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Correlation Analysis of Land Surface Temperature and Built-up Indices for Metropolitan Cites in Tamil Nadu

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ABSTRACT: This study combines constructed multispectral indices, designed to enhance satellite imagery, to introduce new urban classification systems. The indices tested are New Construction Index (NBI), Built-up Area Exploitation Index (BAEI) and Normalized Differential Concrete Condition Index (NDCCI), Normalized Difference Built-up Index (NDBI).

Landsat level 1 data covers the cities of Chennai, Coimbatore, Madurai, and Trichy. Four major metropolitan cities has been taken and was compared for the following indices, The built-up area extraction index is a tool used in remote sensing and geographic information systems (GIS) to identify and delineate areas that have been developed or urbanized, The importance of a Built-Up Area Extraction Index provides quantitative information about the extent and spatial distribution of built-up areas within urban environments.

The "Normalized Difference Concrete Condition Index" (NDCCI) is a specific index tailored to identifying concrete-built structures within urban areas, derived from remote sensing data, particularly satellite imagery. Land surface temperature (LST) is a fundamental parameter in various fields such as meteorology, climatology, environmental science, agriculture, urban planning, and public health.

The New Built-Up Index (NBI) holds significance due to its ability to provide updated and refined information about built-up areas within urban environments. BAEI, NBI, NDBI and NDCCI and its relationship with LST.

KEYWORDS: ArcGIS; LST; BAEI; NDBI; NBI; NDCCI

I. INTRODUCTION

Urbanization refers to the process of increasing the population density and infrastructure development in urban areas, often leading to the expansion of cities and towns [1]. Land surface temperature (LST) refers to the temperature of the Earth's surface as measured from space or with remote sensing technologies[2]. Metropolitan urban cities in Tamil Nadu have high population densities and extensive infrastructure development, including skyscrapers, industrial zones, and transportation networks[3].

These urban features contribute to increased heat generation and retention, further exacerbating the urban heat island effect. Cities like Chennai, Coimbatore, Madurai, and Tiruchirappalli experience significant urban heat island effects due to intense urbanization [4]**.** However, urbanization can disrupt natural coastal ecosystems and alter local climate dynamics, leading to complex interactions between urban development and land surface temperatures [5]. Despite urbanization, some metropolitan cities in Tamil Nadu maintain green spaces such as parks, gardens, and tree-lined streets [6]. These vegetated areas can help mitigate the urban heat island effect by providing shade, reducing surface temperatures through evapotranspiration, and enhancing local air quality [7].

Land surface temperature (LST) refers to the temperature of the Earth's surface as measured from space or with remote sensing technologies. LST is typically measured using remote sensing instruments onboard satellites, such as thermal infrared sensors [8]. The Built-up Area Extraction Index (BAEI) is a remote sensing index used to quantify the extent of built-up or urbanized areas within a given region [9]. It's derived from satellite imagery and helps identify areas that have been transformed from natural land cover to build infrastructure, such as buildings, roads, and other urban features [10]. The index typically ranges from 0 to 1, with higher values indicating a greater proportion of built-up areas [11].

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The NBI would likely be a remote sensing index designed to quantify the extent and intensity of built-up areas within urban regions. The index would provide a comprehensive assessment of urbanization patterns, capturing both the spatial extent and density of built-up areas [12]**.**The Normalized Difference Built-up Index (NDBI) is a remote sensing index commonly used to delineate built-up areas within urban regions. It is calculated from satellite imagery and compares the difference in reflectance between visible and near-infrared bands to highlight built-up features such as buildings and roads[13] .

When comparing NDBI with land surface temperature (LST) in Tamil Nadu's metropolitan cities. The Normalized Difference Concrete Condition Index (NDCCI) could hypothetically be a remote sensing index aimed at assessing the condition or quality of concrete surfaces within urban areas. NDCCI maps could reveal spatial patterns of concrete condition within Tamil Nadu's metropolitan cities. Areas with higher NDCCI values may indicate well-maintained infrastructure, such as roads, pavements, and buildings, while lower NDCCI values could signify areas with deteriorating or degraded concrete surfaces [14].

II. LITERATURE REVIEW

(Magalie Técher et al.2023) The study evaluates the vulnerability of the Urban Heat Island in Montpellier, France, by incorporating urban planning policies to mitigate the effects of urban overheating, with an emphasis on green areas, ventilation improvement, and reduced heat generation. **(Dechao Chen et al.2019)** The study assesses urban heat risk in Chongqing, China, because of urbanization's impact on land use and land surface temperature, with the goal of promoting sustainable urban development and planning.

