Applications and prospects of terrestrial LiDAR and drones for an improved forest inventory

A review based on current literature

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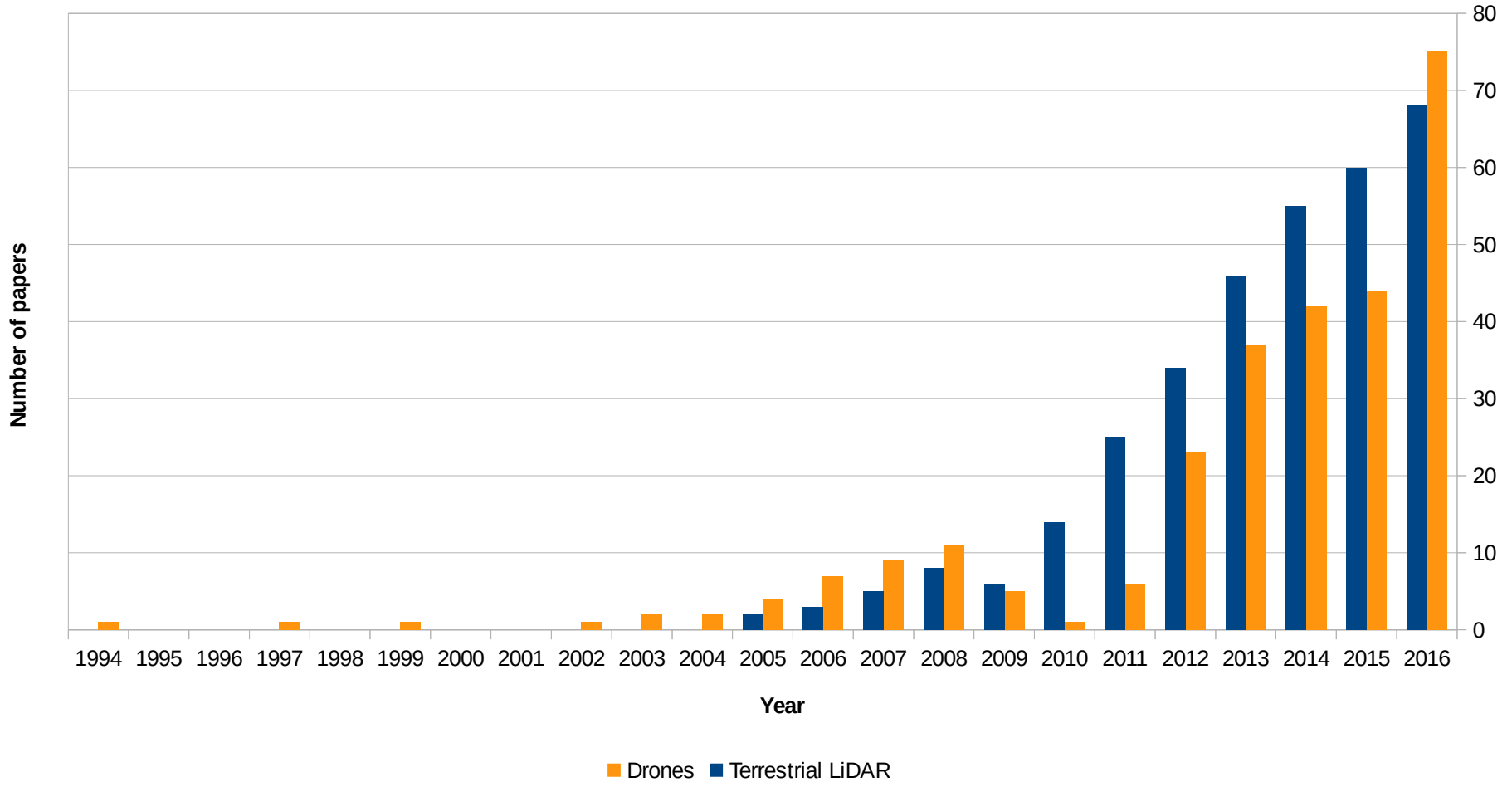
Bibliometrics
Publications over time



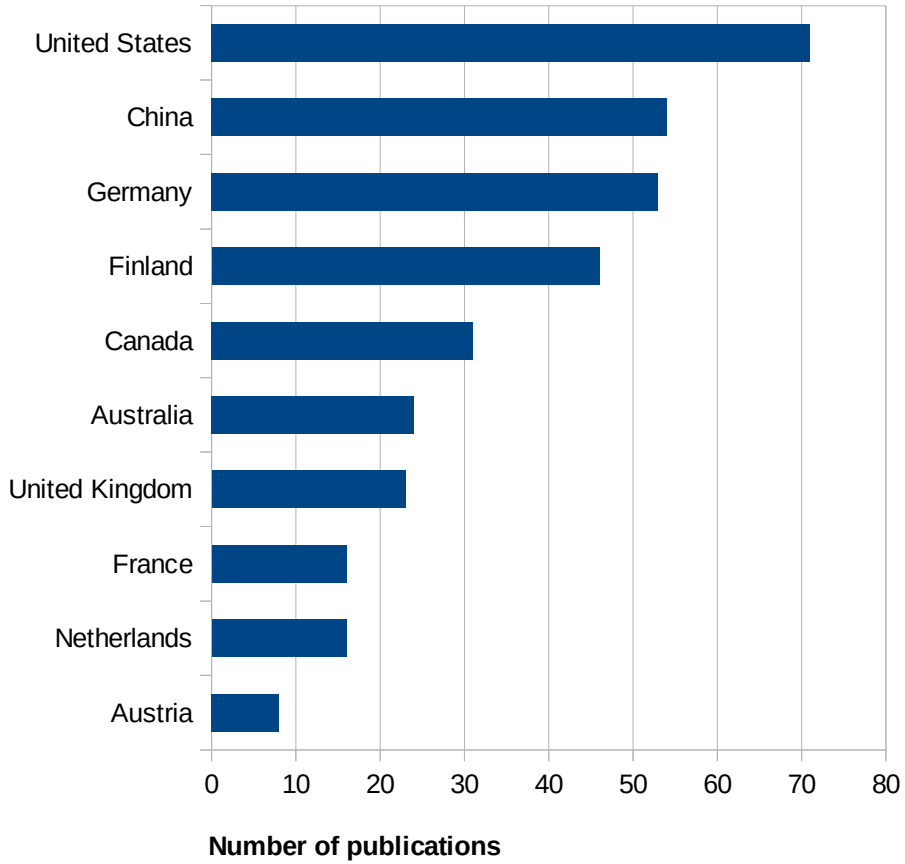
Data source: Scopus search for

("terrestrial laser scanning" OR "terrestrial LiDAR" OR "t-LiDAR") AND ("forest" OR "forestry")

