Land Cover Classification of Lahore Using Unsupervised Techniques in Remote Sensing and GIS

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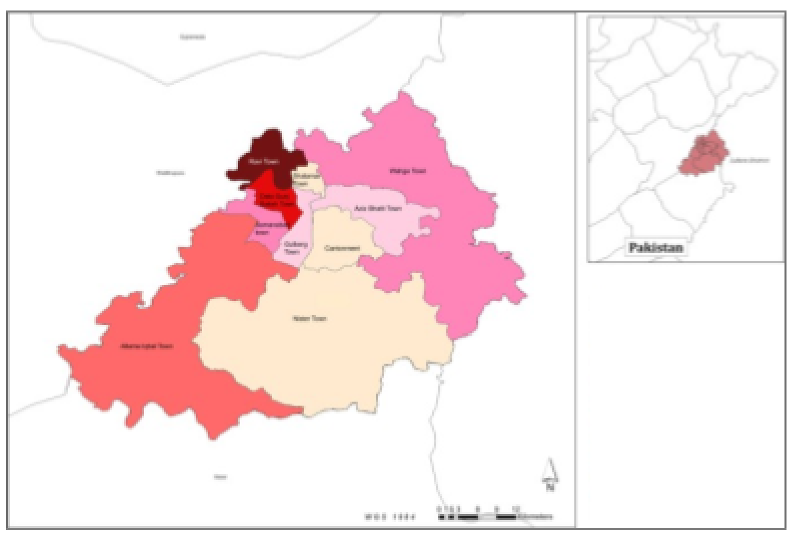
1. Introduction

Remote sensing and Geographic Information Systems (GIS) play a crucial role in the study and management of Earth's surface features. These technologies help in gathering, processing, and analyzing spatial data for a wide range of applications, including land use planning, resource management, and environmental monitoring. One of the fundamental tasks in remote sensing is land cover classification, which involves identifying and categorising different types of surface materials and land use types in satellite imagery.

In this project, we performed a land cover classification for Lahore, a major metropolitan city in Pakistan. We used an unsupervised classification method in ENVI to extract 50 initial spectral classes based on pixel values. These classes were then grouped into meaningful categories in ArcGIS to simplify interpretation. The area of each reclassified land cover type was calculated and visualized through a histogram to better understand the spatial distribution of different surface types in the city. This process is valuable for supporting urban development, infrastructure planning, and environmental conservation.

2. Study Area



Lahore, the capital of Punjab province, is among the largest and fastest-growing cities in Pakistan. It lies at 31.5204° N latitude and 74.3587° E longitude and spans approximately 1,772 square kilometres. As a cultural and historical hub, Lahore is known for its rich heritage, educational institutions, commercial zones, and government infrastructure. The city is undergoing rapid urban expansion, which makes it an ideal subject for land cover analysis.

Dense urban settlements, open green spaces, agricultural lands, barren patches, and a network of water bodies, including the Ravi River and several canals, characterise the city's landscape. As the city expands, it becomes increasingly important to monitor and evaluate changes in land cover to support sustainable development and environmental stewardship.

3. Methodology

The methodology consisted of five major steps: data acquisition, image preprocessing, classification, post-classification reclassification, and statistical analysis.

3.1 Data Collection

- **Satellite Source:** Landsat imagery
- **Spatial Resolution:** 30 meters
- **Software Used:** ENVI for classification; ArcGIS for spatial analysis and mapping

3.2 Data Processing

The satellite imagery was preprocessed to ensure focused and efficient classification. The key preprocessing steps included **Layer Stacking**, **Subsetting**, and **Clipping**. These steps were performed using **ENVI** and **ArcMap (GIS)**.

3.2.1 Layer Stacking

Initially, individual spectral bands of the satellite imagery were combined into a single multiband raster to enable spectral-based classification.

- **Input:** Individual band images (e.g., Bands 1–7 from Landsat 8).
- **Tool Used: ENVI – Layer Stack Tool**.
- **Output:** Multiband composite image.

