loss of biodiversity. Nevertheless, despite the comprehensive study undertaken on UHI analysis, issues remain in estimating UHI spatial patterns across time due to inherent limitations, utilizing definitive LST values. The normalization of LST has been suggested as a method to effectively compare spatial distributions of LST [5]. This study examines the temporal pattern of land surface temperature (LST) from 2003 to 2023, with the objective of identifying geographical trends and potential sources of surface warming. However, factors like spatial autocorrelation in normalized land surface temperature readings require additional scrutiny when evaluating urban heat island patterns over time. [4]. The study seeks to delineate spatial differences in Land Surface Temperature (LST) for the years 2003, 2008, 2013, 2018, and 2023, while examining its temporal dynamics across two decades to discern trends associated with urbanization, land-use alteration, and climate variability. It aims to assess the environmental consequences of increasing land surface temperature (LST), encompassing effects on microclimate, human health, agriculture, water resources, and biodiversity, so offering a comprehensive perspective on surface temperature variation and its ramifications. Initially, verdant and permeable land surfaces are progressively being supplanted by impermeable materials like asphalt and concrete. Secondly, the concentration of densely populated urban areas. Increased populations have resulted in heightened anthropogenic heat emissions and greenhouse gas outputs. [1,2,9]. Land Surface Temperature (LST) is extensively employed to delineate the urban thermal environment and examine Urban Heat Island (UHI) dynamics at both local and regional levels. [6,10]. Recent study has further revealed that LST is influenced by a combination of biophysical, landscape, and socioeconomic factors [3,11].

2. Study Area

The study area is under Kohima district under the state of Nagaland on the North-East of India with an area of 352.7 sq. km. This area is located on the foothills of Mt. Japfü range situated on the Southern part of Nagaland. The geographical location of Kohima is between 25°6′ and 27°4′ latitude, North of Equator and between the longitudinal lines 93°20′ E and 95°15′ E. the study area comprises of western Angami region with places like Khonoma, Jotsoma, and Sechu Zubza, Mezoma, Sechuma, Kiruphema, Peducha, Dzuleke, Dzudza Village. The study area is important since it holds vast scope for developmental activities chiefly due to ongoing rail head connectivity and 4 lane road connecting Kohima and Dimapur. The impact of globalization and modernity will have immense impact in the form of urban heat island, lesser NDVI values, higher rate of settlement and lesser moisture content etc.

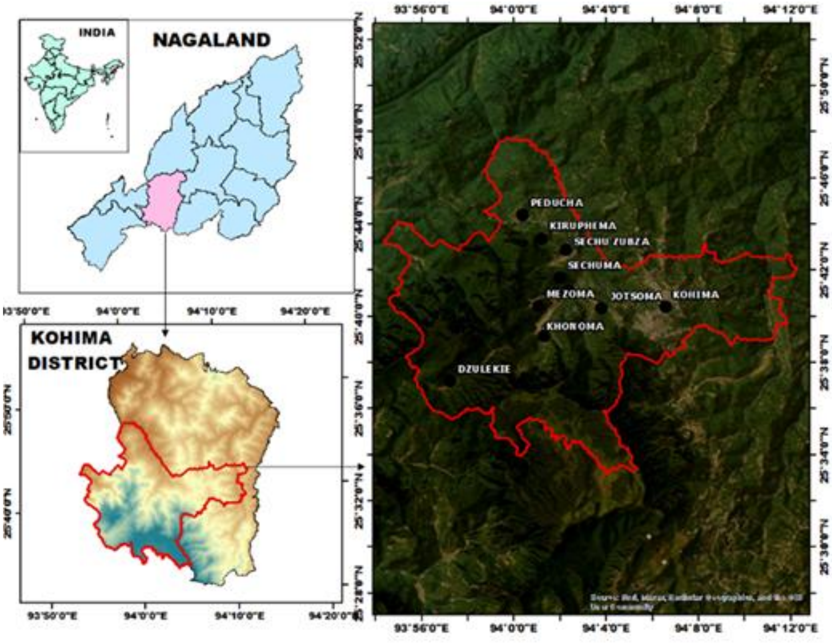

Figure 1: Location map of the study area (West Kohima District)

3. Data and Methodology

a) **Data Sources**: Thermal bands collected from Landsat were utilized to extract Land Surface Temperature (LST) for the years 2003, 2008, 2013, 2018, and 2023.

b) **Processing:** The images were rectified, standardized, and transformed into LST values in Degree Celsius. Temperature ranges were categorized as follows: < 21°C, 21–25°C, 25–29°C, 29–31°C, and > 31°C.

c) **Analysis:** Land Surface Temperature (LST) maps were produced annually, thereafter undergoing spatio-temporal comparison to identify alterations in temperature zones.