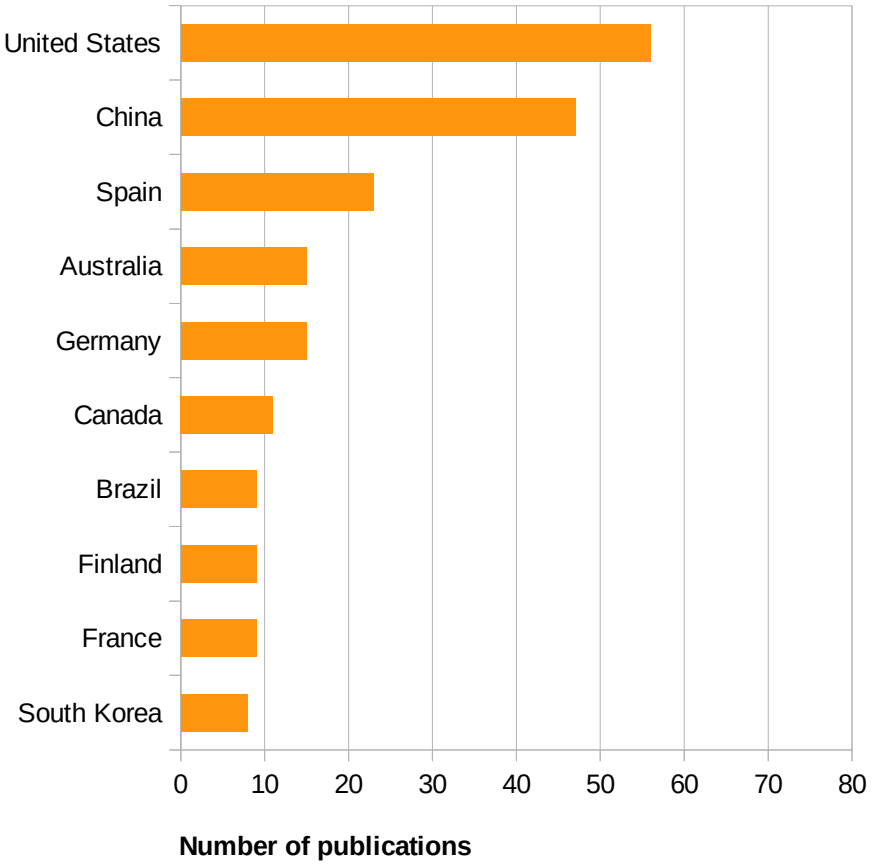
("UAV" OR "drone" OR "umanned aerial") AND ((forest OR tree) AND measurement OR forestry)

Bibliometrics
Publications per country

Terrestrial LiDAR



Drones



Data source: Scopus

Terrestrial LiDAR Technology

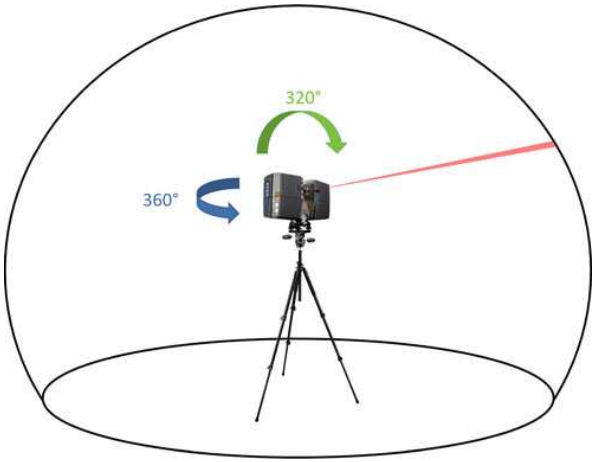
Time-of-flight (pulse-based)

