ASSESSMENT OF URBAN HEAT ISLAND (UHI) USING REMOTELY SENSED IMAGERY & GIS TECHNOLOGY OF ERNAKULAM DISTRICT

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the

Degree of Master of Technology in Civil Engineering of

A P J. Abdul Kalam Technological University

Submitted by

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University Reg. No: TVE23CEGI18

M1 – GEOINFORMATICS

DEPARTMENT OF CIVIL ENGINEERING

COLLEGE OF ENGINEERING TRIVANDRUM

DECEMBER 2023

DECLARATION

I undersigned hereby declare that the project report “Assessment of water quality in Pookode Lake Using GIS”, submitted for partial fulfilment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Dr. Manju V S. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Place: Trivandrum　　　　　　　　　　　　Signature

Date: 15/12/2023　　　　　　　　　　　　DILFA CP

DEPARTMENT OF CIVIL ENGINEERING
COLLEGE OF ENGINEERING TRIVANDRUM

CERTIFICATE

*This is to certify that this Project report entitled "***ASSESSMENT OF URBAN HEAT ISLAND (UHI) USING REMOTELY SENSED IMAGERY & GIS TECHNOLOGY OF ERNAKULAM DISTRICT***" is a bonafide record of the Project presented by* ***DILFA CP (University Reg. No: TVE23CEGI18)*** *towards the partial fulfilment of the requirements for the award of the* ***Degree of Master of Technology in Civil Engineering (Geoinformatics****) of A P J Abdul Kalam Technological University during the academic year 2023-2024.*

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ACKNOWLEDGEMENT

First and foremost, I thank the Almighty, for bestowing with His profound grace, without which I could never have completed this Project work.

I express my unfathomable gratitude to the faculty in charge **Prof. SABU P** Professor, Department of Civil Engineering, College of Engineering Trivandrum for her help, advice, support, and encouragement.

I avail this opportunity to express my profound thanks to **Dr. Anil R.,** Head of Department, Department of Civil Engineering, College of Engineering Trivandrum.

I wish to record my gratefulness to **Dr. ANU P ALEX,** Staff Advisor, Department of Civil Engineering, College of Engineering Trivandrum for providing necessary facilities and for their sincere co-operation.

I extend my sincere gratitude to all other teachers in the Department of Civil Engineering and to all my family and friends, whose continued support and inspiration helped me in this endeavour.

DILFA CP

ABSTRACT

Rapid urbanization poses a significant challenge to the microclimates of cities, giving rise to the Urban Heat Island (UHI) effect. This study focuses on Ernakulam District, an urbanizing region in southwestern India, employing state-of-the-art Remotely Sensed Imagery and Geographic Information System (GIS) technology to comprehensively assess UHI dynamics.

High-resolution satellite imagery is leveraged to discern intricate land cover patterns, facilitating a nuanced analysis of temperature differentials. GIS technology serves as a powerful tool for spatial modelling, allowing for the mapping of UHI variations across the district. The study aims to unravel the complex interplay between urban development and localized temperature increases, providing a robust foundation for evidence-based decision-making.

Preliminary findings indicate distinctive UHI patterns, revealing areas of heightened temperature correlated with specific land cover characteristics. This research contributes valuable insights to the broader understanding of UHI in rapidly urbanizing regions, emphasizing the need for adaptive urban planning and sustainable development practices.

The outcomes of this study hold practical implications for Ernakulam's urban planners and policymakers, offering a guide for the implementation of climate-resilient strategies. Moreover, the findings contribute to the global discourse on urban climate dynamics, providing a template for cities grappling with the challenges of balancing development and environmental sustainability.

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INTRODUCTION

1.1 GENERAL

The UHI effect, characterized by elevated temperatures in urban areas compared to their rural surroundings, results from complex interactions between land use changes, infrastructure development, and natural factors. Ernakulam, experiencing rapid urbanization, serves as a pertinent case study to unravel these complexities. Leveraging Remotely Sensed Imagery enables the acquisition of high-resolution spatial data, while GIS technology provides a sophisticated platform for spatial analysis and mapping.

This research seeks to unravel the spatial nuances of UHI in Ernakulam, shedding light on temperature differentials influenced by varying land cover types. The integration of cutting-edge technologies not only facilitates precise temperature mapping but also allows for a comprehensive evaluation of the impact of urban development on local climates.

The outcomes of this study hold significant implications for urban planning, climate resilience, and sustainable development in Ernakulam. By identifying UHI "hotspots" and understanding the correlation between land cover features and temperature variations, this research aims to inform evidence-based decision-making. Ultimately, the study Endeavour’s to contribute to the growing body of knowledge guiding cities towards a more sustainable and climate-conscious future.

1.2 NEED OF STUDY

Understanding the impact of land use on the Urban Heat Island in Ernakulam is crucial for assessing urbanization effects, promoting climate resilience, safeguarding public health, optimizing energy use, and guiding sustainable urban planning.

1.3 OBJECTIVES

- To study the temperature distribution across the different land use types
- To investigate the influence of various land use types on the urban heat island
- Analyze Urban Heat Island (UHI) intensity and spatial distribution.

CHAPTER 2
LITERATURE REVIEW

The urban air temperature is gradually rising in all cities in the world. Several factors become the cause of it, such as diminishing of green area, low wind velocity due to high-building density and change of street surface coating materials. This may lead to overheating by human energy release and absorption of solar radiation on dark surfaces and buildings. This problem will be further aggravated by increasing demand on air conditioning, which will again lead to further heating and CO2 release. The session discusses previous literature which gives an insight into the current thinking and research in this field

2.1 REVIEW OF LITERATURE

An extensive survey has been conducted on the research works done on the urban heat island. The literature relevant to the investigation is discussed in this session**.**

The study conducted by **D.M. Senevirathne a, V.M. Jayasooriya et al,(2021)** "Effects of pavement texture and colour on Urban Heat Islands: An experimental study in tropical climate". In tropical cities, common pavement building materials like cement and concrete can dramatically amplify the Urban Heat Island (UHI) effect. But by changing the capacities to absorb heat and radiation, the optimised pavement designs can mitigate the UHI effect's temporal intensities. In order to determine the inverse relationship between pavement texture and colour and the unique thermal performance of concrete pavers in a tropical environment, this study empirically investigates and quantifies the relationship. Concrete pavers of three common textures (Smooth, Rough, Jagged) and three common colours (Red, Grey, Black) were studied under controlled ambient conditions, considering 27 experimental pavement setups (1 ft. × 1 ft. and three replicates). The results showed that during peak hours, within each texture, Red and Grey coloured pavers displayed surface temperatures up to 4.2 ◦C and 4.5 ◦C lower, respectively, in comparison to Black pavers. The Smooth texture demonstrated a temperature retention of up to 2.6 ◦C lower as compared to the Grey paver texture. But out of all the pavement kinds that were taken into consideration, Red Jagged had the lowest recorded surface temperature, at 42.9 ◦C, which is 0.6 ◦C lower than Grey Smooth. Overall, it can be said that the red-colored jagged paver can reduce the pavement's contribution to the UHI effect when taking into account both the colour of the paver and the concrete's roughness.

