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With a pinch of salt

Effects of distance on the accuracy of terrestrial laser scanning for branch volume determination

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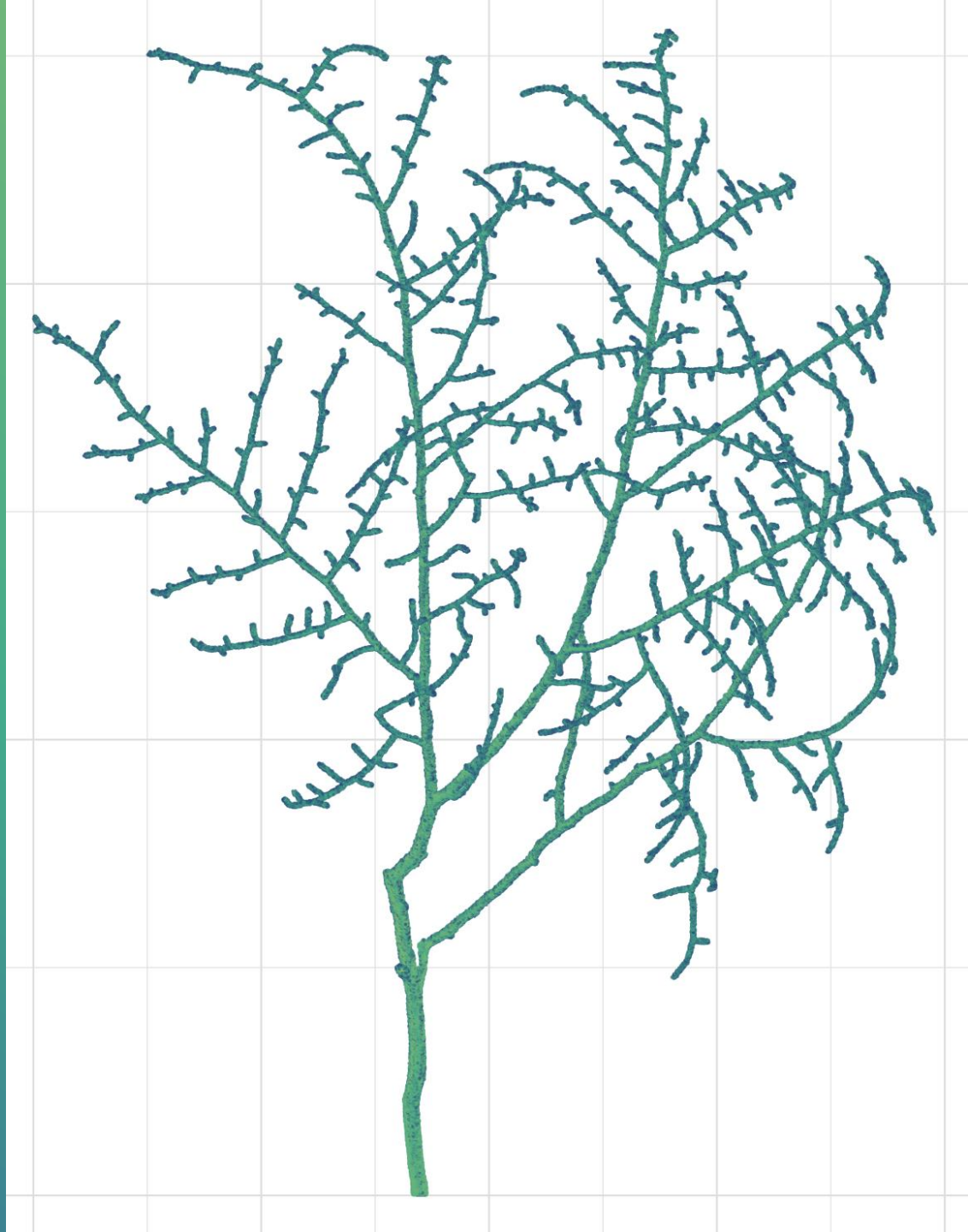
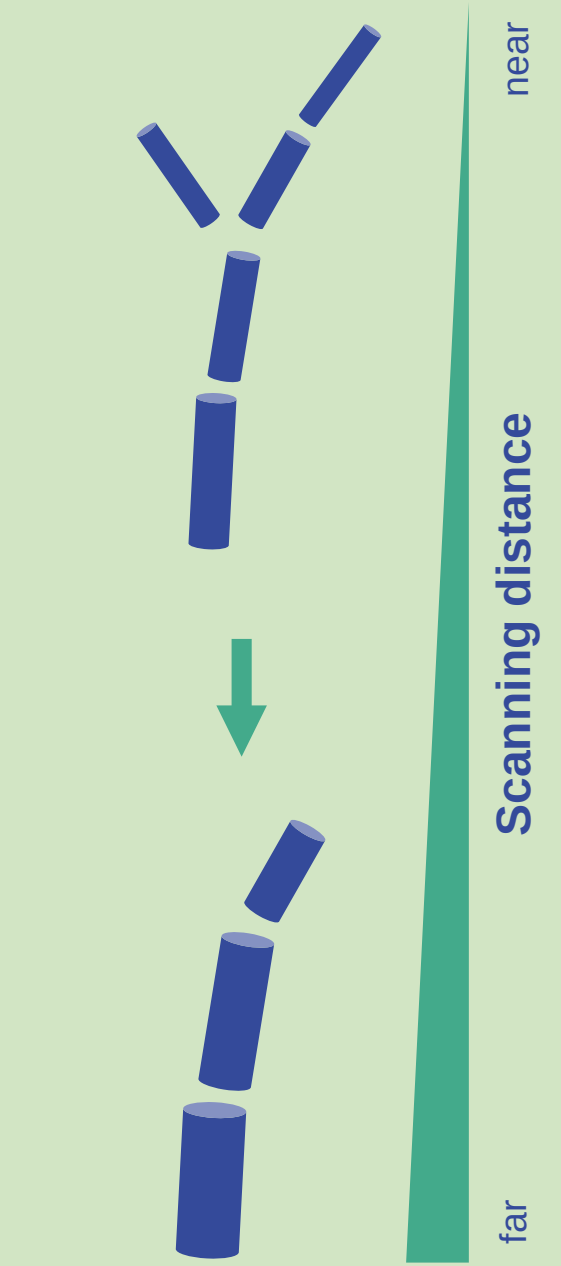


