Canopy biomass of tropical forest

Evaluating the SAM Model for Individual Tree Crown Delineation Across a Forest Successional Gradient in Central Africa (DRC)

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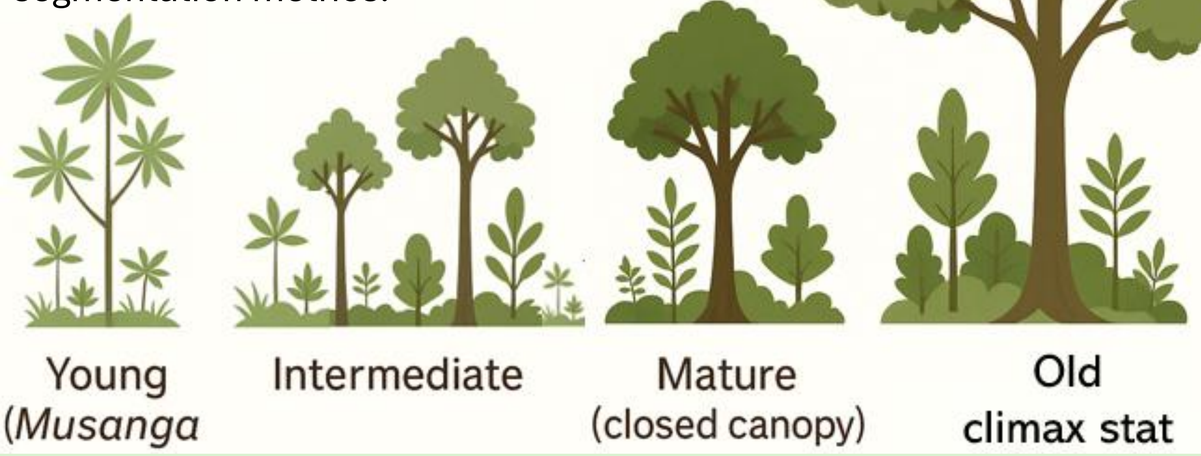
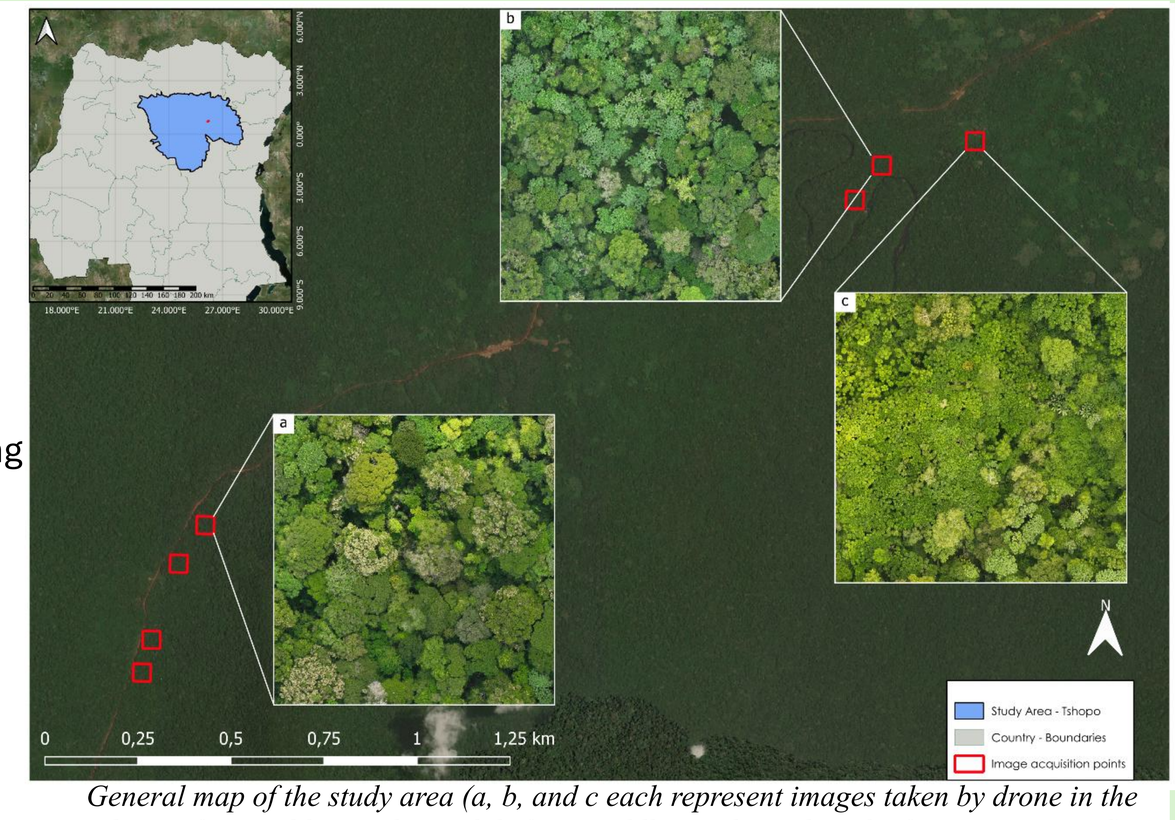
•Context