The study conducted by **Monsingh David, Lilly Rose et al. (2009)** "Mapping of Micro-Urban Heat Islands and Land Cover Changes: A Case in Chennai City, India" Land use shifts give rise to environmental challenges that have a profound influence on urban planning processes. The replacement of naturally occurring surfaces with highly reflecting parking lots, concrete masses, asphalt roads, etc., is a common example of how land use changes impact urban heat environments. Studies reveal that Metropolitan areas often referred to as "urban heat islands"—are warmer than the surrounding rural areas. This research aims to analyse the differences in the city's thermal environment caused by various circumstances of land cover. Using TM and ETM+ data from 1991 and 2000, this study examines the variations in temperature inside Chennai and examines the association between land cover types and surface temperature. The ETM+ data shows the increase in urban built up areas and the reduction of vegetated areas. The thermal bands of Landsat TM and ETM+ are used in identifying the specific locations of micro urban heat islands within the city. The various land cover types such as dense vegetated areas, barren land and industrial areas, dense built up spaces, water bodies etc contributes to the variation in temperatures leading to the formation of urban micro heat islands. With the increasing energy demand it is possible to reduce the energy needs by mitigating the effects of these micro urban heat islands. This study can be a source data for the urban planners and designers in improving the environmental quality by planning green lands, altering the surface cover and formulating urban design guidelines.

The study conducted by **Li Yang, Feng Qian et al**. **(2016)** “Research on Urban Heat-island Effect”. A type of heat buildup phenomena brought on by urban development and human activity is known as the urban heat island (UHI) effect. It is acknowledged as the most blatant feature of the metropolitan climate. The urban heat island (UHI) effect will undoubtedly raise land surface temperatures, which will change the structure and functions of urban ecological systems and affect material and energy flow. These changes will have a range of ecological and environmental effects on urban climates, urban hydrologic situations, soil properties, atmospheric environments, biological habits, material cycles, energy metabolism, and the health of the population. UHI effects could be greatly reduced by increasing energy efficiency, optimising urban landscapes, building green roofs, using high reflectivity materials, and cultivating green land. Based on remote sensing technology and numerical simulation methods, research on the ecological and environmental effects of UHI has been multi-scaled conducted, providing theoretical reference for the improvement of urban ecological environment and realization of urban sustainable development.

The study conducted by **de Almeida, Ana Cláudia et al. (2021)** “Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review”. When compared to rural areas, urbanised areas frequently experience greater temperatures, which is known as an urban heat island (UHI). This effect can worsen the effects of pollution, increase energy usage, and cause thermal discomfort during the warmer months. Land Surface Temperature (LST) can be estimated by the use of Remote Sensing (RS) data and procedures with thermal sensors on board satellites, drones, or aeroplanes. This article provides a comprehensive overview of works on UHI analysis using RS data/techniques and LST that have been published in Scopus and Web of Science (WOS) between 2000 and 2020. When choosing articles, the whole text was taken into consideration in addition to the keywords, title, and abstract. Two separate researchers carried out the process, and 579 English-language publications were chosen. There were both quantitative and qualitative analyses carried out. Cfa climate areas are the most represented, as the Northern Hemisphere concentrates the most studied areas, especially in Asia (69.94%); Landsat products were the most applied to estimates LST (68.39%) and LULC (55.96%); ArcGIS (30.74%) was most used software for data treatment, and correlation (38.69%) was the most applied statistic technique. There is an increasing number of publications, especially from 2016, and the transversality of UHI studies corroborates the relevance of this topic.

The study conducted by **Widya Ningrum (2014) "**Urban Heat Island towards Urban Climate". The temperature differential between urban and suburban regions and rural areas within a given region is referred to as the urban heat island (UHI). Scholars have talked about a number of methods for assessing the phenomenon. Urban heat island sources and effects are reviewed in this work, with a focus on how they affect urban climate. The UHI affects many areas both directly and indirectly. This means that in order to lower the temperature, scientists and the government must establish a systematic mitigation plan.

The study conducted by **Ammar Abulibdeh (2021)** "Analysis of urban heat island characteristics and mitigation strategies for eight arid and semi-arid gulf region cities". The classification of land cover (LC)—urban, green, and bare areas—is the foundation of the analysis. In comparison to urban and green regions, the study indicated that barren areas had the highest mean LST values. The findings indicate that there is a temperature differential of between 1 and 2 °C between bare areas and urban areas, between 1 and 7 °C between bare areas and green areas, and between 1 and 5 °C between urban areas and green areas. Moreover, the LST values differed for every LULC category, meaning that certain regions within the three categories had LST values that were higher or lower than those of other categories. Hence, one category may not always have the highest LST value compared to other categories. The outcomes of this study may, therefore, have critical implications for urban planners who seek to mitigate UHI effects in arid and semiarid urban areas.

The study conducted by **Angel Hsu, Glenn Sheriff et al. (2021)** "Urban heat stress poses a major risk to public health". According to case studies of certain cities, heat exposure may not be evenly distributed among different income levels, just like other environmental stressors. However, there isn't much data to suggest that these differences are widespread. In order to address these problems during summer days, when heat exposure is likely to be at its highest, we combine census tract-level demographic data with surface urban heat island (SUHI) data, a proxy for isolating the urban contribution to increased heat exposure in constructed environments. We find that in all but six of the 175 major urbanised areas in the continental United States, the typical person of colour resides in a census tract with higher SUHI intensity than non-Hispanic whites. A similar pattern emerges for people living in households below the poverty line relative to those at more than two times the poverty line.

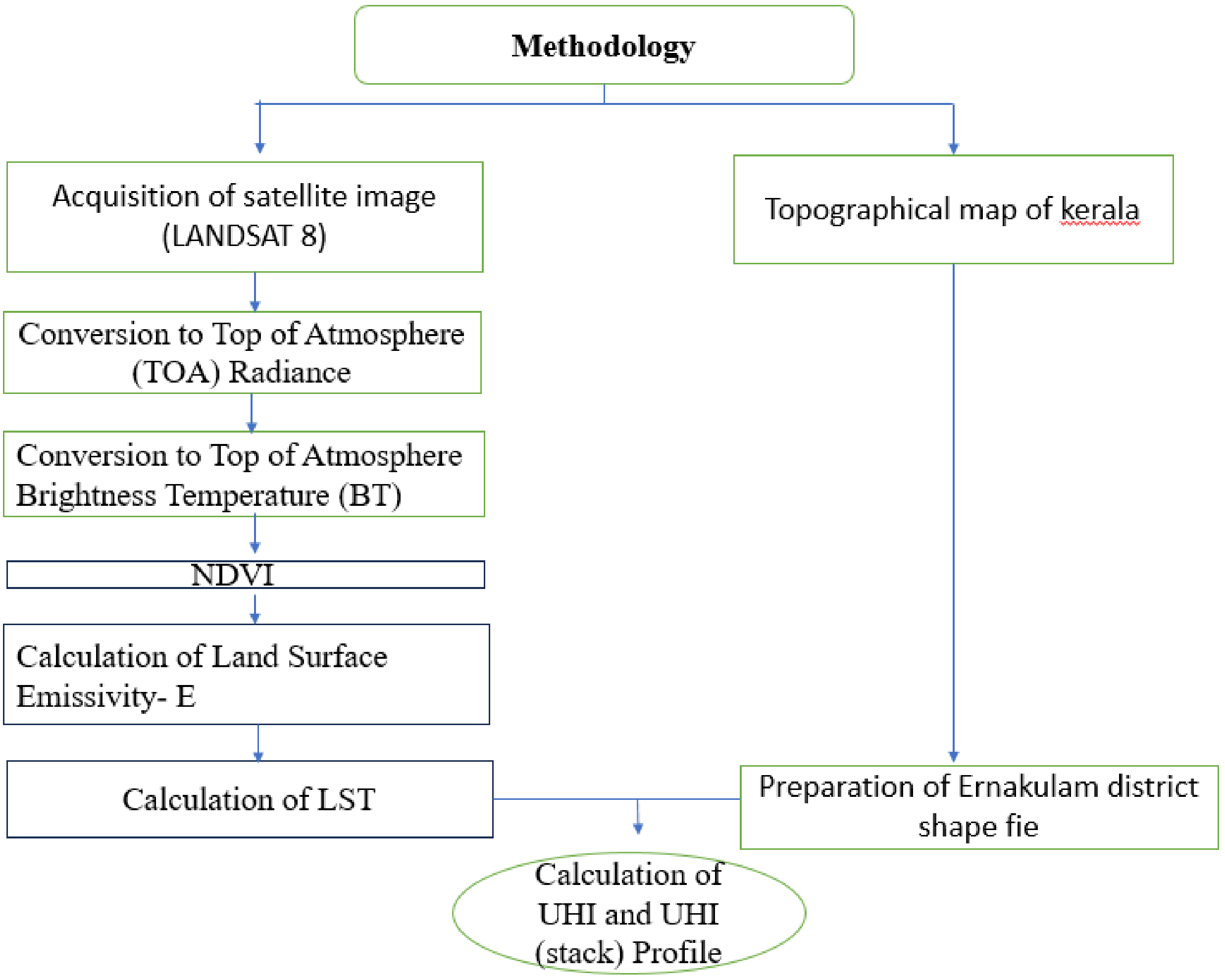
The study conducted by **Gitika Kaur1, Garima Sharma et al. (2021)** "Urban Heat Island Prediction Using ANN". An urban heat island (UHI) is a region or territory that, due to human activity, is inherently hotter than the surrounding rural areas. The difference in air or surface temperatures between urban and rural areas can be used to explain the urban-rural heat island effect (UHI). The study "Urban Heat Island prediction using ANN" that forms the basis of the project is based on the values of different test results conducted on a single technique. In order to accurately identify a location as an urban heat island, the Artificial Neural Network (ANN) method and Time Series analysis are employed in this study. Six weather stations (WS) with a total of 12929 incidences each were gathered to provide data on whether or not a certain region qualifies as a UHI. The ANN model was implemented on all the six weather stations and after examining the ANN model, the two weather stations WS4 and WS6 proved out to be the best in terms of correlation between dependent and independent variable that was evaluated using MAE and R2 score. The two weather stations WS6 and WS4 having R2 score or accuracy as 79.6 and 79.3 respectively was further chosen for time series analysis. In time series analysis, we just have one variable i.e., time. We can analysis the time series data in order to extract meaningful insights and other features. Time series is a set of observation taken at specified times at equal interval.