(Bijay Halder et al.2021) The study uses land surface temperature and geospatial indicators to assess the impact of Urban Heat Island (UHI) in the Kolkata metropolitan area caused by urbanisation, industrial development, and climate change. **(Murat Atasoy,2020)** Land-use/land-cover changes in Osmaniye, Turkey, from 2000 to 2018 resulted in more urban areas, less forest cover, and rising land surface temperatures, exacerbating Urban Heat Island effects.

(Stephanie Cleland et al.2022) Urban heat islands in US metropolitan areas have an impact on cardiovascular morbidity among adults aged 65 and up, with higher risk in areas with intense urbanisation. Heat-related cardiovascular risk is higher among vulnerable urban populations. **(Jia-Yu Zhang,2023)** Urban heat islands, caused by urbanisation, raise temperatures in the city centre while lowering temperatures on the outskirts. This phenomenon affects urban climate, energy consumption, and human health, necessitating adaptation and mitigation strategies.

(Sabiha Sultana et al.2019) Urbanisation has an impact on the intensity of the Urban Heat Island (UHI) in Indian metropolitan cities, with summer UHIs ranging from 10.5 to 14 degrees Celsius. LST patterns vary by season, with higher temperatures and UHI intensities in summer. **(Sinasi Kaya et al.2012)** The study assesses Urban Heat Islands (UHI) in Istanbul using Landsat 5 TM data, linking urban growth to increased thermal radiation due to unplanned urbanization over three decades. **(Usha et al.2015)** The research assesses Urban Heat Island impact in Udupi due to urbanization using MODIS data, GIS, and remote sensing technology, highlighting temperature variations and land cover changes.

(Blanca Arellano et al.2020) The paper assesses nocturnal Urban Heat Islands (UHI) in the Metropolitan Area of Barcelona, focusing on different urban landscapes' nighttime heat accumulation and cooling models using Landsat thermal data. **(Gary J. Jedlovec et al.2017)** Urban heat wave hazard and risk assessment in metropolitan areas are influenced by urbanization, demographics, and climate change, impacting public health and necessitating advanced warning systems for mitigation.

(Tirthankar Chakraborty et al.2020) The paper characterizes Surface Urban Heat Island (SUHI) intensities in US urbanized areas, highlighting higher summer daytime SUHI and exploring how vegetation density affects variability. **(Rui Zhu et al.2016)** The research tracks the spatial evolution of Urban Heat Islands (UHIs) in urban areas due to urbanization, providing a qualitative interpretation of UHI behavior over time and space.

III. METHODOLOGY

Spectral built-up indices are derived from remote sensing data, typically multispectral satellite imagery, to identify and quantify built-up areas within urban environments [29]. These indices utilize the spectral properties of different land cover types, such as buildings, roads, and paved surfaces, to distinguish built-up areas from other land cover classes [30]**.**

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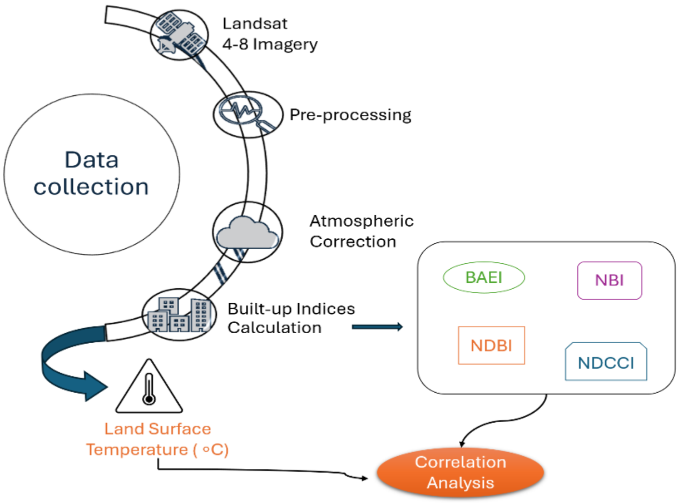
While there are various spectral indices used for this purpose, here's a general explanation of how they work and their relevance to Tamil Nadu's metropolitan cities for Chennai, Coimbatore, Madurai, and Tiruchirappalli [31].