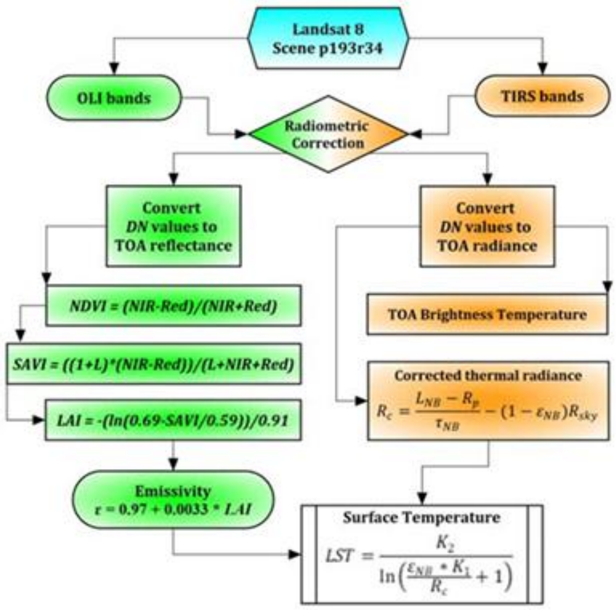

Figure 2: Flow chart of the methodology.

4. Discussion

The study reveals a distinct warming trend over the past twenty years. The escalating prevalence of high-temperature regions correlates with swift alterations in land use, diminished plant cover, and the proliferation of urbanized areas. The southern regions including those of Khonoma and Western Dzükou valley maintain a cooler climate owing to dense vegetation, whereas urbanized areas have elevated land surface temperatures, signifying the emergence of heat islands. These results correspond with worldwide trends of surface warming and urban development.

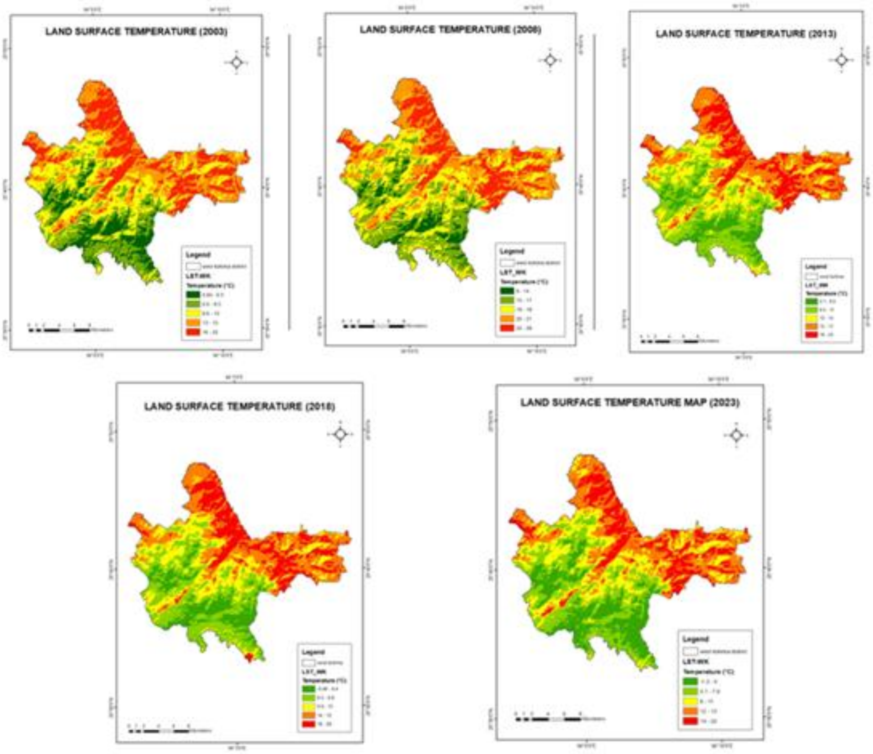

Figure 3: Spatial distribution of Land Surface Temperature (LST) in West Kohima District of the years (2003, 2008, 2013, 2018, 2023)