The study conducted by **Je-Woo Hong a, Jinkyu Hong et al, (2019)**. "Temporal dynamics of urban heat island correlated with the socioeconomic development over the past half-century in Seoul, Korea". An emblematic result of human activity and climate change, urban heat island (UHI) influences energy use, air pollution, and health. Therefore, in order to decrease air pollution in the context of a changing climate, sustainable urban planning requires a deeper understanding of the temporal dynamics of UHI. Here, we show the evolution of UHI intensity (UHIi) and the factors that have influenced it in the Seoul metropolitan region, Korea, during the past 56 years (1962–2017), a period marked by unusually rapid urban transformation and constricted economic growth due to the monsoon climate. With the advancement of urban transformation and the state of the economy, the analysis showed an inverted U-shape long-term variation of UHIi, which has never been documented in Asian cities. Meanwhile, short-term variations in UHIi are related to both diurnal temperature range and duration after rainfall event unlike previous studies, and the UHIi was exacerbated by heat waves. Our findings suggest that the UHIi will exhibit different temporal dynamics with future changes in the monsoon climate, and heat waves in the urban area will be reinforced if current rapid urbanization continues without a shift toward sustainable and equitable development. Asian cities that are likely to face the similar urbanization trajectory and the implications are that urban (re) development strategy considers changes in rainfall magnitude and timing due to monsoon system variation under changing climate and plans to mitigate synergy between heat wave and UHI in this area.

The study conducted by **Steve Kardinal Jusuf, N.H. Wong et al, (2007).** "The influence of land use on the urban heat island in Singapore". Every city on the planet is seeing a slow increase in the temperature of the urban air. The sharp decline in urban green space is one of the potential causes. This implies that assessing the quality of the environment depends heavily on land use planning. The goal of this study is to determine which land use categories in Singapore are most responsible for the rise in the country's average temperature. The geographic information system (GIS) and remote sensing data are the primary tools for obtaining a macro image of Singapore and doing in-depth research simultaneously. Both qualitative and quantitative methodologies were used to analyse the data. Both the qualitative and quantitative analysis results show that the land usage will influence urban temperature. In the daytime, the order of surface temperature in different land use types is industrial, commercial, airport, residential, and park respectively. However, during the night time, the order is commercial, residential, park, industrial, and airport. Therefore, with appropriate land use planning, the urban heat island (UHI) could be mitigated.

CHAPTER 3
METHODOLOGY

Landsat images provide the longest continuous records of earth's surface since 1972 and meet the requirements to capture the changes of Earth's land cover and conditions. Landsat-8 images collected from US Geological Survey (USGS) in the Date of 31/08/2023, were used to construct time series data to obtain the information of LUCC and to characterize the thermal environment in this study. All of the images were of good quality with 25% cloud coverage.



Conversion to Top of Atmosphere (TOA) Radiance:

Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers can be converted to TOA spectral radiance.

Lλ = ML * Qcal + AL-Oi

Lλ = 0.0003342*Band10+0.10000-0.29

Where:

$L\lambda$ = TOA spectral radiance (Watts/ (m2 * sr * µm))

ML = Radiance multiplicative Band number

AL = Radiance Add Band (No.)

Qcal = Quantized and calibrated standard product pixel values (DN)

Oi = correction value for band 10 is 0.29

Conversion to Top of Atmosphere (TOA) Brightness Temperature (BT):

Spectral radiance data can be converted to top of atmosphere brightness temperature using the thermal constant Values in Meta data file.

Kelvin (K) to Celsius (0C) Degrees **BT = K2 / In (k1 / Lλ + 1) - 273.15**

BT= (1321.0789/Ln (774.8853/ToA+1))-273.15

Where:

BT = Top of atmosphere brightness temperature (°C)

$L\lambda$ = TOA spectral radiance (Watts/ (m2 * sr * µm))

K1 = K1 Constant Band (No.)

K2 = K2 Constant Band (No.)

Normalized Difference Vegetation Index (NDVI):

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which Calculated using Near Infra-red (Band 5) and Red (Band 4) bands.

NDVI = (NIR – RED) / (NIR + RED)

NDVI = (Band 5-Band 4)/ (Band 5+Band 4)

Where:

RED= DN values from the RED band

NIR= DN values from Near-Infrared band

Land Surface Emissivity (LSE):

Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI values.

PV = ((NDVI – NDVI min) / (NDVI max – NDVI min))2

Where:

PV = Proportion of Vegetation

NDVI = DN values from NDVI Image

NDVI min = Minimum DN values from NDVI Image

NDVI max = Maximum DN values from NDVI Image

E = 0.004 * PV + 0.986

Where:

E = Land Surface Emissivity

PV = Proportion of Vegetation

0.986 corresponds to a correction value of the equation

Land Surface Temperature (LST):

The Land Surface Temperature (LST) is the radiative temperature Which calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance, Land Surface Emissivity.