The tropical forests of Central Africa play a key role in the carbon cycle and landscape restoration.Monitoring their dynamics requires high-resolution approaches based on remote sensing.
Accurate delineation of individual tree crowns is essential for reliable forest structure assessment and biomass estimation. Crown segmentation errors propagate into derived metrics and reduce the robustness of forest monitoring workflows. This study evaluated the performance of the **Segment Anything Model (SAM)** applied to drone imagery across a tropical forest successional gradient, comparing its outputs to field-based validation indices and internal segmentation metrics.



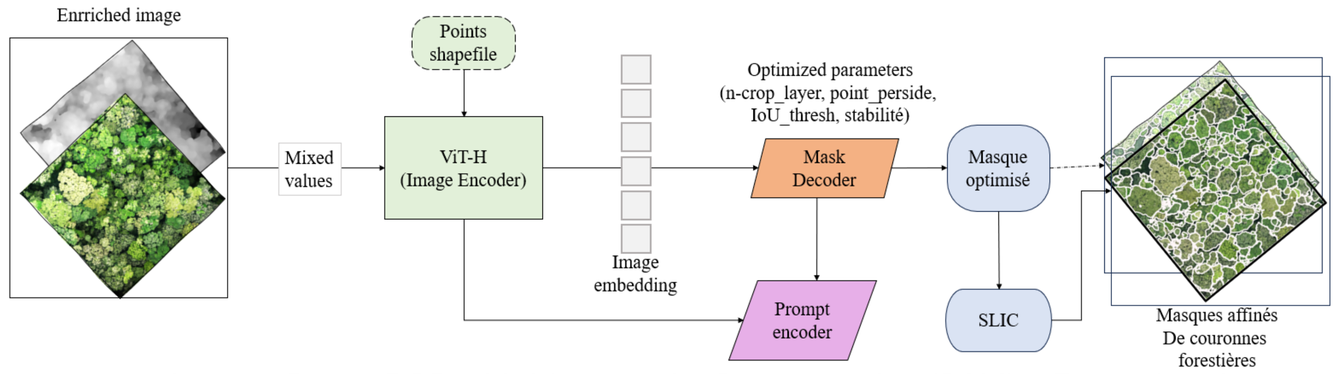


General map of the study area (a, b, and c each represent images taken by drone in the plots. a for an old-growth stand, b for a middle-aged stand, and c for a young stand).

