AI-based Single Tree Analytics for Harvest Optimization

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Abstract

Summary: *This contribution presents a novel approach to precision forestry that bridges the gap between remote sensing and industrial production planning. By leveraging EUSI 15cm satellite imagery and high-resolution drone data, Arboair utilizes proprietary AI models to perform single-tree analytics. The core innovation is the capability to optimize cross-cutting (bucking) virtually and generate optimized harvester files prior to machine arrival. This methodology offers proven efficiency gains in harvesting, logistics, and timber value recovery.*

1 The Challenge

The forestry industry is currently facing a dual pressure: rising operational costs and the increasing need for precise raw material flow to sawmills. Harvesting costs (typically ranging between €18–27/m3) and transport costs have seen significant inflation.

Traditionally, harvest planning relies on subjective manual inventory or low-resolution estimates, often leading to:

- **Suboptimal Bucking:** High-value timber is inadvertently processed as pulpwood due to lack of pre-harvest data.
- **Logistical Inefficiency:** Inaccurate volume and assortment forecasts result in inefficient transport planning and ”empty runs.”
- **Planning Bottlenecks:** Conventional inventory is time-consuming (taking up to 6–8 hours per site), slowing down the production pipeline.

The challenge is to transition from rough area-based estimates to precision single-tree analytics that can directly inform industrial machinery.

2 Stakeholders

This technology impacts stakeholders across the entire forestry value chain:

- **Forestry Companies & Landowners:** Benefiting from higher net value per harvested hectare.
- **Production Planners:** Gaining accurate forecasts of raw material inflow to optimize sawmill schedules.
- **Harvesting Contractors:** Reducing machine idle time and optimizing cutting instructions.

- **Logistics Managers:** Improving fleet utilization through precise volume data.

3 Solution and Methodology

Our contribution, based on the *Slutavverkningsanalys* (Final Harvest Analysis) product, introduces a scalable workflow for ”Strategic Wood Security.”

3.1 DataAcquisitionStrategy

We employ a flexible multi-tiered approach to data collection:

1. **Large Area Coverage:** Utilization of **EUSI 15cm satellite imagery** allows for cost-effective scanning of vast forest holdings.
2. **High Precision Areas: Drone data** collection is deployed for smaller, complex areas requiring maximum granularity.

3.2 The USP: Pre-Harvest Optimization

The unique selling point (USP) of our solution is not merely counting trees, but understanding their industrial value before harvesting begins. We have trained specialized AI models to perform **virtual crosscutting optimization**.

Unlike standard inventory tools, our system calculates optimal bucking instructions based on current market pricelists and stem profiles derived from the imagery. This data is converted into **optimized harvester files** (compatible with StanForD standards) that can be uploaded directly to the harvester’s onboard computer. This effectively creates a ”digital twin” of the harvest plan, allowing decisions to be made in the office rather than solely in the chaotic environment of the harvester cab.

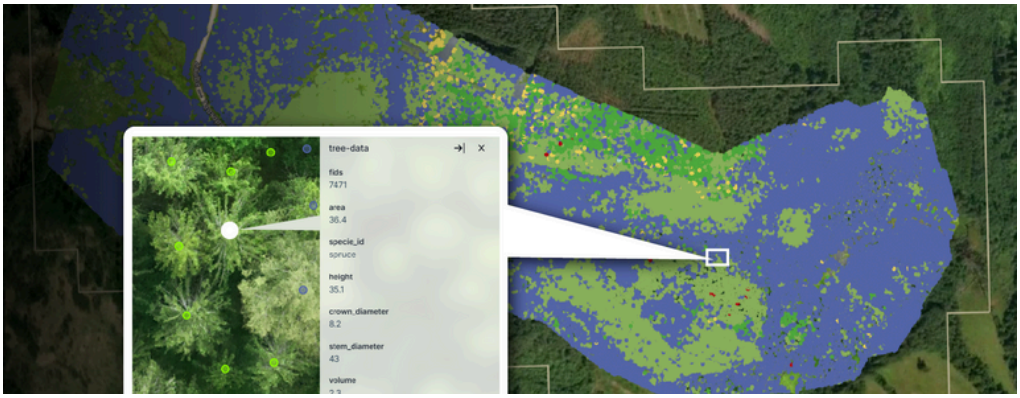

Figure 1: AI-based single tree analytics enabling virtual bucking.

4 Practical Relevance and Impact

The practical application of this technology delivers measurable financial and operational improvements, verified through pilot programs and customer operations:

- **Increased Timber Value (1–2%):** By identifying tree properties accurately beforehand, we shift volumes from pulpwood to timber assortments. A 1–2% improvement in assortment outcome significantly impacts the bottom line.

- **Harvesting Efficiency (2–3%):** Pre-generated harvester files reduce the operator's decision load and optimize machine movement, lowering fuel consumption and time per cubic meter.
- **Logistics Optimization (2–3%):** Exact volume and assortment data per landing allows for precise transport planning, reducing fuel costs and carbon footprint.
- **Administrative Efficiency:** The digital workflow reduces planning time from 6–8 hours to just 2–3 hours per site, freeing up forest managers for strategic tasks.

Figure 2: The Arboair workflow: From raw image data to actionable harvester files.

5 WorkabilityandValidation

This approach is not theoretical; it is fully workable and deployed in active forestry operations. The technology has been verified against actual Harvester Production (HPR) files from 67 harvested sites.

Validation Metrics:

- **Volume Precision:** The analysis achieved a mean volume error of only -0.7% across validated sites.
- **Reliability:** 83% of analyzed tracts fell within a ±15% margin of error for total volume, which exceeds traditional manual inventory standards.
- **Scalability:** TheuseofEUSIsatellitedataensuresthesolutionisscalabletoregional and national levels without the logistical bottleneck of deploying ground crews.

By integrating AI-driven single-tree analytics into the harvest planning phase, we provide the industry with the data quality necessary to move towards fully automated and optimized forestry.