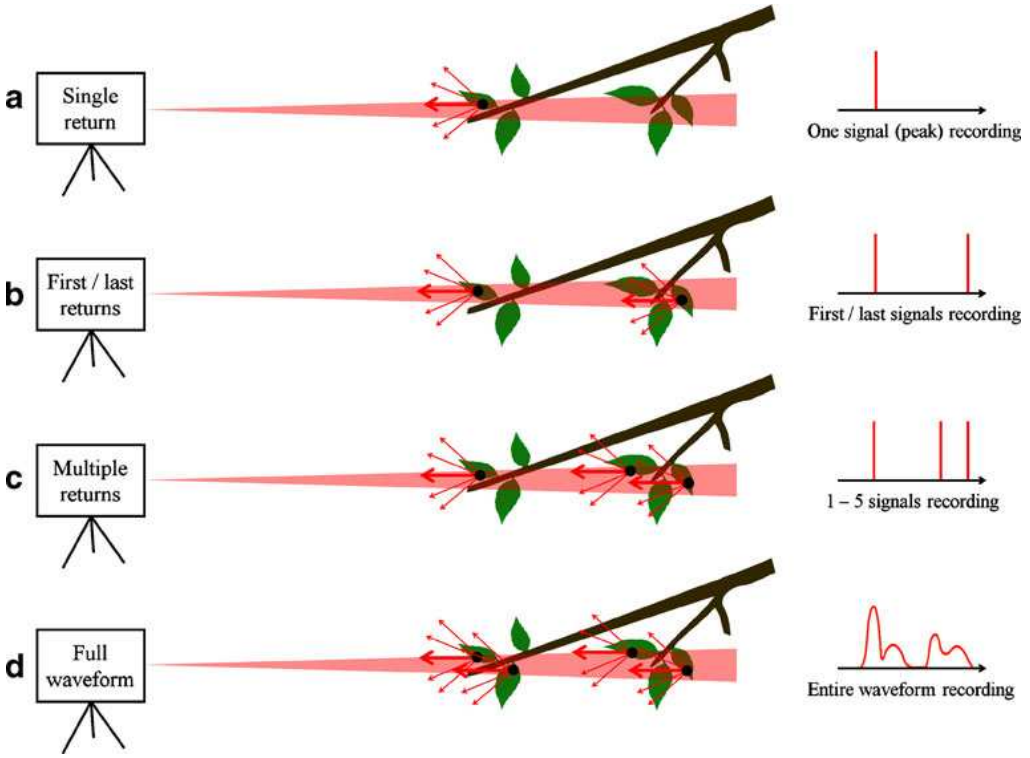
Source: Stefan Seifert

Phase-shift

Source: Zoller+Fröhlich GmbH

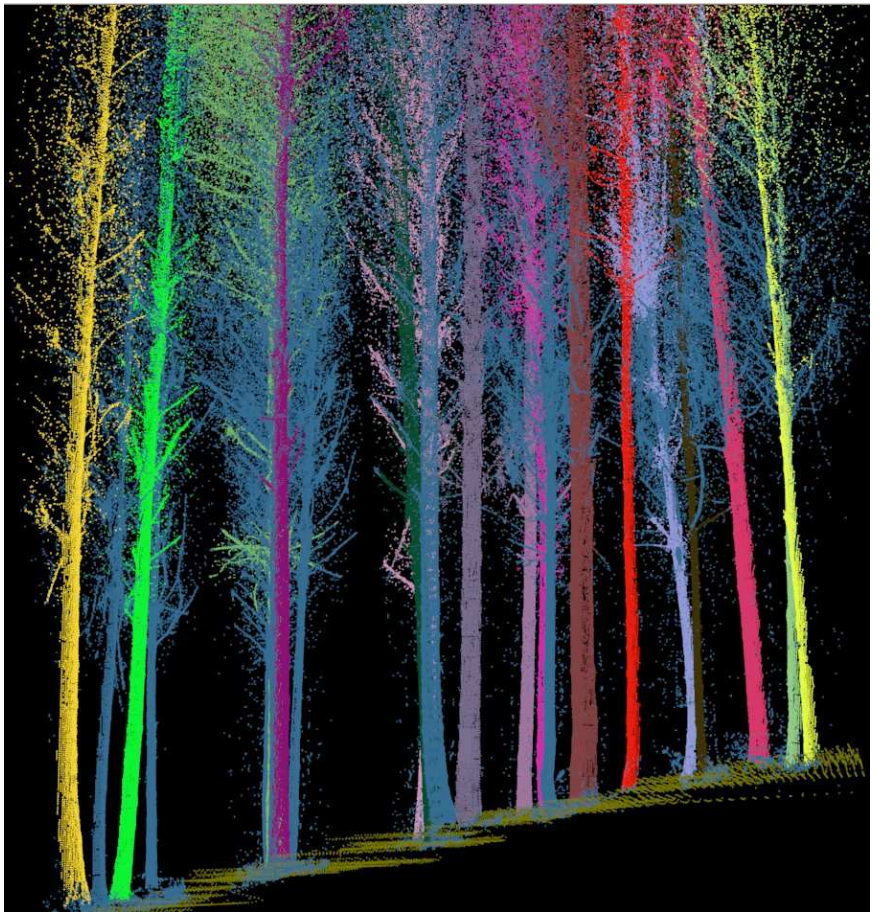
Terrestrial LiDAR Technology





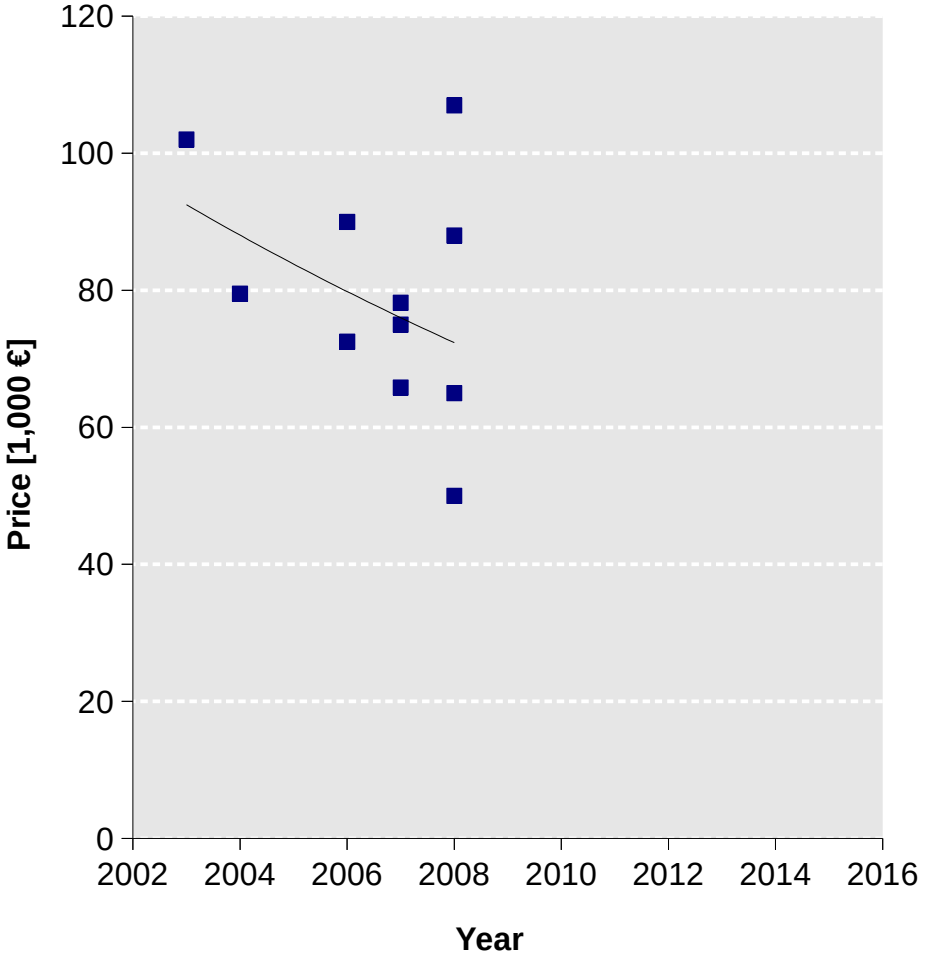
Source: Dassot et al. 2016

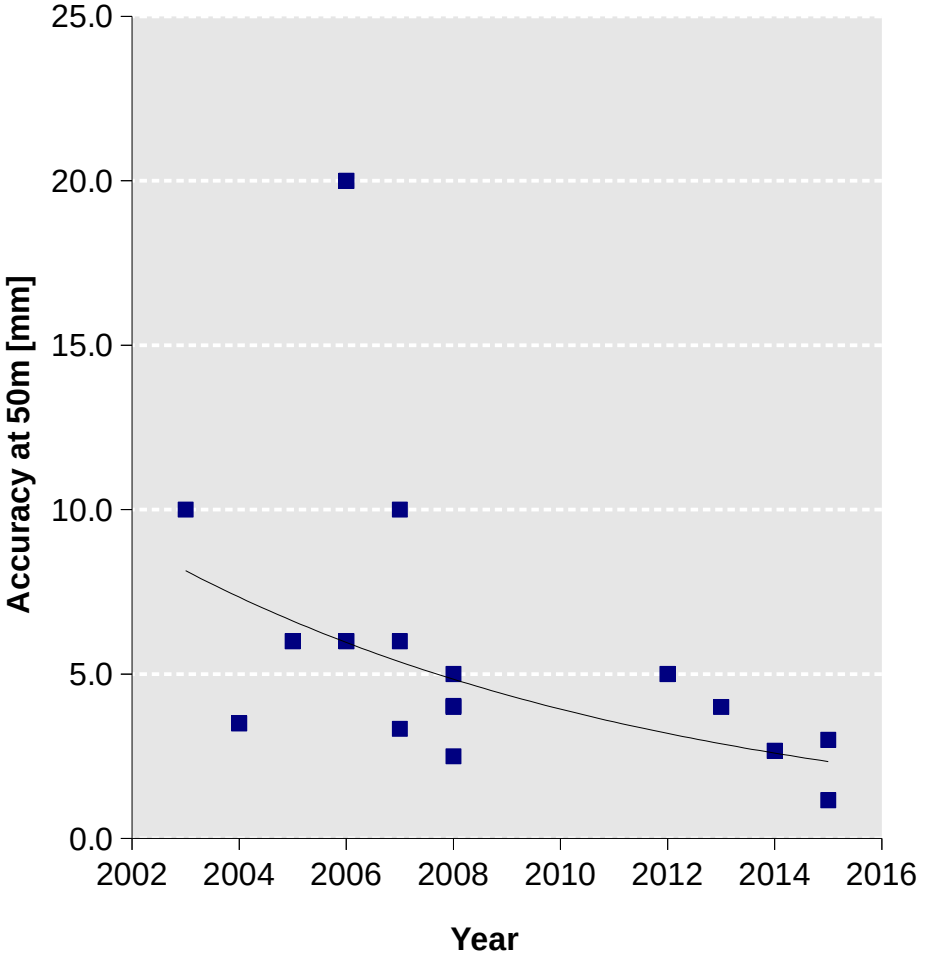
