Title: Spatio-Temporal Analysis of Chandigarh (2000–2025) Using Remote Sensing and GIS Techniques.

OBJECTIVE:

The primary objective of this study is to assess the long-term spatio-temporal changes in Chandigarh over a span of 25 years (2000–2025).

The project applies remote sensing indices and classification techniques to:

- Classify Land Use/Land Cover (LULC) into five major classes using supervised classification.
- Evaluate vegetation health through NDVI (Normalized Difference Vegetation Index).
- Detect changes in water resources through NDWI (Normalized Difference Water Index).
- Assess urbanization using NDBI (Normalized Difference Built-up Index).
- Derive Land Surface Temperature (LST) from thermal bands.
- Study the Urban Heat Island (UHI) effect in Chandigarh.

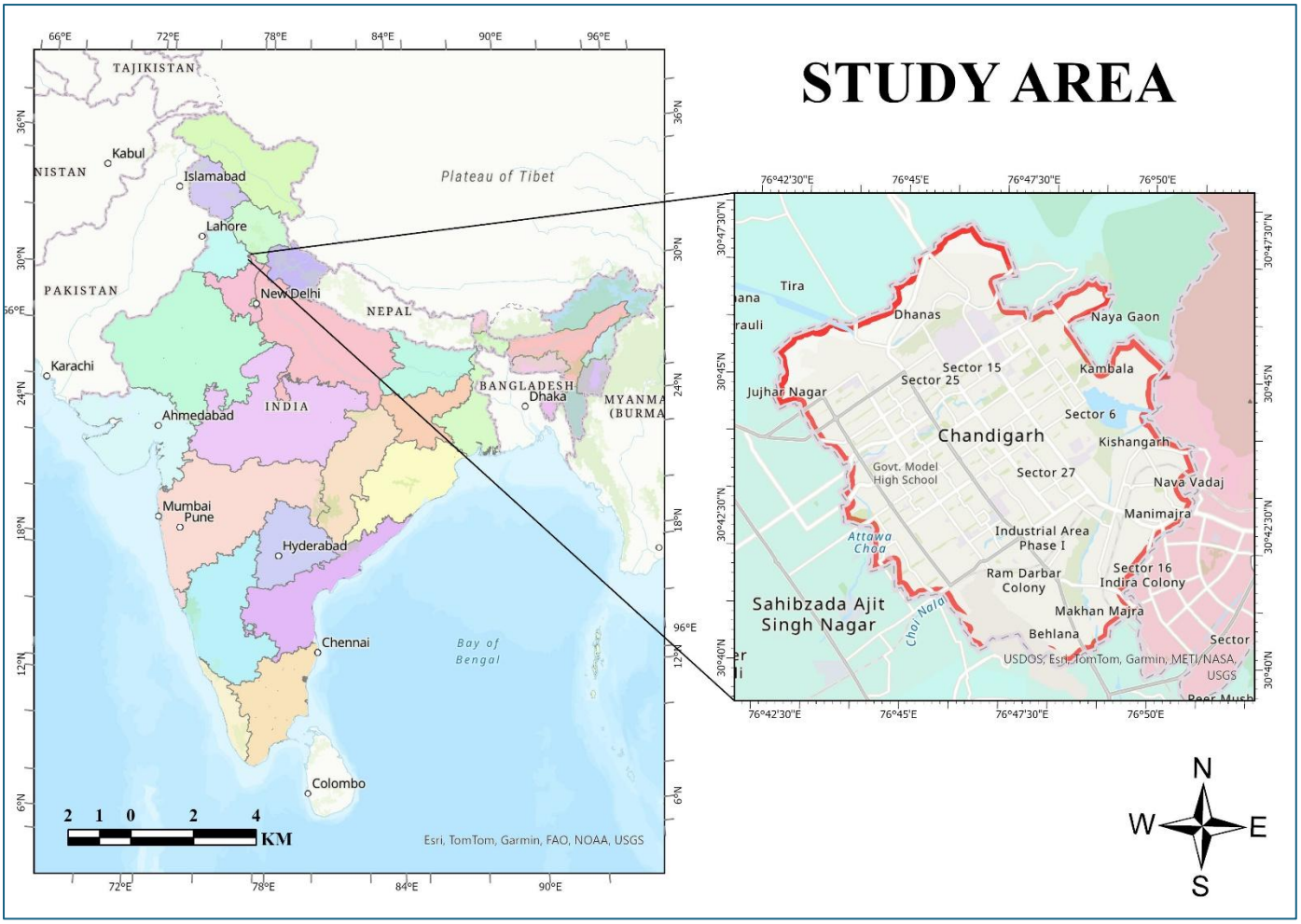
This integrated assessment provides a comprehensive picture of urbanization, ecological stress, and climate impacts in Chandigarh.

STUDY AREA:

The study area is Chandigarh, a Union Territory of India which is located between 30°40′0″N to 30°48′0″N latitude and 76°42′0″E to 76°55′0″E longitude.

Why Chandigarh is suitable for this study:

- It is known as India's first planned city designed by Le Corbusier symbolizing modern urban development.
- The city has undergone rapid expansion since 2000 due to population pressure, migration, and infrastructural growth.
- Chandigarh contains diverse land uses: residential, commercial, agricultural, institutional, waterbodies (Sukhna Lake), and forest patches.
- The city's compact yet diverse geography makes it ideal for analyzing urban-environment interactions over time.



