A PROJECT REPORT

On

Identifying Urban Hotspots and Cold Spots in Delhi Using Biophysical Landscape Framework

Submitted in the partial fulfillment of requirements to

CS- 363 - Term Paper

By

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1. Problem Statement

Urbanization, while often a sign of progress and development, has its darker consequences — and one of the most persistent, yet underestimated of them, is the **Urban Heat Island (UHI)** effect. In simple terms, UHI is the temperature difference observed between urban areas and their surrounding rural regions due to **intensive human activities**, **dense concrete infrastructure**, and the **systematic removal of natural landscapes** like forests, water bodies, and open green spaces.

In the case of **Delhi**, one of the most populated and rapidly urbanizing metropolises in the world, this issue is **not just theoretical** — it's on the ground, in the air, and affecting the daily lives of millions. The **variation in UHI intensity** across the city is stark and spatially uneven, leading to the emergence of **Urban Hotspots (UHSs)** — areas where the intensity of heat is significantly higher — and **Cold Spots** — areas that still retain cooler microclimates due to the presence of vegetation, water bodies, or sparse construction.

The complexity arises because not all urban elements contribute equally to UHI. For instance:

- **Dense built-up zones** and **impervious surfaces** trap heat and contribute heavily to LST (Land Surface Temperature).
- **Industries** and **thermal power plants** emit heat as a by-product.
- **Traffic congestion** increases localized temperature due to vehicular emissions and idling engines.
- Conversely, **vegetation** and **open spaces** absorb less heat, provide shade, and release moisture, making them natural coolants.

Despite multiple studies focusing on UHI in Indian cities, **few have offered a zonal-level, geospatial, and data-driven classification** of UHI regions based on a combination of **satellite-derived thermal data** and **biophysical indicators**. This lack of high-resolution spatial zoning limits the ability of **urban planners, climate scientists, and policy-makers** to develop localized and effective mitigation strategies.

Hence, this project attempts to bridge that critical gap by:

- Utilizing **MODIS LST** and **Landsat-derived NDVI** data.
- Digitally mapping various **biophysical landscape features**.
- Applying **weighted overlay methods using GIS tools**.
- **Classifying Delhi into four distinct UHI zones**.

2.Functional Requirements

To meet the project's objectives, the following functionalities are required:

1. Data Acquisition and Preprocessing

- Collect satellite imagery:
  - **MODIS (MOD11A1)** for Land Surface Temperature (LST).
  - **Landsat-8** for NDVI and biophysical features.
- Reproject data to match spatial resolution and correct for atmospheric interference.

2. Biophysical Landscape Layer Creation

- Digitize and layer the following features from Google Earth and secondary data:
  - **Built-up density zones** (low, moderate, high).
  - **Industrial zones** and **thermal power plants**.
  - **Traffic congestion hotspots**.
  - **Vegetation cover** using NDVI.

3. LST Estimation

- Convert brightness values (DN) to TOA Radiance.
- Calculate brightness temperature using MODIS thermal bands and thermal constants.
- Apply emissivity correction to obtain accurate LST values in Celsius.

4. Vegetation Index Computation (NDVI)

- Calculate NDVI using:

  NDVI = (NIR – RED) / (NIR + RED)
- Classify vegetation cover into sparse, moderate, and dense.

5. Weighted Overlay Analysis in ArcGIS

- Assign weights to each feature based on its impact on UHI:
  - Built-up density: 30%
  - LST: 25%
  - Industries: 20%
  - Thermal power plants: 15%

    - Traffic congestion: 10%
- Normalize and overlay all raster layers to produce a **UHI Intensity Index**.

6. Zone Classification

- Divide Delhi into 4 categories:
    - **High UHI zone (urban hotspots)**
    - **Moderate UHI zone**
    - **Low UHI zone**
    - **Very Low UHI zone (urban cold spots)**

7. Result Visualization

- Generate heat maps and classification layers using GIS tools.
- Create a **tabular mapping** of zones with associated locality names.