Land Surface Temperature (LST)

LST refers to the temperature of the Earth's surface as measured by remote sensing instruments; typically, onboard satellites equipped with thermal infrared sensors [32]. These sensors detect the thermal radiation emitted by the Earth's surface and convert it into temperature values. LST measurements are obtained in Kelvin (K) or Celsius (°C) and represent the temperature of the ground or other surfaces, excluding the influence of the atmosphere [33]. Urban areas tend to have higher temperatures compared to surrounding rural areas due to human activities, land cover changes, and the built environment [34]. The UHI effect exacerbates LST in metropolitan cities, especially during daytime hours when built surfaces absorb and retain heat. Different surface materials, such as concrete, asphalt, vegetation, and water, have varying thermal properties that influence LST [35].

Urban areas with extensive impervious surfaces tend to exhibit higher temperatures compared to areas with more green spaces. The distribution of land use and land cover within metropolitan cities affects LST. Built-up areas, industrial zones, and densely populated areas typically have higher temperatures compared to vegetated or open spaces [36]. LST data contributes to environmental monitoring efforts by assessing temperature variations, detecting heat anomalies, and evaluating the impact of urbanization on local climate conditions. It supports studies on urban heat island dynamics, air quality, and ecosystem health [37]. $\boldsymbol{TB}$ represents the estimated land surface temperature, and $\boldsymbol{L\lambda}$ represents some parameter related to the thermal properties of the land surface. In this case, $\boldsymbol{K}1$ and $\boldsymbol{K}2$ would be constants specific to the particular model or algorithm used for LST retrieval.by using Landsat EMT+ Value for K1 is 666.09 and k2 is 1282.71 for Landsat TM K1 is 607.76 and K2 is 1260.56 [38].

1. Estimation of Land Surface Emissivity (LSE)

LSE = 0.004Pv +0.986
Where,
LSE = Land Surface Emissivity
Pv = Proportion of Vegetation

2. Estimating Land Surface Temperature

LST= (BT/1) + W * (BT / 14380) * In(E)
Where,
BT = At-sensor brightness temperature
w = wavelength of emitted radiance
e = Land Surface Emissivity

3. Estimation of Normalized Difference Built-Up Index (NDBI)

NDBI = (SWIR – NIR) / (SWIR + NIR)
For Landsat 7 data, NDBI = (Band 5 – Band 4) / (Band 5 + Band 4)
For Landsat 8 data, NDBI = (Band 6 – Band 5) / (Band 6 + Band 5)

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4. Estimation of New Built-up Index (NBI)
NBI = (RED−SWIR1)/(NIR)
For Landsat 7 data, NBI = (Band 5 – Band 4) / (Band 5 + Band 4+ Band 6)
For Landsat 8 data, NBI = (Band 6 – Band 5) / (Band 6 + Band 5+ Band 10)

5. The Built-Up Area Extraction Index (BAEI)
BAEI = (NIR - SWIR)/ (NIR + SWIR)
For Landsat 7 data, NBI = (Band 4 – Band 5) / (Band 4 + Band 5)
For Landsat 8 data, NBI = (Band 5 – Band 6) / (Band 5 + Band 6)

6. Estimation of Normalized Difference Concrete Condition Index (NDCCI)
NDCCI = (NIR - VIS)/ (NIR + VIS)
For Landsat 7 data, NBI = (Band 4 – Band 3) / (Band 4 + Band 3)
For Landsat 8 data, NBI = (Band 5 – Band 4) / (Band 5 + Band 4)

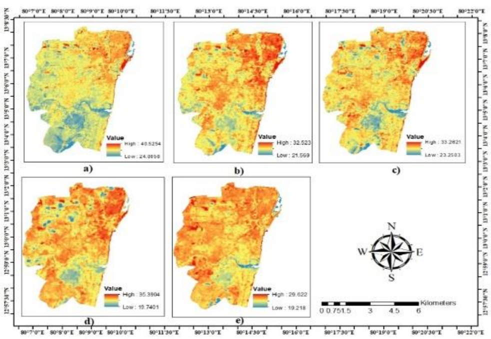
IV. RESULTS

LST Trends (2000–2020)
Chennai: High in 2000, followed by a decrease in 2010 due to greening efforts, remaining stable thereafter.
Coimbatore: Fluctuating temperatures with peaks in 2000 and 2010 linked to rapid industrial growth
Madurai & Trichy: Both cities showed temperature peaks in 2005 and 2015, with lower values recorded in 2020.

