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Detection of the Change in Land cover and Land Surface Temperature of Dhaka District from 1989 to 2019

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A B S T R A C T

This study investigates the changing of land cover (LC) and land surface temperature (LST) in Dhaka city over a span of three decades (1989-2019). Utilizing satellite images and remote sensing techniques, the temporal evolution of various land cover types, including built-up areas, vegetation, water bodies, and bare soil were mapped. The findings indicate a significant increase in built-up areas, accompanied by a decline in vegetation and water bodies. This transformation has led to an observable rise in LST, particularly in densely urbanized zones. The correlation analysis revealed a strong inverse relationship between vegetation cover and LST, emphasizing the cooling effect of green spaces and water bodies as well as the warming effect of dense urban areas. The study underscores the importance of proper urban planning and green infrastructure in mitigating the urban heat island effect and enhancing the livability of Dhaka city. The insights derived from this research can guide policymakers in sustainable urban development and climate adaptation strategies.

Keywords: *Land cover, LST, GIS, Remote sensing, Dhaka, UHI.*

1. Introduction

The Urban Heat Island (UHI) phenomenon is a significant factor contributing to the warming of urban micro-climates (He et al., 2007). It is characterized by the elevated air and land surface temperatures (LST) in cities compared to their neighboring regions (Ahmed et al., 2013). The urban heat island effect is becoming a growing concern in metropolitan regions, particularly in areas where climate change is escalating the occurrence of extreme temperature events (Braun et al., 2023). UHI is linked to various local challenges including biophysical threats, heightened air pollution, and resultant public health issues. Thus, devising strategies to counter UHI has become a pivotal policy objective to diminish urban micro-climate heating and to improve the quality of urban life, ensuring public health and overall well-being (Patz et al., 2005). This study delves into the aspects of land cover and LST related to the UHI effect.

Land cover describes the natural features found on the Earth's surface, while land use pertains to how areas are utilized for human-related activities (Burley T.M, 1961; Chamling & Bera, 2020; Lo, 1986). Recognizing changes in land use and land cover (LULC) promptly and accurately is vital for both macro and micro sustainable development of any region (S. Kumar & Singh, 2021). Humans, being the planet's most dominant modifiers, perpetually alter land use and cover. Historically, through urbanization, agriculture, industry, settlements, and other activities, humans have reshaped the landscape to cater to their needs and ensure their survival (Taloor A.K., 2020). Furthermore, the adverse effects of climate change in recent decades, manifested as droughts, salinization, and rising sea levels, have directly impacted the patterns of land use proportion variations (Phuong et al., 2020).

Studies have found that various elements play a role in creating UHI, including shifts in land use like urban growth, the reduction of plants and water sources, and more. The primary cause of these land alterations is urbanization, which is seen as a major factor influencing UHI (Chen et al., 2006; Kalnay et al., 2003). Changes in land cover, such as transitioning from greenery to non-absorbent surfaces like pavements and rooftops, are the primary reasons for variations in LST. This is because different land covers have distinct energy radiation and absorption characteristics.

Remote sensing data can be utilized to examine changes in land use and land cover across various temporal and spatial scales, especially as landscapes evolve in structure, location, and size (Stow et al., 1990). Geospatial tools are the best means to assess these changes in land use and cover. GIS is invaluable for planners, as it facilitates the combination of data from various origins and enables spatial analysis, making processes that once took a long time much quicker. GIS comprise data management tools that utilize geographic data to produce valuable insights (R. Kumar, 2022). Both remote sensing and GIS technologies offer potent techniques for evaluating land use issues and furnish tools for land use planning and simulation (Kumar S, 2018). By merging satellite information with data on drainage, rock types, and land use or cover, a more precise evaluation of land formations and the state of eroded terrains can be achieved (S. Kumar, 2017)

Drawing from the discussion, this study sets forth two primary goals: firstly, to map the land cover and land surface temperature in the Dhaka district for the years 1989 and 2019; and secondly, to analyze the transformations in land cover and land surface temperature in the Dhaka district over the span of three decades.

2. Study area

The research took place in Dhaka, Bangladesh's capital. Recognized as one of the world's rapidly expanding mega-cities, Dhaka is situated in the heart of Bangladesh, along the eastern side of the Buriganga River at coordinates 23° 42′ N 90° 22′ E. It's surrounded by the districts of Munshiganj, Gazipur, Narayanganj, Rajbari, Tangail, and Manikganj. Positioned in the Ganges Delta's lower parts, Dhaka spans an area of 306.38 square kilometers, marked by tropical flora and damp soil on a terrain that's predominantly flat and near the sea level. Dhaka stands out as one of the world's most crowded mega-cities with a high density of inhabitants. The city's growth, largely due to the influx from rural areas, has been pinpointed as a key factor in the rise of its local surface temperature (Ahmed, 2011).

