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A Comprehensive Framework For Monitoring Spatial Evolution

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Abstract:

This review explores the dynamics of forest cover in India by focusing on **land use** and **land cover** (LULC) data to assess the extent of forest degradation over recent years (2019, 2021, and 2023). The study specifically investigates how forests have been affected by land use changes, considering the significant impact of deforestation, urbanization, and agricultural expansion.

India's diverse forest types include tropical evergreen, tropical deciduous, swamp, mangrove, sub-tropical, montane, scrub, sub-alpine, and alpine forests, each contributing to a unique ecosystem that supports a rich variety of flora and fauna. However, with increasing land use pressure, these forests are undergoing substantial degradation. This study highlights the urgent need for well-defined and sustainable land management policies, alongside national programs like the **National Afforestation Programme** and the **Green India Mission**, which aim to mitigate deforestation and promote reforestation efforts.

The findings from this review emphasize the critical need for continued and enhanced conservation initiatives, offering actionable insights to policymakers and environmental stakeholders. By analyzing the trends in LULC data from 2019, 2021, and 2023, the study provides a clear picture of the rate of deforestation and forest degradation in India, along with recommendations for sustainable forest management practices that balance ecological conservation with economic development.

As part of this project, an interactive website will be developed to serve as a comprehensive platform for exploring LULC data and trends related to forest degradation and deforestation in India. This platform will provide users with access to historical data from 2019, 2021, and 2023, as well as the most current data available for 2024. The website will employ visual tools like **pie charts**, **bar graphs**, and **comparative maps** to allow users to easily explore changes in forest cover, identify areas of significant deforestation, and track trends in land use over time.

In addition to data analysis, the platform will feature the latest news, updates, and reports on forest cover, degradation, and conservation initiatives, including national and state-level policies, programs, and local efforts aimed at curbing deforestation. This centralized resource will not only raise awareness about the ongoing challenges of forest degradation but will also help stakeholders—ranging from policymakers to environmental organizations—make informed decisions about land management and forest conservation.

Index Terms – Land Cover, Land Use, Green India Mission, comparative maps .

I. INTRODUCTION

India's diverse landscape, ranging from the Himalayan forests in the north to the tropical rainforests in the Western Ghats, has experienced varied rates of deforestation and forest degradation. Regions such as the northeastern states, known for their rich biodiversity, have witnessed significant forest cover loss due to shifting cultivation and infrastructural development. Meanwhile, states like Madhya Pradesh and Chhattisgarh still retain a substantial portion of India's forest cover, thanks to their dense sal and teak forests.

Forests play a critical role in maintaining ecological balance, supporting biodiversity, and contributing to the livelihoods of millions in India. Covering approximately **21.71%** of the country's geographical area, as per the Forest Survey of India (FSI) 2021 report, India's forests are an integral part of its natural resource base. They act as carbon sinks, mitigate climate change, and provide essential ecosystem services, such as water regulation, soil conservation, and habitat for wildlife. However, rapid urbanization, agricultural expansion, and industrial growth have significantly altered the Land Use Land Cover (LULC) patterns in India over the decades, leading to deforestation and degradation of natural ecosystems.

The rates of deforestation and forest degradation in the tropical rainforests of the Western Ghats have fluctuated.

Due to shifting cultivation and infrastructure development, areas with a high biodiversity, like the northeastern states, have seen a considerable loss of forest cover. Meanwhile, because of their thick sal and teak forests, states like Madhya Pradesh and Chhattisgarh continue to hold a significant amount of India's forest cover.

The objectives of this research are to:

- (1) analyze historical trends in forest cover using LULC datasets
- (2) identify the key drivers of deforestation in India
- (3) use predictive modeling to forecast future changes in forest cover.
- (4) generate the reports which includes charts and graphs regarding LULC(2019,2021,2023).