3.2.2 Subsetting

Before proceeding to classification, subsetting was applied to focus on the specific region of interest within the satellite image, reducing data size and processing time.

- **Input:** Layer-stacked image and shapefile of the area of interest (AOI).
- **Tool Used: ENVI – ROI Tool and Subset Data Using ROI**.

- **Output:** Subset image covering only the desired region for analysis (e.g., urban zones of Lahore).

3.2.3 Clipping

After classification and reclassification were completed, clipping was done in **ArcMap** for layout and presentation purposes. This step helped in finalizing the output visuals and map layout.

- **Input:** Classified image and AOI boundary shapefile.
- **Tool Used: ArcMap – Extract by Mask (Spatial Analyst)**.
- **Output:** Final clipped map used in layouts and result visualization.

3.3 Data Analysis

3.3.1 Unsupervised Classification in ENVI

Unsupervised classification is a data-driven method that identifies natural groupings in imagery without prior knowledge of the area. For this study, the ISODATA (Iterative Self-Organising Data Analysis Technique) algorithm was used in ENVI. The algorithm assigned pixels to 50 classes based on spectral reflectance values. This approach allowed for a fine-grained classification, useful for detailed interpretation and grouping in later steps. The high number of initial classes helped in isolating subtle spectral differences across the urban, vegetated, and bare areas.

3.3.2 Reclassification in ArcGIS

Following the classification, the output raster with 50 spectral classes was imported into ArcGIS. Through visual inspection and comparison with the satellite imagery, these classes were manually reclassified into four broader categories:

- **Built-up Area:** Includes all infrastructure such as roads, buildings, and other impervious surfaces.
- **Vegetation:** Covers both natural and cultivated green areas, including parks, fields, and plantations.
- **Water Bodies:** Encompasses rivers, canals, ponds, and other aquatic features.

- **Barren Land:** Refers to exposed soil, construction zones, and vacant plots.

The Reclassify tool in ArcGIS was employed to simplify the raster data into these four main land cover types.

3.3.3 Statistical Analysis

3.3.3.4 Area Calculation

Using the raster calculator, we measured area by calculating the number of pixels in an area. Area values were recorded in square kilometres and also converted into percentages relative to the total area of Lahore for comparison and analysis.

3.4 Data Presentation

3.4.1 Multiple Bar Generation

To visualize the spatial distribution of land cover classes, a histogram was created in ArcGIS. The chart displayed land cover types on the x-axis and the corresponding area (in km^2) on the y-axis. This graphical representation highlighted the dominance or scarcity of each land cover class across the region.

4. Results

The land cover classification was carried out for two time periods: 2021 and 2025. This allowed for a temporal comparison of changes in land use patterns across Lahore. The results indicate an increase in built-up and barren land, while vegetated areas have declined.