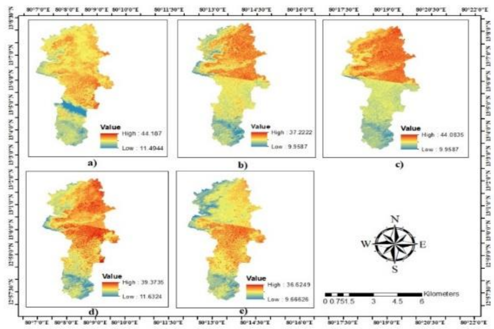
Correlation Analysis (R^{2} values)
NDBI vs. LST: Showed a positive correlation across all cities. In Chennai (2000), $R^2 = 0.244$, meaning 24.4% of LST variation was explained by built-up density.
NBI vs. LST: Generally showed weak to moderate positive relationships. Madurai (2000) showed a higher R^{2} of 0.2759
BAEI vs. LST: Frequently displayed a **negative correlation** (e.g., Chennai 2000 and Coi
mbatore 2005), suggesting complex interactions between urban exploitation levels and surface heat.
NDCCI vs. LST: Consistently weak correlation ($R^2 < 0.10$), indicating that concrete *condition* has a lower impact on temperature than the total *area* of concrete.

NDBI	2000		2005		2010		2015		2020	
	Area(sq.km)	Area %	Area(sq.km)	Area %	Area(sq.km)	Area %	Area(sq.km)	Area %	Area(sq.km)	Area %
CHENNAI	725.184	**18.01%**	736.155	**18.28%**	858.033	**21.31%**	872.109	**21.66%**	834.57	**20.73%**
COIMBATORE	15607.09	**16.50%**	18097.5	**19.13%**	18842.66	**19.92%**	22073.69	**23.33%**	19983.7	**21.12%**
MADURAI	9396.792	**14.37%**	13863.83	**21.20%**	14589.24	**22.31%**	13615.01	**20.82%**	13928.24	**21.30%**
TIRUCHY	15999.97	**19.04%**	18422.77	**21.92%**	17769.45	**21.14%**	16950.35	**20.17%**	14901.06	**17.73%**

1. CHENNAI



2. COIMPUTTUR



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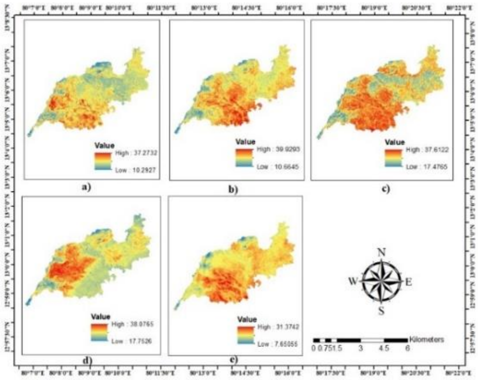
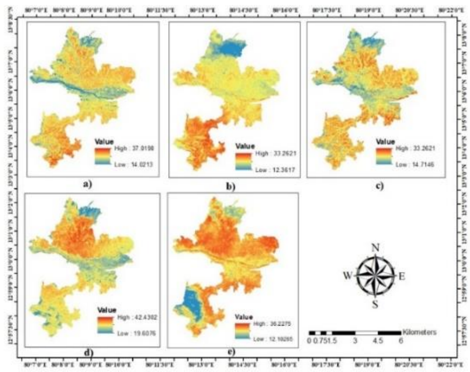
3. MADURAI



4. THIRUCHIRAPALLI



V. CONCLUSION

The study concludes that urban indices are effective tools for monitoring the thermal impact of city expansion. **NDBI and NBI** were found to be the most reliable indicators of LST increases in Tamil Nadu's metropolises. Peak urbanization and LST were often observed around 2010–2015. Notably, concrete quality (NDCCI) was highest in Chennai in 2005 but declined by 2010. These findings highlight the need for "cool roof" technologies and increased urban vegetation to mitigate rising temperatures in densely built environments.

VI. FUTURE SUGGESTING AND RECOMMENDATION

- To enhanced Urban Planning
- Green Spaces Index
- Heat smart Building design
- Community Engagement and Education
- To improve the Satellite Imagery pixels

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