

Satellite Image-Based Tree Enumeration and Sustainable Route Planning for Forest Land Diversion

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Abstract: *Forest land diversion requires accurate tree enumeration and environmentally sustainable planning to minimize ecological impact. Traditional manual survey methods are time-consuming, costly, and prone to inaccuracies, especially in large forest regions. This project proposes an automated system using satellite imagery and deep learning techniques for efficient tree detection and counting. A YOLOv8-based object detection model is employed to identify individual trees and generate bounding boxes with confidence scores. Tree density analysis is performed to identify ecologically sensitive areas. Based on this analysis, optimized routes are generated using shortest path algorithms to reduce environmental disturbance. The proposed system ensures scalability, improved accuracy, and supports data-driven decision-making for sustainable forest management*

Keywords: Tree Detection, YOLOv8, Satellite Imagery, Density Analysis, Route Planning

I. INTRODUCTION

Trees play a vital role in maintaining ecological balance, biodiversity, and environmental sustainability, making their accurate assessment essential during forest land diversion activities. Traditional methods of tree enumeration rely on manual surveys and field-based measurements, which are time-consuming, costly, and often prone to inaccuracies due to varying forest conditions. These limitations create challenges in large-scale forest analysis and can impact environmental decision-making. With the advancement of remote sensing and artificial intelligence, automated approaches have emerged as effective solutions for efficient forest monitoring. This project proposes a satellite image-based tree enumeration system that utilizes deep learning techniques, specifically the YOLOv8 object detection model, to accurately detect and count individual trees. In addition to tree detection, the system performs density analysis to identify ecologically sensitive areas and supports environmentally optimized route planning to minimize ecological damage during land diversion. By integrating image analytics, density mapping, and intelligent route optimization, the proposed system provides a scalable, accurate, and data-driven solution for sustainable forest management.

II. LITERATURE SURVEY

In the field of satellite image-based tree detection and forest monitoring, several research works have utilized artificial intelligence. Deep learning techniques to improve accuracy and efficiency in large-scale analysis.

[1] P. Kovacovic et al., IEEE, 2025 – “Satellite-based Forest Stand Detection using Artificial Intelligence” focuses on using deep learning models such as CNN, YOLO, and mask r-CNN for detecting forest stands from satellite imagery. It highlights the importance of automated systems in large-scale forest monitoring and provides a strong foundation for ai-based tree analysis.



- [2] **Irfan Abbas and R. Damasevicius**, IEEE, 2025 – “*Tree Detection in RGB Satellite Imagery using YOLO-based Models*” applies yolo-based object detection models for identifying individual trees in rgb satellite images. it demonstrates high accuracy and scalability, making it suitable for automated tree enumeration systems.
- [3] **Surya prakash et al.**, IEEE, 2024 – “*Artificial Intelligence-Driven Multimodal Route Planning*” introduces AI-based route planning techniques that optimize paths based on environmental and spatial constraints. It is useful for designing eco-friendly routes in forest land diversion projects.
- [4] **H. Amini Amirkolaei et al.**, IEEE, 2023 – “*Treeformer: Transformer-Based Framework for Tree Counting*” presents a transformer-based approach for tree counting and density estimation from high-resolution images. It improves accuracy in detecting trees and supports advanced forest analysis.
- [5] **C. Kwenda et al.**, IEEE, 2022 – “*Machine Learning Methods for Forest Image Analysis and Classification: Survey*” reviews various machine learning and deep learning techniques used in forest image analysis. It provides insights into algorithm selection and highlights the effectiveness of AI in forest monitoring systems.

III. METHODOLOGY

3.1 Satellite Image Acquisition and Dataset Preparation

The first step of the proposed system involves collecting satellite images of forest regions from available datasets. These images are organized into a structured format, and a subset of images is selected for annotation. The annotated dataset includes labeled tree instances, which are essential for training the deep learning model. This step ensures that the model learns to accurately identify trees from satellite imagery.

3.2 Image Preprocessing

The collected images undergo preprocessing to improve their quality and enhance model performance. This includes resizing images to a standard dimension, normalizing pixel values, and applying data augmentation techniques such as rotation, flipping, and brightness adjustment. These techniques help increase dataset diversity and improve the robustness of the model. The processed images are then converted into a YOLO-compatible format for training.

3.3 Tree Detection Using YOLOv8

The core component of the system is the YOLOv8 object detection model. The model is trained using the annotated dataset to detect individual trees in satellite images. It generates bounding boxes around detected trees along with confidence scores. YOLOv8 is chosen for its high speed and accuracy, making it suitable for real-time and large-scale analysis.

3.4 Tree Counting and Density Analysis

After detection, the system counts the total number of trees present in each image. Tree density is calculated based on the number of trees per unit area. The system classifies regions into high-density and low-density zones, which helps in identifying ecologically sensitive areas. This analysis is crucial for making informed decisions during forest land diversion.