Terrestrial LiDAR Technology



Source: Anton Kunneke

Terrestrial LiDAR
Development of hardware





Terrestrial LiDAR
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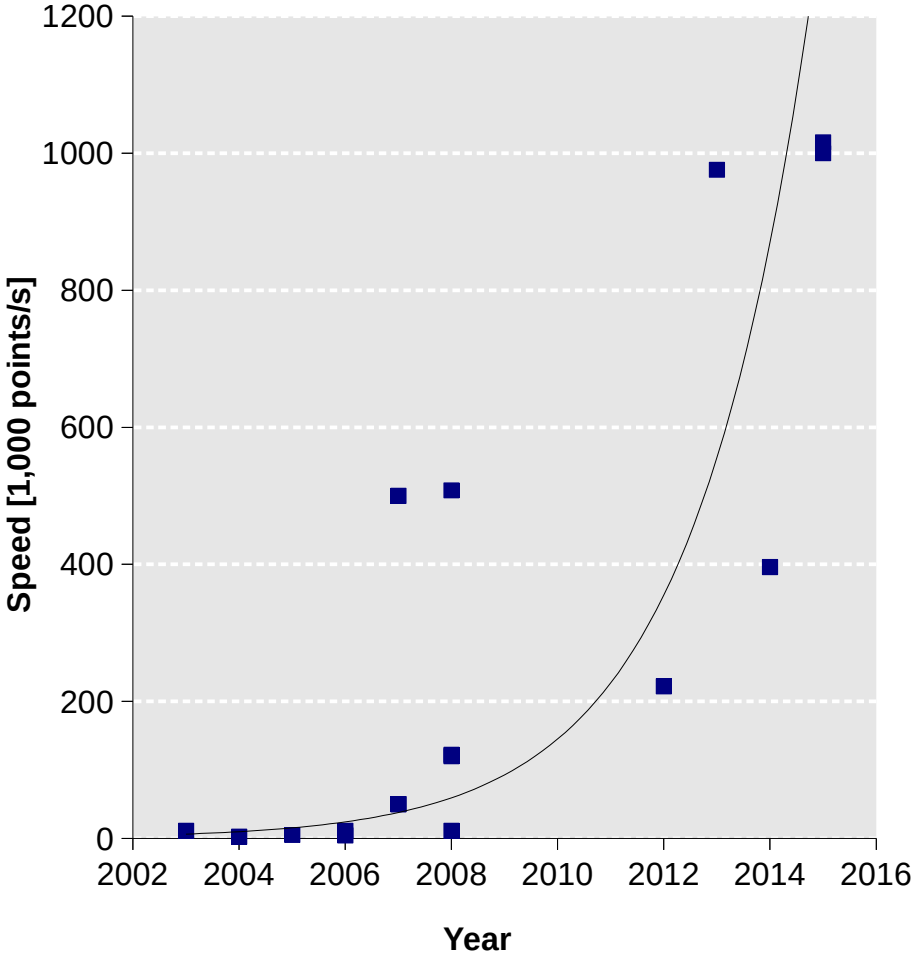
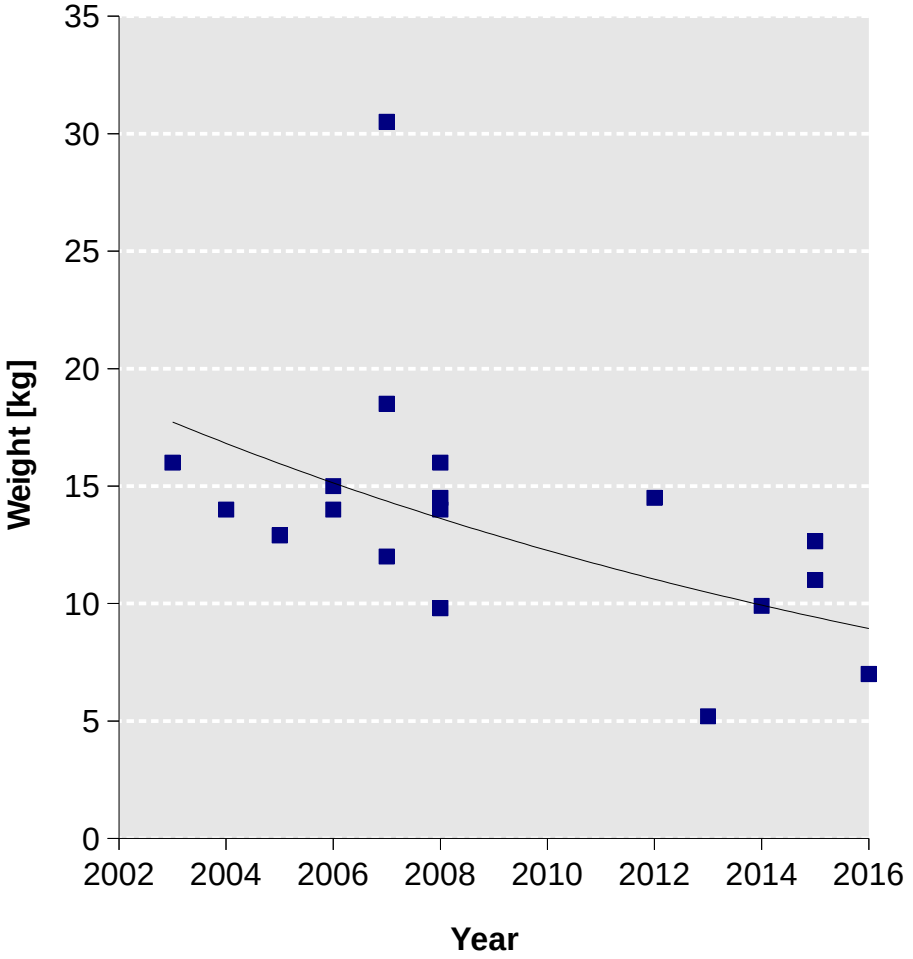




