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RESEARCHARTICLE

ASSESSMENT OF URBAN HEAT ISLAND USING GEOSPATIAL TECHNIQUES: A CASE OF VAGAMON HILL STATION, KERALA

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ABSTRACT

This study investigates the formation of Urban Heat Island (UHI) of Vagamon, a hill station, Kerala, India, with a focus on winter months (December and January). While UHI is typically studied during summer, this study examines its presence and characteristics in cooler months of winter season. Utilizing satellite imagery from 2013 and 2024, the study employs Land Surface Temperature (LST), Normalized Difference Built-Up Index (NDBI), and Normalized Difference Vegetation Index (NDVI) for analysis. The findings reveal the presence of UHI in Vagamon during winter. Four specific UHI spots exhibit high LST and high NDBI, indicating a correlation between built-up structures and high surface temperatures. Temporal analysis from 2013 to 2024 suggests an increase in UHI intensity, with the spatial extent when low UHI values decreases in Vagamon. This highlights the potential expansion of UHI further in Vagamon. Notably, despite the area's rich ecosystem and high elevation, UHI formation persists even during winter. The study concludes that non-climatic factors like land-use change (LULC), urbanization, and human activities contribute to UHI development in Vagamon, even within its winter months. The increasing UHI intensity necessitates mitigation strategies to reduce surface temperature and safeguard the ecological balance of this unique hill station.

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INTRODUCTION

Densely populated areas, especially urban landscapes are producing heat more than the country side creating a microclimate because of various man-made activities that occurs with advanced technology (NIHHIS). The overall situation of land surface temperature is amplifying largely owing to land use change which eventually converts green vegetation cover land surface to heat emission built up areas (Congyuan Li and *at el*, 2023). The effect of such piled-up heat island is a serious issue to human health and well- being as given strong impact on pollution related mortality and reduction of the habitats comfort(Parham A Mirrzaei,2015 and Abbas Mohajerani and *at el*, 2017). The spatial extension of Urban Heat Island (UHI) and its intensity varies between the far-off rural areas, rural inhabitant areas, peri -urban areas and small urban areas to large urban areas or mega cities. Larger the urbanized areas, there will be large difference of temperature between the rural and urban, and the UHI predominance is strongly related with the expansion of urban areas (Amed S, 2018).The variation and magnitude of LST will naturally depend on the artificial built-up structure, economic activities, population density, mode of transportation, location and terrain in addition to global warming.

The estimated LST can be examined collecting the data products from satellite images along with those associated parameters including observed data of the place / area sothat one can understand and take necessary action for abating the impact of temperature increase. A serious effect of UHI is that it couples to exacerbate extreme events such as heat waves, triggering of cyclonic wind and unexpected weather phenomena creating volatile atmospheric situation as there is highly unstable atmospheric condition above the surface. Because, changing of land cover properties alters the thermal condition, surface radiation and humidity of the urban areas (Manisha Maharjan and *at el*, 2021). Through urbanization the green land cover is replaced by impervious land surfaces of concrete buildings and bituminous roads, so there is need to evaluate UHI of urban center to analyze for changing in surface albedo, emissivity and evapotranspiration (Oke, TR, 1973). Since, the growth of urbanization continues in both vertical and horizontal scales, UHI phenomenon is rising all over the world that ultimately brings hazards to the normal natural and human systems by changing rainfall patterns, worsening air quality, increasing flood risk, decreasing water quality , among others. The quantification of UHI based on observational and simulation methods is essential to know the direct and indirect risks exerted causing extreme heat stress due to rising temperature on surface and near surface.

The findings may able to predict and mitigate the UHI phenomenon (Parham A Mirzaei and Faribarz Haghighat, 2010). A broad range of techniques and measuring methods are also available using ground based fixed and transient data, satellites airplanes, radio sounds and meteorological models to access UHI and distribution (RuiSilva *at el*. 2021),At the same time a significant number of studies focusses on the observation and prediction of the spatio-temporal UHI variation (Anupriya RS and Rubeena, 2023). Emphasising on UHI spatial and temporal variation, this study aims to investigate the unique wintertime Urban Heat Island (UHI) effect in the hill station of Vagamon, Kerala, India, by leveraging satellite imagery and geospatial techniques.