3. Materials and methods

3.1 Materials

Landsat satellite images of the year 1989, and 2019 were obtained from the US Geological Survey (USGS) official website and used to fulfill the research goals. Landsat 5 images were used for the year 1989, while for the year 2019, Landsat 8 images were analyzed. The research site is situated in the Landsat's path 137 and row 44. The images were processed using the Universal Transverse Mercator (UTM) projection situated within Zone 46 North, in conjunction with the World Geodetic System (WGS) 1984 datum. Each pixel in the images measured 30 x 30 meters. Given that the photos were taken at different times, atmospheric conditions could vary. Nonetheless, the images underwent processing to become level-one terrain-corrected (L1T) products. L1T ensures consistent radiometric and geometric precision by integrating ground control points and using a Digital Elevation Model (DEM) for topographical accuracy. The geodetic precision of this product is determined by the reliability of the ground control points and the DEM's resolution (Ahmed et al., 2013).

3.2 Methods

The obtained satellite images were classified into six land cover types like, Water, Grassland, Forest, Urban, sparsely vegetated and Bare land. However, for effective analysis, these classes were compressed into four categories, like, Water body, Vegetation, Urbanization and Bare land. The images were examined based on their spectral and spatial characteristics to establish training sites (Ahmed, 2011). A specific color composite (RGB = 742) was employed to digitize polygons around every training site for same land cover. Subsequently, a distinct identifier was allocated to every recognized land cover category (Table-1) (Ahmed & Ahmed, 2012).

Table-1: Land covers and their respective colors in the images.

Identifier (Color)	Land cover
Blue	Water
Light green	Grassland
Olive Green	Forest
Magenta	Urban
Brown	Sparsely Vegetated
Pink	Fallow Land

The surface radiant temperature is obtained from the geometrically corrected TM and ETM+ thermal infrared (TIR) channel, specifically band 6. This band captures radiation in the spectral range of 10.4–12.5 μm emanating from the Earth's surface. These corrected images are devoid of distortions associated with the sensor, satellite, and the Earth itself.

While the influence of the daily heating cycle on LSTs would be a compelling topic to explore, this study did not delve into it. The reason being, TM/ETM+ images don't offer both day and night infrared visuals on the same day. Consequently, the LST variability at the satellite's overpass time across different years wasn't examined. Additionally, since absolute temperatures weren't employed for calculations, no atmospheric correction was applied at this juncture, meaning radiometric normalization wasn't executed. These aspects can be viewed as potential constraints of this study. The LST values were extracted from individual thermal images and then contrasted across various time frames (Ahmed et al., 2013)

4. Results and discussion

Figures 1(a) and 1(b) illustrate the changes in land cover in the Dhaka district between 1989 and 2019. The analysis reveals that urbanization in the district grew from 10.4% in 1989 to a staggering 70.2% by 2019. Water bodies, which covered 14.5% of the area in 1989, shrank to just 5.75% in 2019. Vegetation covers also decreased from 24% in 1989 to 13.75% in 2019. Conversely, bare land expanded from 30.67% in 1989 to 38.28% in 2019.

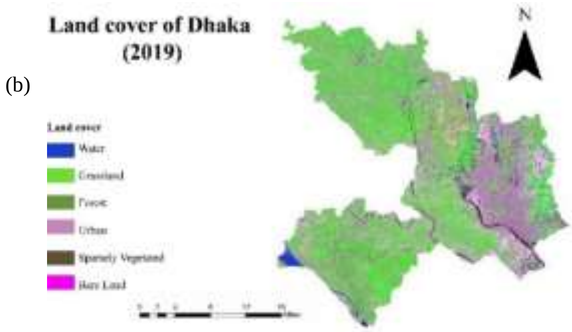
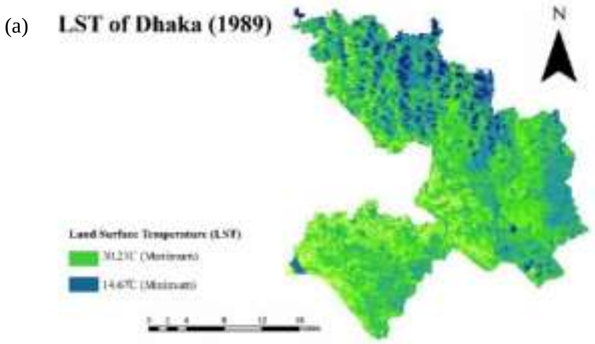