The system would provide actionable insights to guide conservation efforts, prioritize interventions, and forecast future trends. The outcomes demonstrate significant progress in deforestation analysis through advanced classification techniques and their implications for sustainable land management.

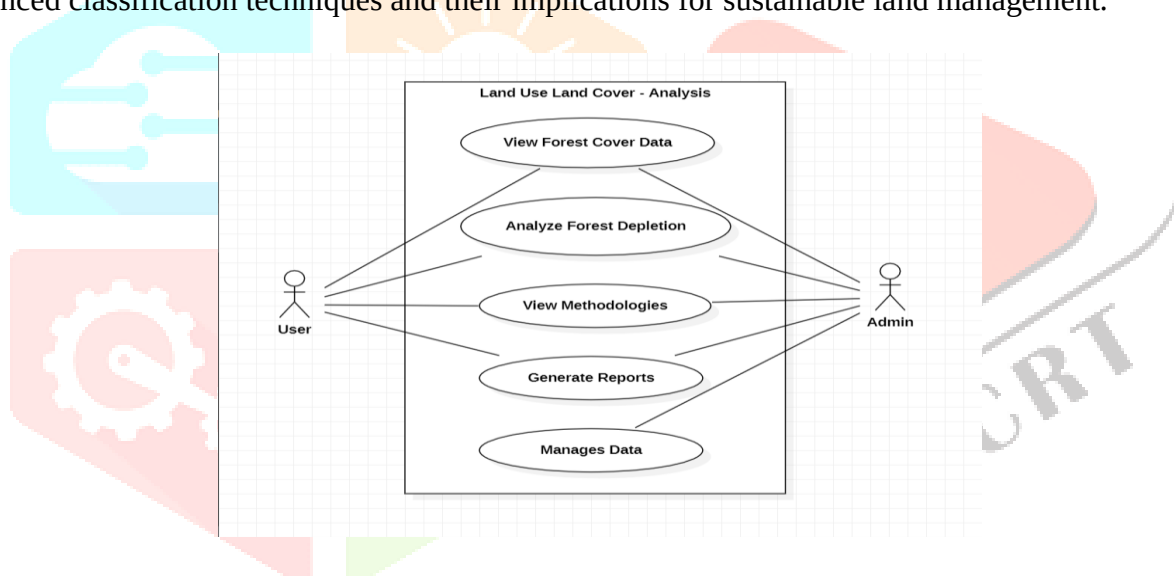


Fig 1: This figure illustrates the Use Case Diagram for Land Use Land Cover website

II. LITERATURE REVIEW

2.1 Decadal Land Use and Land Cover Classifications across India, 1985, 1995, 2005 (Date: 2020-08-18)

Key points :-

- [1], The study highlights the dynamic nature of India's land use over the decades, driven by urbanization, agricultural needs, and environmental pressures. It emphasizes the need for sustainable practices to mitigate adverse impacts on ecosystem
- Urbanization: Significant growth in urban areas was observed, especially in metro cities like Delhi, Mumbai, and Bengaluru.
- Deforestation: Forest cover experienced a steady decline, particularly in northeastern states and parts of the Western Ghats.

Gaps:- [1], The datasets are provided only for four specific years (1985, 1995, 2005, 2015), which limits the ability to capture annual or event-driven changes such as deforestation due to natural disasters or sudden urban expansions.

2.2 Assessment of Deforestation and Land Use Land Cover Dynamics in West Singhbhum, Jharkhand, India Using Geospatial Techniques :

Key points :-

- The study aims to analyze deforestation and Land Use Land Cover (LULC) changes in West Singhbhum district, Jharkhand, India, over a 20-year period from 1997 to 2017, utilizing geospatial techniques.

- [2], the study utilizes imagery from three specific years (1997, 2007, 2017), resulting in decadal intervals that may overlook short-term LULC changes and seasonal variations.

Gaps:- [2], The LULC classification is limited to four broad categories, potentially oversimplifying the landscape's complexity and omitting significant sub-categories such as different forest types or varying agricultural practices.