Study Area: Vagamon, a picturesque hill station nestled amidst the majestic Western Ghats in Kerala, India. It has thepopulation of about 14,641 persons residing within its 78 square kms area. Vagamon's location is marked by coordinates 9°41′16″ North and 76°54′25″ East, placing it near the border of both Kottayam and Idukki districts (Fig.1). The hill station has its breathtaking beauty with the lush green vegetation and rolling hills punctuated by vibrant tea and coffee plantations. The undulating topography creates a visually stunning environment of the station. Being about 1,200 meters above sea level, Vagamon offers a unique ecological setting with rich plants life, refreshing mountain air and diverse flora and fauna Pradip KumarPal,2010).The presence of "Shola forests," characteristic of tropical mountains, further underscores Vagamon's ecological significance(www:dreamstime.com). But, due to anthropogenic factors, the hill station is becoming withered.

In general, during summer UHI is warmer han winter season (Kikon, *at el*, 2023).However, despite its seemingly pristine environment, recent observations suggest a potential concern – the formation of Urban Heat Islands (UHI) even during the winter months. UHI is the area that becomes significantly hotter than the surroundings, typically associated with densely populated city. The present work delves deeper into this possibility, aiming to understand the presence, characteristics, and potential changes in UHI within Vagamon's unique winter climate. By investigating Vagamon, researchers hope to gain valuable insights into how seemingly less susceptible environments might be affected by UHI dynamics and inform strategies for sustainable development in mountain regions around the world.

METHODOLOGY

Methods involved are: Quantifying the intensity of UHI in Vagamon during winter months (December and January) of Landsat 7 and 8, 2013 and 2024 by using Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-Up Index (NDBI) data obtained from satellite imagery. The relationships of the simulation data are of great importance to assess the UHI urban planning as well as climate management strategies (Utkarsh Mishra and *at el*, 2023, Ahmed Yaseen G and *at el*, 2022, Mehmet Cetin and *at el*, 2024, Paul Macar of and Statescu Florian, 2017)

An attempt is made here to nalysethe spatial distribution of UHI of Vagamon using LST, NDBI, and NDVI derived from the Landsat satellite imageries,

The investigation and analysis of present study are followed with the chart shown hereunder (Fig.2).

RESULTS AND DISCUSSION

As observed in Fig. 3 that Vagamon hill station experiences high LST in four parts in north, south and middle portions with red colour where prominent built up structure is there and a vast areas are under low LST with greenish and the medium range of LST with grey / pink colour covers about one third of the total area, in December, 2013.

A similar spatial distribution of LST in the station is found even between 2013 and 2024 in January month. It is supported by the values of 30.13 ˚C and 31.78 ˚C of high LST and 19.80 ˚C and 20.83 ◦C low LST for both the years. This has reflected that human settlement process in construction is progressing in this hill resort.

The spatial allocation of NDBI high and low indicates that high surface temperature is concomitant with the low NDBI, however, appearance of more areas in Vagamon station under relatively low NDBI adjacent to high LST spots cited above is significant in both January and December months of 2024 and 2013. When examined at temporal scale, many spots in north, middle and south are coming up highlighting the probable prominence of construction activities in the station. In fact UHI's effect is more with the built up areas of townscape (Subhani Guha and *at el*, 2018). The NDVI map (Fig.3) reflects in opposite to the results of LST and NDBI scoring below 0.1 below as low and 0.5 above as high. The western portion is with low LST but high NDVI in both years. The spatial and temporal analysis of three models under two periods 2013 and 2024 reflect the formation of UHI in spite of its rich ecosystems, humid tropical climate and temperature attenuated by elevation in the station. Urban Heat Island is directly concerned with non-climatic factors such as LULC, urbanization, population density and other anthropogenic activities in areas where the hill ecosystem exists with green vegetation cover in the humid atmosphere (Ajay Kumar T and *at el*, 2024). The existing UHI of Vagamon hill station during winter has shown that four noted spots of the formation of UHI in north, south and middle in 2013(Fig.4). The red spots are being appeared by clustering which get 23.10 ˚C UHI as high. The spread of medium range UHI between low and high is seen everywhere in the station, exhibiting the background of various anthropogenic activities including degradation of forests for human -made structure on surface as many as UHI spots appeared after a gap of more than a decade since 2013 in the area.