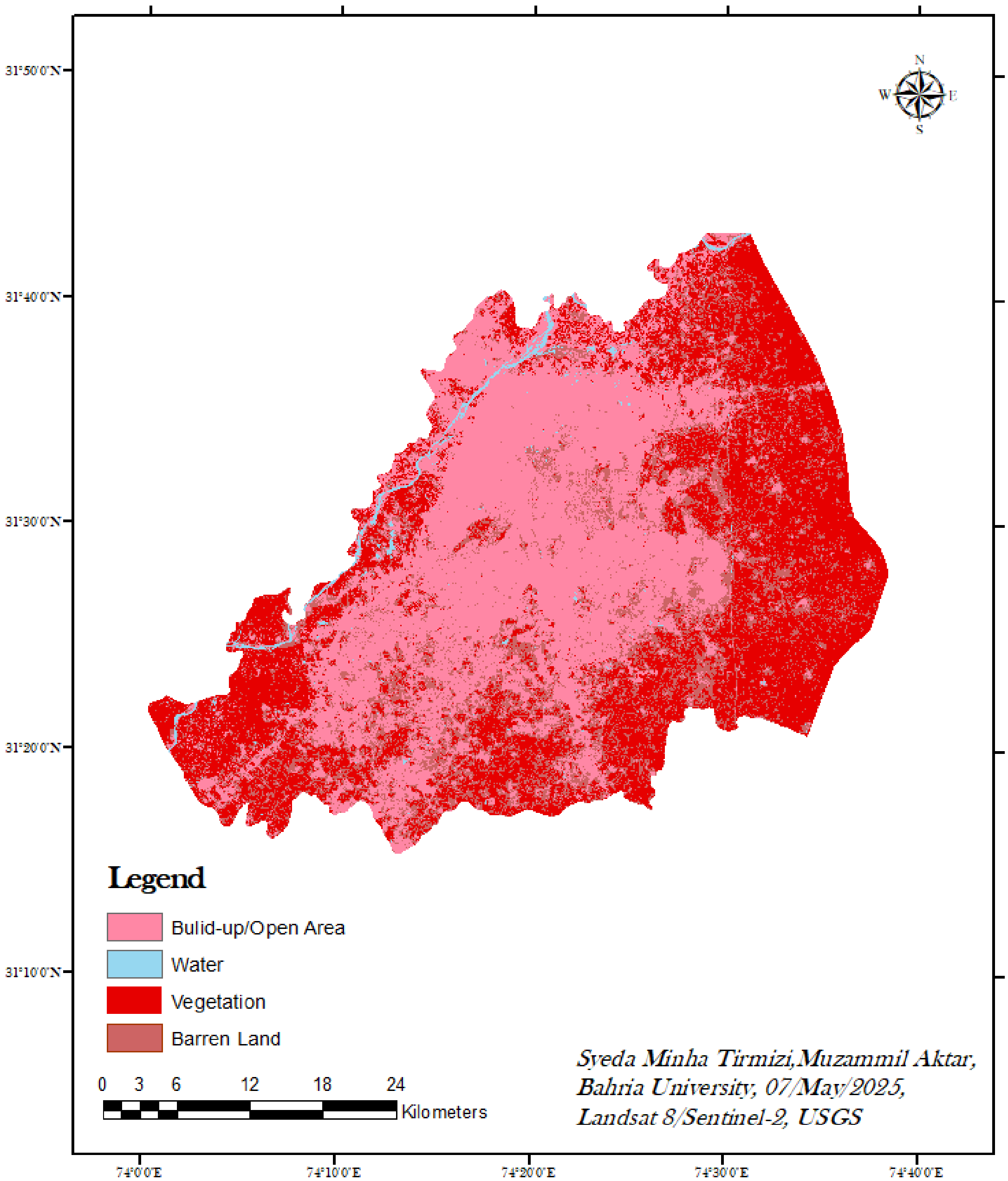
Land Cover Comparison (2021 vs 2025):