3.5 Route Planning for Sustainable Land Diversion

The system incorporates a route planning module that determines optimal paths for land diversion projects. Using algorithms such as Dijkstra or A*, the system identifies routes that avoid high-density forest areas. This ensures minimal environmental impact and promotes sustainable planning.



3.6 Visualization and Report Generation

The final stage involves visualizing the results and generating reports. Detected trees are displayed with bounding boxes, and density maps are presented for analysis. A user interface is developed using Streamlit to display outputs clearly. The system also generates reports that assist in decision-making and environmental planning.

IV. SYSTEM ARCHITECTURE

The proposed system is designed to automate tree detection, counting, density analysis, and eco-friendly route planning using satellite imagery and deep learning techniques. The architecture consists of multiple modules that work together to process input data and generate meaningful outputs for sustainable forest management.

4.1 Satellite Image Acquisition Module

This module is responsible for collecting satellite images of forest regions from available datasets. The images are stored in a structured format for further processing. A portion of the dataset is annotated to identify tree locations, which is used for training the detection model.

4.2 Image Preprocessing Module

In this module, input images are preprocessed to improve quality and ensure compatibility with the model. Techniques such as resizing, normalization, and data augmentation are applied. These steps enhance image clarity and improve the performance and accuracy of the detection model.

4.3 Tree Detection Module (YOLOv8 Model)

This module uses the YOLOv8 deep learning model to detect individual trees in satellite images. The model processes the input images and generates bounding boxes around detected trees along with confidence scores. This enables accurate identification of tree locations.

4.4 Tree Counting and Density Analysis Module

The detected trees are counted, and tree density is calculated based on the area. The system categorizes regions into high-density and low-density zones. This information is used to identify ecologically sensitive areas and analyze forest distribution.

4.5 Route Planning Module

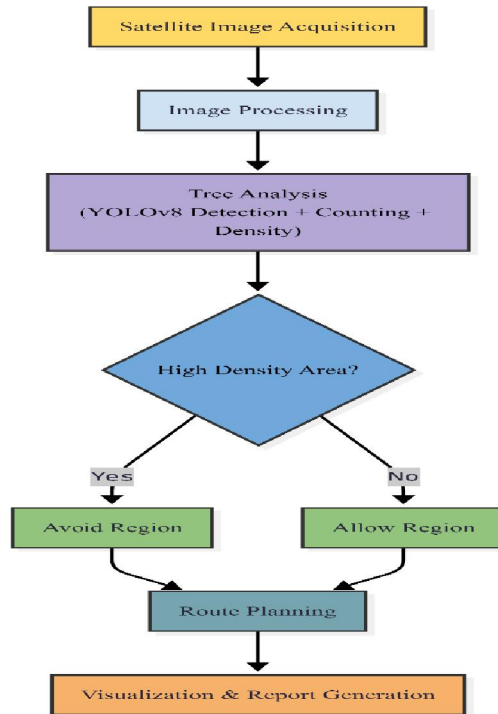
This module determines optimal routes for forest land diversion projects. It uses shortest path algorithms such as A* to generate routes that avoid high-density tree regions. This ensures minimal environmental impact and supports sustainable planning.

4.6 Visualization and Report Generation Module

The final module displays the results through a user-friendly interface developed using Streamlit. It shows detected trees with bounding boxes, density analysis, and optimized routes. The system also generates reports to assist in decision-making and environmental assessment.