DATA SOURCES:

1) Landsat Satellite Imagery (2000 & 2025) – Downloaded from USGS Earth Explorer

- Landsat 4/5 TM (2000)
- Landsat 8 OLI/TIRS (2025)

2) Software Used: ArcMAP, ArcGIS Pro – for preprocessing, classification, band ratio analysis, map preparation, and results visualization.

METHODOLOGY:

1. Image Acquisition & Preprocessing:

- Landsat images of 2000 and 2025 acquired.
- Radiometric and atmospheric corrections applied.
- Images clipped to Chandigarh boundary.

2. Supervised Classification:

- Training samples identified for 5 classes: Built-up, Agricultural Land, Vegetation, Waterbody, Barren Land.
- Maximum Likelihood Classifier (MLC) applied.

3. Indices Calculation:

- NDVI = (NIR − Red) / (NIR + Red) → Vegetation density & health.
- NDWI = (Green − NIR) / (Green + NIR) → Water presence.
- NDBI = (SWIR − NIR) / (SWIR + NIR) → Built-up intensity.

4. Land Surface Temperature (LST) Derivation:

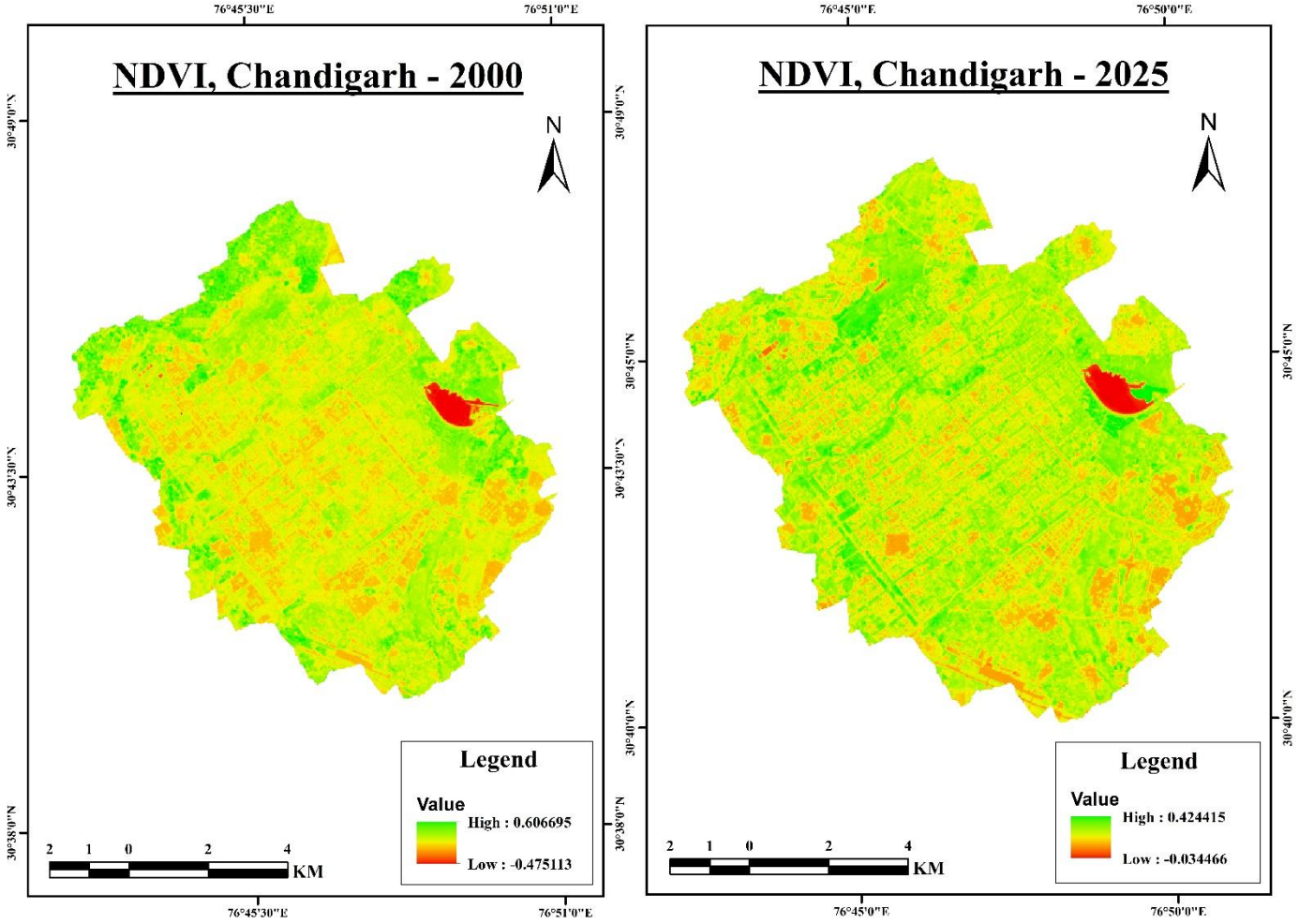
- Thermal bands processed → Radiance → Brightness Temperature → LST.
- Maps generated for both years.

5. Urban Heat Island (UHI) Analysis:

- LST of built-up vs non-built-up zones compared.
- UHI intensity quantified as temperature difference.

