Analyzing Land Use and Land Cover (LULC) Changes in IIT Kanpur Over 20 Years

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Abstract — **This project investigates Land Use and Land Cover (LULC) changes within the IIT Kanpur campus over the last 10 years. By classifying satellite imagery into categories such as forests, open land, buildings, and roads, it aims to visualize these changes through an animated video or GIF. The analysis includes generating accuracy metrics for each classification year and producing charts or trend analyses to illustrate LULC shifts. The results will reveal patterns in campus development and environmental impact.**

Keywords—
1. Land Use and Land Cover (LULC)
2. IIT Kanpur
3. Satellite Imagery
4. Classification
5. Change Detection

I. INTRODUCTION

The project aims to analyze the evolution of Land Use and Land Cover (LULC) within the IIT Kanpur campus over the past 10 years. Using satellite imagery, it focuses on tracking and categorizing the campus environment into four primary classes: forests, open land, buildings, and roads. With advances in remote sensing, accurate LULC classification enables precise monitoring of campus development, land utilization, and environmental impact. By employing supervised classification techniques, along with metrics to validate classification accuracy, this study provides insights into spatial and temporal patterns in land cover. The project outcomes, including visualizations and quantitative analyses, will serve as a foundation for understanding the environmental and infrastructural transformations within the IIT Kanpur campus over the years.

II. METHODOLOGY

After comparing the details we acquired *Sentinel-2 satellite* data spanning from **2015 to 2024**, specifically focusing on October and November month images each year to maintain seasonal consistency. We compared data from USGS Earth Explorer, Copernicus Open Access Hub and Google Earth Engine. Finally the data was accessed and downloaded using Google Earth Engine, which provided cloud-free imagery at a spatial resolution of 10 m.

The process proceeded through the following key stages:

(a) Data Acquisition & Preprocessing: Images were preprocessed to correct for any sensor-specific and atmospheric effects, ensuring uniformity across the dataset. The imagery was then cropped to the IIT Kanpur campus boundary for focused analysis. We also analyzed data from Planet and Landsat, using them we concluded to use *Sentinel-2 data.*

Radiometric Filtering was done after acquiring the masked maps from Google Earth Engine.

The code used for the same has been attached as a link.[1]

Fig. 1 *IIT Kanpur masked map after radiometric correction*

(b) Ground Truth Collection: Ground truth points were obtained using high-resolution references from Google Earth, marking areas representing forests, open land, buildings, and roads within the campus to train and validate the classification model.

Stored the ground truth data in a CSV or shapefile format with latitude, longitude, and class labels.

Fig. 2 *IIT Kanpur maps training data*

(c) Supervised Classification: Supervised Classification was done on Google Earth Engine to categorize each pixel in the imagery into one of the four LULC classes. Model used is Maximum Likelihood Classifier. MLC calculates the probability of it belonging to each class by considering the pixel's spectral values and the statistical parameters (mean, variance-covariance matrix) of each class. The classifier assumes that the spectral values follow a normal (Gaussian) distribution. The classification model was trained with 80% of the ground truth data and validated with the remaining 20%.

The code used for the same has been attached as a link.[2]

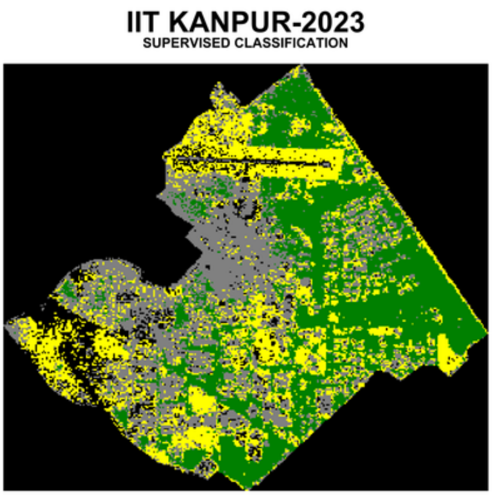

Fig. 3 *IIT Kanpur map after Supervised Classification : categories - forest ; open land; building; roads*

(c) Accuracy Assessment: A confusion matrix was generated for each year to calculate metrics such as overall accuracy, producer's and user's accuracy, and the kappa coefficient. These metrics evaluated the precision of the classification.