LST = BT/ (1 + (λ * BT / c2) * ln(E))

Here, c2= 14388 □m K

The Values of λ for Landsat 8: For Band 10 is 10.8 and for Band 11 is 12.0

Where

BT = Top of atmosphere brightness temperature (°C)

λ = Wavelength of emitted radiance

E = Land Surface Emissivity

c2= h*c/s=1.4388*10-2 mK =14388 mK

h=Planck's Constant =6.626*10-34 J s

s= Boltzmann constant =1.38*10-23 JK

c=velocity of light =2.998*108 m/s

Urban Heat Island (UHI) and UHI (stack) Profile

Urban heat island (UHI) refers to the phenomenon where urban areas experience higher temperatures due to human activities and the built environment. Causes include land surface modification, reduced vegetation, heat from buildings and infrastructure, altered air circulation, and waste heat. UHI has adverse effects on human health, energy consumption, and air quality.

Calculation Urban Heat Island using GIS

$UHI = LST - LSTmSD$

Where,

UHI= Urban Heat Islands

LST= Land Surface Temperature

LSTm= The mean temperature of the land surface temperature in the study area

SD= Standard deviation of temperature

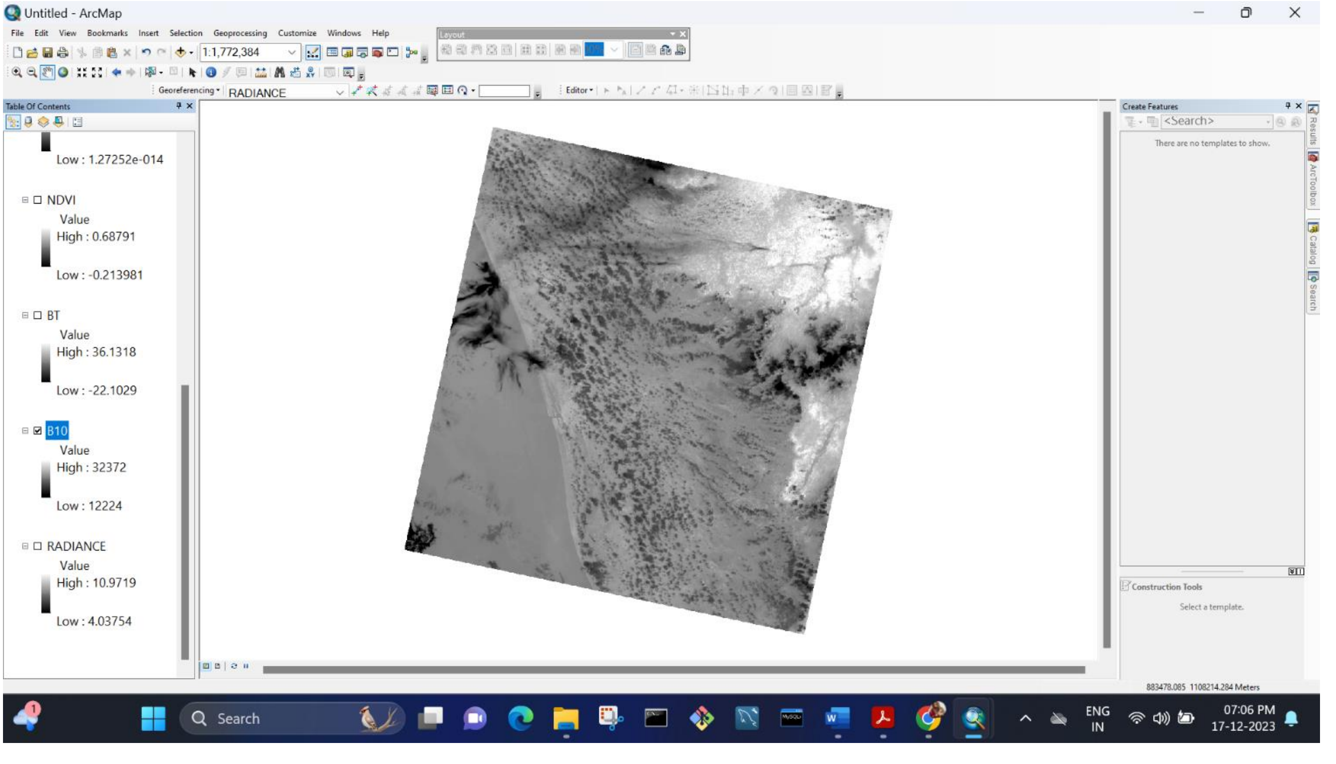


FIG 3.1: Landsat 8 Band 10

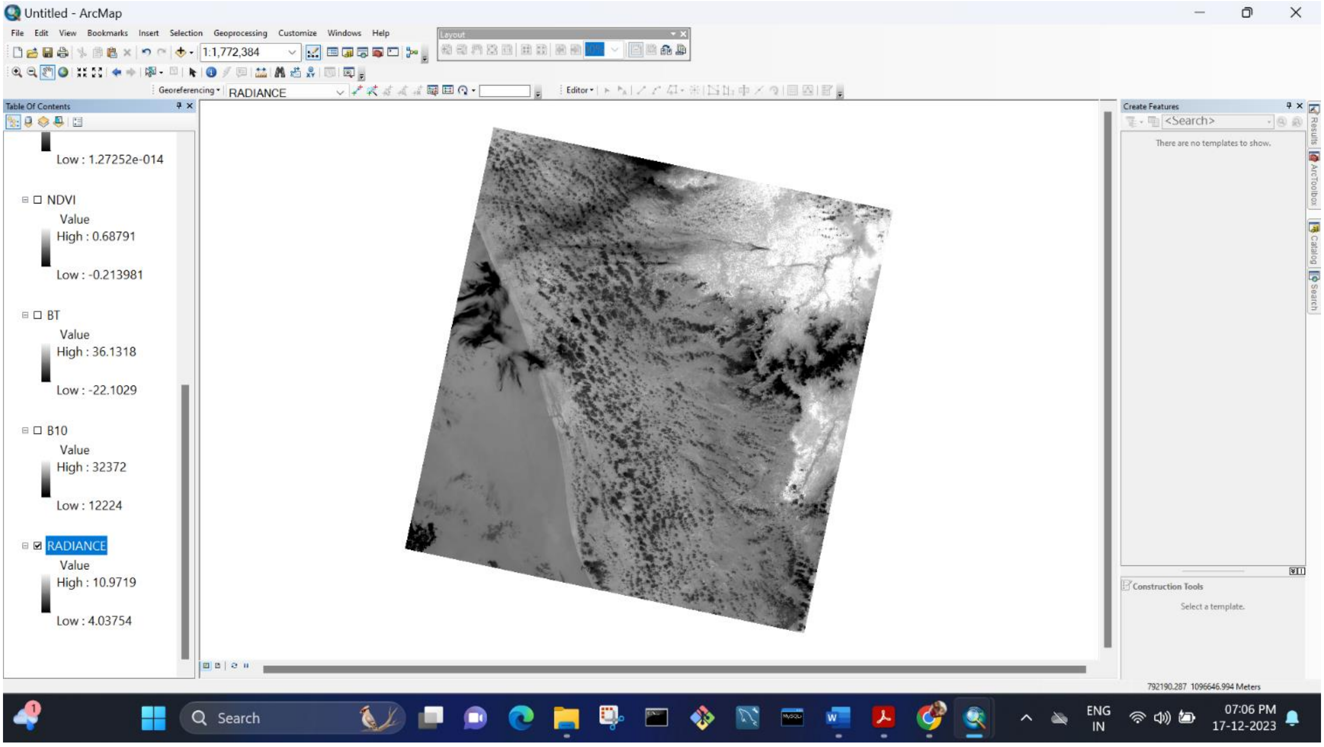


FIG 3.2: Conversion to Top of Atmosphere (TOA) Radiance

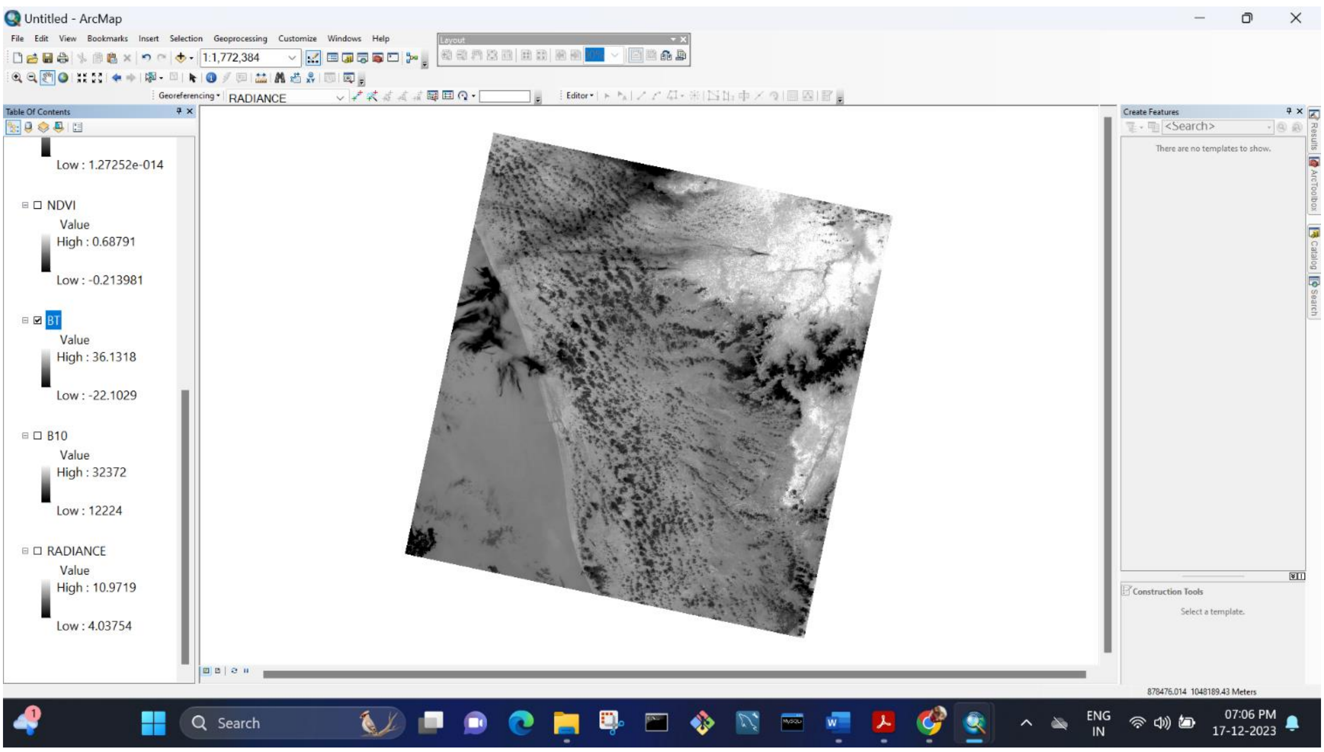


FIG 3.3: Conversion to TOA Brightness Temperature

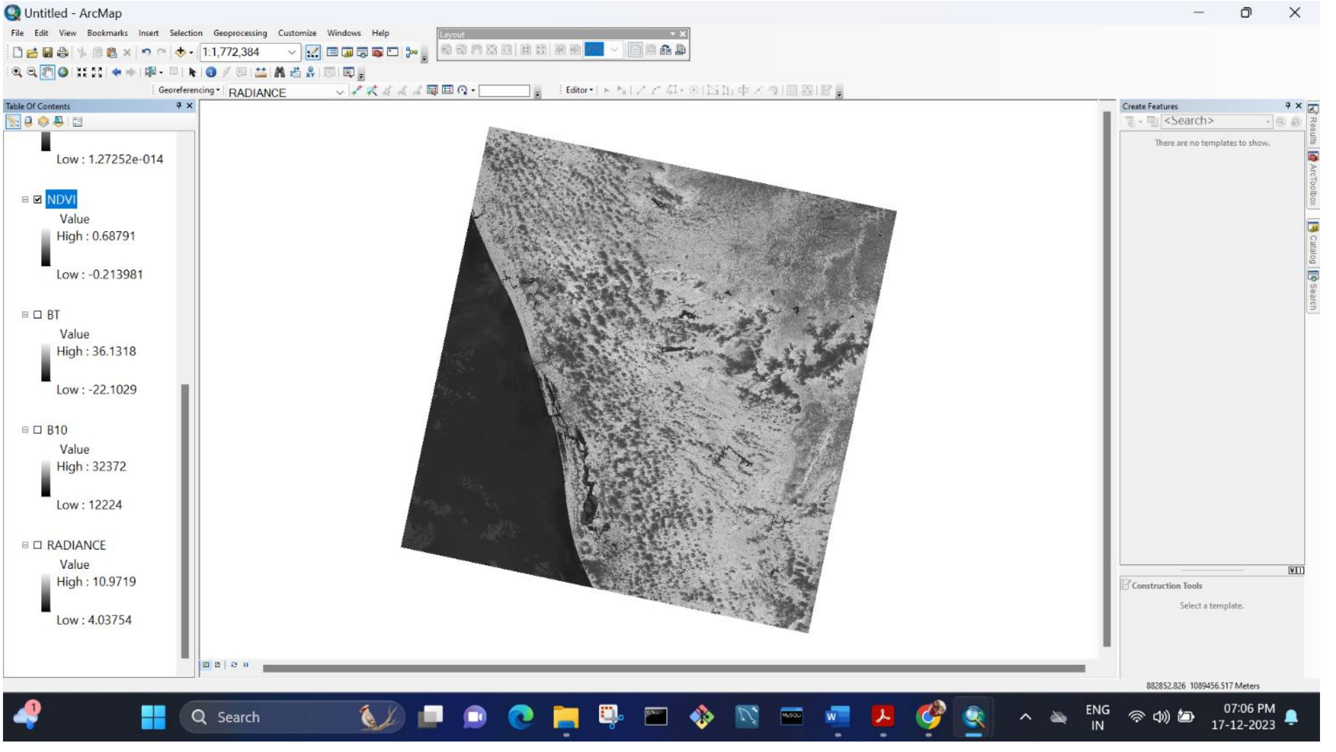


FIG 3.4: Normalized Difference Vegetation Index (NDVI)

