A Case Study of the Temporal Evaluation of the Urban Heat Island (UHI) Effect: Impacts on Water Availability and Air Quality of Dhaka City

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Introduction

The Urban Heat Island (UHI) effect is becoming a big issue for Bangladesh's bustling capital city of Dhaka. Due to this phenomenon, it gets noticeably warmer in urban areas than in nearby rural areas. This 'urban heat island' effect is caused by several factors, including reduced ventilation and heat-trapping due to the proximity of tall buildings, heat generated directly from human activities, the heat-absorbing properties of concrete and other urban building materials, and the limited amount of vegetation. Continued urbanization and increasingly severe heatwaves caused by climate change will amplify this effect in the future. Dhaka's UHI has far-reaching and negative consequences. Temperature increases cause thermal discomfort, exacerbating many residents' already difficult living conditions [1] [2]. The existing UHI-based studies in the context of Dhaka city have still not addressed the statistical relationship between UHI and several indicators (individually), such as water availability, air quality, and vegetation index. Therefore, the current study focuses on filling the study gap. The study will be insightful for sustainable urban planning and environmental management by better understanding the above-mentioned complex relationship and help to develop an enhanced understanding of Dhaka's urban heat dynamics and their influence on water availability and air quality. Additionally, the outcomes will be helpful for policymakers to increase resilience to minimize the adverse effect of UHI in quickly rising cities like Dhaka.

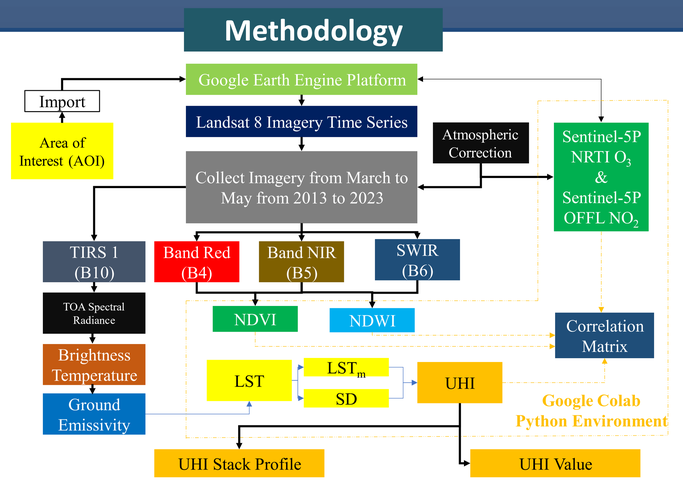
Objectives

In this study, we aim:

(1) To examine the temporal evolution of urban heat in Dhaka using the developed UHI map to identify trends, patterns, and hotspots.

(2) To explore the relationship between air quality, urban heat, water availability, and vegetation index of Dhaka city.

Methodology



LST: Land Surface Temperature; LSTm: Mean of Land Surface Temperature; SD: Standard Deviation of Land Surface Temperature; UHI: Urban Heat Island; NDVI: Normalized Difference Vegetation Index; NDWI: Normalized Difference Water Index; SWIR: Shortwave Infrared; NIR: Near Infrared