QGIS was used to calculate the confusion matrix. The results are attached with the final submission.

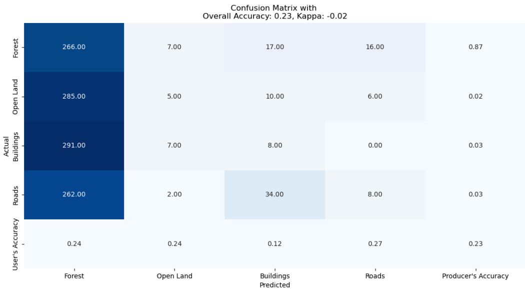

Fig. 4 Confusion matrices

(d) Change Detection and Visualization: GIF was created to illustrate LULC changes over time, while trend analysis and visual analytics, like bar and pie charts, quantifying the shifts in each class over the years are calculated. MATLAB software was used for the same.

The code used for the same has been attached as a link.[3]

III. RESULTS

The graphs of trend analysis are given below.

(a) Year-over-Year Percentage Change in LULC Categories

To display the percentage change in each LULC category across the years.

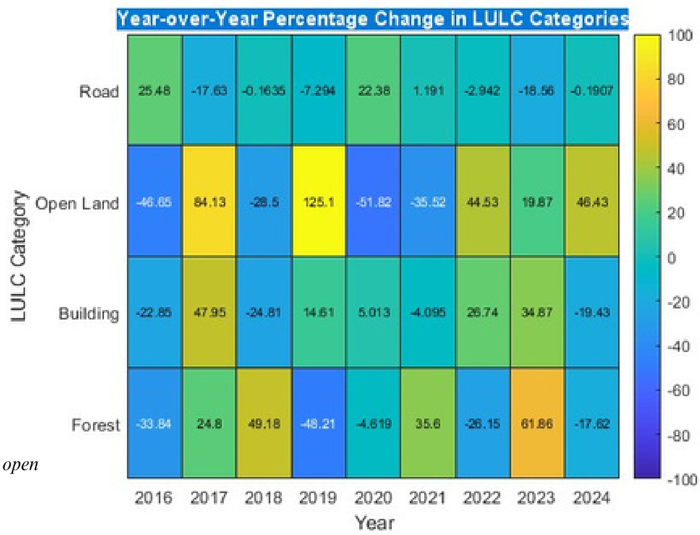

Fig. 5 *Year-over-Year Percentage Change in LULC Categories*

(b) LULC Composition Over Time

To show how each LULC category contributes to the total land use over the years.

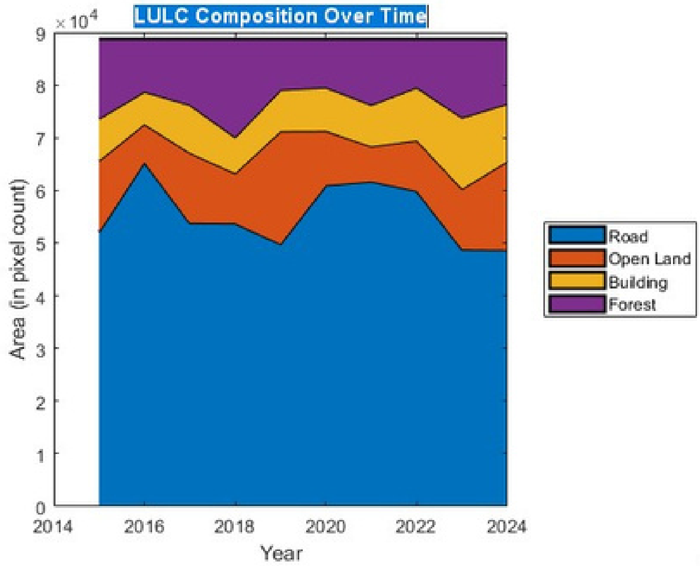

Fig. 6 *LULC Composition Over Time*

(c) Environmental Impact: Forest Loss vs Urban Growth (2015-2024)

Highlight the environmental impact of LULC changes, such as loss of green space. This reveals shifts toward urbanization, emphasizing potential ecological concerns.

