

BUILD WITH GEMINI

AI & Drone-Based Afforestation
Monitoring System

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INTRODUCTION

Large-scale afforestation initiatives play a critical role in climate mitigation, biodiversity restoration, and sustainable land management. This work is developed strictly using the drone imagery and orthomosaic datasets provided by the event organizers for evaluation purposes. In

India, state forest departments undertake plantation drives involving millions of saplings every year across geographically diverse and irregular forest patches. Despite substantial investment,

post-plantation monitoring remains largely manual, fragmented, and resource-intensive, resulting in limited visibility into sapling survival rates, mortality causes, and long-term plantation success. This abstract presents a professional, scalable, and technology-driven proof-of-concept (PoC) for monitoring afforestation outcomes using drone imagery, orthomosaic analysis, and machine learning techniques.

The proposed system focuses on detecting sapling survival and casualties by comparing multi-temporal drone images captured across different plantation stages. By leveraging image processing, spatial analytics, and AI-based classification, the solution aims to deliver accurate survival percentages, geolocated casualty points, and actionable insights for forestry stakeholders.

BACKGROUND & PROBLEM CONTEXT

Afforestation programs are often implemented across irregular forest patches varying in size, canopy density, and terrain. Traditional monitoring methods rely heavily on field surveys, which are labor-intensive, time-consuming, prone to human error, and economically unviable at scale. As plantation sizes increase into thousands of hectares annually, manual verification becomes impractical.

Drone technology offers a transformative opportunity by enabling high-resolution aerial data acquisition at relatively low cost. However, raw imagery alone is insufficient. The true challenge lies in automated interpretation of drone-derived orthomosaics to identify plantation pits, saplings, and subsequent survival or mortality across multiple timeframes. Variations in vegetation density, illumination, soil texture, and spatial accuracy further complicate automated analysis.

This problem statement addresses the urgent need for an AI-powered, repeatable, and scalable monitoring framework that can reliably assess afforestation success using existing drone data without requiring expensive upgrades or ultra-high-resolution sensors.

OPERATIONAL LIFECYCLE OF AFFORESTATION

- Afforestation activities follow a well-defined physical sequence that provides critical temporal markers for image analysis:
- Pit Preparation Phase (OP1) – Pits of uniform dimensions are excavated and remain exposed, making them highly visible in aerial imagery.
- Plantation Phase (OP2) – Saplings are planted during monsoon onset, initially exhibiting minimal foliage.
- Maintenance & Weeding Phase (OP3) – Circular soil clearance around saplings enhances visibility and aids spatial identification.
- Drone surveys are conducted before and after each operational phase, generating time-series datasets. These datasets form the backbone of the proposed analytical framework, enabling temporal comparison, object persistence tracking, and survival validation.

TECHNICAL CHALLENGES & CONSTRAINTS

The proposed solution is designed within realistic operational constraints to ensure field applicability:

- Fixed Image Resolution: Algorithms must function effectively at medium resolution, avoiding dependence on costly ultra-high-resolution imagery.
- Vegetation Interference: Existing greenery can obscure saplings, complicating detection.
- Geospatial Inaccuracy: Absence of RTK modules introduces positional uncertainty of up to one meter.
- Scale & Speed Requirements: Thousands of patches must be processed annually, necessitating high computational efficiency.

These challenges demand robust feature extraction, tolerance to spatial noise, and intelligent matching strategies across temporal datasets.

PROPOSED AI & ML SOLUTION ARCHITECTURE

The proposed system employs a multi-stage analytical pipeline:

- Orthomosaic Preprocessing: Noise reduction, contrast normalization, and spatial alignment.
- Pit Detection & Anchor Point Generation: Identification of plantation pits from OP1 imagery to establish ground truth coordinates.
- Temporal Image Matching: Mapping pit locations to corresponding positions in post-plantation images.
- Sapling Survival Classification: Machine learning models classify locations as alive or dead based on vegetation signatures, texture, and spectral features.
- Spatial Output Generation: Geo-referenced casualty maps and survival statistics.

This modular architecture ensures adaptability, scalability, and ease of deployment across varying forest conditions.

EVALUATION METRICS & IMPACT ASSESSMENT

System performance is evaluated using:

- Detection Accuracy: Correct identification of known sapling casualty locations.
 - Survival Percentage Estimation: Reliable computation of live vs dead saplings.
 - Processing Speed: Time required to analyze large orthomosaic datasets.
 - Scalability: Ability to generalize across different patch sizes and canopy densities.
- The expected impact includes reduced monitoring costs, faster decision-making, improved accountability, and enhanced success rates of afforestation programs.

SOCIETAL, ENVIRONMENTAL & POLICY RELEVANCE

- This AI-driven monitoring framework supports:
- Evidence-based forestry management
- Transparent reporting for government initiatives
- Early intervention in failing plantation zones
- Long-term ecological planning and carbon accounting
- By transforming raw drone imagery into actionable intelligence, the solution bridges the gap between plantation execution and measurable ecological outcomes

CONCLUSION & FUTURE SCOPE

This abstract demonstrates the feasibility of using drone imagery combined with machine learning to autonomously monitor afforestation success over multi-year periods. The proposed PoC establishes a foundation for scalable deployment across multiple afforestation patches, integration with GIS dashboards, and extension to growth analysis, species classification, and predictive survival modeling.

Future enhancements may include multispectral analysis, AI-assisted anomaly detection, and integration with satellite data for macro-scale monitoring.



THANK YOU