RESULTS AND OBSERVATIONS:

1) NDVI (Normalized Difference Vegetation Index):



- In 2000, the NDVI ranged from -0.47 to 0.60, with large patches in the green spectrum (>0.4) indicating the presence of healthy vegetation, agricultural land, and tree cover across Chandigarh's periphery.

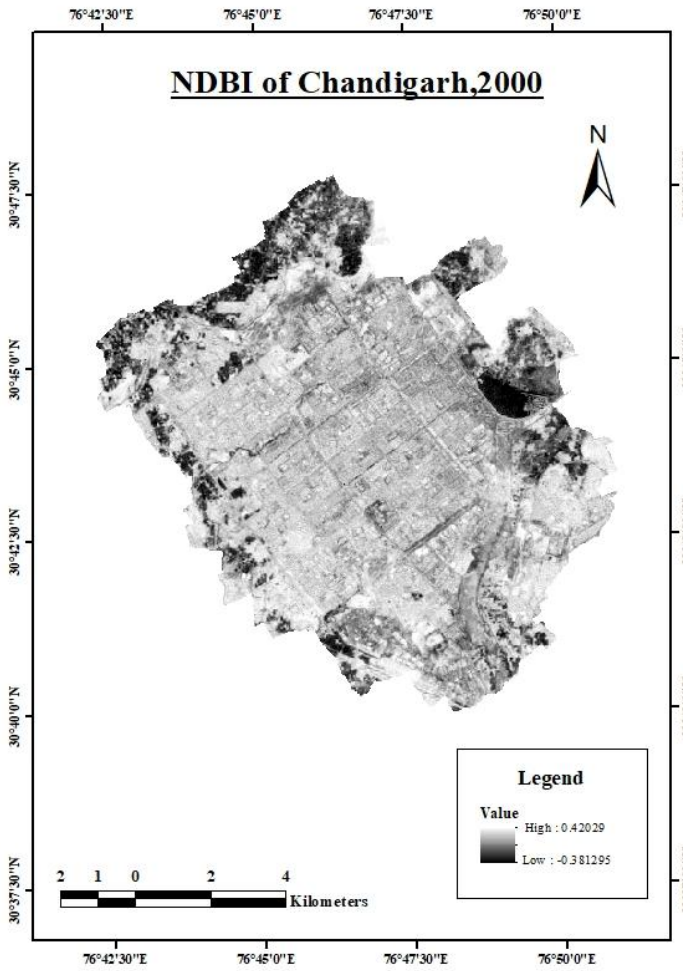
- By 2025, the NDVI range shifted to -0.03 to 0.42, representing an overall decline in vegetation density and health. The maximum NDVI values in 2025 are notably lower than those in 2000 showing reduced photosynthetic activity.

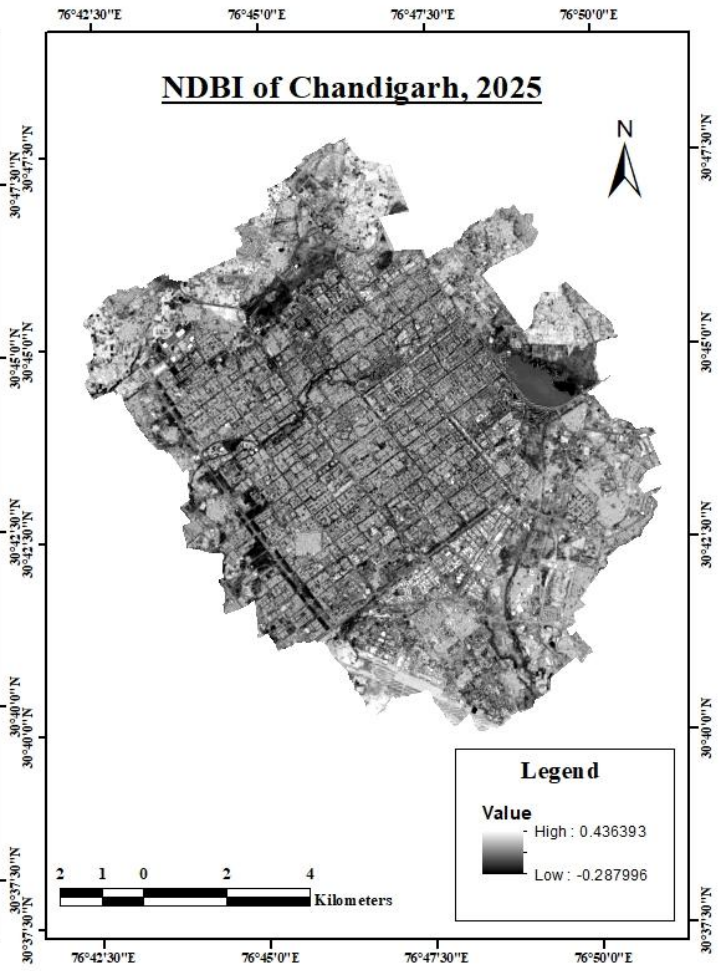
- Areas surrounding Sukhna Lake, forest belts, and institutional campuses that had high vegetation density in 2000 now appear fragmented, with only patchy green zones persisting in 2025.

- Peripheral agricultural fields visible in 2000 have largely been converted to built-up areas by 2025, resulting in declining NDVI values.

- The shift of minimum NDVI values closer to zero in 2025 suggests a reduction in barren/agricultural-vegetation contrast, mainly because barren/fallow areas have transitioned into impervious built-up.