4.7 FLOWCHART



V. RESULTS AND DISCUSSION

5.1 OUTPUT

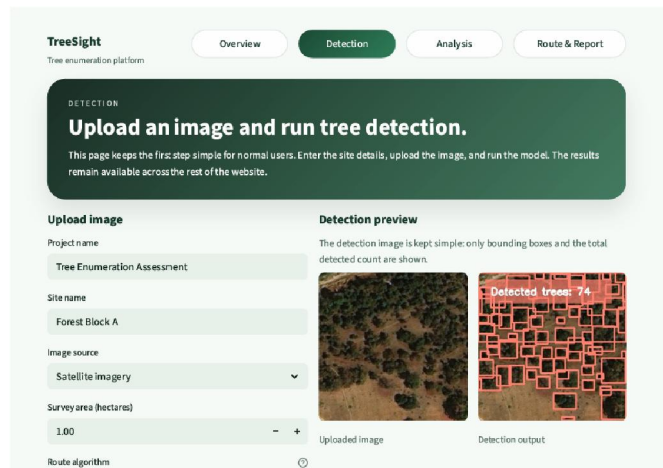


Fig 5.1 Tree Detection



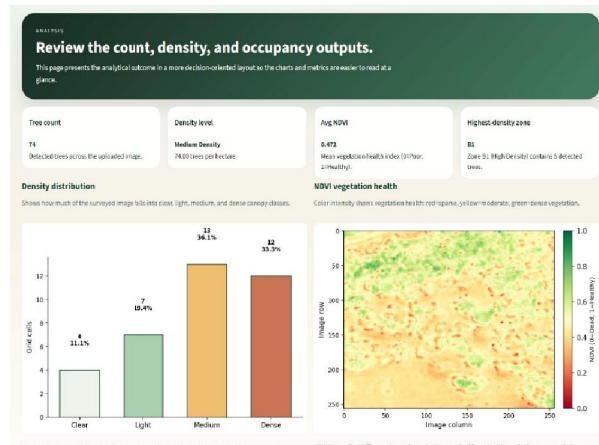


Fig. 5.2 Density Distribution and NDVI-Based Vegetation Analysis

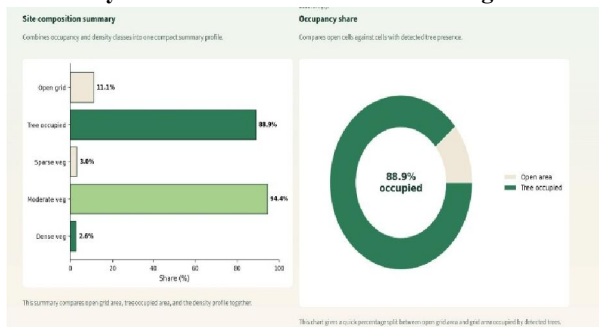


Fig. 5.3 Site Composition Summary and Tree Occupancy Analysis

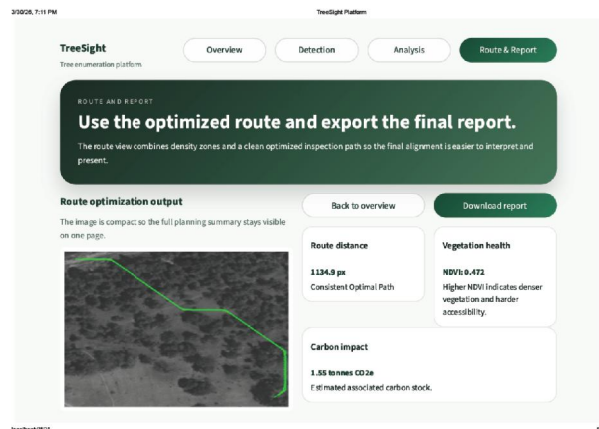


Fig. 5.4 Optimized Route Generated Using A* Algorithm



Analysis summary	
Metric	Value
Tree count	74
Density label	Medium Density
Density score	74.00 trees per hectare
Average confidence	56.2%
Tree occupancy share	88.9%
Trees per hectare	74.00
Route length	599 segments 1134.9 px
Route method	Consistent Optimal Path
Model	best.pt

Estimated carbon impact	1.55 tonnes CO2e
Compensatory plantation	222 saplings

Vegetation composition snapshot	
Vegetation class	Share of image
Sparse	3.0%
Moderate	94.4%
Dense	2.6%

Fig. 5.5 Final Report Summary of Tree Detection and Density Analysis

5.2 PERFORMANCE ANALYSIS

The system demonstrates improved efficiency and accuracy compared to traditional manual and GIS-based methods. The YOLOv8 model provides reliable detection of individual trees, even in complex forest regions. The preprocessing techniques and data augmentation methods contribute to better model performance and generalization. The system is capable of handling large-scale satellite images, making it suitable for real-time and scalable applications in forest monitoring.

5.3 DISCUSSION

The results indicate that the integration of deep learning and satellite imagery significantly enhances tree enumeration accuracy and reduces manual effort. The density analysis module effectively identifies ecologically sensitive areas, which plays a crucial role in sustainable decision-making. Furthermore, the route planning module successfully generates eco-friendly paths by avoiding high-density regions, thereby minimizing environmental impact. Overall, the system provides a reliable, efficient, and scalable solution for forest land diversion and environmental management.

5.4 Challenges and Improvements

Some challenges include variations in image resolution, overlapping tree canopies, and limited availability of annotated datasets. These factors may affect detection accuracy in certain scenarios. Future improvements can include the use of higher-resolution imagery, advanced models such as transformer-based architectures, and integration with real-time GIS systems to further enhance performance and usability.

VI. CONCLUSION

This paper presents an automated system for tree enumeration and sustainable route planning using satellite imagery and deep learning techniques. The proposed approach utilizes the YOLOv8 model for accurate detection and counting of individual trees, overcoming the limitations of traditional manual and GIS-based methods. The system further performs tree density analysis to identify ecologically sensitive areas, enabling informed decision-making during forest land diversion. By integrating route planning algorithms, the model generates environmentally optimized paths that minimize ecological impact. The results demonstrate improved accuracy, efficiency, and scalability in forest analysis.



Overall, the proposed system provides a reliable and data-driven solution for sustainable forest management and environmental conservation.

REFERENCES

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