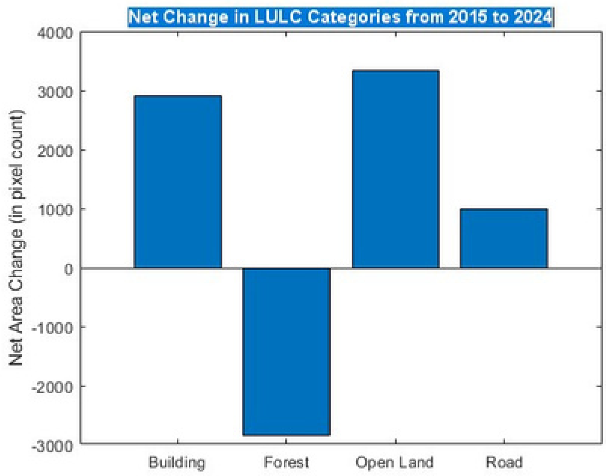

Fig. 7 *Environmental Impact: Forest Loss vs Urban Growth (2015-2024)*

(d) Net Change in LULC Categories from 2015 to 2024

Quantify the total area change for each category over the full period.

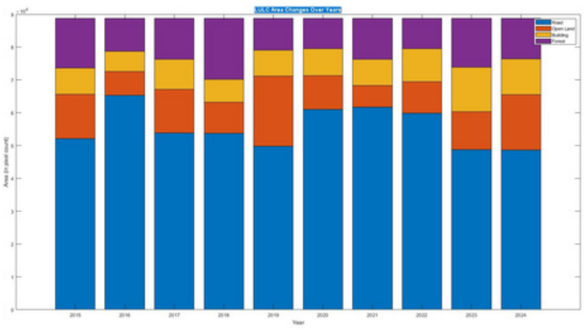

Fig. 8 *Net Change in LULC Categories from 2015 to 2024*

(e) LULC Trend Analysis Over Years

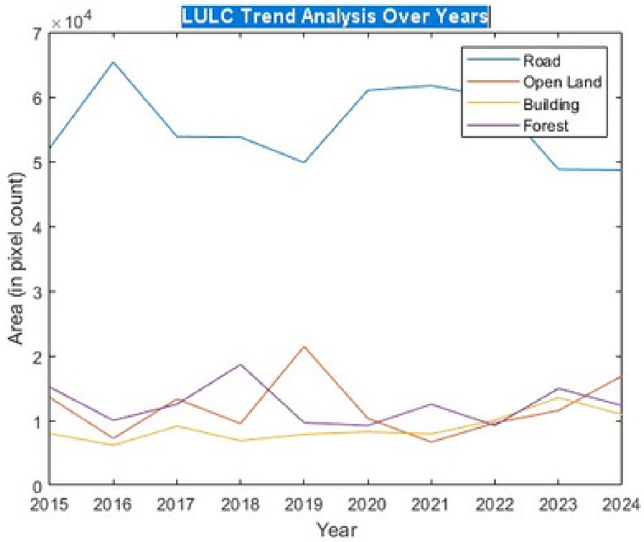

Fig. 9 *LULC Trend Analysis Over Years*

(f) Environmental Impact Forest Loss vs Urban Growth

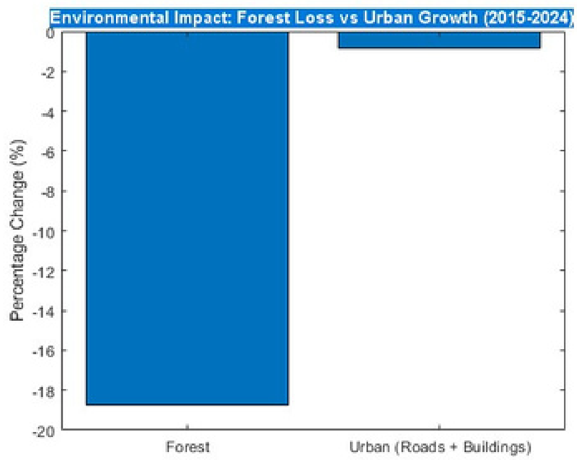

Fig. 10 *Environmental Impact Forest Loss vs Urban Growth*

Confusion matrices are given below-

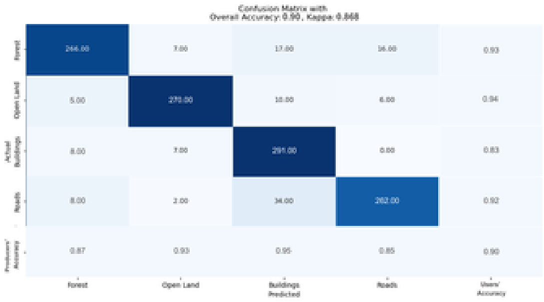

Fig. 11 *Confusion matrix 2015*

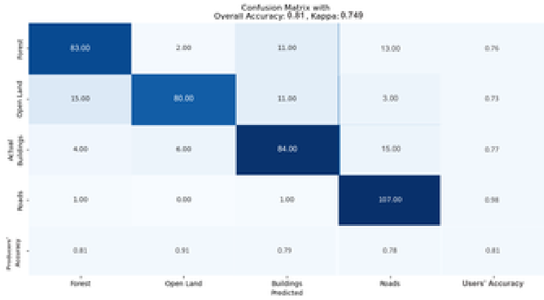

Fig. 22 *Confusion matrix 2016*

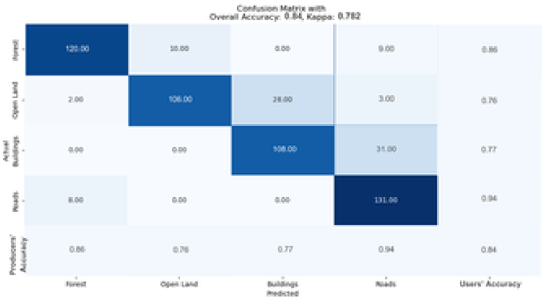

Fig. 13 *Confusion matrix 2017*

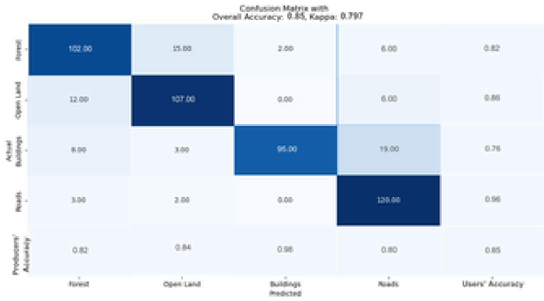

Fig. 14 *Confusion matrix 2018*

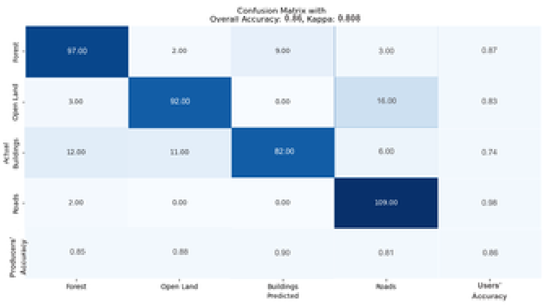

Fig. 15 *Confusion matrix 2019*

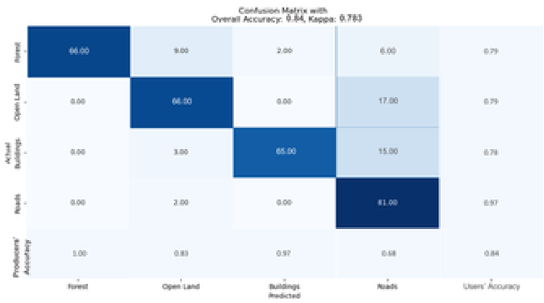

Fig. 16 *Confusion matrix 2020*

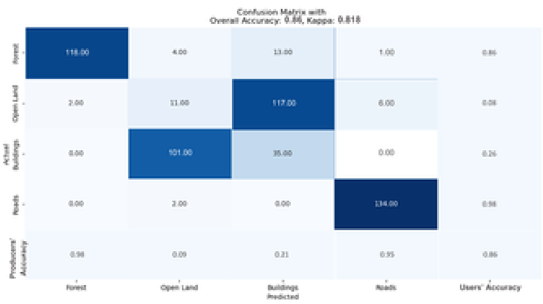

Fig. 17 *Confusion matrix 2021*

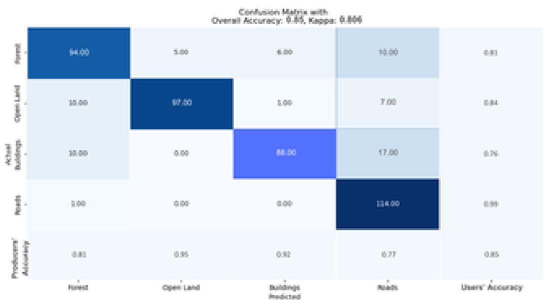

Fig. 18 *Confusion matrix 2022*

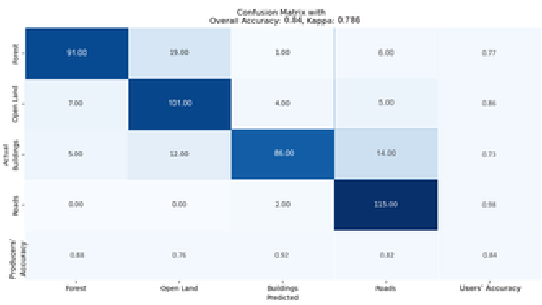

Fig. 19 *Confusion matrix 2023*

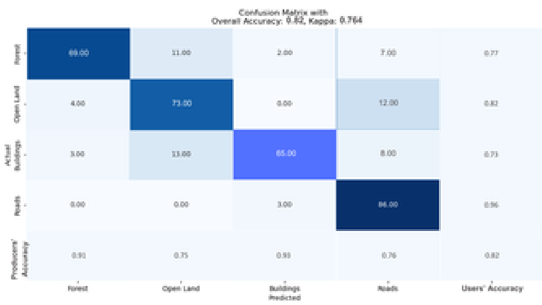

Fig. 20 *Confusion matrix 2024*

IV. DISCUSSIONS