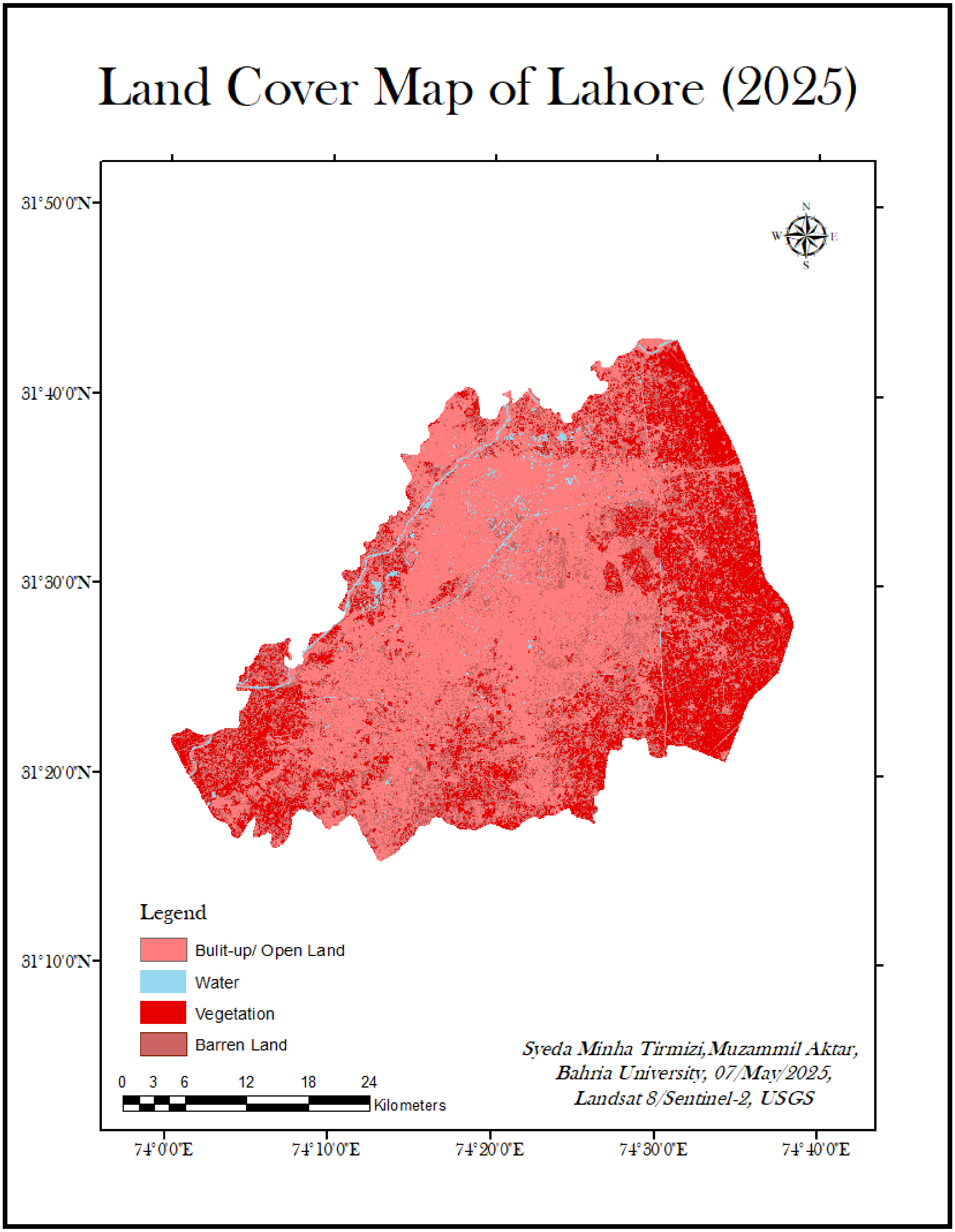
Years		2021		2025
Name	Area (Km^2)	Percentage %	Area (Km^2)	Percentage %
Built-up/Open Area	725.2965	41.96%	820.971	47.49%
Water	18.1881	1.05%	30.6441	1.77%
Vegetation	633.204	36.63%	428.7123	24.80%
Barren Land	352.0323	20.36%	448.3935	25.94%
Total	1728.7209	100.00%	1728.7209	100.00%