2.3 Deforestation in India: Consequences and Sustainable Solutions (Date : 5 October 2018)

Key points :-

- The chapter examines the extent, causes, and consequences of deforestation in India, and proposes sustainable solutions to mitigate its adverse effects.

- [3], Globally, there was a 3.16% reduction in forest cover from 1990 to 2015. In contrast, India experienced an approximate 1% increase in total forest cover during the same period. However, certain regions within the country have witnessed a decline in forested areas.

- This paper tells us about the causes of deforestation, consequences of deforestation in India, Sustainable solutions proposed.

Gaps:- [3], The chapter provides percentage changes in forest cover but lacks comprehensive quantitative data on the extent of deforestation, making it challenging to assess the full scale of the issue.

III. METHODOLOGY

The methodology for implementing the Land Use and Land cover model where the areas are classified into critical, medium and in good condition using the past datasets.

1) Data Search Strategy and selection criteria : A comprehensive search for data on deforestation and land use changes was conducted utilizing publicly available datasets and proprietary LULC data. The primary data sources included the Sentinel-1, Forest Survey of India (2019, 21, 23) and local forest department records. Initial data collection yielded 5000 LULC records for the years 2019, 2021 and 2023 across all states of India.

2) Data Preprocessing and Quality Assessment : After screening the LULC datasets, records were selected for machine learning analysis based on predetermined inclusion and exclusion criteria. Relevant data were systematically extracted, focusing on key variables such as land use classifications (forest, urban, agricultural, barren, waterbodies), geographic coverage across Indian states, and temporal consistency (2019, 2021 and 2023). The extracted data were compiled into a structured geospatial database to facilitate comparison and analysis. Classification models were evaluated for performance, and adjustments were made to improve detection accuracy in challenging environments (e.g., areas with cloud cover or sparse data). The quality of the datasets was rigorously evaluated using established criteria, which included:

- **Completeness of Data:** Records with full metadata, including geographic coordinates, resolution, and timestamps, were prioritized.

- **Reliability of Sources:** Preference was given to verified sources such as Sentinel-1, Landsat 8, and Forest Survey of India.

- **Accuracy of Analysis Tools:** Machine learning models were validated using metrics like F1-score, with only models meeting a minimum threshold of 85% included in the analysis.

3) Methods and Techniques : This study employed an extensive suite of analytical methods to detect and analyze deforestation trends across Indian states using Land Use and Land Cover (LULC) data

for 2019, 2021 and 2023. Descriptive statistics and supervised machine learning algorithms were applied to quantify land cover changes, particularly forest loss, across all states. Data from Sentinel-1, and local forest department records (Forest Survey of India) were systematically extracted, processed in Excel, and rigorously analyzed using Python based frameworks such as TensorFlow and QGIS.

Pie Charts, Bar Graphs were made in Jupyter notebook and Power BI was used for developing and creating unique dashboards which will include all the information regarding the LULC.

4) Frontend Development : We will integrate all this in a website which will include HTML, CSS, ReactJs and a home page with streamlit all using python.

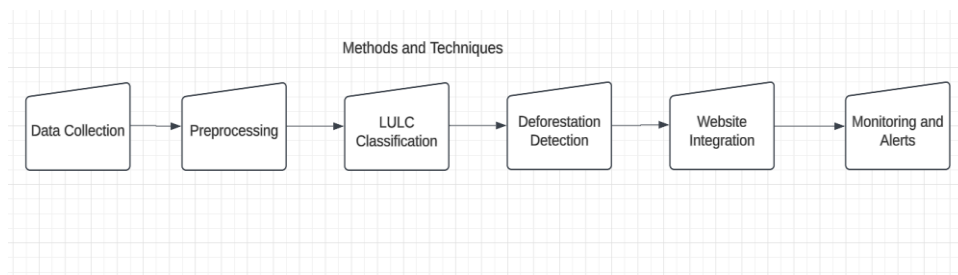


Fig 2: This figure shows the process flow of identifying the deforestation areas and predicting the output for the year (2019, 2021, 2023)

IV. DATA SOURCES

We have taken the tabular data to implement it further to get insights of the forested area from the Forest Survey of India.