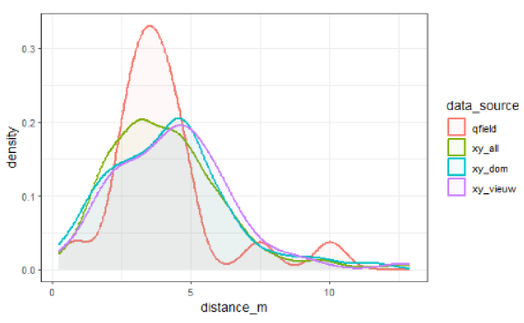
The study was conducted in forest around Kisangani(DRC) across a chronosequence consisting of: Young stands: 8–13 years; Intermediate stands: 23–33 years; Mature stands: 56 years and old-growth forests (OGT)
Drone RGB imagery (high-resolution) and detailed field measurements (DBH, height, crown position, spatial mapping) were used as reference data for segmentation validation.

• Methodes

1. Crown delineation
•Segmentation performed with **SAM** using a tuned configuration optimized for tropical forest canopy complexity.
•Internal metrics computed:
- *Mean IoU internal*
- *Stability score*
- *Fractional crown cover*
- *Mean crown count*



Images Drone RGB + Multispectral → Segmentation (SAM) → Extraction des variables

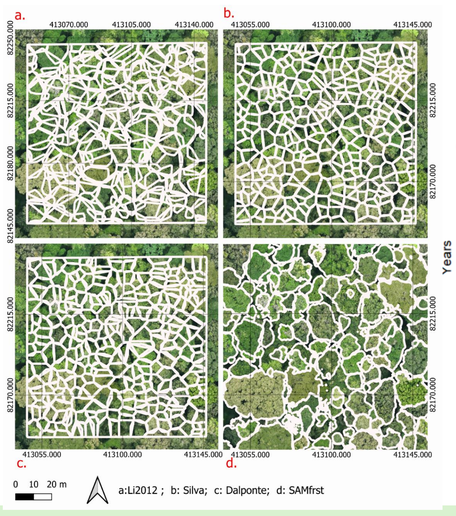


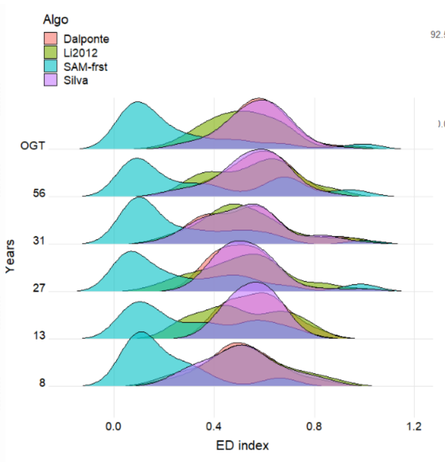
Density of distances (in meters) between tree positions measured in situ

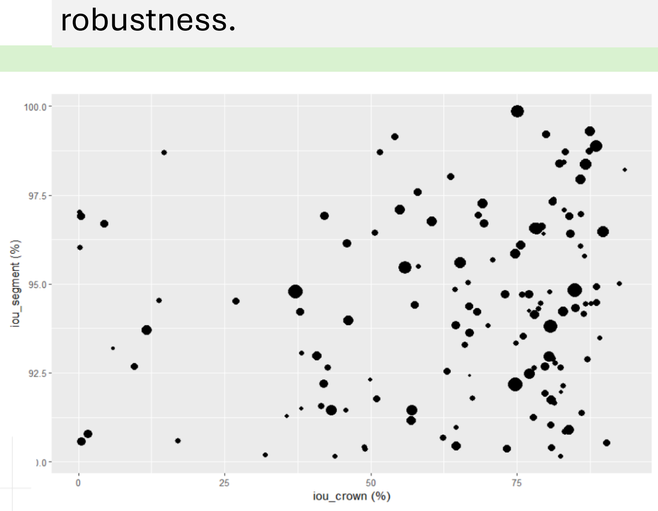
2. Validation against field data
Three standard crown-based validation metrics were calculated:
•**ED (Euclidean Distance)** – spatial alignment between predicted and observed crown centroids
•**US (Under-segmentation)** – number of merged crowns
•**OS (Over-segmentation)** – number of split crowns

3. Successional gradient analysis
Performance was evaluated across age classes to assess how canopy structure affects segmentation robustness.