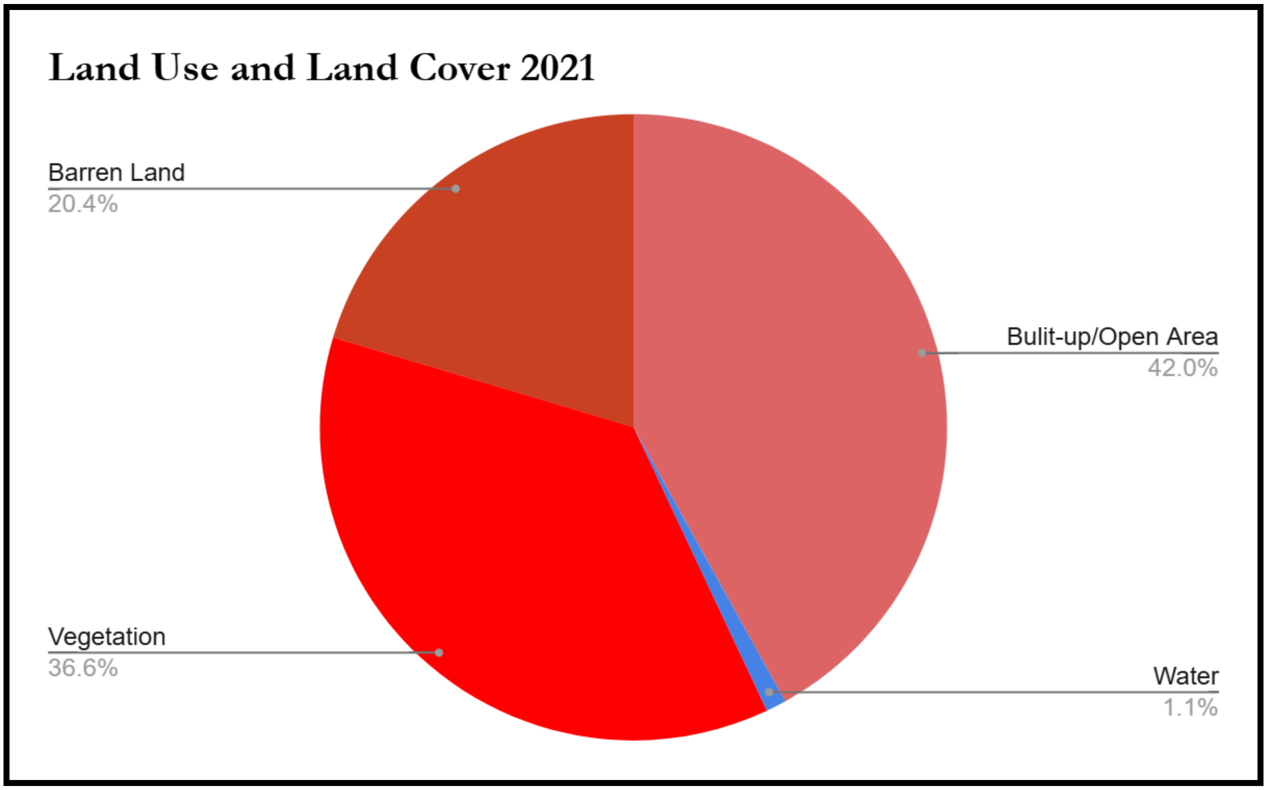
These figures highlight a significant shift in land use over four years:

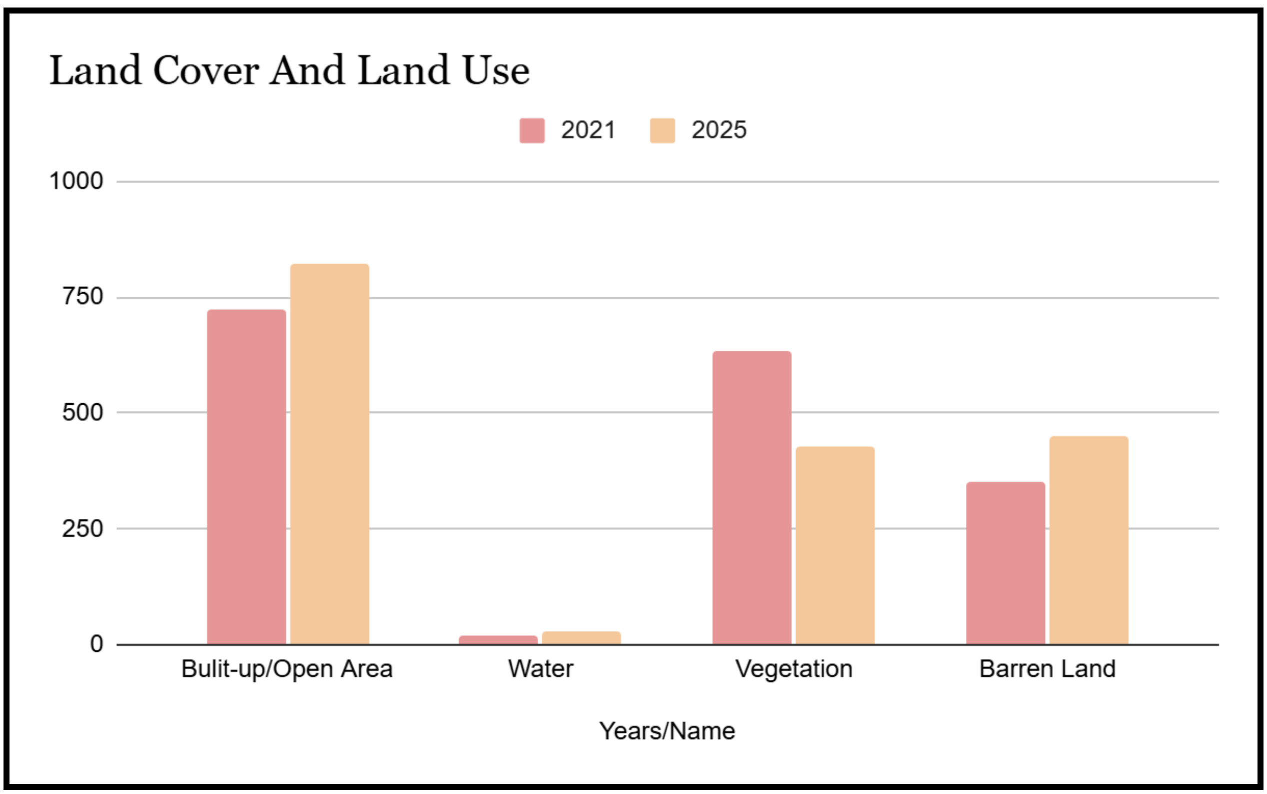
- **Built-up/Open Area** increased by nearly 96 km^2, reflecting urban growth and infrastructure expansion.
- **Vegetation** declined sharply by over 200 km^2, suggesting either conversion to urban land or seasonal effects.
- **Water Bodies** nearly doubled in area, which could indicate expanded canal networks or seasonal water presence.
- **Barren Land** also increased, possibly indicating construction sites or cleared vegetation zones.

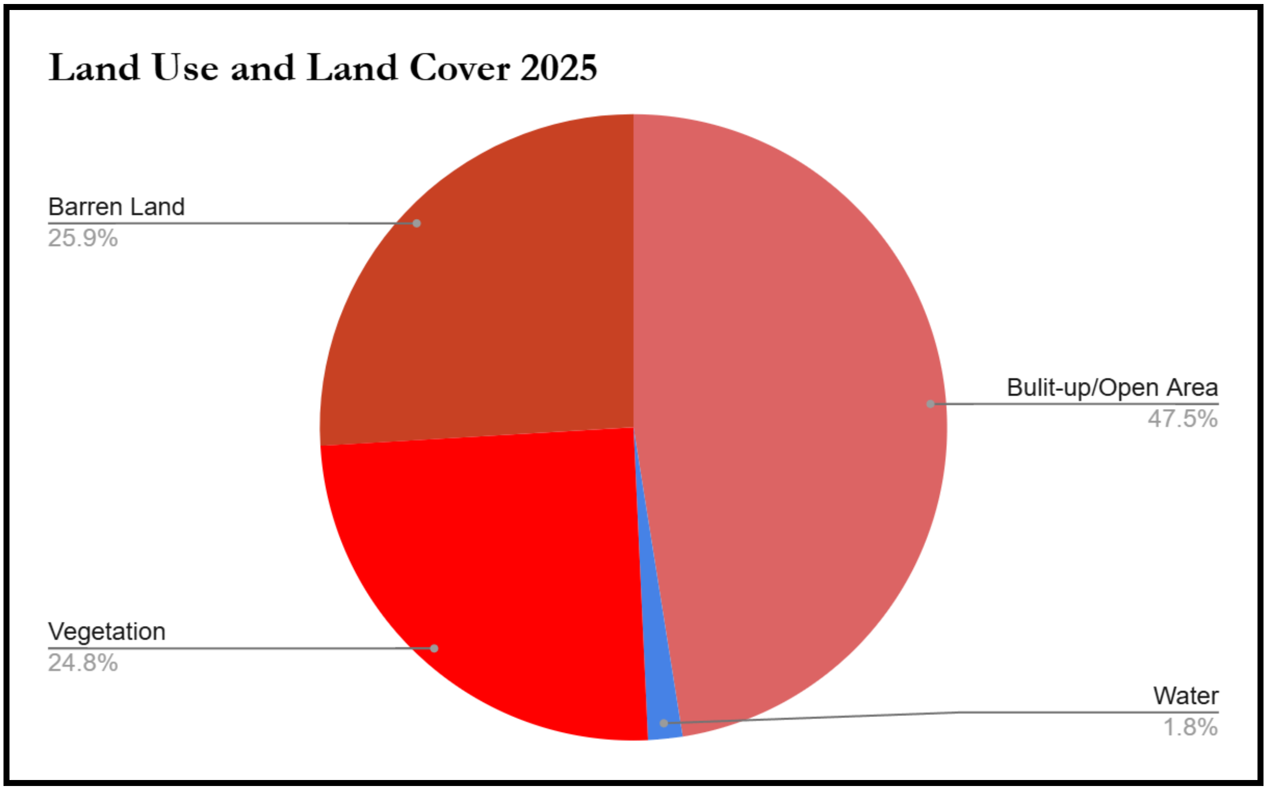
Land Cover Map of Lahore (2021)