Drones
Technology

Fixed-wing

Source: senseFly SA

Source: QuestUAV

Multicopter

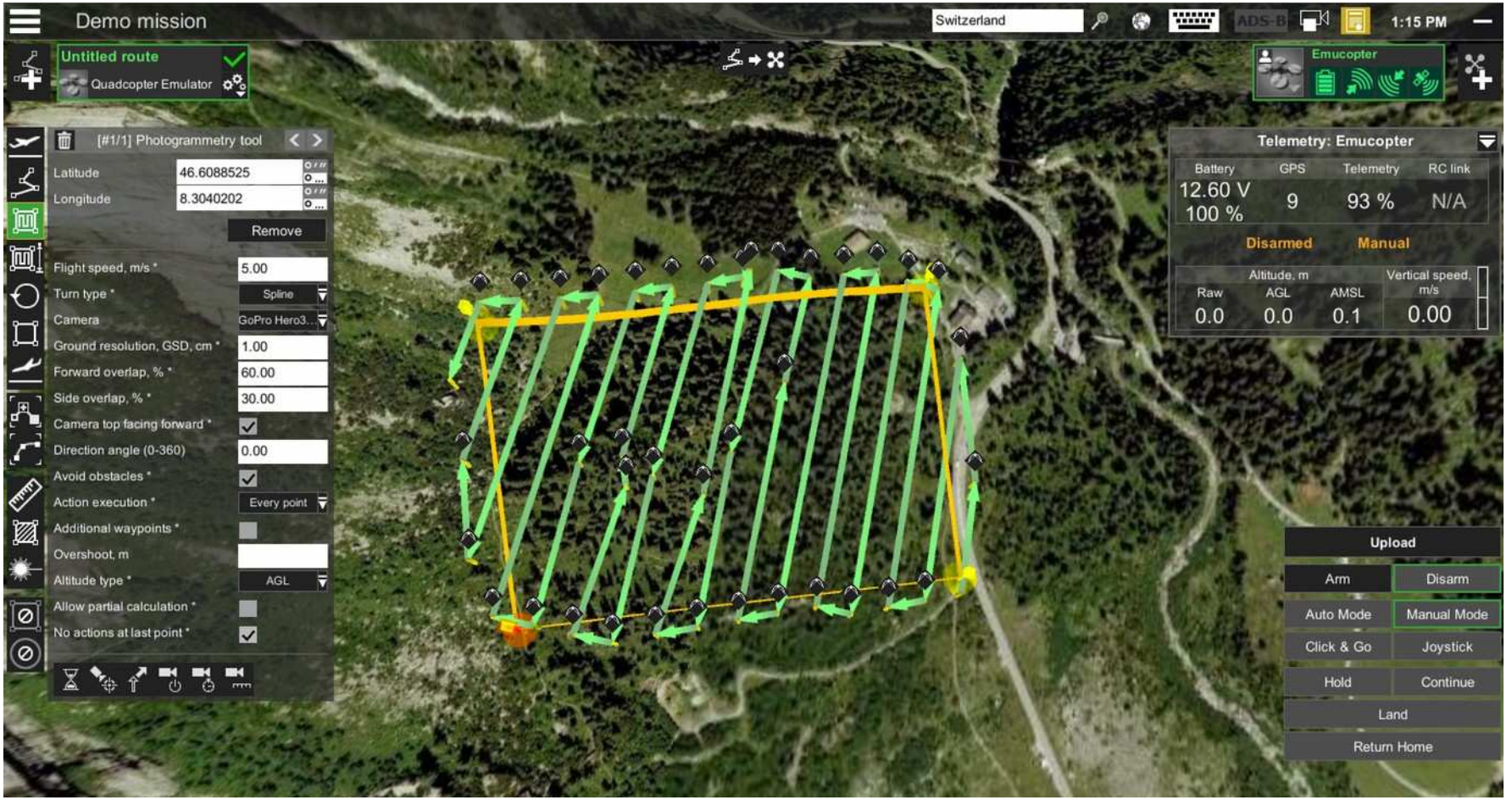
Source: DJI

Source: multikopter.cc

Drones
Technology

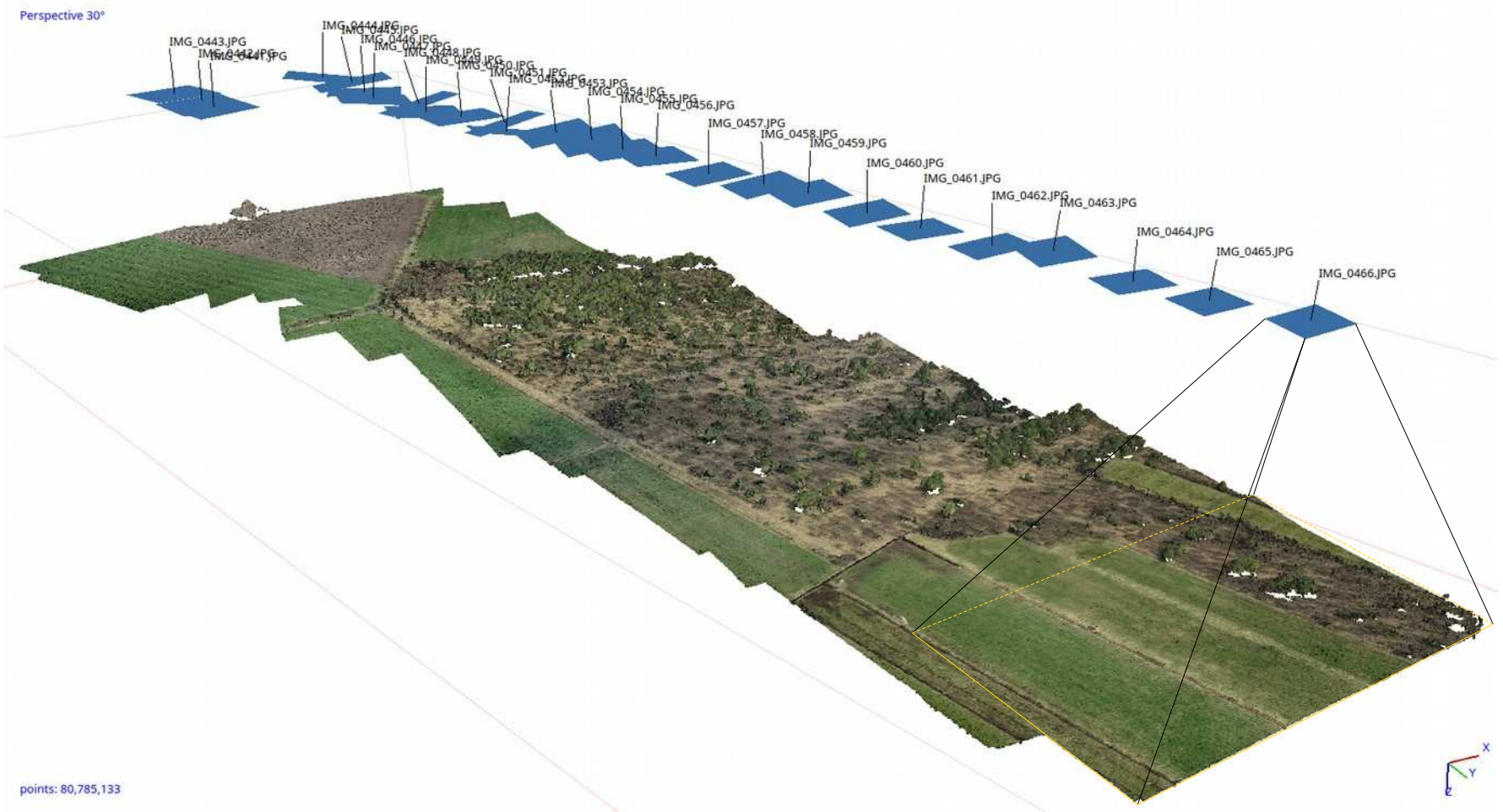
	Fixed-wing	**Multicopter**
Take-off and landing area	**Large** e.g. 20 m × 15 m	**Very small** vertical take-off/ landing
Cruise speed	**High** 40 – 90 km/h	**Low – Medium** 15 – 50 km/h
Maximum flight time	**High** 45 – 60 minutes	**Low** 15 – 20 minutes
Maximum coverage (single flight)	**High** ~ 12 km²	**Low** ~ 0.3 km²