8. Documentation and Output Reporting

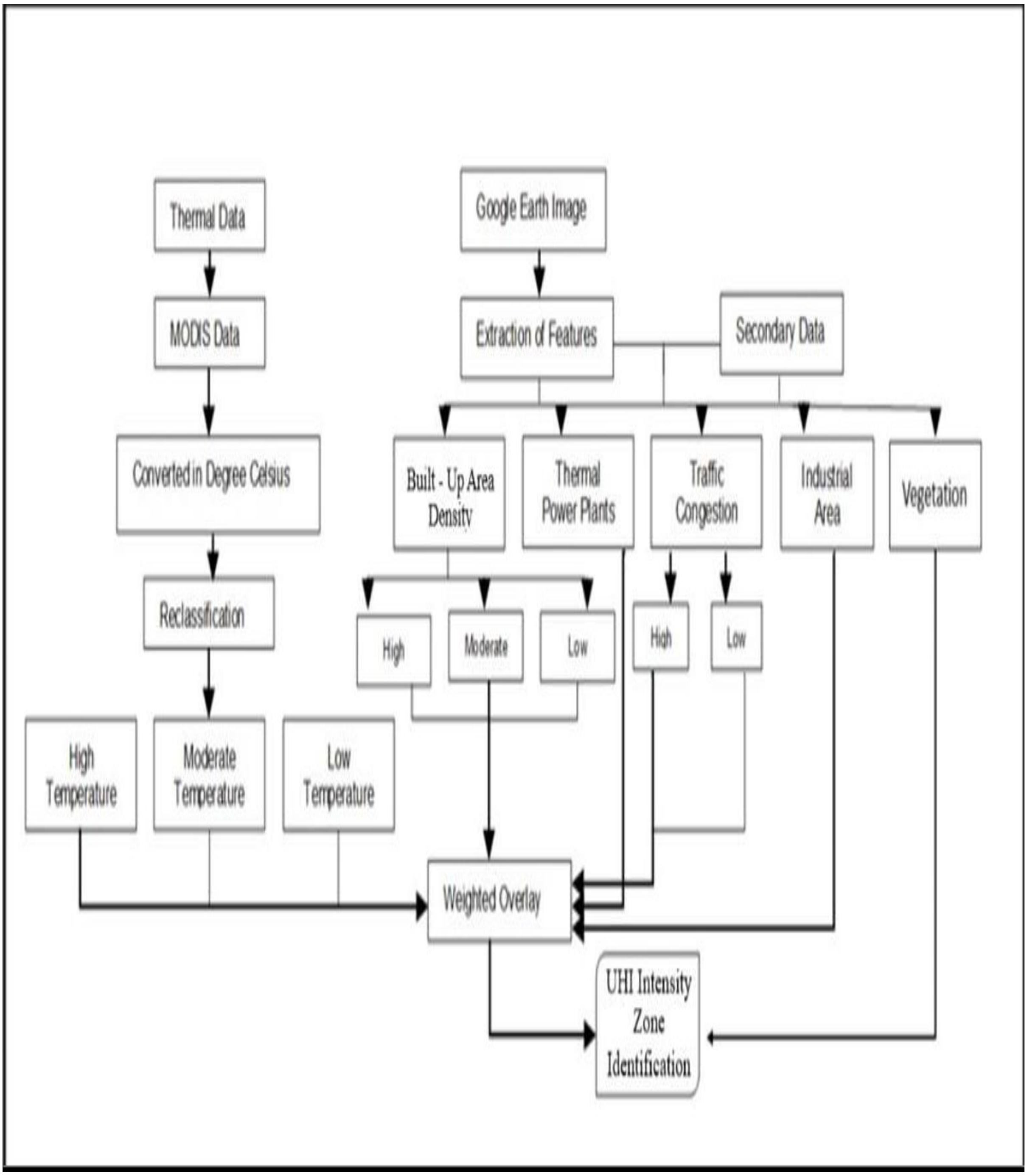
- Maintain reproducible data pipelines and logs.
- Present analytical findings in a report format for urban planners and policymakers.

3. Basic Architecture

a)Major Components

Component	Description
Satellite Input Module	Fetches and preprocesses MODIS and Landsat-8 imagery for Delhi.
LST Calculator	Computes land surface temperature from thermal bands.
NDVI Processor	Generates vegetation health index using NIR and RED bands.
GIS Layer Creator	Maps built-up zones, traffic hotspots, industries, and thermal power locations.
Weight Engine	Assigns influence weights to each landscape feature based on UHI contribution.
Overlay Analyzer	Performs GIS-based weighted overlay to determine cumulative UHI impact score.
Zone Classifier	Classifies the city into UHI intensity categories using rule-based logic.
Map Output Generator	Produces thematic heat maps with zonal markings and locality labels.