Background

- Terrestrial Laser Scanning (TLS) and Quantitative Structure Models (QSMs) are frequently used in forestry for estimating tree volume
- Method has been shown to provide good volume estimates for whole trees
  (e.g. Calders *et al.* 2015, Gonzalez de Tanago *et al.* 2018)
- Recent research has revealed inaccuracies in fine branch material
  (e.g. Demol *et al.* 2022, Abegg *et al.* 2023)

→ **Goal: Isolation and quantification of the effect of scanning distance on QSMs**



Research hypotheses:

(1) With increasing scanning distance, branch length estimates decrease.

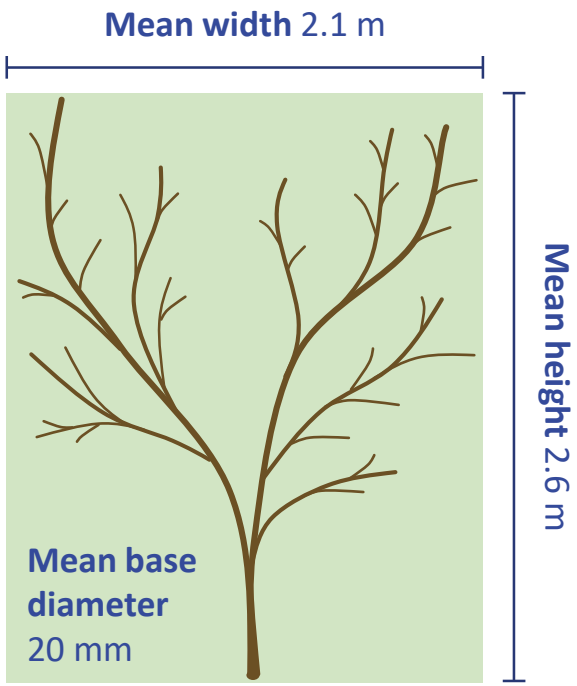
(2) With increasing scanning distance, branch volume estimates increase.

Abegg *et al.* 2023: 10.1016/j.agrformet.2023.109348 | Calders *et al.* 2015: 10.1111/2041-210X.12301
Demol *et al.* 2022: 10.14214/sf.10550 | Gonzalez de Tanago *et al.* 2018: 10.1111/2041-210X.12904

