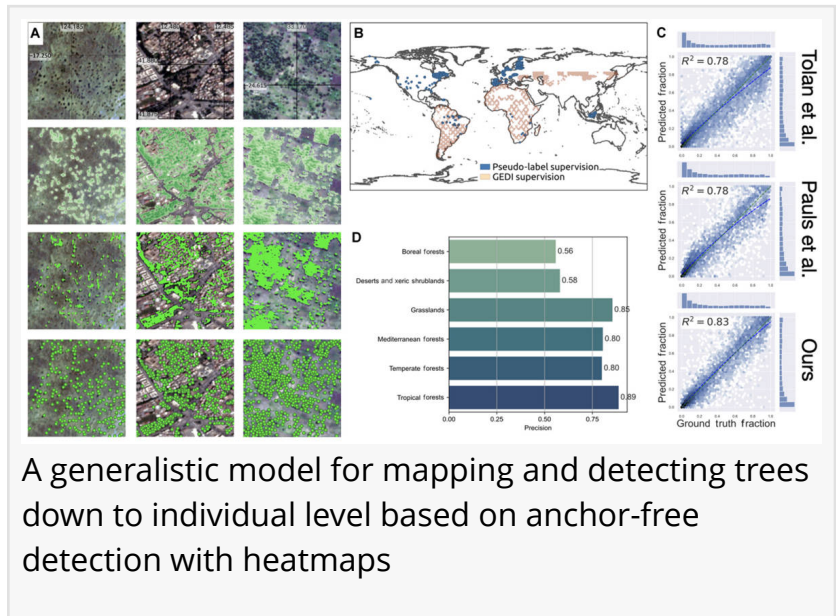


# Counting trees from space with artificial intelligence

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/EINPresswire.com/ -- Trees shape climate, biodiversity, rural livelihoods, and the global bioeconomy, yet many remain invisible to today's large-scale monitoring systems. Most [satellite](#) products describe forests as broad areas of tree cover or canopy height, but they do not locate trees as individual objects. A new deep learning framework changes that view by representing tree crowns as scalable Gaussian patterns in high-resolution satellite imagery. Trained with billions of automatically extracted tree points from airborne light detection and ranging (LiDAR) data, the model can detect large individual trees and produce detailed tree cover maps across diverse landscapes, from dense forests to scattered trees outside forests.



A generalistic model for mapping and detecting trees down to individual level based on anchor-free detection with heatmaps

Satellite monitoring has transformed how researchers track deforestation, land-cover change, and ecosystem dynamics. However, widely used global products based on medium-resolution imagery often work at scales too coarse to distinguish single trees, especially in open landscapes, farms, savannas, and fragmented forests. Very-high-resolution imagery can reveal individual crowns, but training such systems usually requires costly manual annotation and large volumes of commercial data. As climate change and land-use pressure reshape tree distributions, scientists need scalable tools that can count, locate, and monitor trees as objects over time. Based on these challenges, deeper research is needed to develop accurate, transferable, and cost-effective individual tree mapping methods at large scales.

Researchers from the University of Copenhagen and Harvard University reported (DOI: [10.34133/remotesensing.1049](https://doi.org/10.34133/remotesensing.1049)) the new approach in Journal of Remote Sensing on April 30, 2026. The study presents an anchor-free deep learning method for detecting large individual trees in 3-meter PlanetScope imagery. Rather than using fixed detection boxes, the model represents each tree crown as a Gaussian heatmap, enabling researchers to extract crown

centers and generate binary tree cover maps. The study combines PlanetScope imagery, airborne light detection and ranging (LiDAR)-derived canopy height models (CHMs), Global Ecosystem Dynamics Investigation (GEDI) data, and satellite-based location embeddings to improve large-scale generalization.

The key advance is a simple but powerful shift in how trees are modeled: each tree center becomes a peak on a heatmap. During training, Gaussian kernels are scaled according to spatial uncertainty, allowing the system to handle different crown sizes, noisy pseudo-labels, and imperfect alignment between LiDAR data and satellite imagery. The training dataset included approximately 14 billion tree points across about 1,030,000 square kilometers, using PlanetScope imagery from 2018 to 2022 and LiDAR sources from 17 countries. A U-Net model with a ResNet50 encoder was trained to produce both a heatmap and a spatial uncertainty map. The heatmap can then be thresholded into tree cover or processed into individual tree detections. The model achieved state-of-the-art cover-mapping performance, with fractional cover  $R^2 = 0.81$  against aerial LiDAR, and showed balanced detection metrics across biomes. Satellite Contrastive Location-Image Pretraining (SatCLIP), based on contrastive language-image pretraining (CLIP), improved generalization, while fine-tuning with manual labels further sharpened predictions.

The authors said the study is about moving from seeing forests as continuous green areas to seeing trees as countable, trackable objects. They said that representing trees as Gaussians gives the model a flexible way to describe crowns in complex landscapes, including places where trees are sparse, mixed with shrubs, or difficult to separate from background vegetation. They also emphasized that the method is not a final global tree census, but a scalable framework that can improve as better imagery, more LiDAR data, and targeted manual labels become available.

The approach could support climate science, forest management, biodiversity assessment, restoration monitoring, and carbon accounting. By locating trees both inside and outside forests, it may help reveal overlooked tree resources in agricultural land, drylands, fragmented forests, and human-managed landscapes. Its heatmap output can be adapted for tree counting or cover mapping, depending on the monitoring goal. The method is also transferable to future satellite missions with higher spatial and radiometric quality. Remaining challenges include limited airborne LiDAR coverage in parts of South America, Africa, and Asia, threshold selection across regions, and reduced performance where small crowns or dense forests visually merge at the current ground sampling distance (GSD).

## References

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