Land Cover Map of Lahore (2025)
31°50'0"N
31°40'0"N
31°30'0"N
31°20'0"N
31°10'0"N
N
W
E
S
Legend
Bulit-up/ Open Land
Water
Vegetation
Barren Land
0 3 6 12 18 24
Kilometers
Syeda Minha Tirmizi,Muzammil Aktar,
Bahria University, 07/May/2025,
Landsat 8/Sentinel-2, USGS
74°0'0"E
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E


Land Use and Land Cover 2021
Barren Land
20.4%
Bulit-up/Open Area
42.0%
Vegetation
36.6%
Water
1.1%


Land Cover And Land Use
2021
2025
1000
750
500
250
0
Bulit-up/Open Area
Water
Vegetation
Barren Land
Years/Name



5. Discussion

The results of this study highlight important spatial and temporal trends in Lahore's land cover. The most notable trend is the significant increase in built-up areas, which is consistent with the city's rapid urbanization and population growth. As urban areas expand, green and agricultural spaces are often converted to residential, commercial, and industrial land uses. This is evident in the sharp decline in vegetation cover from 2021 to 2025.

The increase in barren land also suggests ongoing development activities, such as construction or land clearing. While an increase in water bodies might seem unexpected, it could be attributed to seasonal variation, improvements in water management infrastructure, or increased surface water from recent developments.

These changes have important implications for urban sustainability. Loss of vegetation can negatively affect urban ecosystems, reduce biodiversity, and increase the urban heat island effect. Effective land use planning and green infrastructure policies will be essential to mitigate these impacts.

One limitation of this analysis is the reliance on unsupervised classification, which can sometimes group dissimilar features into the same class due to spectral similarity. Future work could benefit from supervised classification approaches and ground truth data to improve accuracy. Additionally, analyzing more time points could help track longer-term trends and better inform policy-making.

6. Conclusion

This study successfully demonstrated the use of unsupervised classification and GIS-based techniques for analyzing land cover changes in Lahore between 2021 and 2025. The workflow provided a clear overview of the city's expanding urban footprint, shrinking vegetated zones, and evolving land use dynamics.

By integrating remote sensing data with spatial analysis tools, we gained valuable insights into the patterns and processes shaping Lahore's urban landscape. These findings can support future planning efforts aimed at balancing development with environmental sustainability.

7. References

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