Drones
Flight planning

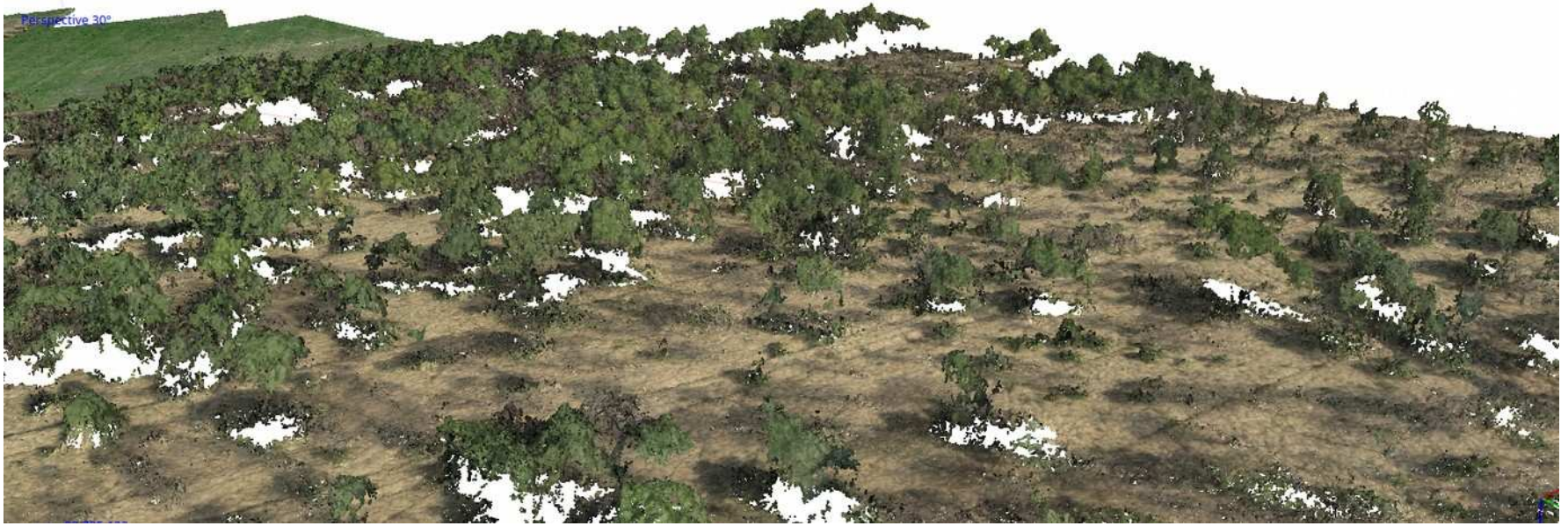


Source: SPH Engineering

Drones
Multiple View Geometry



Drones
Multiple View Geometry



Forest inventory
Traditional inventory

Measured values

DBH

Height

Number of trees

Species

Position

Secondary target variables

Taper and volume

Biomass

Log assortments

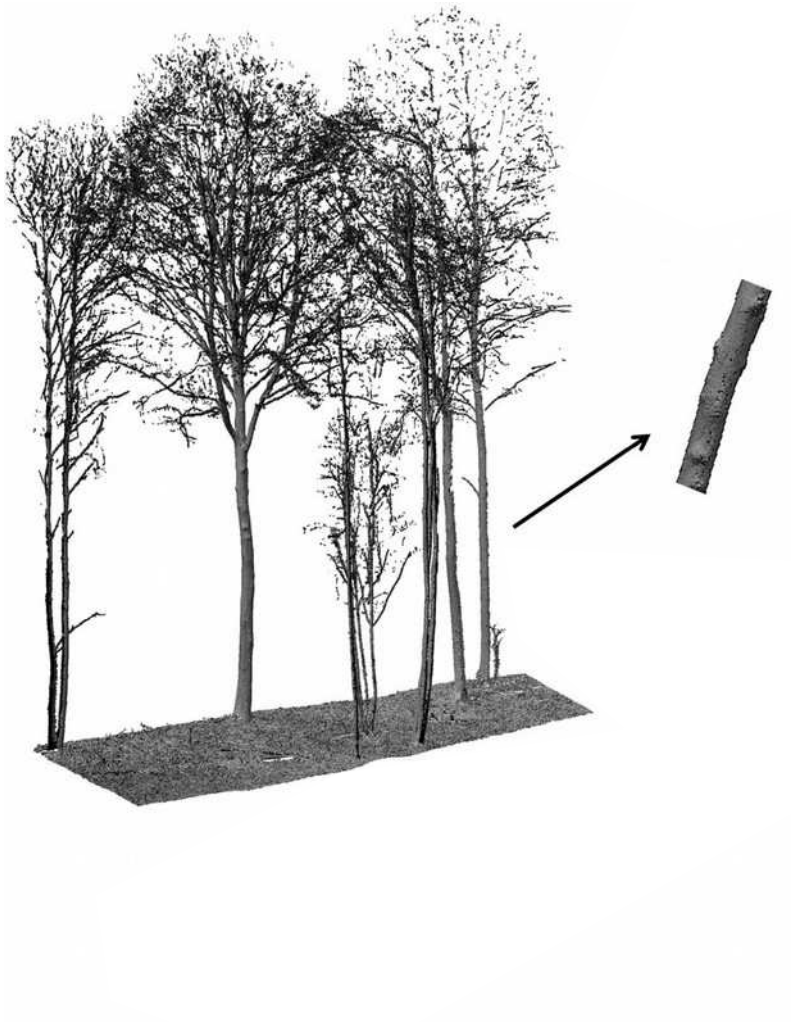
$$\underbrace{\qquad\qquad}$$

$$f\,(DBH,\ h)$$

Forest inventory
Additional information from Terrestrial LiDAR

Source: Dassot et al. 2016

Forest inventory
Additional information from Terrestrial LiDAR



Bark texture analysis

- Tree species recognition
- Detection of external wood defects

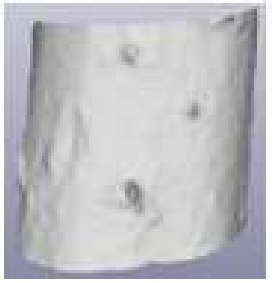
Source: Dassot et al. 2016

Forest inventory
Additional information from Terrestrial LiDAR

Bark texture analysis

hornbeam

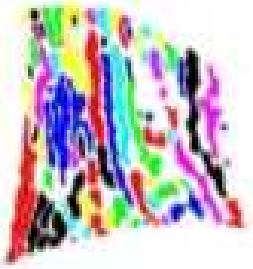
oak

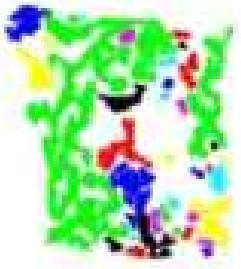


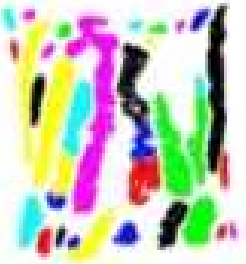
spruce

beech

pine

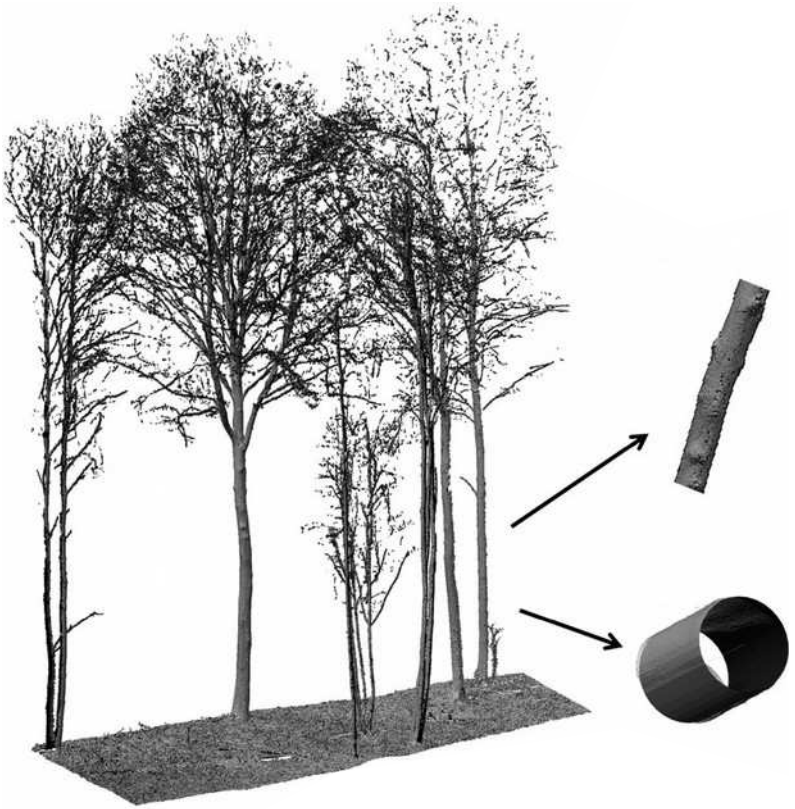






Source: Othmani et al. 2013

Forest inventory
Additional information from Terrestrial LiDAR



Bark texture analysis

- Tree species recognition
- Detection of external wood defects

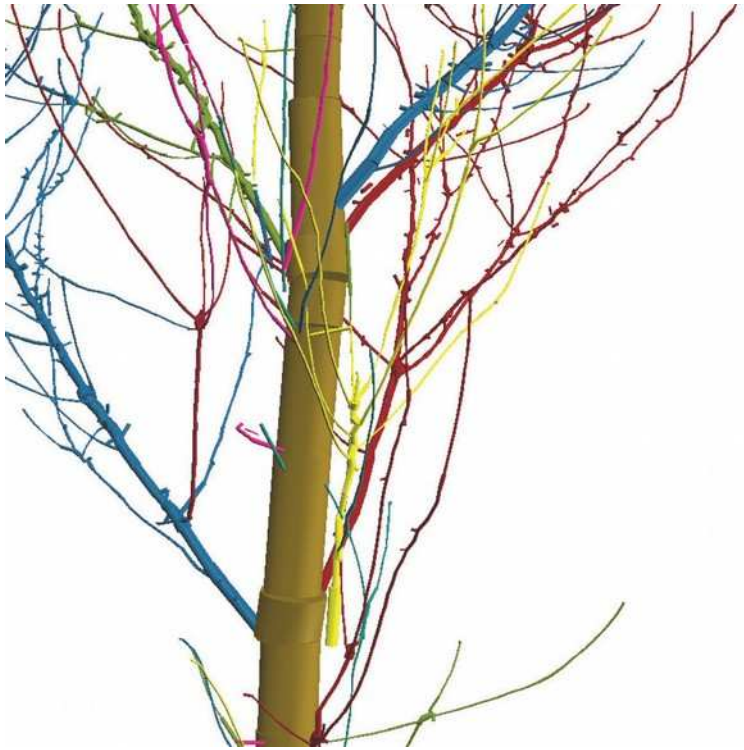
Geometrical fitting

- Diameters (DBH, stem and branch profiling)
- Wood volumes / Stand value
- Stem density / Basal area
- Tree height