Material & Methods

Experimental Setup

- **Scanner:** RIEGL VZ-400i
- **Species:** *Fagus sylvatica*



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Material & Methods

Experimental Setup

- **Laser scanner:**
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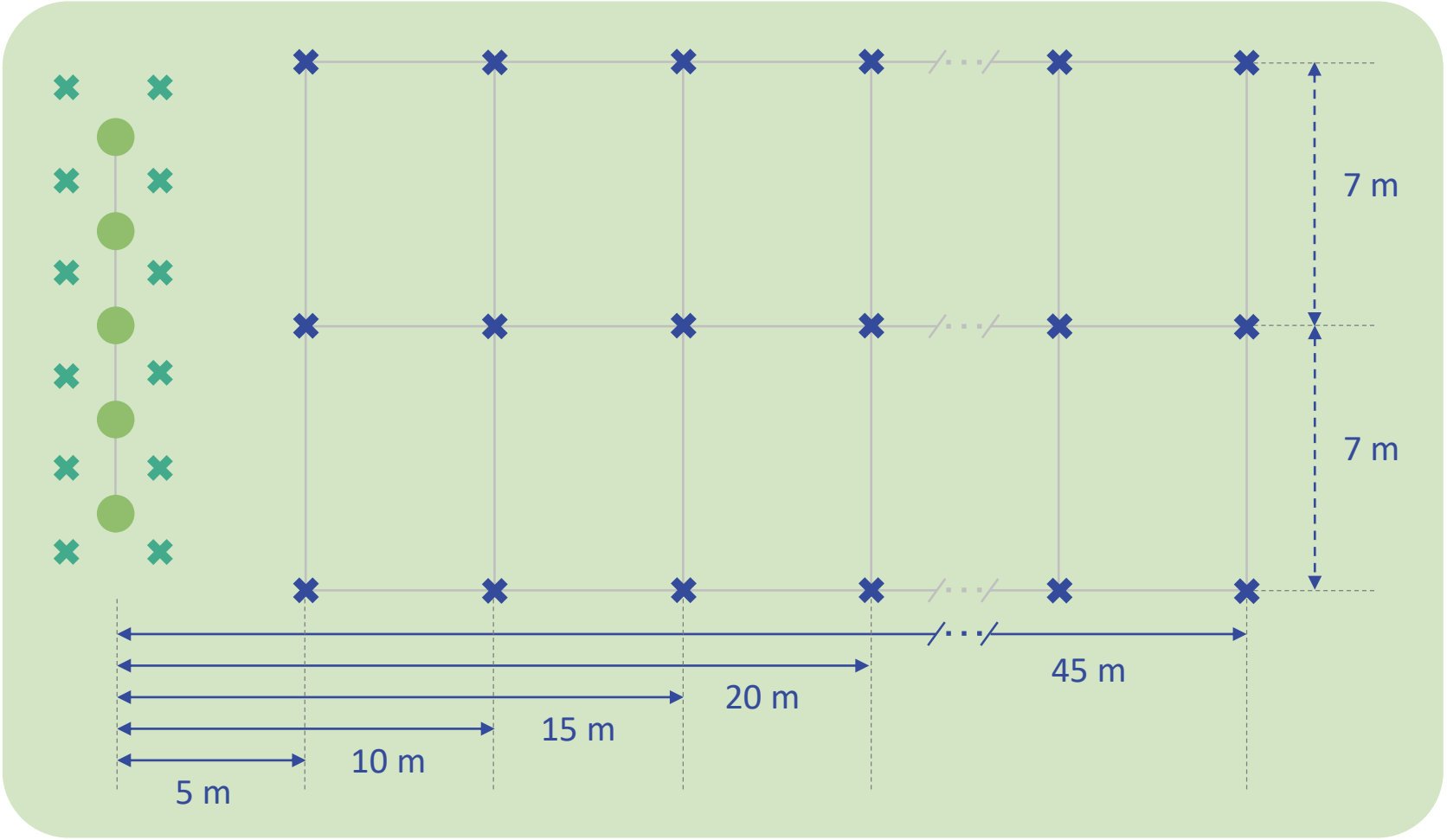
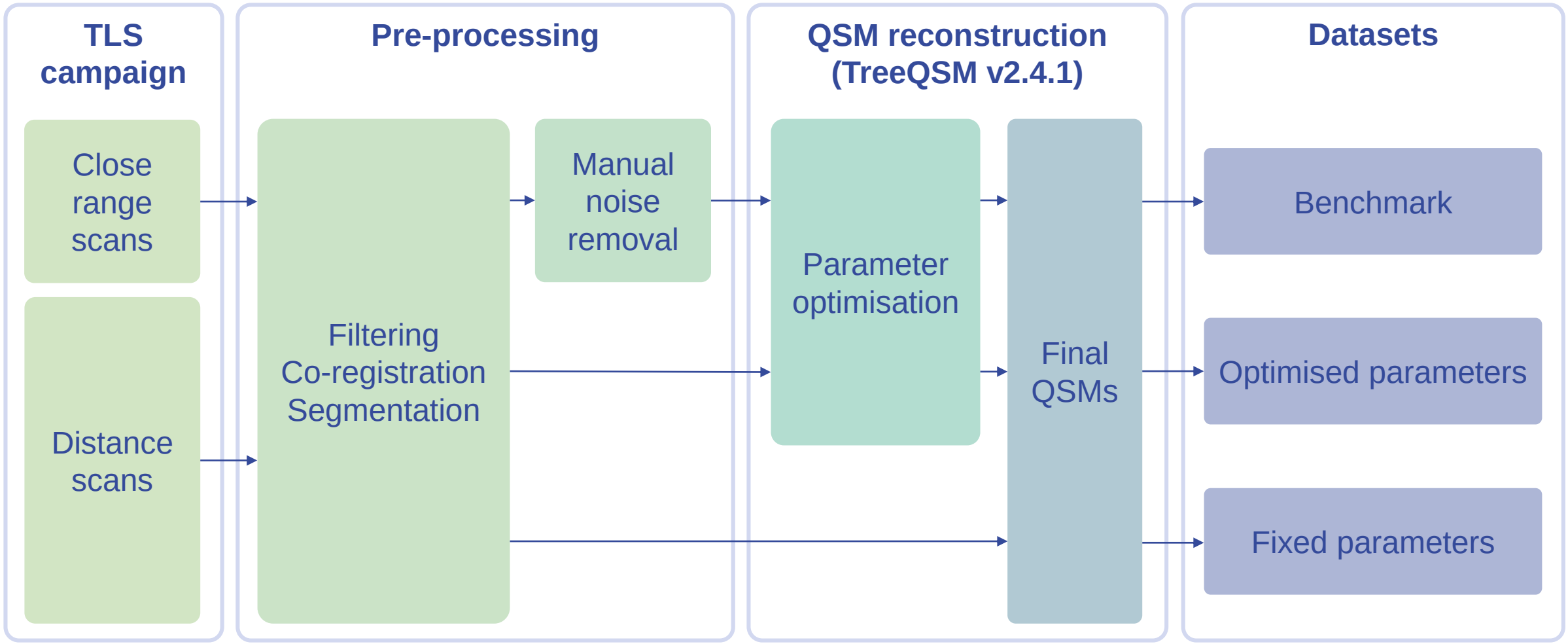