Fig 1(a) Land cover in Dhaka district during 1989 Land cover in Dhaka district during 2019

Figures 2(a) and 2(b) present the land surface temperature (LST) changes in the Dhaka district over the same period. In 1989, the highest LST recorded was 30.21°C, which rose to 35.71°C by 2019. The lowest LST in 1989 was 14.67°C, and this increased to 20.17°C in 2019.



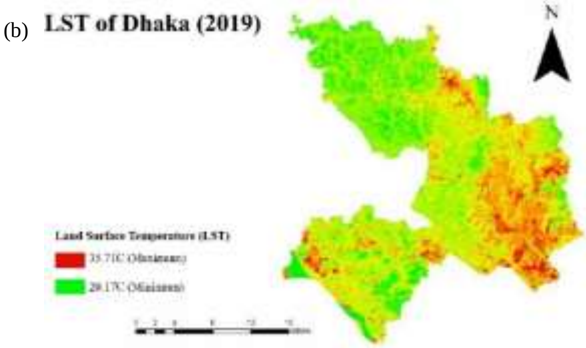


Fig 2(a) LST in Dhaka district during 1989 **Fig 2(b)** LST in Dhaka district during 2019

In summary, between 1989 and 2019, Dhaka district experienced a 60% surge in urbanization. Vegetation and water bodies saw reductions of 10.25% and 9%, respectively. Bare land coverage grew by 7.61%. Additionally, the average LST in the district rose by 5.5°C over these three decades.

5. Possible Measures

The rapid change in land cover and the upward trend in land surface temperature have become serious issue for the environment of Dhaka city. Reducing the adverse effects of these events requires a combination of mitigation and adaptation strategies. Implementation of green and cool roofs to reflect sunlight and absorb less heat, and increasing green spaces and urban forests to provide shade may be introduced to the urban planning and design to reduce the urban heat island effect. Also, planning for compact, mixed-use developments may be executed to reduce heat generated by extensive pavement and buildings. Besides, Afforestation and Reforestation should be encouraged. Effective water management, including the implementation of green infrastructure and sustainable water practices, aids in maintaining soil moisture. The use of cool pavements and reflective materials, along with promoting renewable energy sources and energy-efficient building designs, contributes to overall temperature reduction. Smart irrigation practices in agriculture, coupled with education and awareness programs, should be promoted for sustainable living.

6. Conclusion

Today, the adverse effects of climate change rank as one of the top challenges facing humankind (Sutradhar et al., 2023). The factor which contributes to the climate change in micro level, is UHI. Over the course of three decades, from 1989 to 2019, Dhaka city has witnessed profound transformations in its land cover, as evidenced by meticulous analysis of satellite imagery and remote sensing data. The urbanized area in the district has seen a staggering increase from a mere 10.4% in 1989 to 70.2% by 2019, marking a 60% surge in urbanization. This rapid urban expansion has come at a significant environmental cost, with vegetation cover dwindling by 10.25% and water bodies shrinking by 9% over the same period. Concurrently, bare land, which accounted for 30.67% of the district's area in 1989, expanded to encompass 38.28% by 2019.

The environmental consequences of these land cover changes are further highlighted by the upward shifts in land surface temperature (LST). The data reveals that the maximum LST in Dhaka has risen by a concerning 5.5°C over the 30-year span, with temperatures in 1989 recorded at 30.21°C and soaring to 35.71°C by 2019. Similarly, the minimum LST has also seen an upward trend, increasing from 14.67°C in 1989 to 20.17°C in 2019.

These findings not only emphasize the cooling effect of green spaces, as evidenced by the strong inverse relationship between vegetation cover and LST, but also underscore the pressing need for sustainable urban planning. The rapid urbanization, coupled with the decline in natural green spaces and water bodies, has exacerbated the urban heat island effect, posing challenges to the livability and environmental health of Dhaka city. It is imperative for policymakers to harness the insights from this research to shape sustainable urban development and climate adaptation strategies, prioritizing the integration of green infrastructure to mitigate rising temperatures and enhance the city's resilience.

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