The four clustering spots are expanding and where there are settlement structure connected with motor able roads network exist, they are emerging. As indicated by map of UHI, 2024, almost a half of the station area is under low with the value , 11.12 ˚C UHI. There is global climatic change which influences to raise the occurrence of UHI and its effects (Gordan Kaplan *at el*., 2018). The increase of townships with the accumulated manmade features adds the dimension. Thus, the cumulative result of LST, NDBI, NDVI has clearly shown, even in hill station during winter month, there is formation of UHI with increasing trend from 2013 to 2024 as depicted in Fig. 4 and 5.

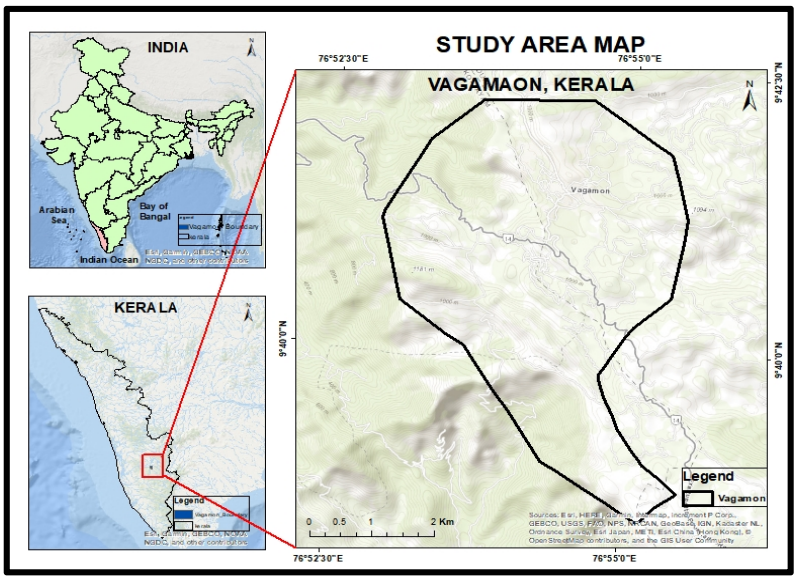

Fig.1. Location of Study Area

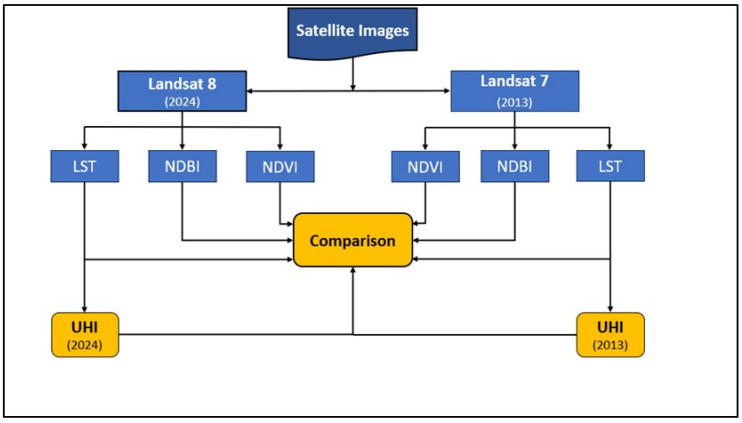

Fig. 2. Methodology Flow chart

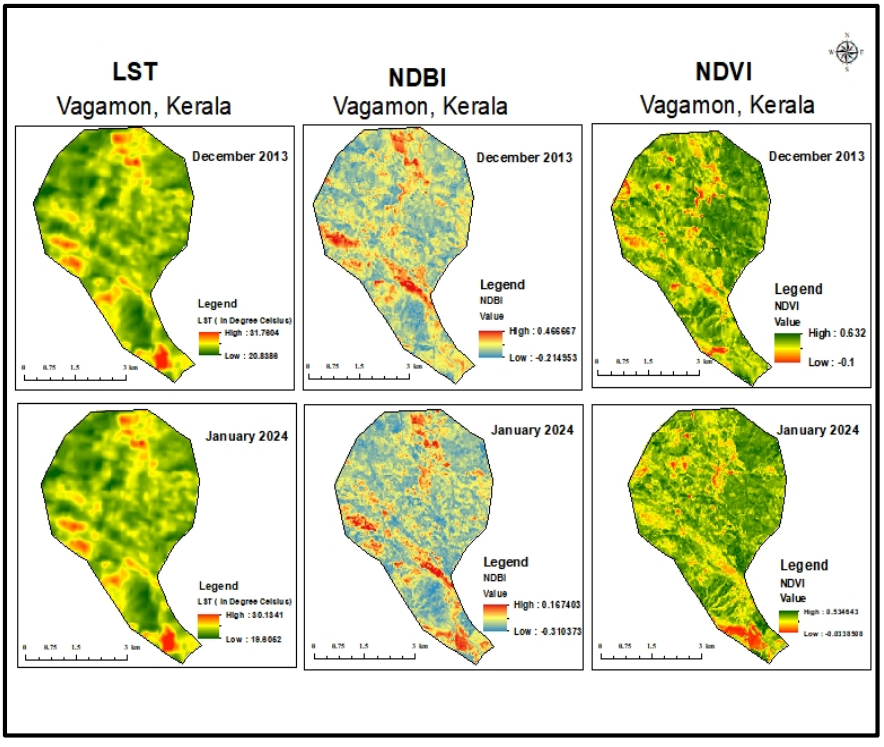

Fig.3. Urban Heat Islandof Vagamon Hill Station, Keralawith reference toLST, NDBI and NDVIforDecember and January, 2013 and 2024