Material & Methods

Data Processing



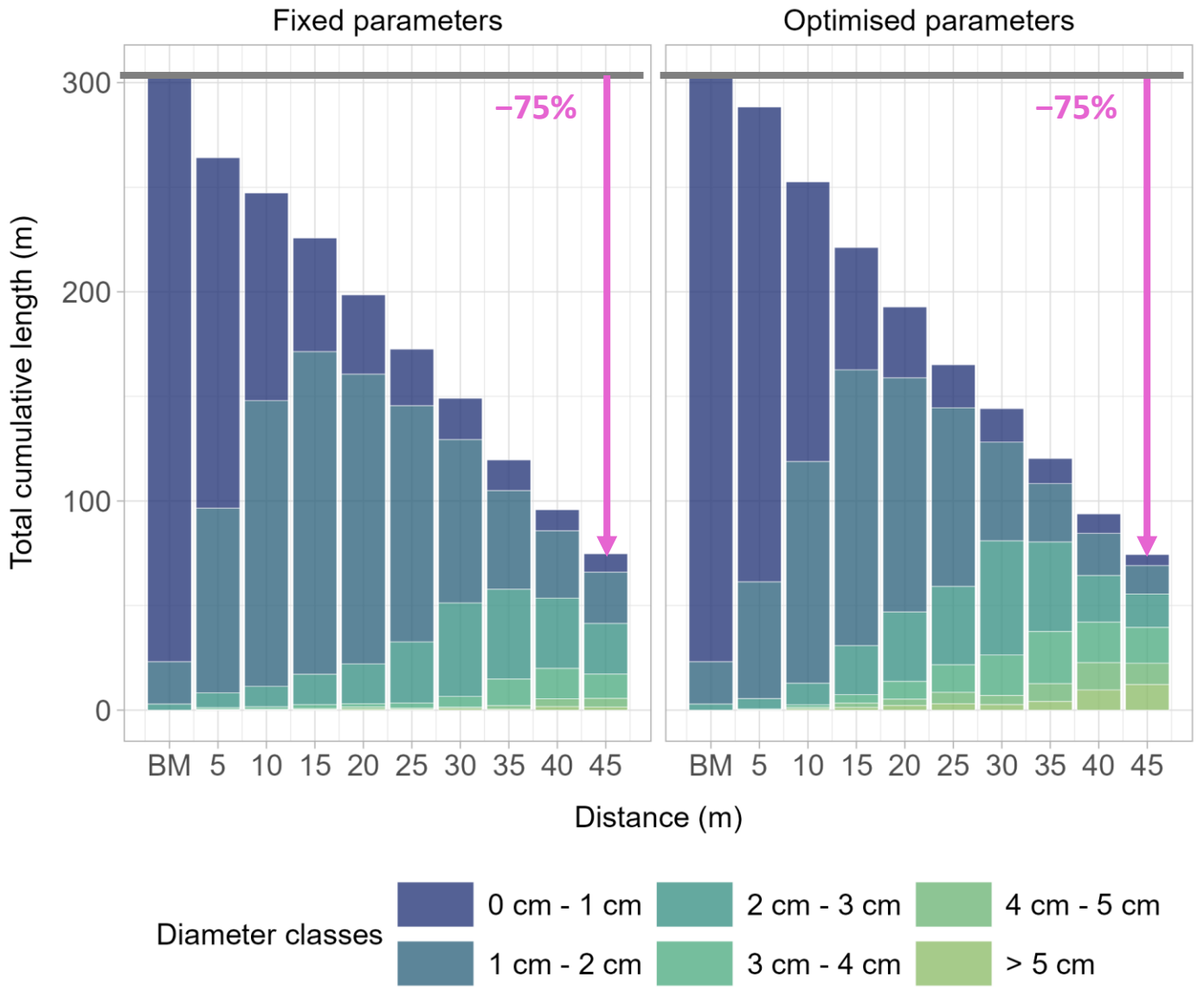
Results

Branch Length

- **Decreasing** cumulative **branch length** with increasing scanning distance
- Distribution of diameter classes shifts towards larger classes
- Effect varies only **slightly** between datasets using different parameters

Research hypotheses:

(1) With increasing scanning distance, branch length estimates decrease. ✓



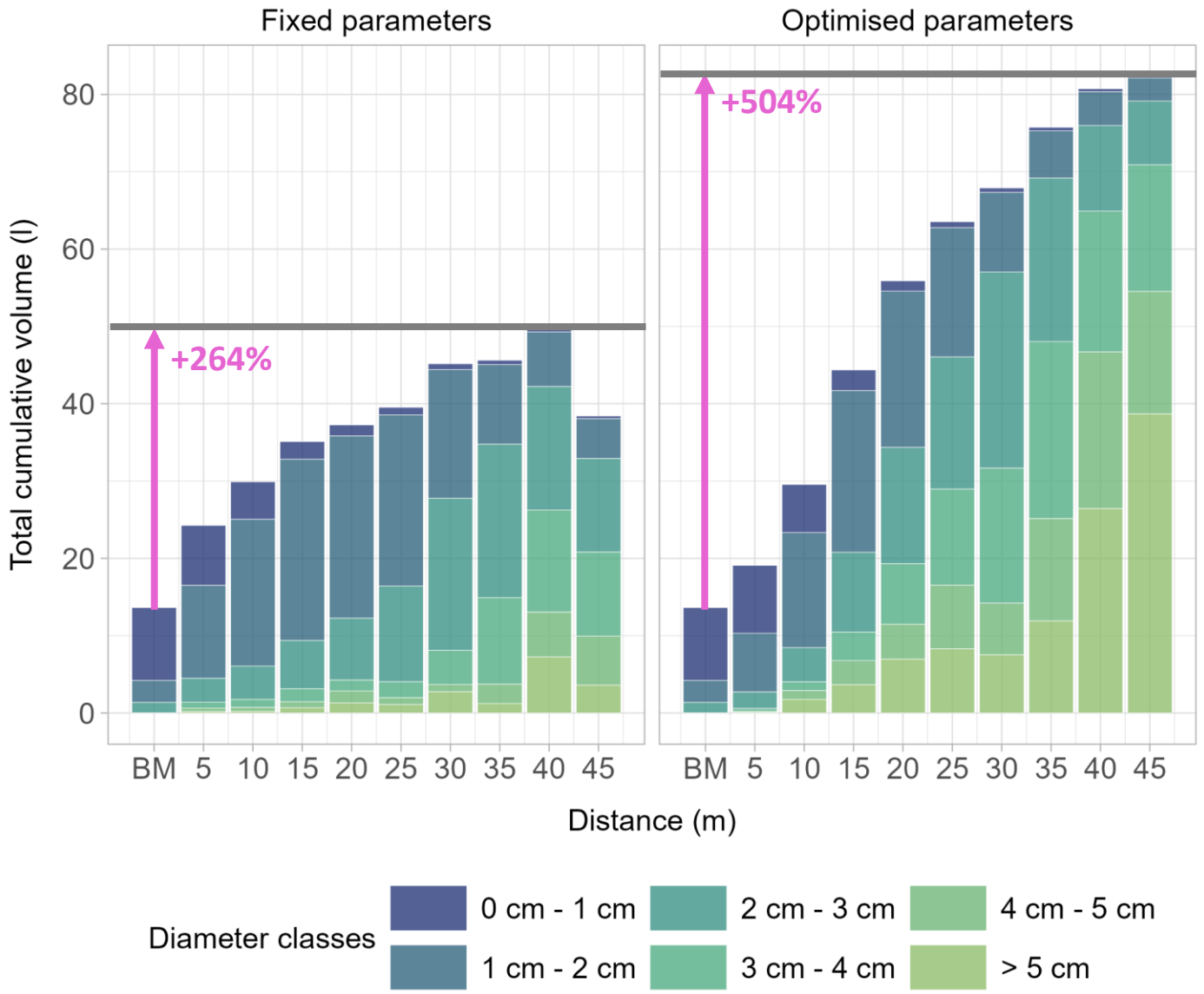
Results

Branch Volume

- **Increasing** cumulative **branch volume** with increasing scanning distance
- Distribution of diameter classes shifts towards larger classes
- Effect varies **considerably** between datasets using different parameters

Research hypotheses:

(2) With increasing scanning distance, branch volume estimates increase. ✓

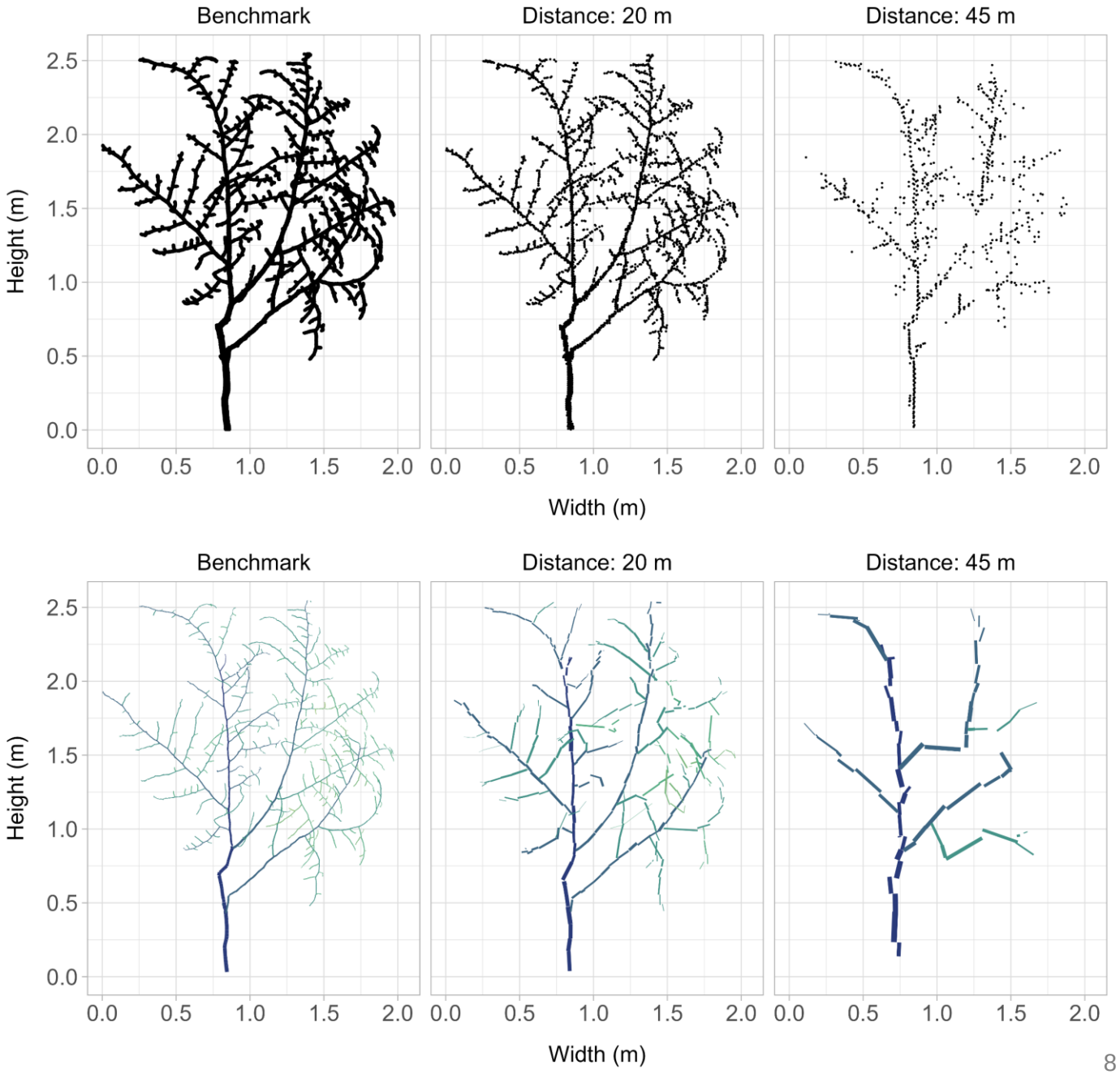


Discussion

Possible Reasons

- QSM reconstruction mainly **data-driven**
  → QSMs only as good as point clouds

- Point cloud quality inadequate due to
  - … increasing beam size
  - … decreasing coverage



Discussion

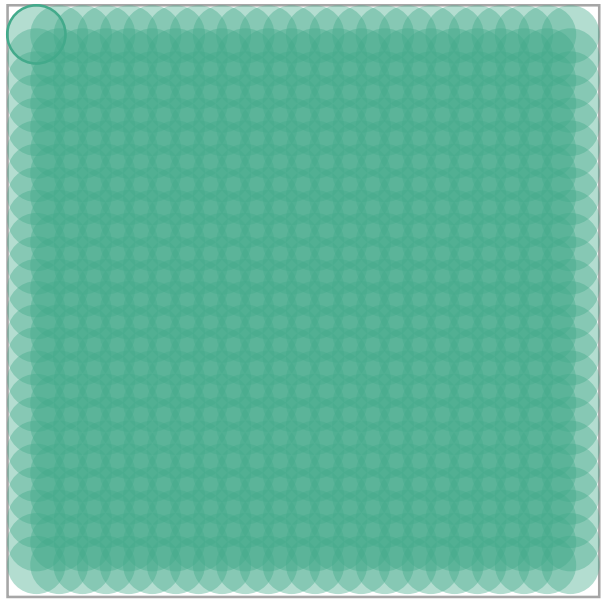
Possible Reasons

Device: RIEGL VZ-400i

Settings:

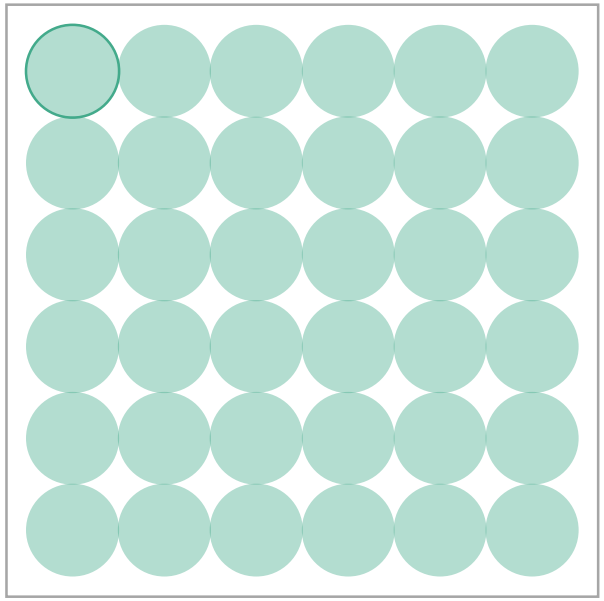
- angular resolution 0.04°
- pulse repetition rate 1,200 kHz