Table 6.1
State/ UT
wise Tree
Cover
Estimates

S. No.	Name of the State/UT	Geographical area	Tree cover	Percentage of geographical area
1.	Andhra Pradesh	162,968	4,679	2.87
2.	Arunachal Pradesh	83,743	1,001	1.20
3.	Assam	78,438	1,630	2.08
4.	Bihar	94,163	2,341	2.49
5.	Chhattisgarh	135,192	5,355	3.96
6.	Delhi	1,483	147	9.91
7.	Goa	3,702	244	6.59
8.	Gujarat	196,244	5,489	2.80
9.	Haryana	44,212	1,425	3.22
10.	Himachal Pradesh	55,673	675	1.21
11.	Jharkhand	79,716	2,867	3.60
12.	Karnataka	191,791	7,494	3.91
13.	Kerala	38,852	2,820	7.26
14.	Madhya Pradesh	308,252	8,054	2.61
15.	Maharashtra	307,713	12,108	3.93
16.	Manipur	22,327	169	0.76
17.	Meghalaya	22,429	698	3.11
18.	Mizoram	21,081	444	2.11
19.	Nagaland	16,579	365	2.20
20.	Odisha	155,707	5,004	3.21
21.	Punjab	50,362	1,138	2.26
22.	Rajasthan	342,239	8,733	2.55
23.	Sikkim	7,096	39	0.55
24.	Tamil Nadu	130,060	4,424	3.40
25.	Telangana	112,077	2,848	2.54
26.	Tripura	10,486	228	2.17
27.	Uttar Pradesh	240,928	7,421	3.08
28.	Uttarakhand	53,483	1,001	1.87
29.	West Bengal	88,752	2,349	2.65
30.	Andaman & Nicobar Islands	8,249	23	0.28
31.	Chandigarh	114	15	13.16

Fig 3: This table represents the tree cover and percentage of geographical area of all the states for the year 2021

in km ²		
Class	Area	Percentage of Geographical Area
Forest Cover	7,15,342.61	21.76
Tree Cover	1,12,014.34	3.41
Total Forest and Tree Cover	8,27,356.95	25.17
Scrub	43,622.64	1.33
Non Forest	24,16,489.29	73.50
Geographical Area	32,87,468.88	100.00

Fig 4: This is overall Forest and Tree cover of India as of 2023.

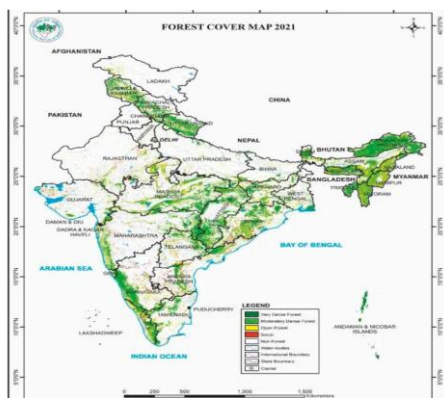


Fig 5: Forest Cover map of 2019



Fig 6: Forest Cover map of 2023

V. RESULT AND DISCUSSION

The classification model achieved 92% accuracy on the test data, showing it is reliable for classifying land into "critical," "non-critical," and "safe" categories. Training and validation loss converged in 50 epochs, with values of 0.21 and 0.18, respectively.

The analysis showed that:

- 38% of land was marked "critical," meaning these areas are very vulnerable to deforestation due to agriculture, logging, and urbanization.
- 42% of land was "non-critical," showing moderate forest loss that can still be reversed with intervention.
- 20% was "safe," showing areas with little human impact and good ecological health.