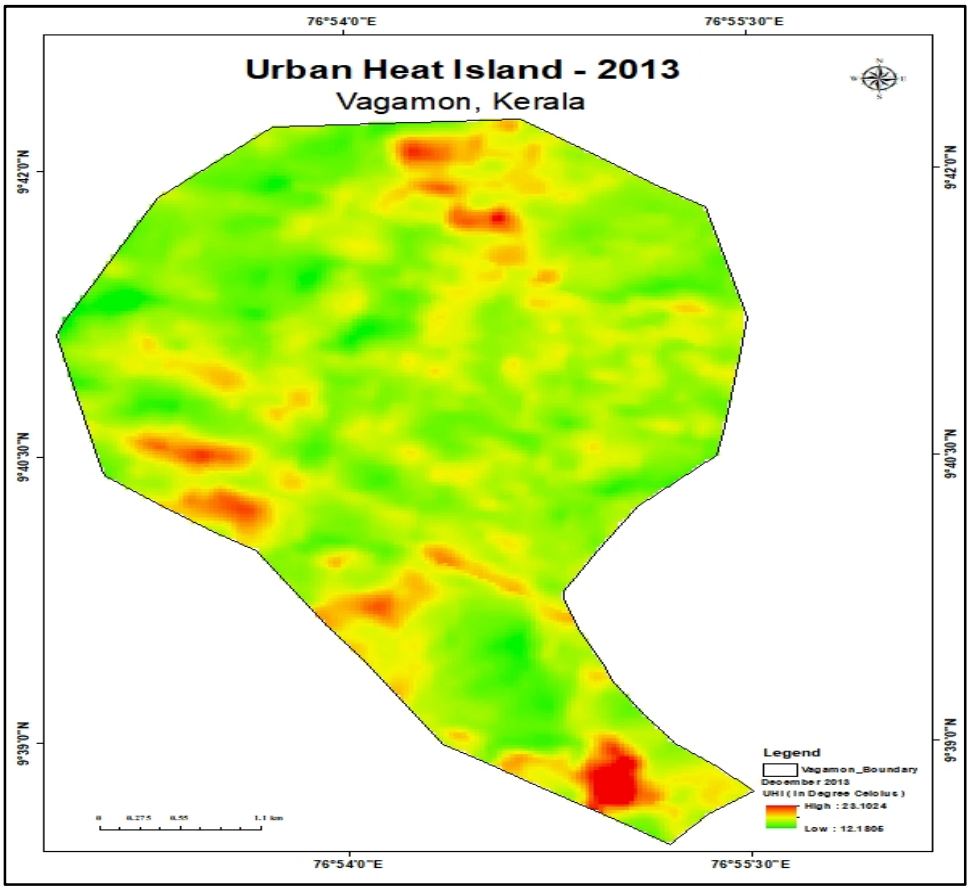

Fig. 4. Urban heat Island of Vagamon Hill Station, 2013

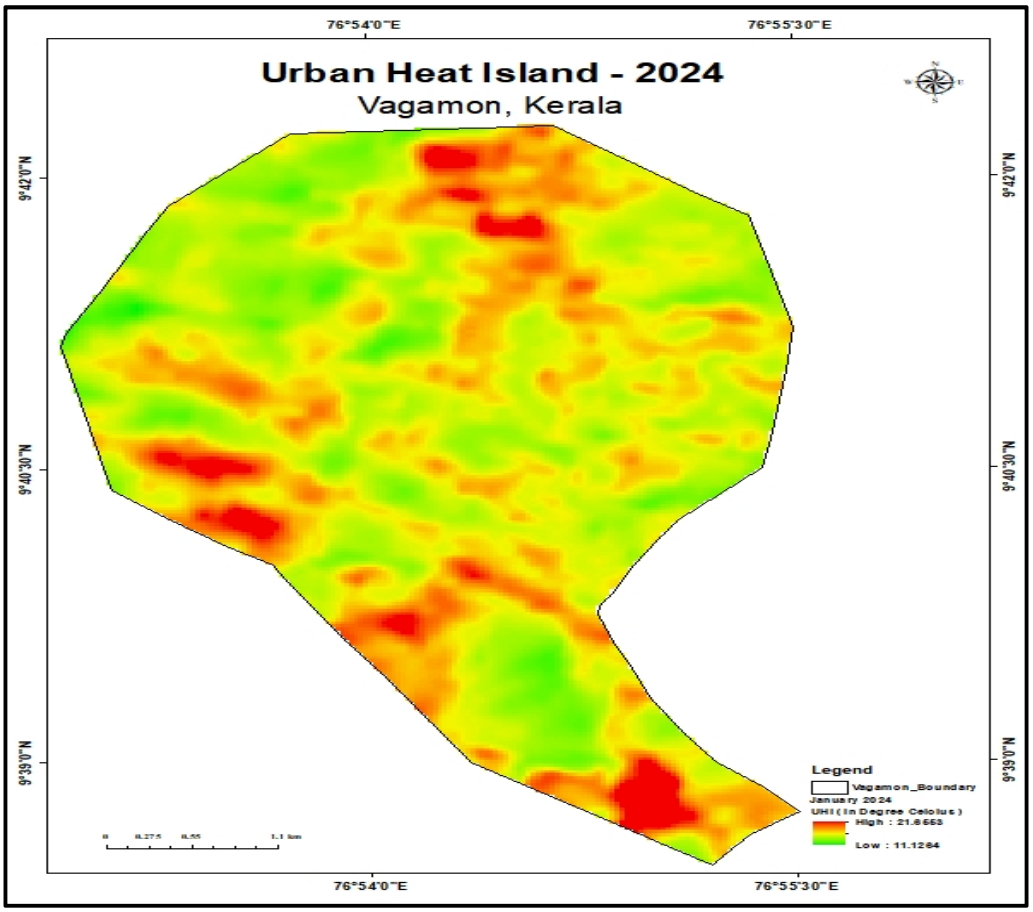

Fig. 5. Urban Heat Island of Vagamon Hill station, Kerala, 2024

CONCLUSION

Urban Heat Island is a phenomenon comes up forming a microclimate on a crowded areas where man induced physical activities for economic development programmes are actively going on. The activities encompass LULC change, infrastructure and residential buildings development, burning of fossil fuels for various economic works including transports taking the advantages of physical environment of the area. Vagamon hill station has also initiated UHI as it is the seat of tourist resort place having supported various infrastructure facilities. The evaluation of magnitude and intensity of UHI for 2013 and 2024 by LST, NDBI and NDVI models has found out that the heat island is expanding through four clustering spots as explained above and it needs reducing the surface temperature through mitigation programme.

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