Towards automated monitoring of tropical forest ecosystems through the largest trees

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Context: Monitoring structural forest attributes helps assess the role of these ecosystems in the context of global change. In Central Africa, field inventories are costly and limited, requiring alternative approaches. In this context, tracking large canopy trees through a combination of remote sensing and artificial intelligence, enabled by the development of Individual Tree Crown (ITC) algorithms, offers significant opportunities.

Objectives: To test, **compare**, and **optimize** ITC approaches—Detectree2, Segment Anything (SAM), and a **hybrid method** (Detectree2SAM, D2S)—for the automatic characterization of **structural attributes** (crown areas and shapes) of canopy trees.

Study Site: Luki Biosphere Reserve, DRC

ITC Algorithms:
- Detectree2 - Mask R-CNN
- SAM - Image encoder + Vision transformer
- Detectree2SAM - Hybrid process

Validation: F1-score per pixel and Intersection over Union (IoU) compared to a reference photo-interpreted inventory.
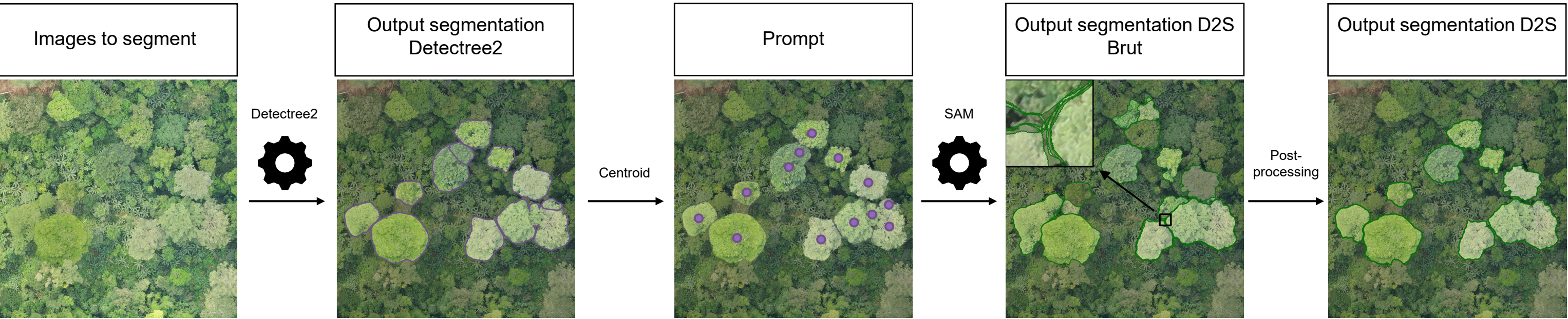