b) Diagram


Thermal Data
MODIS Data
Converted in Degree Celsius
Reclassification
High Temperature
Moderate Temperature
Low Temperature
Google Earth Image
Extraction of Features
Secondary Data
Built - Up Area Density
Thermal Power Plants
Traffic Congestion
Industrial Area
Vegetation
High
Moderate
Low
High
Low
Weighted Overlay
UHI Intensity Zone Identification

c) Workflow

1. **Acquire** satellite data (MODIS, Landsat).
2. **Compute** LST and NDVI using equations and rescaling factors.
3. **Digitize** landscape features using Google Earth and secondary sources.
4. **Assign weights** based on expert literature (e.g., Gupta 2012, Hang & Rahman 2018).
5. **Overlay** all weighted features using ArcGIS.
6. **Classify** UHI zones and generate maps.
7. **Tabulate and visualize** final results with locality-based heat rankings.

d) Pattern

The architectural pattern resembles a **Layered Geospatial Analytical System**, with the following layers:

- **Input Layer**: Raw satellite and contextual data.
- **Processing Layer**: LST, NDVI, and classification computation.
- **Logic Layer**: Weighted decision rules and spatial overlay.
- **Output Layer**: Zonal maps, statistical tables, and decision support insights.

This follows the **Data-Driven GIS Pattern** — where input data guides the computational flow and directly influences the visualized output.

4.Non-Functional Requirements

Aspect	**Details**
Performance	Image processing, layer classification, and raster overlay should execute within 10 seconds per 100 km^2.
Scalability	The model is scalable to any other urban region where satellite data is available.
Portability	Can be executed on any system supporting ArcGIS or QGIS with minimal configuration.
Reliability	MODIS and Landsat provide stable, validated datasets; ArcGIS workflows ensure reproducible outputs.
Accuracy	LST validated using thermal standards; features verified from Google Earth and field cross-checks.
Usability	Final outputs (heatmaps, tables) are digestible by planners, environmentalists, and urban bodies.
Maintainability	Layered modular structure allows easy updating — e.g., changing weights, importing new layers.
Security	All data used is public, with no privacy-sensitive information — eliminating regulatory barriers.
Flexibility	Weight matrices, classification thresholds, and input types can be adjusted as needed.
Transparency	Decision logic is fully documented and open to audit or expert review.

5. Technology Stack

Layer	**Technology/Tool**
Remote Sensing	MODIS (MOD11A1) for LST; Landsat-8 (bands 4 & 5) for NDVI
GIS Platform	ArcGIS (primary), QGIS (optional fallback)
Visualization	ArcGIS Symbology, QGIS Layer Styling
Data Source	Google Earth Pro (industries, thermal plants, traffic), Census Maps
Programming	Python (for preprocessing LST, NDVI scripts if automated), GDAL
Documentation	MS Word, LaTeX (for formal academic report generation)
Storage Format	GeoTIFFs, Shapefiles (.shp), CSV (for weight matrices)

6. Summary

Delhi — the capital of India, a historical city now transforming into a high-density urban megapolis — is heating up faster than many realize. The project titled “Identifying Urban Hotspots and Cold Spots in Delhi Using the Biophysical Landscape Framework” aimed to bring a structured, data-driven approach to understanding the invisible danger of Urban Heat Islands (UHI) through cutting-edge geospatial technology.

The study used satellite-derived LST (MODIS) and NDVI (Landsat-8) to quantify surface temperature variations across Delhi. The city was digitally layered with critical biophysical indicators including built-up density, vegetation, industrial areas, thermal power plant locations, and traffic zones. These were not just mapped but weighted, scored, and overlaid using a multi-criteria decision model in ArcGIS.

The outcome? A powerful heat zoning of Delhi, classifying its landscape into four thermal categories:

- High UHI Zones (Hotspots): Found in central and eastern Delhi — where concrete jungles, factories, power plants, and absent greenery converge. These areas showed the most critical need for greening, cool-roof policies, and decongestion plans.
- Moderate UHI Zones: Transitional belts, typically around growing urban fringes — a mix of vegetation and emerging construction.
- Low UHI Zones: Residential clusters with decent vegetation coverage, lower traffic, and planned layouts.
- Very Low UHI Zones (Cold Spots): Found near ridge zones, riverbanks, or preserved green pockets — like parts of South Delhi, university campuses, and green-belt colonies.

This classification is not just academic. It is actionable. The heat maps and locality-based zone tables are tailor-made for urban policy-makers, environmental agencies, and planners. They show where to plant more trees, which zones need reflective surfaces or air corridors, and how to prioritize interventions.

Additionally, this framework is scalable. Mumbai, Chennai, Lucknow, Hyderabad — any Indian city facing thermal stress — can plug into this model using their own data layers. The logic is flexible, the methods are replicable, and the implications are real-world critical.

In conclusion, this project combines rigorous thermal science, spatial data intelligence, and urban policy foresight. It highlights not only the urgent need to cool our cities but also how exactly to do it — one pixel, one feature, one locality at a time.