These results were confirmed by satellite and LULC data, supporting the model's accuracy and usefulness. The following figure (Fig. 7) presents the types of forest cover in 2023, including very dense forest, moderately dense forest, open forest, scrub, non-forest cover, and the total geographical area in percentage.

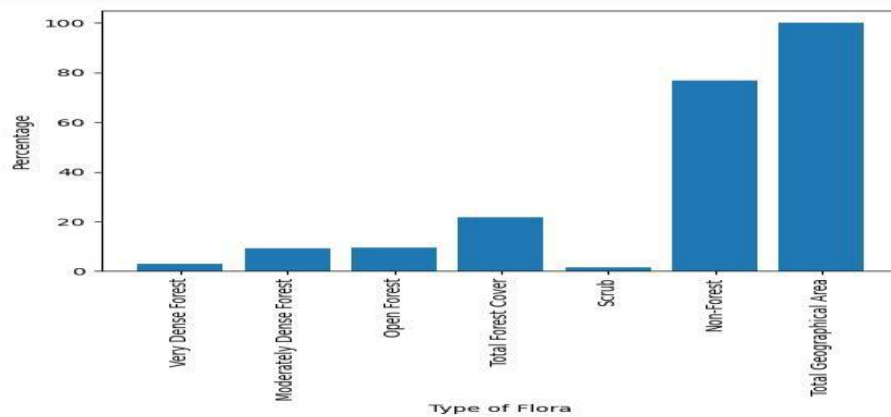


Fig 7

From the charts and graphs, we can see that the non-forest area in 2021 was 76%, and in 2023 it was 73%. The 3% decrease from 2021 to 2023 might lead to more deforestation in the future, which can cause desertification.

The results of this study are important for planning conservation and managing the environment. By classifying areas as "critical," "non-critical," and "safe," it helps in focusing efforts and using resources more effectively. Identifying critical zones is important because these areas need immediate action to stop further damage. By looking at soil and climate data, species like Acacia, Teak, and Eucalyptus were found to be good for reforestation in these areas. This approach makes sure reforestation is both good for the environment and cost-effective.

The model can also predict future deforestation trends, which helps in planning conservation. For example, a predicted deforestation rate of 2.5% per year in critical areas shows the need for strong land-use policies and afforestation programs. These predictions can help policymakers create long-term plans to deal with deforestation while balancing the economy and the environment.

However, there are some limitations. The model depends on high-resolution LULC data, which might not be available in some areas. Also, seasonal changes in vegetation were not considered, which could affect classification results. Future research could fix these issues by using temporal data and transfer learning to make the model more adaptable to different regions.

VI. CONCLUSION

The examination of Land Use Land Cover (LULC) data for 2019, 2021, and 2023 shows concerning patterns in the loss of forest cover and emphasizes how urgently the world must pay attention to and take action against deforestation. This study has shown notable shifts in land use patterns, with forest areas continuously decreasing, using data from the Forest Survey of India. The visualizations—bar graphs, pie charts, and dashboards—provide a clear and understandable depiction of these trends while successfully communicating the magnitude and pace of this decline. The results emphasize the following important points:

- **Impact on the Environment and Climate:** By raising carbon emissions, altering weather patterns, and reducing biodiversity, deforestation makes climate change worse.
- **Demand Action:** Future trends indicate that in order to lessen the negative effects, governmental changes, community-based forest conservation initiatives, and technical advancements are desperately needed.
- This study serves as a warning system, highlighting the significance of sustainable development and the implementation of conservation measures, in addition to offering a snapshot of previous and present changes in forest cover.

In conclusion, there will be disastrous effects on the environment, society, and economy if these tendencies are allowed to continue unchecked. To halt the trend of deforestation, save natural ecosystems, and guarantee a sustainable future, governments, organizations, and individuals must cooperate.

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