2) NDBI (Normalized Difference Built-up Index):





- In 2000, NDBI values were relatively low -0.38 to 0.42, concentrated in central sectors and along main transportation corridors.

- By 2025, NDBI values expanded across almost the entire city -0.28 to 0.43, showing higher spatial spread of impervious surfaces.

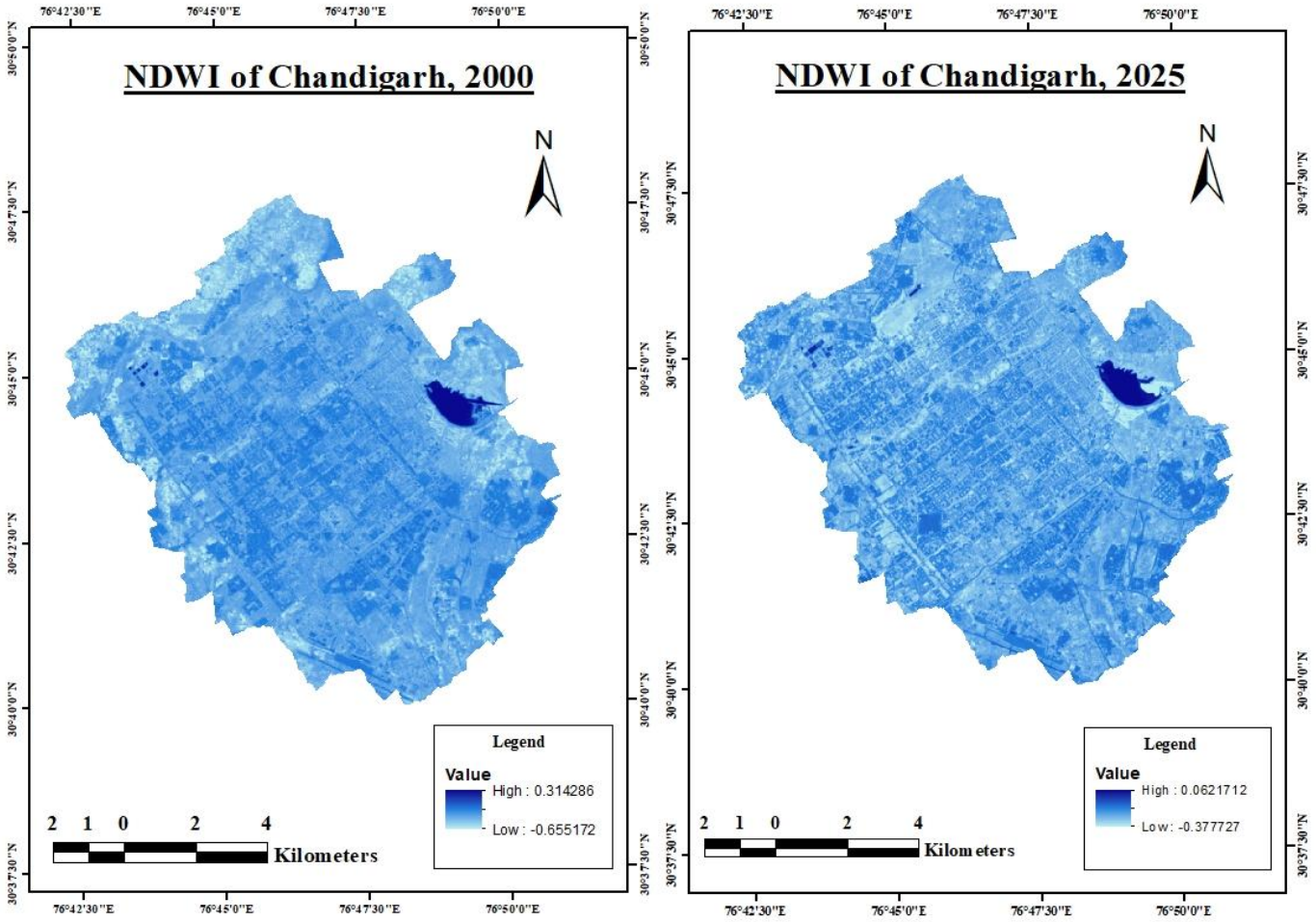
- New residential colonies, commercial hubs, and institutional expansions are clearly reflected in elevated NDBI values.

- Peripheral agricultural lands converted into concrete infrastructure exhibit the sharpest NDBI rise.

- Increased NDBI reflects reduced natural infiltration, higher surface runoff, and greater contribution to urban flooding risks.

- Scientifically, NDBI increase highlights urban densification and growing anthropogenic dominance over Chandigarh's landscape.

3) NDWI (Normalized Difference Water Index):



- In 2000, NDWI values 0.31 indicated healthy water surfaces, with Sukhna Lake and adjoining wetlands playing an important role in the hydrological system.

- By 2025, NDWI values dropped to 0.06, showing shrinkage of open water surfaces and deterioration in water body conditions.