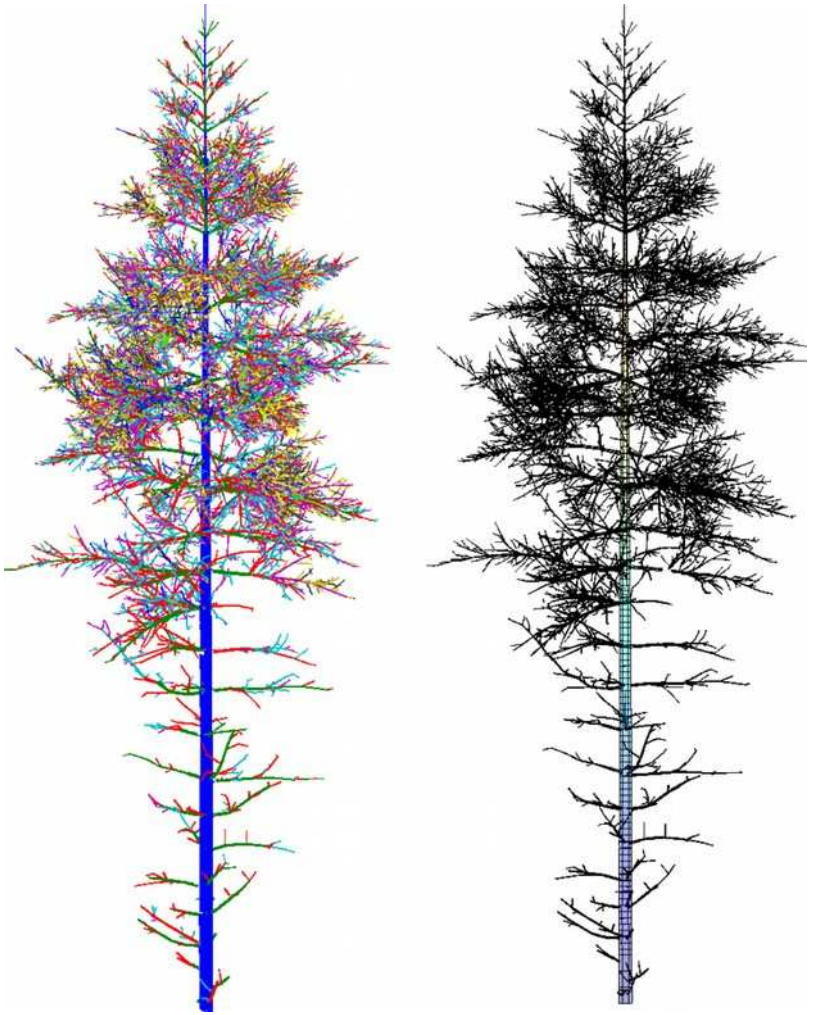
Source: Dassot et al. 2016

Forest inventory
Additional information from Terrestrial LiDAR

Geometrical fitting

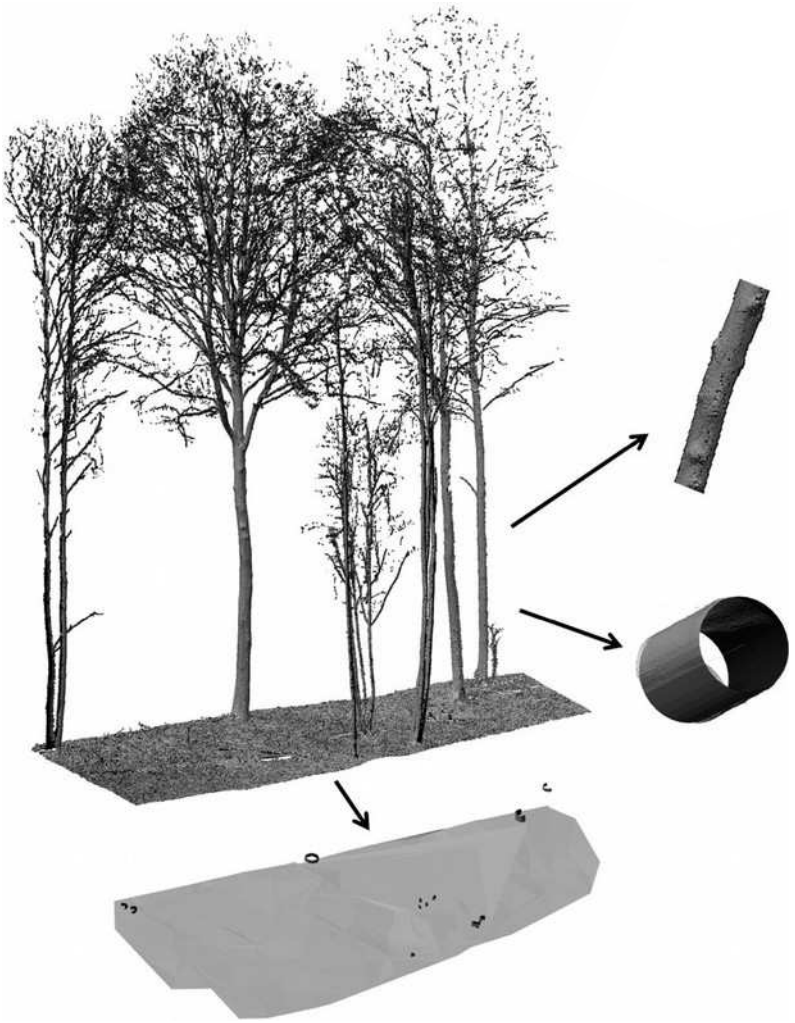


Source: Hackenberg et al. 2014



Source: Raumonen et al. 2011

Forest inventory
Additional information from Terrestrial LiDAR



Source: Dassot et al. 2016

Bark texture analysis

- Tree species recognition
- Detection of external wood defects

Geometrical fitting

- Diameters (DBH, stem and branch profiling)
- Wood volumes / Stand value
- Stem density / Basal area
- Tree height

Plot cartography

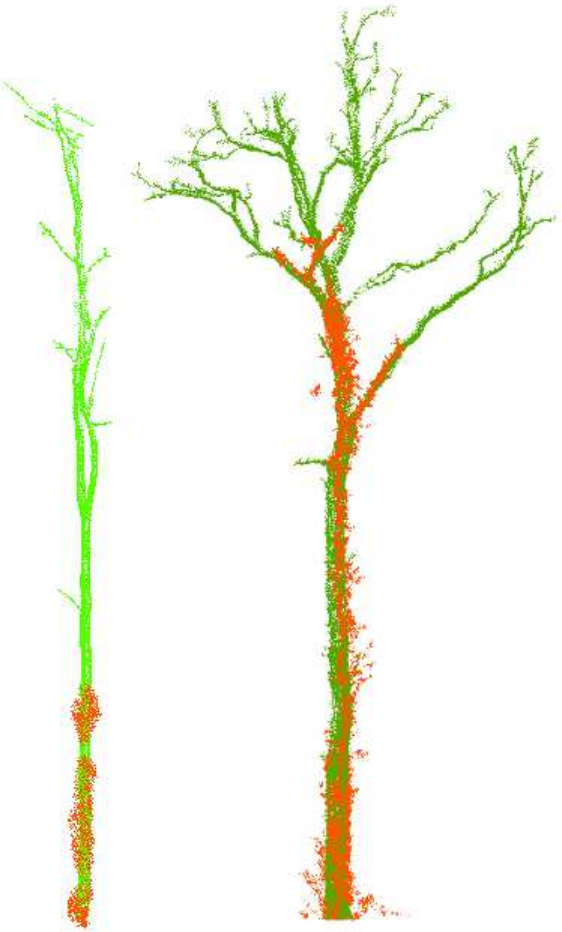
- Digital Terrain Model
- Stem detection and location