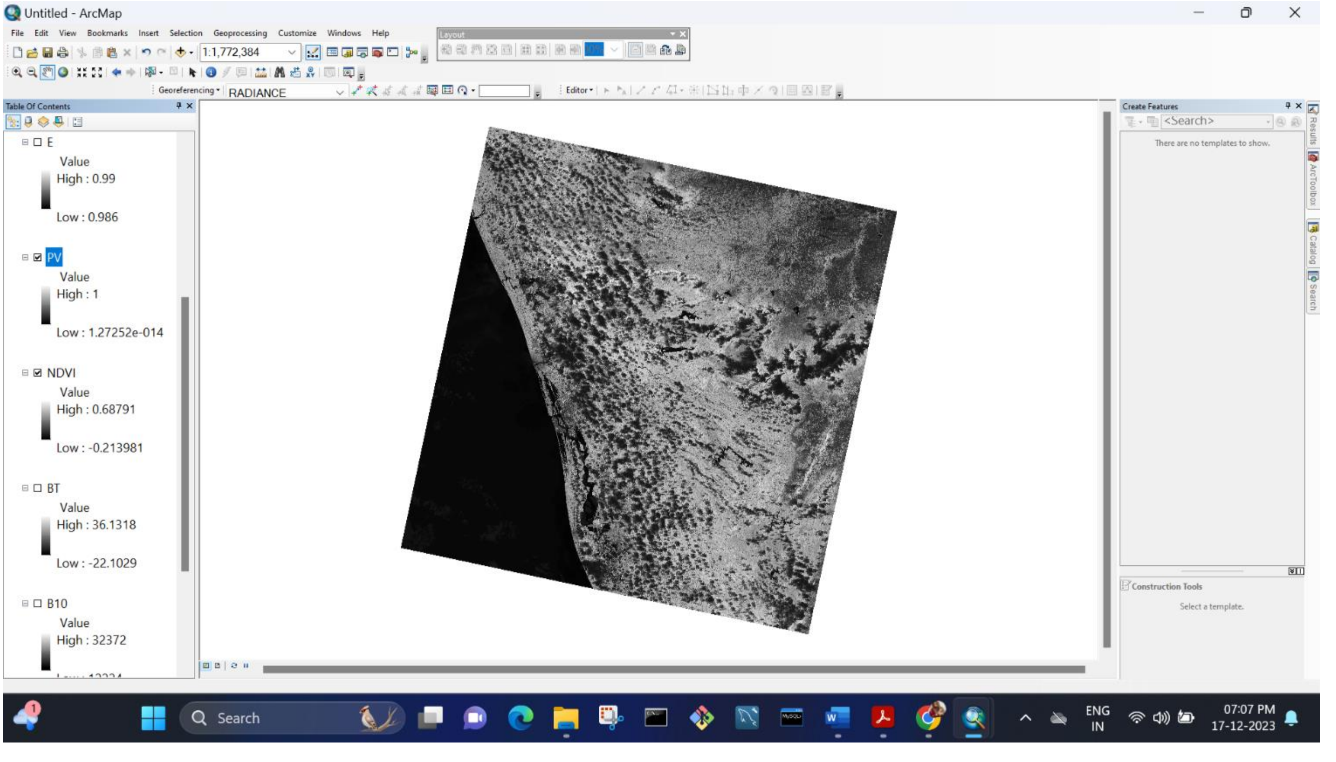


FIG 3.5: Proportion of Vegetation

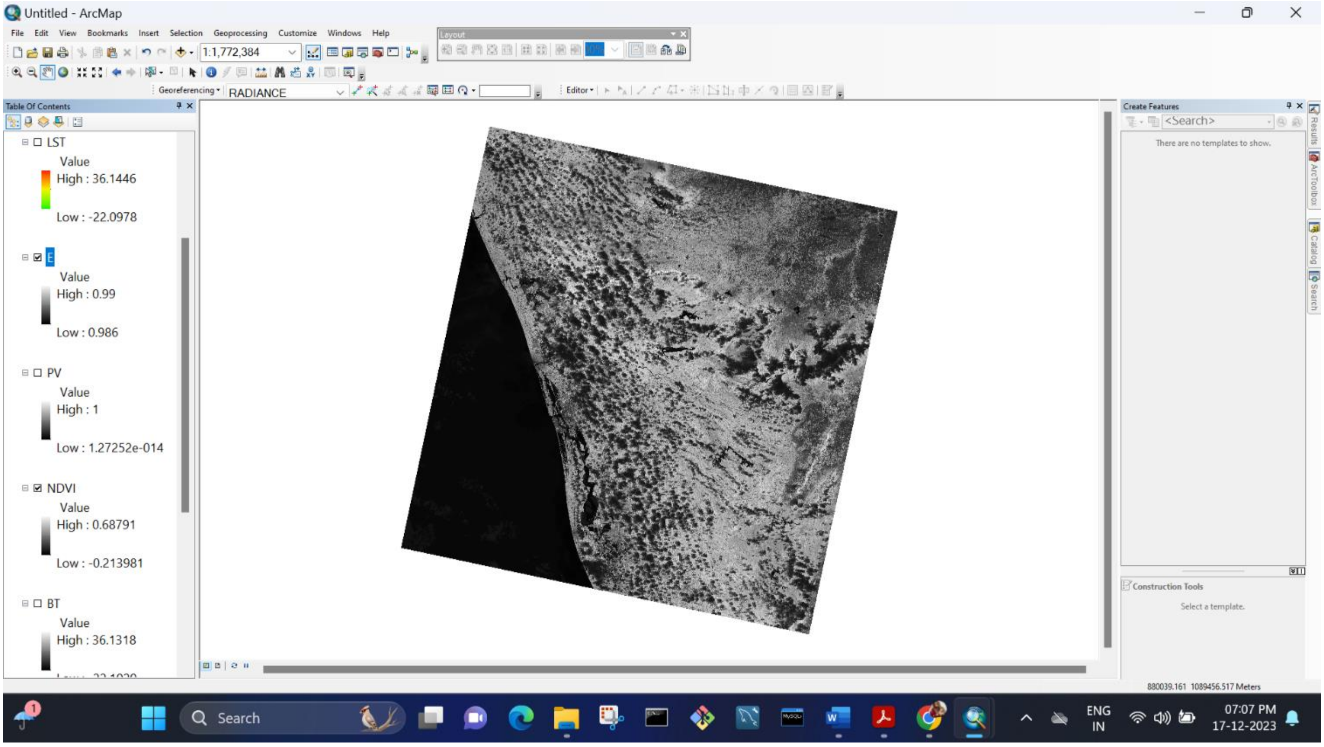


FIG 3.6: Land Surface Emissivity

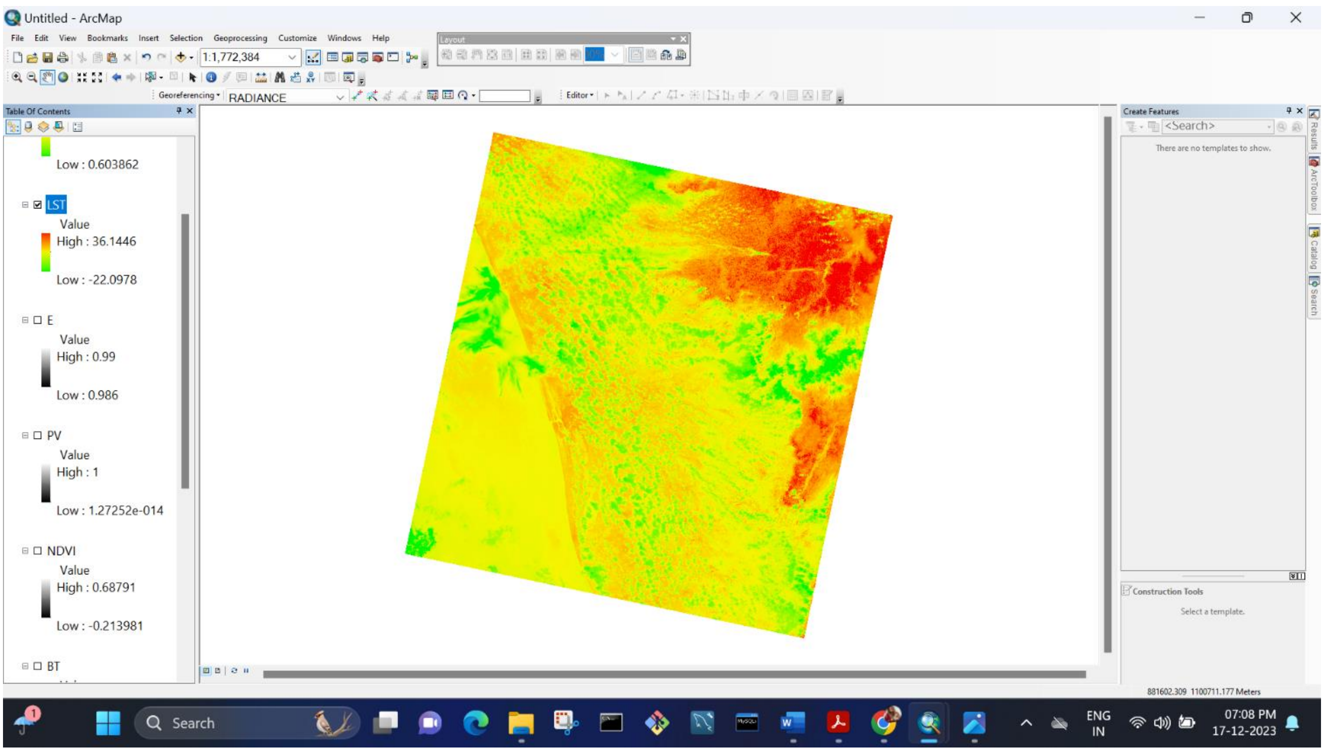