Figure 1 – Detectree2SAM process

$F1_{Pixel}: 0,8114 - F1_{IoU}: 0,697$ — Detectree2

$F1_{Pixel}: 0,8249 - F1_{IoU}: 0,673$ — SAM
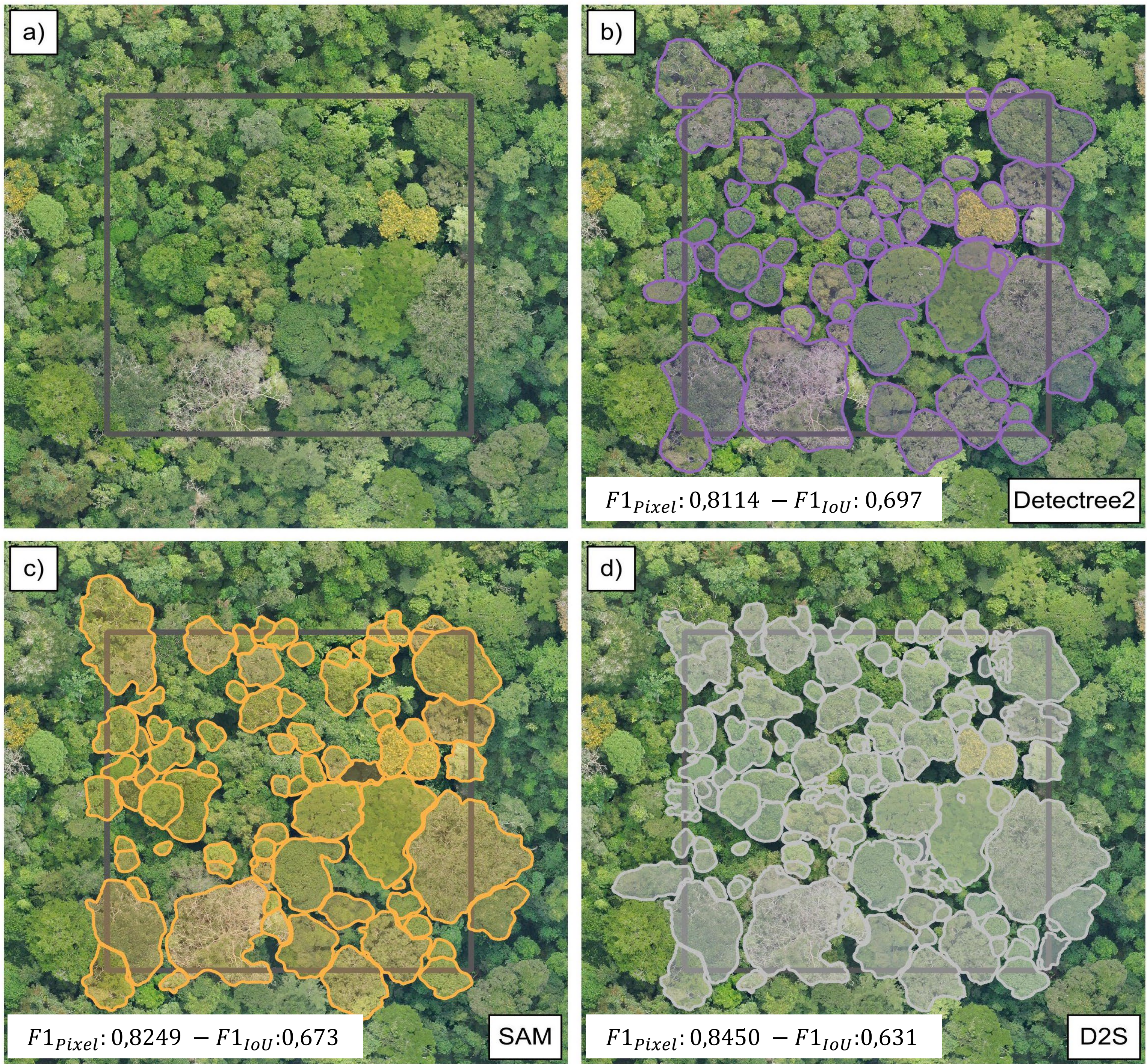
$F1_{Pixel}: 0,8450 - F1_{IoU}: 0,631$ — D2S

Figure 2 – Example of the outputs of the three ITC algorithms on: a) 1 ha representative of the Luki Biosphere Reserve site, with b) Detectree2, c) SAM, and d) Detectree2SAM.