Forestry
Usage of drones

Individual trees / stems

Multicopter, 45° angle, MVG reconstruction,

Comparison with TLS



Source: Fritz et al. 2013

Forestry
Usage of drones

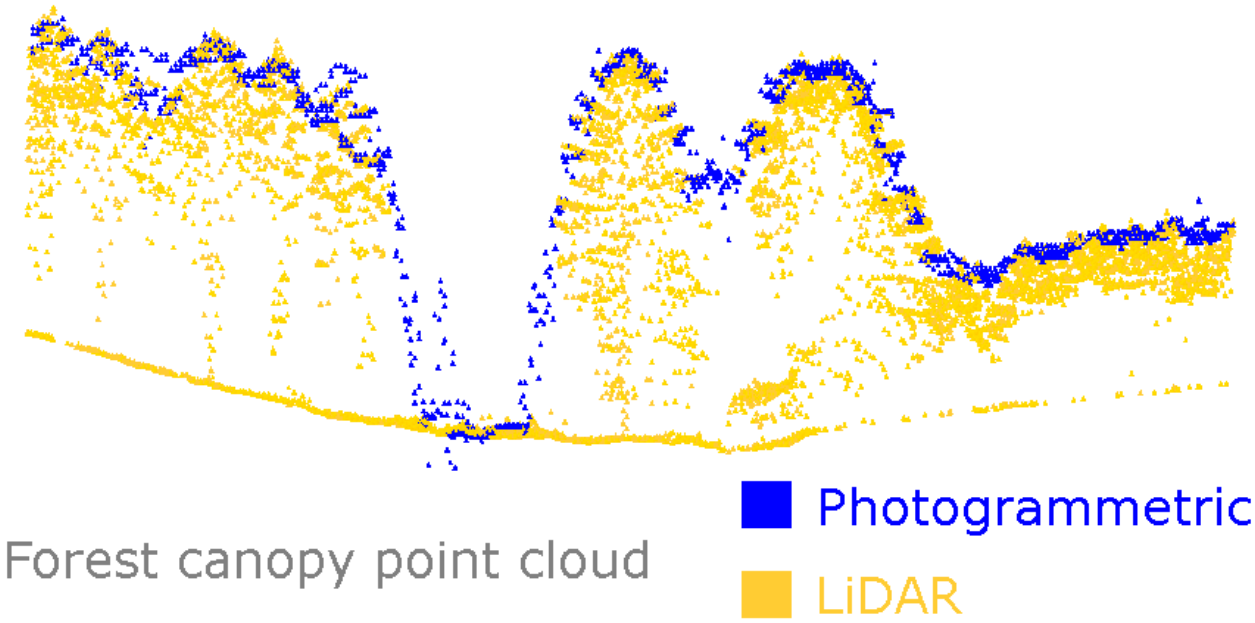
Tree height

Fixed-wing drone

Reconstruction with MVG

Comparison with TLS data

Source: Lisein et al. 2013

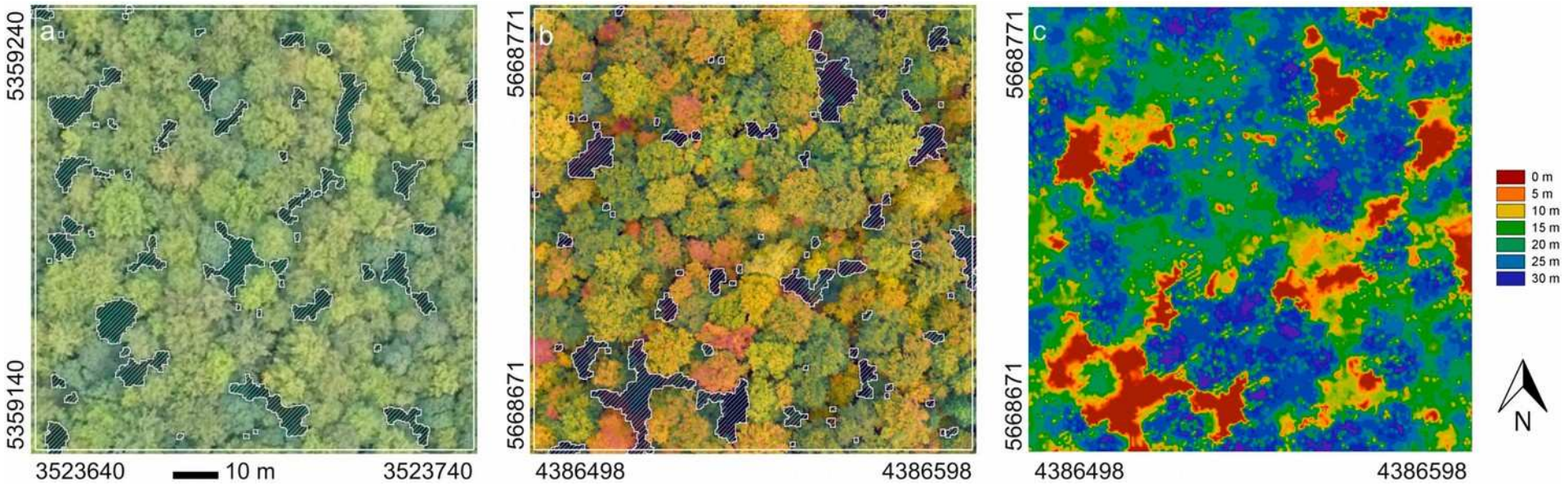


Forestry
Usage of drones

Spatial gaps in forests

Fixed-wing drone

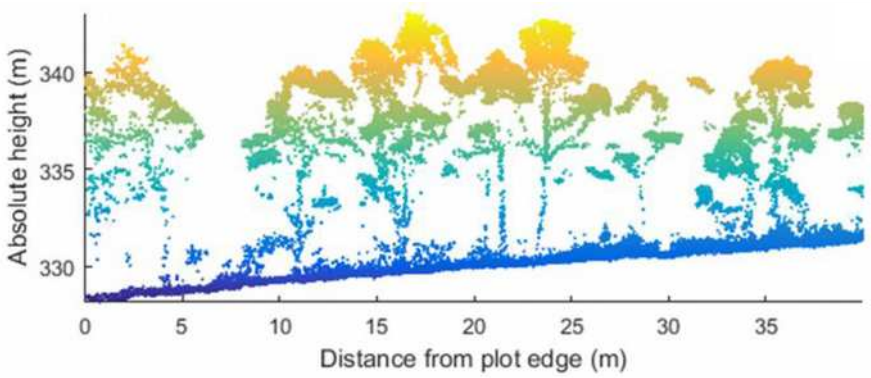
10 ha area



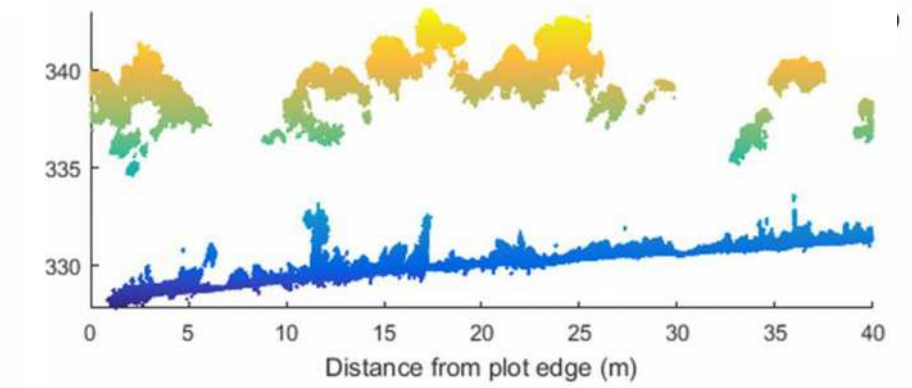
Source: Getzin et al. 2014

Drone point clouds
Airborne LiDAR vs. Digital Aerial Photogrammetry

Airborne LiDAR



Photogrammetric reconstruction



Source: Wallace et al. 2016

Conclusion

- **Terrestrial LiDAR** can provide detailed below-canopy information, but it requires intensive field work, so it cannot be applied to large areas
- **Drones** can provide improved above-canopy and forest structure information at a fraction of the cost of terrestrial LiDAR. However, it does not reach the same level of accuracy and detail.
- **Both technologies** have considerably matured in the past decade and have reached a technological level that warrants their use for forest inventory

Outlook

Source: Astec

Acknowledgements

Co-authors

Stefan Seifert
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Stellenbosch University

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Stellenbosch University

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