FIG 3.7: Land Surface Temperature (LST)

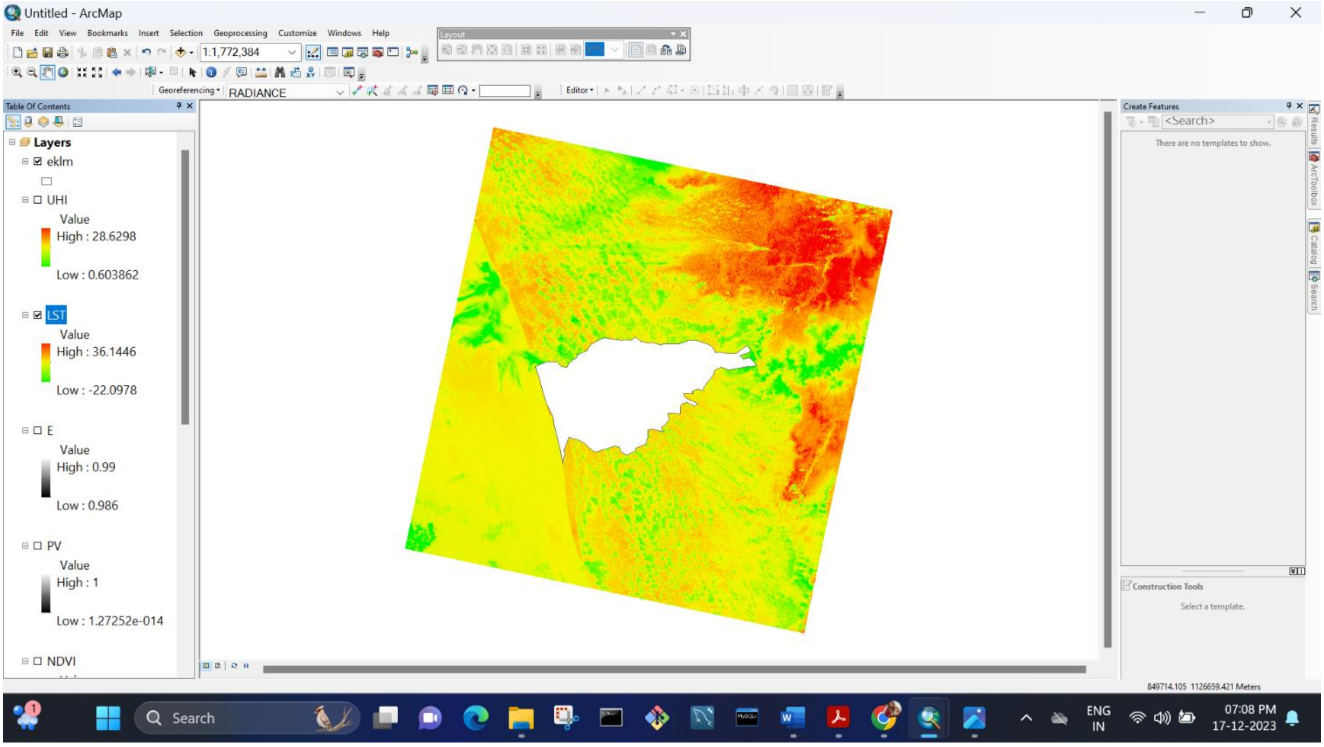


FIG 3.8: LST Of Study Area

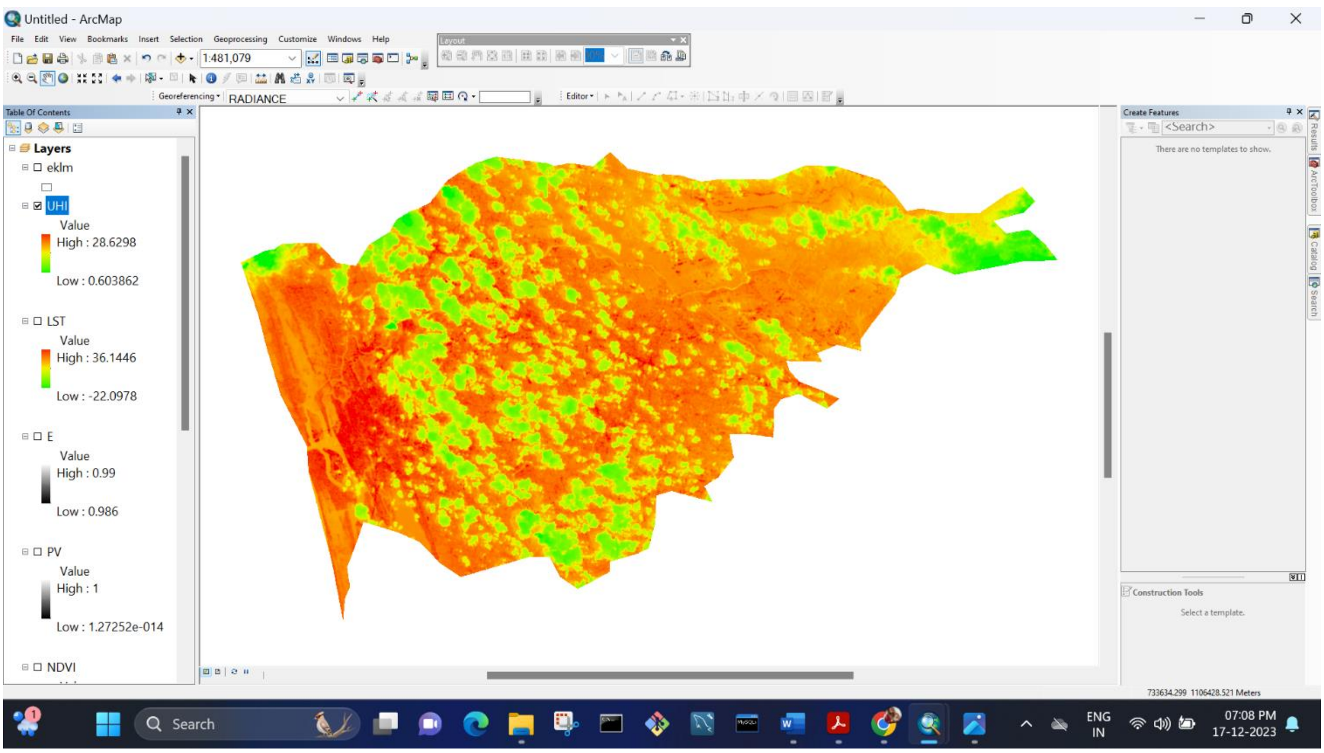


FIG 3.9: Urban Heat Island (UHI)