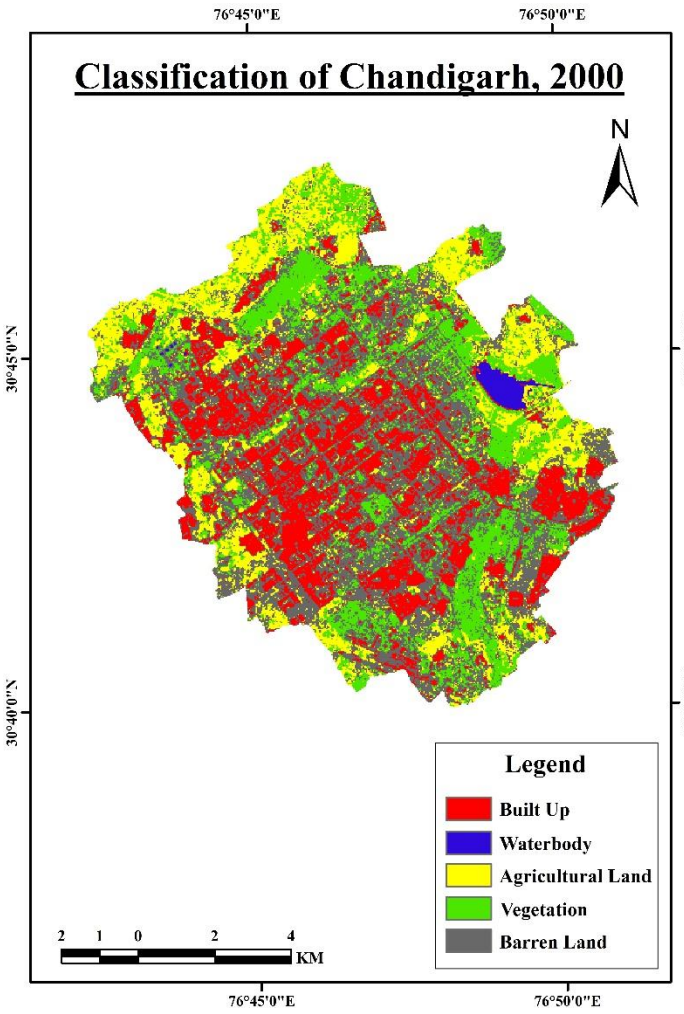
- The decline is likely due to sedimentation, encroachment, and increased water extraction for urban needs.

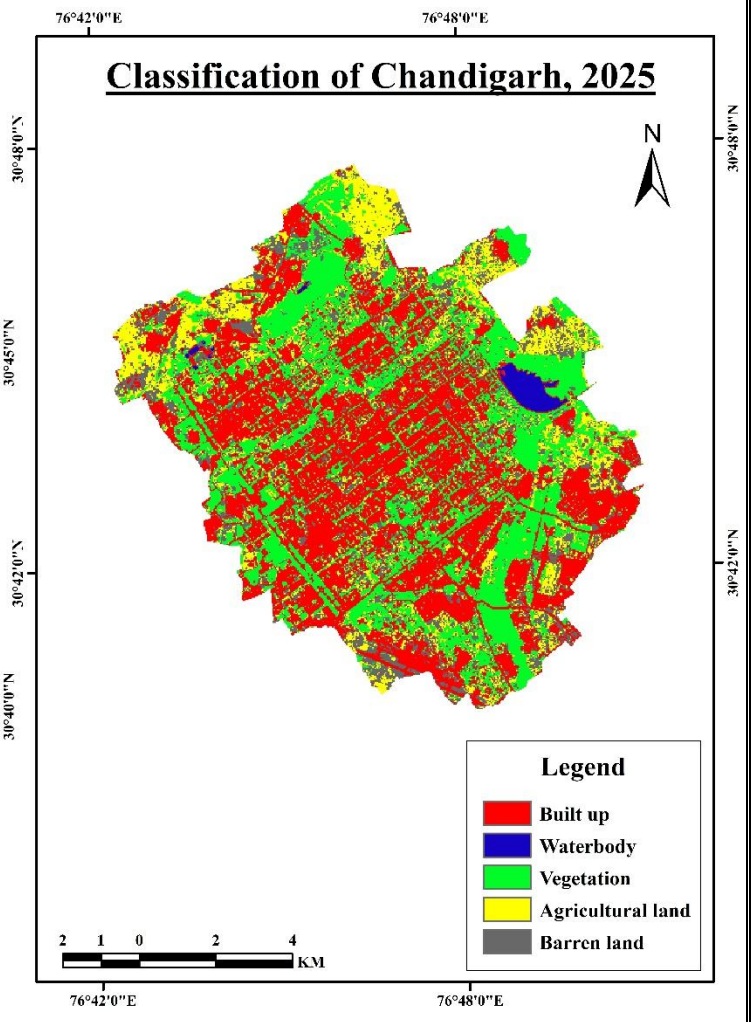
- Seasonal agricultural canals that contributed to higher NDWI in 2000 are now mostly absent due to land conversion.

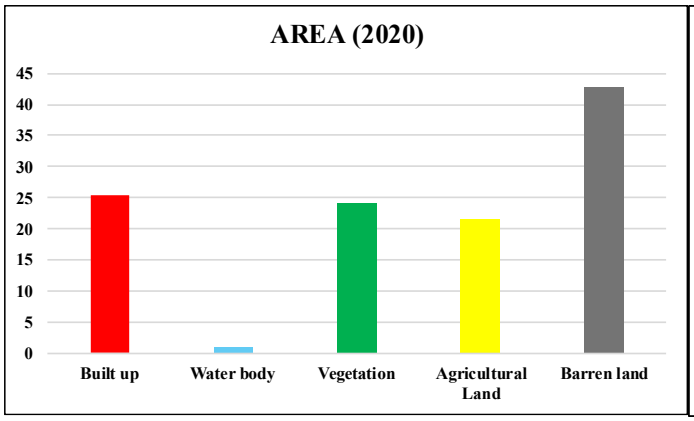
- Urban expansion has reduced percolation zones, contributing to groundwater stress and reduced recharge.