Figure 1: Schematic representation of the study workflow

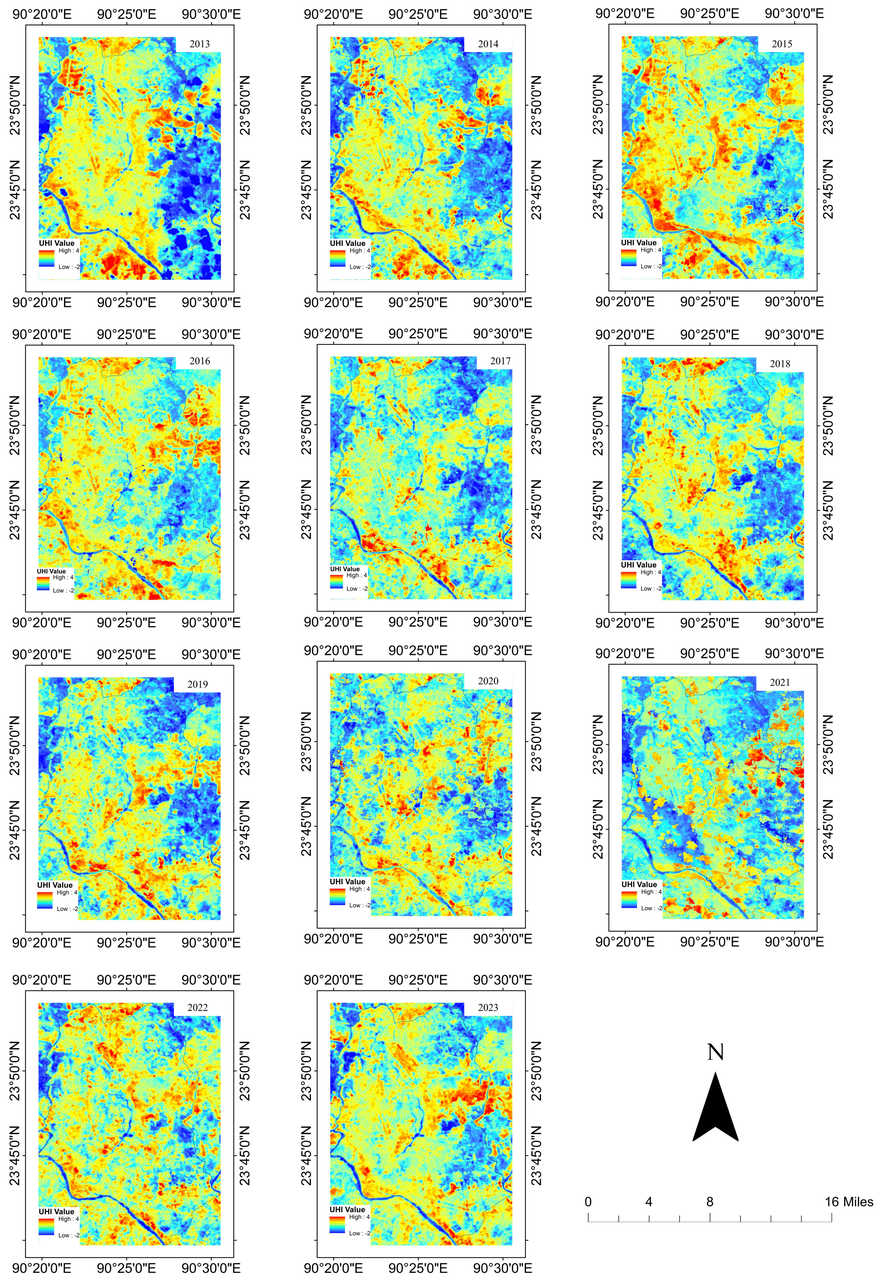


Figure 2: Urban Heat Island (UHI) intensity of Dhaka City from 2013 to 2023

Results

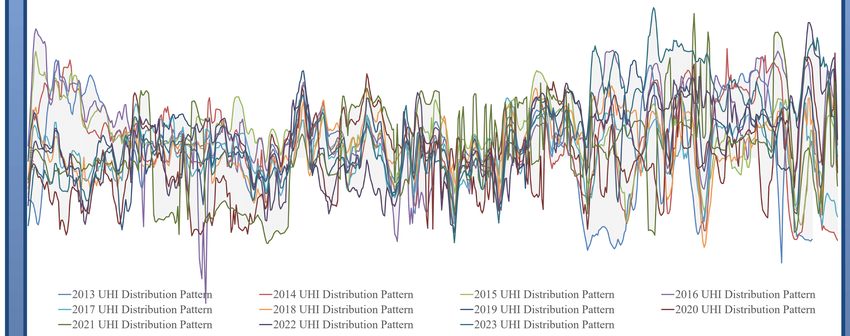


Figure 3: Urban Heat Islan (UHI) distribution pattern of Dhaka city from 2013 to 2023

The data presented in Figure 2 clearly shows that the Urban Heat Island (UHI) value has experienced a significant increase over the last ten years. The UHI phenomenon is a condition when urban areas experience higher temperatures than their surrounding rural areas due to human activities such as transportation, industrialization, and construction. Figure 3, on the other hand, presents an insight into the stack profile distribution during this period. Although there have been fluctuations in the stack profile, the graph shows a significant rise in the UHI profile since 2016. The temperature rise in UHI in Dhaka city is nearly 6°C, which is a cause for concern. The increase in temperature can adversely affect the environment, public health, and urban infrastructure.

This research indicates that Urban Heat Island (UHI) has a strong positive correlation with some air quality indexes such as Ozone (O_3) and Nitrogen Dioxide (NO_2) for Dhaka city. On the other hand, Urban Heat Island (UHI) has a negative correlation with the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) for Dhaka city.

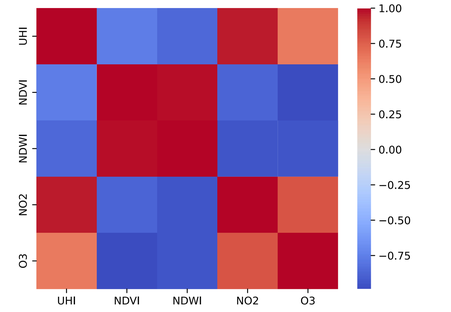


Figure 4: Correlation Matrix

Conclusion

This study aims to understand the Urban Heat Island (UHI) phenomenon and its relationship with water availability and air quality. UHI is the increase in temperature in urban areas compared to surrounding rural areas due to human activities and heat-absorbing materials. Further research is needed to provide concrete evidence of UHI's impacts, considering factors like land-use patterns, urban design, and green spaces. It's essential to assess the impact of UHI on human health, biodiversity, and energy consumption. This study highlights the critical need to understand the implications of UHI on urban areas and develop effective strategies to mitigate its effects. Doing so can ensure a more sustainable and livable future for urban residents.

Reference:

[1] Intergovernmental Panel on Climate Change, 2021. Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009157896.

[2] Trego, S., Meerow, S., & Keith, L. (2023). Heat planning in small and medium-sized cities: A collaborative application of PIRSTM for heat in Kent, WA, USA. Socio-Ecological Practice Research, 5(4), 409–422. https://doi.org/10.1007/s42532-023-00166-6

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