Distance: 5 m



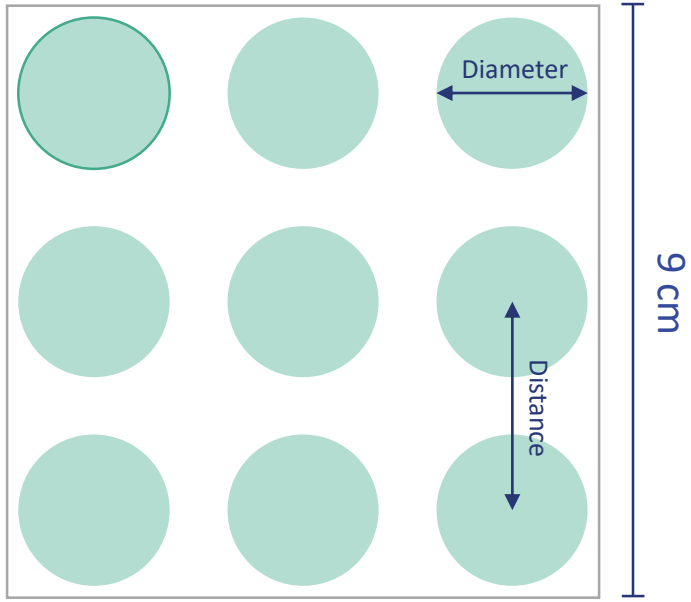
Beam diameter:	9 mm
Beam distance:	3 mm
Full hits:	576

Distance: 20 m



Beam diameter:	14 mm
Beam distance:	14 mm
Full hits:	36

Distance: 45 m



Beam diameter:	23 mm
Beam distance:	31 mm
Full hits:	9

Discussion

Possible Solutions

What **could** be a solution?

- Bring TLS device closer to the crown (e.g. Wilkes *et al.* 2021, Griese *et al.* 2025)
- Combine TLS with airborne data, e.g. UAV data (e.g. Terryn *et al.* 2022)
- Use deep learning to improve point cloud quality (e.g. Bornand *et al.* 2024)

Data quality

- Incorporating plausiblility of data during QSM reconstruction (e.g. Verhoeven *et al.* 2025)
- Extrapolate QSMs using allometric functions & coefficients

Data processing

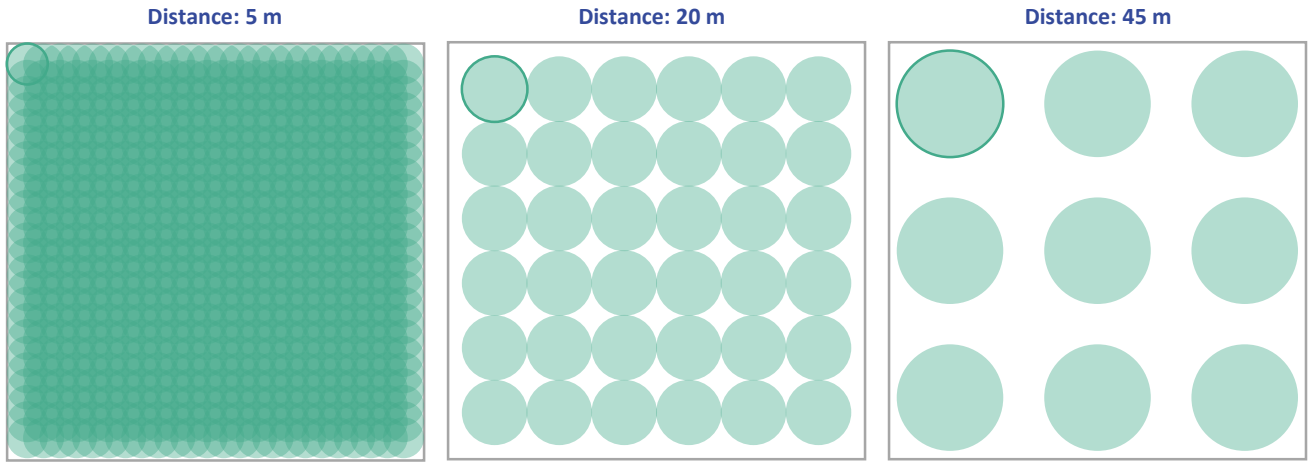
What **could not** be a solution? (in my opinion)