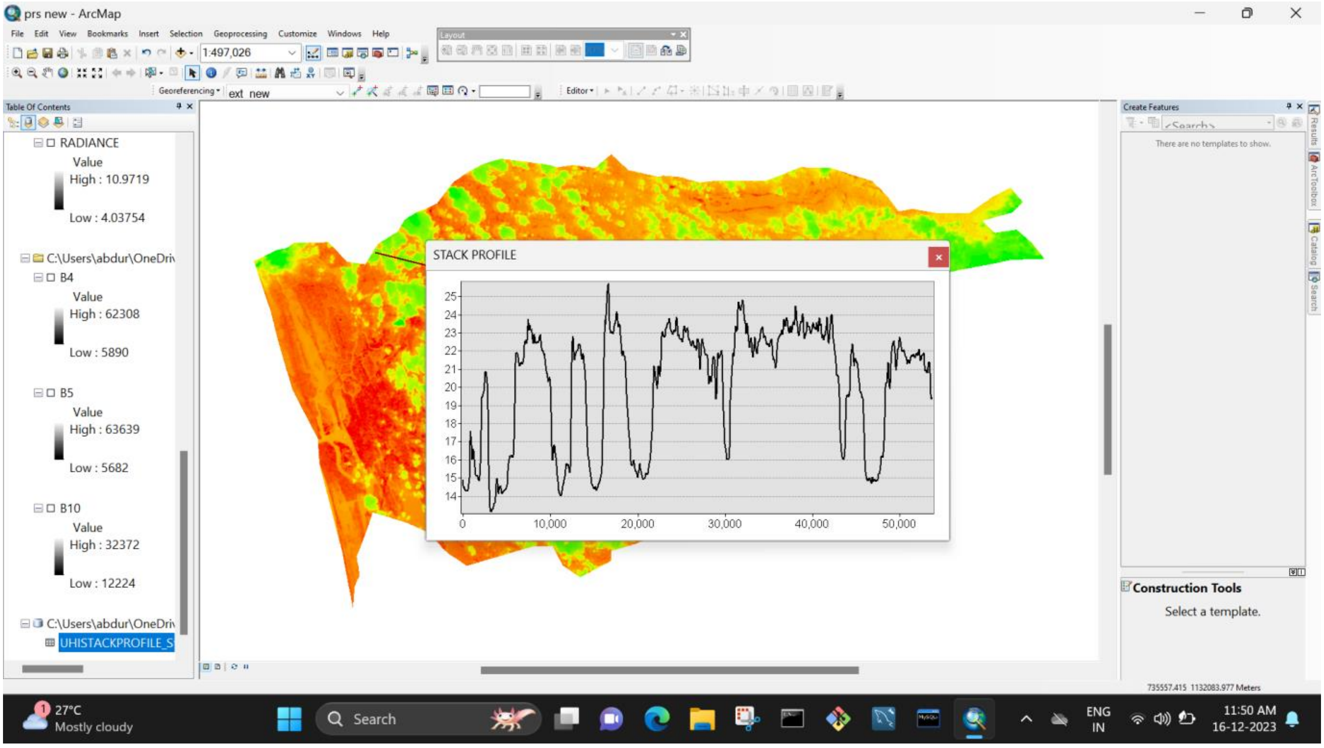


FIG 3.10: Stack Profile

CHAPTER 4

RESULTS

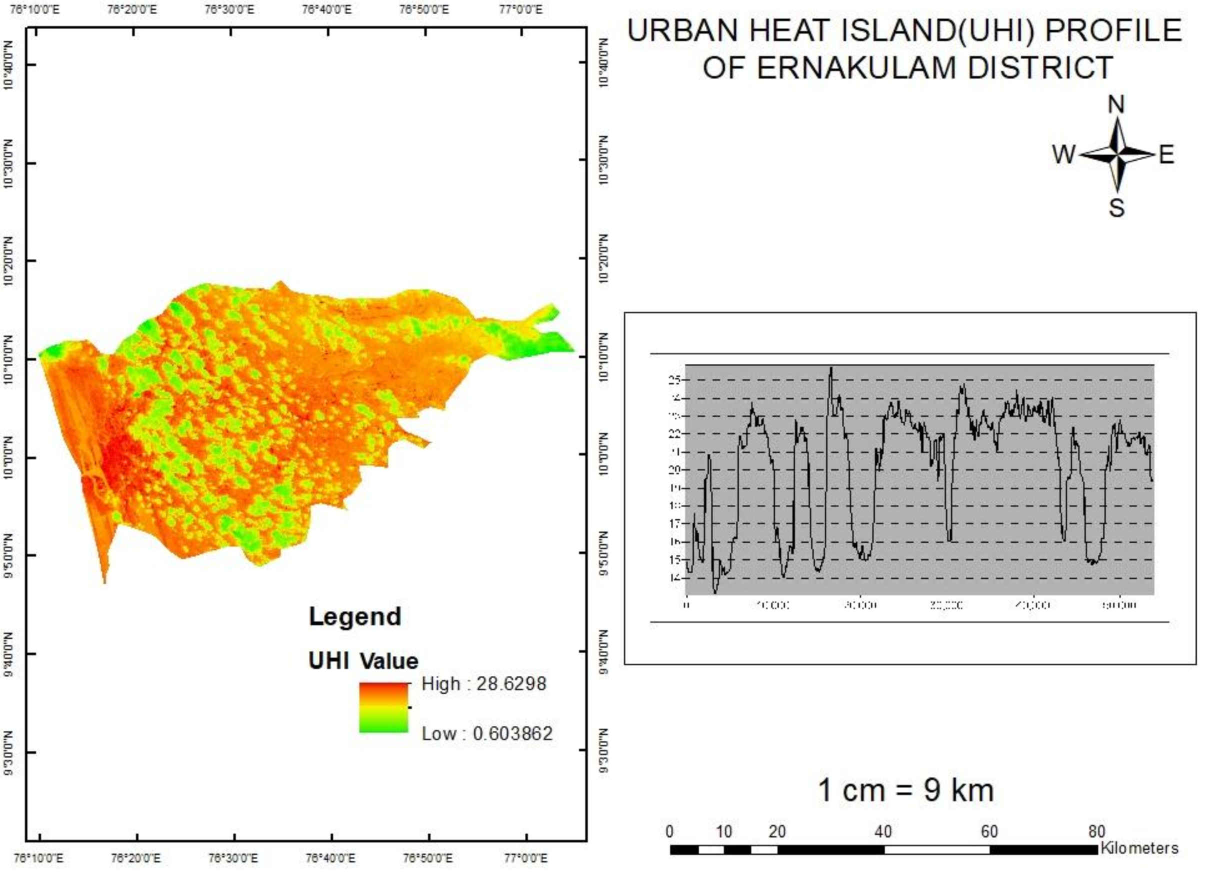


FIG 4.1: Urban Heat Island Profile of Ernakulam District

CHAPTER 5
CONCLUSION

The Assessment of urban heat island (uhi) in Ernakulam district, employing remotely sensed imagery and GIS technology, unveils distinctive spatial patterns of temperature variations. This study underscores the impact of urbanization on microclimates, identifying areas of heightened temperature linked to specific land cover types. The integration of advanced technologies not only enhances precision but also lays the groundwork for evidence-based urban planning. As Ernakulam undergoes urban transformation, the findings emphasize the urgency of incorporating green spaces and climate-resilient strategies to mitigate uhi effects. This assessment serves as a pivotal tool for informed decision-making, fostering sustainable and adaptive urban development in the region.

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