5. Results

The spatio-temporal analysis of Land Surface Temperature (LST) from 2003 to 2023 indicates a distinct trend of surface warming and the strengthening of thermal hotspots. In 2003, most of the region displayed moderate temperatures between 21–29°C, with only a few areas above 31°C. By 2008, elevated temperature zones (29–31°C) commenced their expansion, especially in central regions, signifying the initiation of localized warming. The year 2013 signified a notable intensification, with expansive regions above 31°C, underscoring the increasing prevalence of thermal stress. The warming trend became increasingly geographically apparent in 2018, as the centre and eastern regions witnessed substantial heating, but the southern sections remained relatively cooler. By 2023, the region documented the highest percentage of land area exceeding 31°C, indicating a persistent and concerning escalation of surface warming over the past two decades. These findings not only indicate the increasing trend in land surface temperature (LST) but also highlight the regional heterogeneity of warming patterns, with consequences for urban planning, ecosystem sustainability, and climate adaption methods.

6. Environmental Implications

The escalation of land surface temperatures presents complex difficulties with significant consequences for human and environmental systems. Increasing heat stress significantly impacts human health and comfort, elevating the risks of heat-related ailments and diminishing general liveability, especially in highly populated regions. Simultaneously, elevated surface temperatures expedite evapotranspiration and diminish soil moisture, consequently jeopardizing agricultural productivity and water accessibility. These thermal fluctuations also contribute to the modification of local climate systems, with urban heat island effects becoming increasingly evident and intensifying temperature extremes in developed areas. Moreover, the ongoing intensification of heat stress disturbs ecological equilibrium, exerting pressure on biodiversity and compromising the resilience of natural environments. These implications highlight the pressing necessity for adaptive methods that tackle human vulnerability and environmental sustainability amid increasing surface temperatures.

7. Conclusion

The temporal analysis of Land Surface Temperature (LST) from 2003 to 2023 indicates a notable and continuous increase in surface heating, with thermal hotspots increasingly prevalent in the regional landscape. Initially limited regions of excessive temperatures have, over the last twenty years, proliferated into vast areas consistently surpassing 31°C, signifying both an increase in average temperatures and a spatial escalation of heat stress. This increased trend highlights the increasing susceptibility of both human and natural systems to severe temperatures. Heightened heat stress directly impacts public health by diminishing thermal comfort and elevating the risk of heat-related ailments, especially among at-risk groups such as the elderly and outdoor labourers. Simultaneously, increased land surface temperature accelerates evapotranspiration and depletes soil moisture, compromising agricultural output and straining water resources. The intensification of the Urban Heat Island (UHI) effect in metropolitan regions disrupts local climate regulation, increases energy requirements for cooling, and aggravates greenhouse gas emissions. The ecological consequences are similarly significant, as biodiversity and habitat stability are increasingly jeopardized by extended heat exposure. These findings underscore the pressing necessity for sustainable land management techniques, urban greening initiatives, and climate adaption strategies to mitigate the effects of increasing surface temperatures. Incorporating green infrastructure, advancing afforestation, utilizing reflecting and permeable materials, and enhancing community resilience are vital strategies to alleviate the compounded effects of thermal stress and promote environmental sustainability amid a changing climate.

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Author Profile

Rokovotso Nagi, Research Scholar, Department of Geography; Nagaland University, Lumami. 79862.
Email: *rokonagi7[at]gmail.com*

Dr. Kedovikho Yhoshu, Assistant Professor, Department of Geography; Nagaland University, Lumami. 798627.
Email: *kedovikho[at]nagalanduniversity.ac.in.*
Specialization/ Area of Interest**:** Physical Geography, RS & GIS application in Geosciences, Planetary Sciences, Geohazards and Urban Environment.