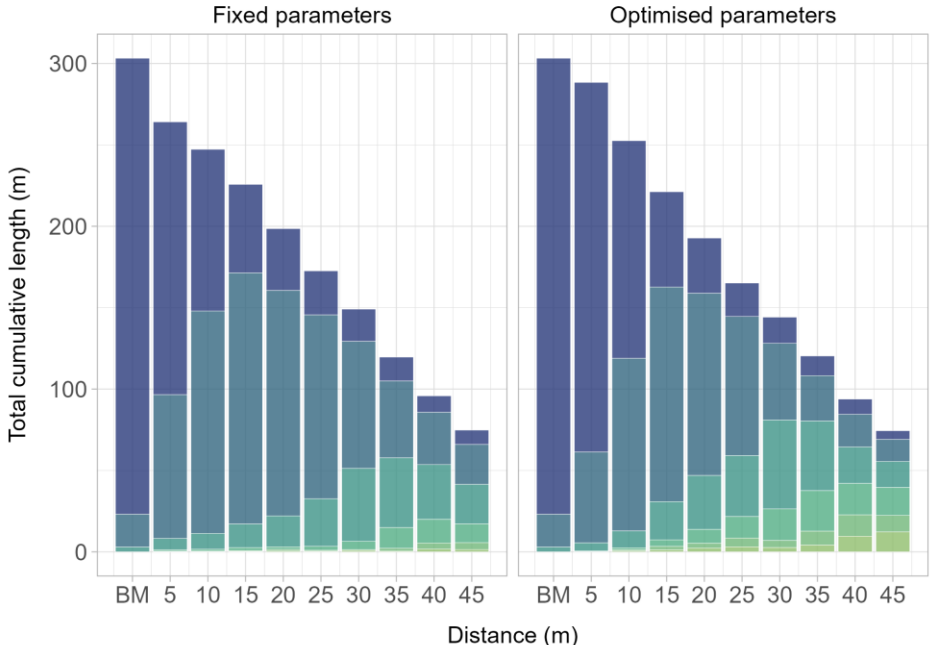
- Calibration curves → inaccuracy dependent on too many factors + correcting length / diameter / volume does not fix overall structure

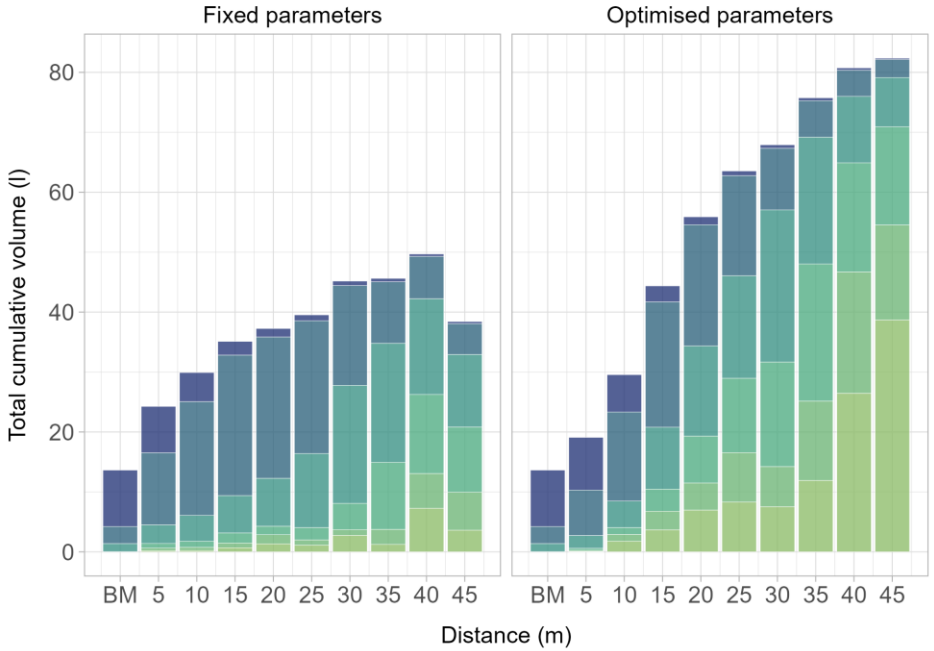
Bornand *et al.* 2024: 10.1111/2041-210X.14412 | Griese *et al.* 2025: 10.2139/ssrn.5412956 | Terryn *et al.* 2022: 10.1016/j.rse.2022.112912 | Verhoeven *et al.* 2025: 10.3390/jimaging11010007 | Wilkes *et al.* 2021: 10.34726/wim.1862

Take-home Messages

- QSM quality is limited by **point cloud quality**
- Point cloud & QSM **quality deteriorates** with increasing **scanning distance**
  - Branch length is increasingly underestimated
  - Branch volume is increasingly overestimated







Thank you for your attention!

Corresponding paper is available as:

Morhart C, Schindler Z, Frey J, Sheppard JP, Calders K, Disney M, Morsdorf F, Raumonen P, Seifert T (2024). Limitations of estimating branch volume from terrestrial laser scanning. *European Journal of Forest Research* **143**, 687–702. https://doi.org/10.1007/s10342-023-01651-z

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Gefördert durch

Bundesministerium für Ernährung und Landwirtschaft

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