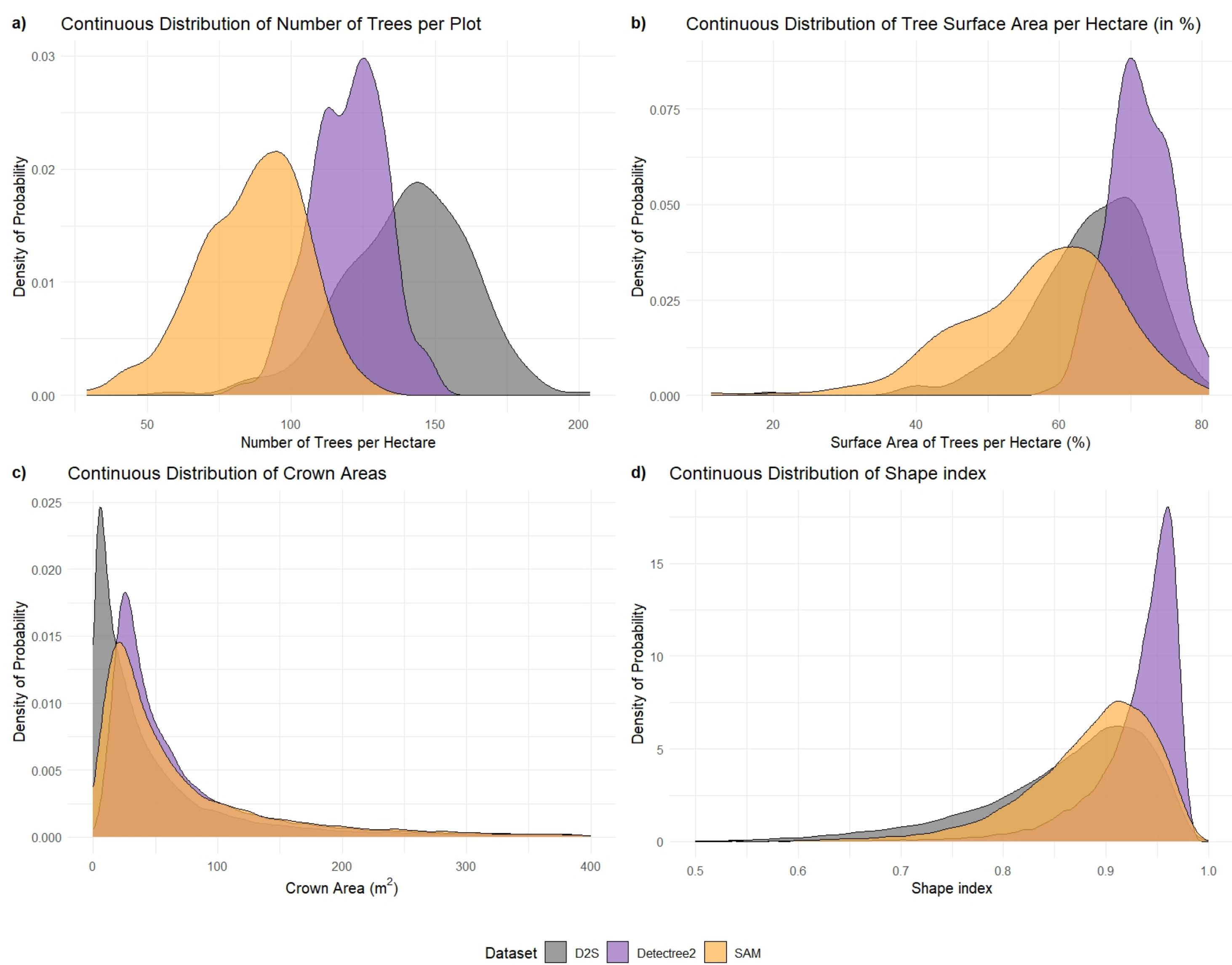## Landscape Structure of Luki:
(Based on multiple ITC methods)

Figure 3 - Structural attributes at the landscape scale of Luki for three automated tree crown identification methods: D2S, Detectree2, and SAM.

Structural Attributes: ITC algorithms characterize tree crown structural attributes differently at the individual tree scale. We assess these differences using RMSD, comparing them to a specific field inventory (IoU > 0.5).

Table 1 – RMSD of structural attributes between the ITC methods and a field inventory

Trees scale	Area	Shape complexity
Detectree2	80,68 m²	0,149
SAM	86,34 m²	0,099
Detectree2SAM	52,90 m²	0,102

Perspectives:
- These results raise questions about the **relationship** between **canopy structure and overall forest** stand composition.
- The divergence in distributions across models, despite similar F1-scores, highlights the **impact of methodological choices**.
- Analyzing crown shapes and their links to **functional traits** and **environmental factors** could provide new insights.
- The broad spatial coverage of these data offers opportunities in **ecology** and **modeling**, particularly for **upscaling** approaches.

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