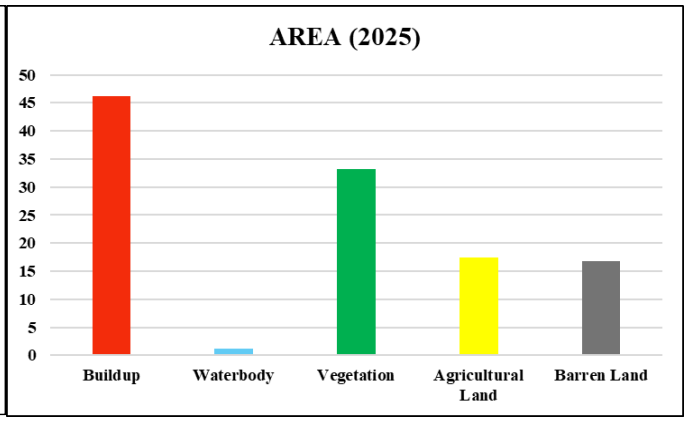
- Scientifically, declining NDWI values signal an alarming trend of water scarcity, which directly impacts vegetation growth, biodiversity, and human consumption.

4) Land Use/Land Cover (LULC):









CHANGE DETECTION (2000-2025)	AREA CHANGE
Built up-Buildup	21.588097
Built up-Waterbody	0.057327
Built up-Vegetation	1.385266
Built up-Agricultural Land	0.962632
Built up-Barren Land	1.353899
Water body-Buildup	0.017417
Water body-Waterbody	0.948664
Water body-Vegetation	0.046158

Water body-Barren Land	0.016816
Agricultural land-Buildup	3.647132
Agricultural land-Waterbody	0.069889
Agricultural land-Vegetation	5.89938
Agricultural land-Agricultural Land	6.831677
Agricultural land-Barren Land	5.07752
Vegetation-Buildup	2.892654
Vegetation-Waterbody	0.065281
Vegetation-Vegetation	14.501473
Vegetation-Agricultural Land	3.790984
Vegetation-Barren Land	2.804322
Barren land-Buildup	17.935458
Barren land-Waterbody	0.061843
Barren land-Vegetation	11.386595
Barren land-Agricultural Land	5.736097
Barren land-Barren Land	7.48108

- Built-up area:

- The period between 2000 and 2025 shows a clear dominance of urban expansion with built-up area increasing from 25% to 45% of Chandigarh's total land.
- The change detection matrix highlights a 21.58% net gain in built-up land, primarily replacing barren land (+17.93%), agricultural land (+3.64%), and vegetation (+2.89%).

- Agricultural land:
  - It has consistently declined reducing from 20% in 2000 to 15% in 2025. Much of this land transitioned into barren areas (+5.07%) or built-up (+3.64%).
  - While some (~5.89%) were converted into managed vegetation reflecting the ongoing replacement of farmland with urban infrastructure and urban landscaping.