Forest Cover: The forest area shows fluctuations over the years. There was an increase in forested areas from 2015 to 2018, followed by a noticeable decline in subsequent years, with 2024 showing a lower percentage of forested pixels compared to 2015. This could indicate deforestation for infrastructure development or a shift in land usage. The reduction in forest area and increase in buildings and roads reflect typical development trends but also raise concerns about the environmental impact. Reduced green spaces and increased built-up areas can affect biodiversity, air quality, and overall campus climate.

Roads: Roads consistently dominate the landscape, with a relatively high and stable pixel count and percentage across the years. The road area peaks around 2020 and 2021, possibly due to new construction or expansions. The consistent dominance of road coverage may suggest ongoing campus development or expanding infrastructure.

Buildings: Building areas have a steady increase in both pixel count and percentage over the years, indicating active development and expansion. This trend aligns with typical campus growth as facilities and accommodation increase to meet student and faculty needs. The steady increase in building and road areas suggests IIT Kanpur is actively expanding its facilities, possibly to accommodate growing student and faculty populations or to improve campus infrastructure. The peak in road area from 2020–2021 may align with significant infrastructure projects or campus expansion initiatives.

Open Land: The open land area has seen fluctuations, initially declining after 2015 but later increasing in 2019 and peaking in 2024. This could suggest areas previously designated as open land are being repurposed or redeveloped but occasionally cleared or left undeveloped temporarily. The fluctuating open land percentages suggest that some areas may be cleared for future development, used temporarily, or left open for specific purposes eg. pronite ground

V. CONCLUSIONS

The LULC analysis from 2015 to 2024 reveals IIT Kanpur's dynamic land use patterns. Infrastructure growth is evident, with significant increases in building and road coverage accompanied by fluctuations in forest and open land. While development is essential, preserving green spaces remains critical for maintaining the campus's environmental health and resilience. Visualizing these trends through infographics provides valuable insights into campus development, highlighting the need for sustainable growth practices as IIT Kanpur evolves.

VI. REFERENECES

[1]https://developers.google.com/earthengine/guides/classification
[2]https://developers.google.com/earth-engine/guides/clustering
[3]https://www.nv5geospatialsoftware.com/docs/TimeSeriesTutorial.html#View

VII. LINKS

[1]
https://github.com/Srijan-github/CE671/blob/main/Radiometric%20Correction/google%20earth%20engine

[2]
https://github.com/Srijan-github/CE671/blob/main/Supervised%20Classification

[3]
https://github.com/Srijan-github/CE671/blob/main/Analysis

[4]
https://github.com/Srijan-github/CE671/blob/main/Supervised%20Classification