Younger stands show lower performance (higher ED, more US/OS). Performance improves in intermediate stands. Older stands show highest stability, though with some dispersion in ED. Recall remains relatively stable across classes.
Segmentation accuracy increased along the successional gradient. Young stands were more challenging due to dense, poorly differentiated crowns, whereas intermediate and older stands exhibited clearer crown boundaries and therefore better delineation

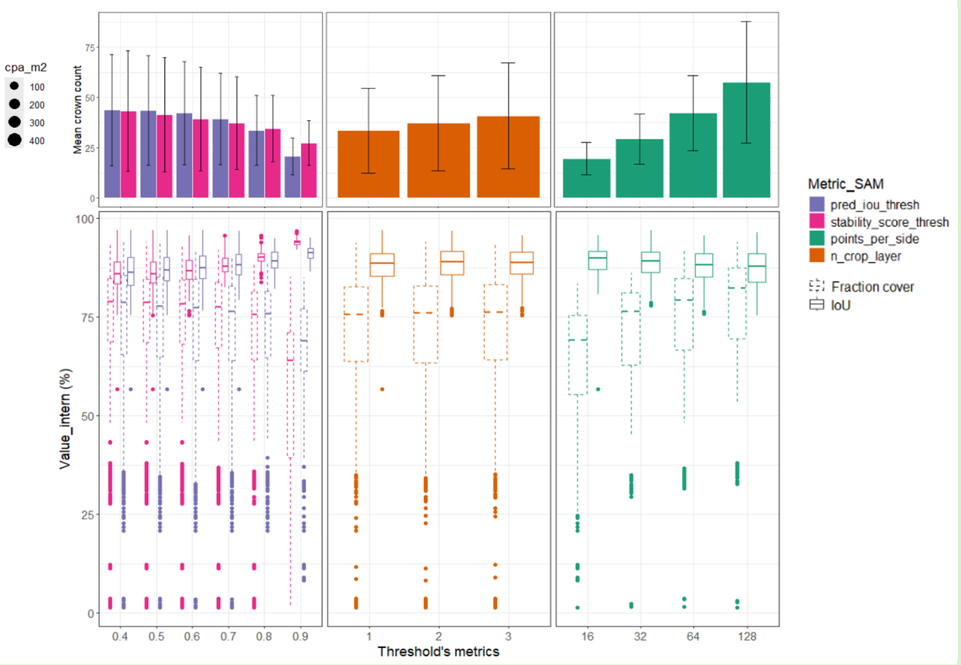






•Internal metrics differ between large and small crowns. Despite this, SAM maintains stable performance even for small, more complex crowns.
Although crown size influenced internal scores, SAM maintained comparable accuracy across crown classes, suggesting resilience to crown-size variability.

•A clear trend of higher internal performance (IoU, stability) for SAM across the tested parameters. Consistent separation of metric values across thresholds.
•SAM achieved stable internal performance across parameter settings, indicating robustness of crown boundary estimation regardless of threshold choice.



• Synthesis (discussion elements)

SAM-frst showed consistently strong performance across internal validation metrics, demonstrating its suitability for tropical crown delineation. Crown size had little influence on accuracy, highlighting the model's robustness across spatial scales. Stand age, however, affected segmentation quality: young forests were more challenging due to dense foliage and poorly defined crowns, whereas intermediate and older stands allowed clearer separation. Despite these structural differences, recall remained stable, indicating that most crowns were detected across all age classes.
Overall, SAM-frst provides a reliable framework for large-scale crown delineation in tropical forests and can be confidently integrated into forest monitoring workflows when combined with field validation.

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