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How robust is mobile laser scanning for forest inventory applications – a Swiss case study

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The Swiss NFI at a glance

- Currently 5th iteration of the NFI (2018 2026)
- >6500 NFI plots regularly distributed over 1.4 km grid
- Forest plots are evaluated by:
 - **Measurements** (tree position, size, etc.)
 - Expert Assessment (e.g. forest structure: layering, vegetation cover etc.)



The Swiss NFI NFI plot evaluation

Tree assessment

- Small circle (200 m²): All trees with DBH \geq 12 cm and < 36 cm
- Large circle (500 m²): All trees with DBH \geq 36 cm
 - Position, DBH, Species

Interpretation area

- Area: 50x50 m²
- Expert assessment on e.g. layering, gaps, vegetation cover (shrub, rejuvenation, ground vegetation etc.)



Brändli et al. (2020): Schweizerisches LFI: Ergebnisse der vierten Erhebung

Close-range remote sensing for Swiss NFI? How can we benefit from close-range remote sensing

Increase in area

- Measure more trees on a larger area
 - Important information for protective function of forests (avalanches, rock fall)

From an expert assessment to more quantitative measurements

• E.g. for canopy layering, misc. coverages etc.

Detailed, non-destructive tree measurements

• Stem curve, AGB (per compartment) etc.

Cal-/Val- Data for large scale products



Close-range remote sensing for Swiss NFI? Constraints for an operational implementation

What is needed for an operational implementation in the Swiss NFI

- Data acquisition during normal NFI field acquisition
- Robust data acquisition and information extraction
 - Season, terrain, forest structure, operator
- **Fast** data acquisition
 - Time on plot should not be significantly increased
 - Max time to acquire 3D data: **15 minutes**



Multi-sensor benchmark



 TLS still gold standard



 UAVLS – Occlusion in lower canopy (esp. under leaf-on)



 GoPro – very low-cost and simple approach but not robust







- MLS comparable to TLS, but much faster.
- K
 ükenbrink et al. (2022). Benchmarking Laser Scanning and Terrestrial Photogrammetry to Extract Forest Inventory Parameters in a Complex Temperate Forest. JAG

Evaluating the robustness Covering the range of the Swiss forests



Data acquisitions should be possible on all forest plots in Switzerland:

- Dense understorey
- Steep and rough terrain
- NFI plot selection: 26 plots



Evaluating the robustness Robustness regarding operator



Swiss NFI @ a Glance - CRS - Benchmark - Make CRS operational? - Conclusions

Occlusion Mapping How much of the canopy can we cover?

- Trace each laser pulse through a 3D voxel grid
- Mapping voxels that cannot be reached by the laser pulses

 As seen in e.g. Kükenbrink et al. (2017) Schneider et al. (2019) Brede et al. (2022)



Robustness against operator

- If acquisition pattern are similar, occluded volume show only minor differences
- Large differences in occluded volume fraction when large differences in acquisition patterns are encountered
- Following target acquisition pattern is important!
 - But this is not always easy!



Tree Detection on NFI plots

- Most plots/acquisitions show a tree detection rate between 80 and 100 %
- Reduced Tree detection rate encountered when:
 - Understorey vegetation density is high
 - Difficult navigation
 - Increased occlusion
 - Terrain gradient is high
 - Difficult and sometimes dangerous navigation



Evaluating the robustness Phenological robustness

How does phenology influence occlusion and extracted forest inventory parameters?

June 1st



Evaluating the robustness Phenological robustness



Conclusions & Outlook

- Close range remote sensing techniques show potential to support the Swiss NFI in the future
- Especially Mobile Laser Scanning looks promising
 - Good compromise between acquisition time and precision
- Data acquisition is mostly robust also under difficult conditions and varying operators
- Strategies for impossible or incomplete data acquisition
 - Data quality and coverage assessment e.g. using occlusion mapping:
- Best practice on data acquisition and automatic feature extraction: ongoing research







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Thank you! Questions?

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