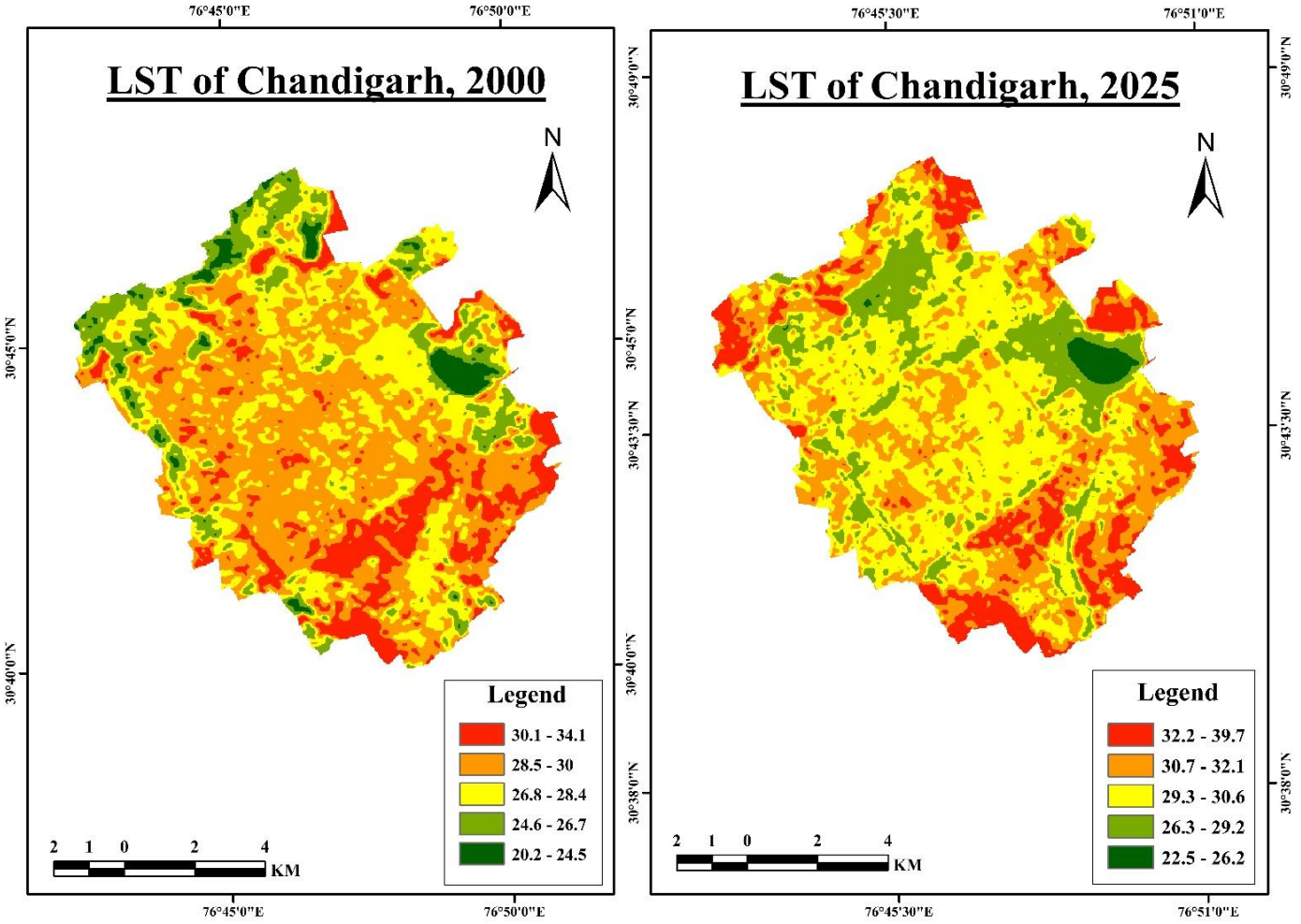
- Vegetation:
  - It shows a mixed trend- in area percentage it rose from 23% to 33%, largely because barren land (+11.38%) and agricultural land (+5.89%) were converted into green patches.
  - However, NDVI analysis reveals that this increase is mostly due to fragmented plantations, parks, and institutional greens rather than dense natural vegetation, indicating that ecological quality has declined even though the spatial cover increased.
- Barren land:
  - It dominated (42%) in 2000 but has sharply reduced to 15% in 2025 confirming its role as a transitional category.
  - Most of this barren land was absorbed into built-up (+17.93%) or vegetation (+11.38%), showing the transformation of open spaces into permanent land uses.

- Water bodies:
  - They mostly remained unchanged with less than ±0.06% variation though stability in area does not necessarily mean stability in ecological health, as issues like sedimentation and encroachment in Sukhna Lake continue to stress the system.

Overall, Chandigarh's land cover has shifted from a balanced urban–rural mosaic in 2000 (with agriculture + barren = 62%) to a predominantly urban landscape by 2025, where nearly half the land is built-up, and the rest is fragmented greens or reduced agriculture.

This transformation illustrates a classic urban sprawl trajectory where productive and natural land covers are systematically replaced by impervious surfaces, altering both ecological balance and microclimatic regulation.

5) Land Surface Temperature (LST)



- The analysis reveals a strong urban expansion trend where built-up areas increased significantly replacing agricultural and barren lands. The decline of NDVI values from 0.60 in 2000 to 0.42 in 2025, indicates a reduction in vegetation health and density despite some spatial gains in green cover.

- With this urban growth, NDBI values rose reflecting the increasing dominance of impervious surfaces. The consequence of such land cover shifts is evident in the rise of LST, where maximum surface temperatures increased from 34 °C in 2000 to nearly 40 °C in 2025.

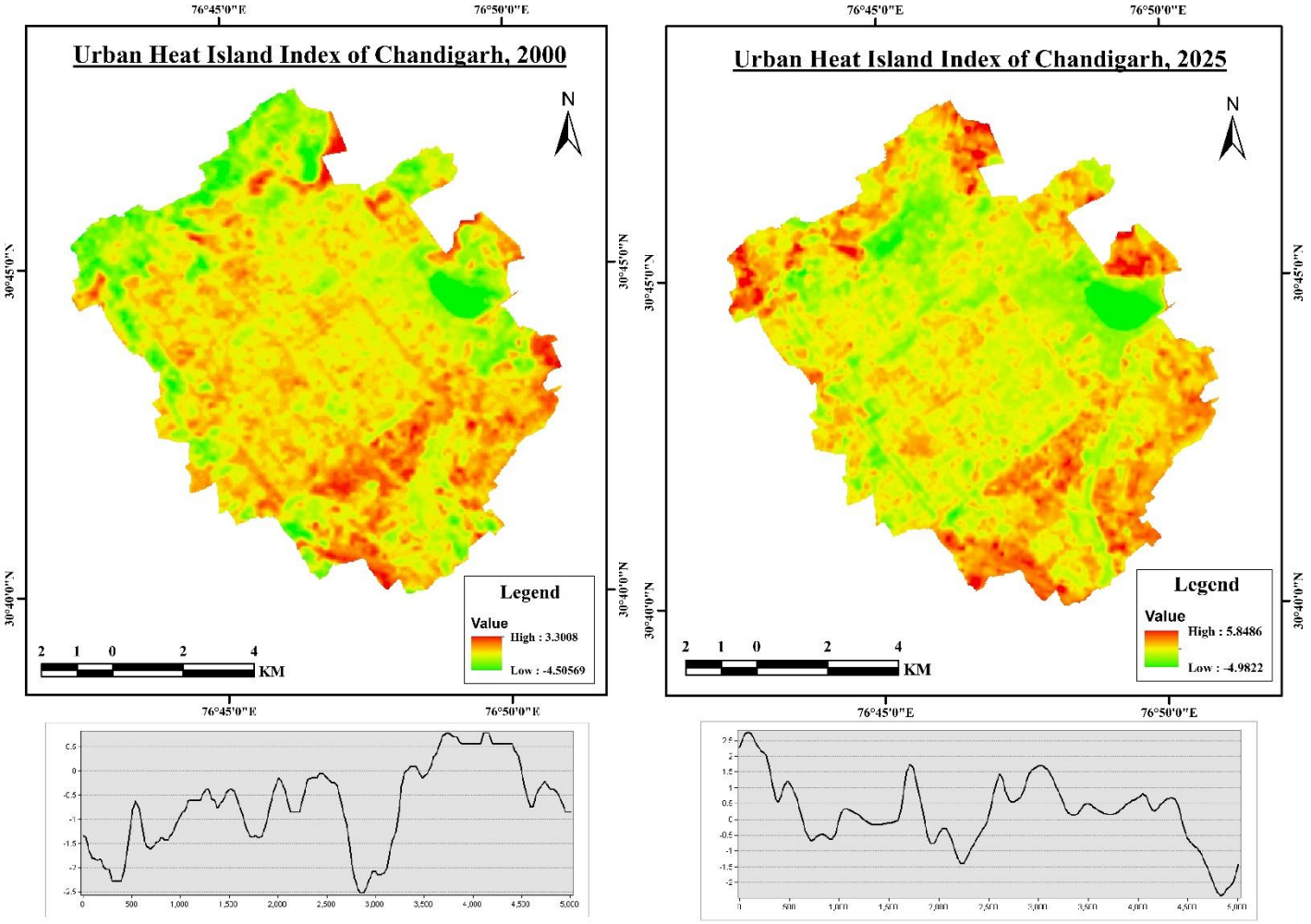
- Simultaneously, the NDWI analysis shows a decline in water body extent and health which reduces natural cooling effects and worsens thermal stress. The shrinking cooling potential of both vegetation and water resources combined with increasing built-up surfaces has contributed to higher intra-city thermal contrasts and reduced resilience against heat waves.

- The change detection matrix further confirms this transformation with substantial conversions of agricultural land and barren land into built-up areas. These conversions reduced productive landscapes thereby raising LST values across the region.

- Overall, the results establish a clear interconnection between urbanization, vegetation degradation, hydrological stress, and rising land surface temperatures. The interplay of reduced NDVI, declining NDWI and rising NDBI strongly explains the observed LST rise.

- Chandigarh's growth pattern thus reflects a classic case of urban sprawl-driven environmental change, where rapid development has compromised ecological balance and increased thermal stress.

6) Urban Heat Island (UHI)



- The UHI intensity in Chandigarh increased from a maximum of 3.3 (2000) to 5.8 (2025) showing a clear rise in localized thermal hotspots. This intensification strongly correlates with the 21.6% growth in built-up areas detected in the LULC analysis.

- Central and peri-urban pockets that were once vegetative/agricultural in 2000 now exhibit stronger UHI signatures in 2025 as natural cooling surfaces have been replaced by concrete structures with higher heat retention.

- Spatial profiles reveal a more fluctuating UHI pattern in 2000 while in 2025 the trendline stabilizes at higher positive values indicating more consistent warming zones across the city.

- The reduction in NDVI from 0.60 to 0.42 and the shrinking NDWI values are directly linked to UHI escalation as less vegetation and water cover reduce evapotranspiration and natural heat dissipation.

- The combined effect of increased LST (34.1 °C → 39.7 °C) and rising impervious surfaces has made Chandigarh's urban sprawl highly prone to thermal stress confirming that UHI is a direct outcome of rapid urbanization and land cover modifications.

CONCLUSION:

This study provided a comprehensive understanding of how Chandigarh has transformed over the last two decades and what these changes mean for its environment. By integrating multiple indices—land use classification, NDVI, NDWI, NDBI, LST, and UHI—it was possible to see not just isolated changes but the larger pattern connecting them.

The findings show that urban growth in Chandigarh has been rapid and often at the cost of natural resources. Expanding built-up areas have reduced vegetation and agricultural land while water bodies have also shrunk.

These changes are not only visible on maps but also reflected in the city's environment where green cover has declined, heat has intensified, and the urban core has become more vulnerable to stress.

The study also highlighted how interconnected these processes are. A loss of vegetation reduces NDVI, which weakens the city's natural cooling ability. Shrinking water bodies lower NDWI, further limiting climate regulation. At the same time, increasing built-up areas reflected in NDBI raise land surface temperatures which directly contributes to the intensification of the Urban Heat Island effect.

Together these indicators paint a clear picture: urbanization without balanced planning has cascading impacts on both ecological health and human comfort.

Through this analysis, the study not only documents the spatial and environmental changes in Chandigarh but also underlines the importance of sustainable planning. It shows how remote sensing and GIS can be powerful tools to monitor, understand, and anticipate urban growth and its consequences.

More importantly, it emphasizes the urgent need to integrate environmental considerations into urban development so that cities like Chandigarh can grow without losing their natural resilience.