Comparison of Laser-based methods to measure stem diameter

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Objective

This study concentrates on the accuracy of measuring stem diameters by different means. Stem diameters were measured by:

- TLS
- Laser-camera
- Laser-relascope
- Steel calipers

The aim of this study was to test the new measuring devices in typical forest conditions. The precision and bias of diameter measurements were studied.

INTRODUCTION

- The most important variable in forest management planning at a single tree level is stem diameter at breast height (dbh).
  - Single tree's dbh cannot be measured directly by remote sensing methods.
- There is a need to develop improved field techniques to measure:
  - stem diameters and stem volume cost-effectively and reliably.
  - other exploitable stand or tree characteristics, where there exist no effective traditional means to measure.

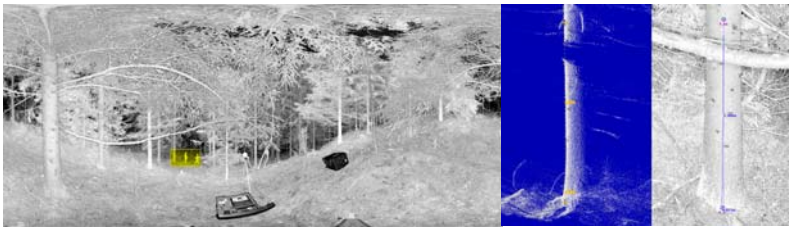
Material and methods

Study area

- Nuuksio and Saunalahti, Espoo, Finland
- 122 trees from 6 sample plots
- The stand development classes were advanced thinning stands or mature stands.
- Varying site conditions

Measurement methods and equipment

- Reference measurements with steel calipers
- **Terrestrial Laser Scanner**
  - Faro 880HE80
  - One scan per sample plot was used for manual dbh measurements
  - Faro Scene software was used for all measurements



Picture 1. TLS measurements.

- **Laser-camera**
  - A Laser-camera consists of a Canon EOS 400D digital reflex camera with an integrated Mitsubishi ML101J27 laser line generator
  - The measurement of the tree diameter is performed by using the length and relative position of the laser line on the image.
  - Image interpretation was performed with specifically designed computer software in a data processing unit.
  - The diameters could be measured automatically or semi-automatically

Picture 2. Laser-camera measurements

- **Laser-relascope**
  - The Laser-relascope is functionally a combination of a relascope and a dendrometer. It uses distance and angle information to determine the diameter of a tree.
  - In addition to a laser rangefinder, it also includes an electronic compass for determining the position of the tree (bearing and distance from the centre of a sample plot), and an electronic inclinometer is included for height measurements.

Picture 3. Laser-relascope

Results

Table 1. Accuracies of diameter measurements (mm), bias and standard error proportioned to the mean diameter in parenthesis.

Method	n	bias	S_E	S_E*	S_E**
TLS	82	0.52 (0.28)	8.31 (4.46)	7.86 (4.21)	4.64 (2.49)
Laser-camera	120	0.58 (0.34)	8.51 (4.94)	8.09 (4.69)	5.02 (2.91)
Laser-relascope	119	9.06 (5.24)	17.49 (10.11)	17.28 (9.99)	16.07 (9.29)

*SE without steel calipers SE as reported in Hyppönen and Roiko-Jokela 1978 (2.7 mm).
**SE without steel calipers SE as reported in Päivinen et al. 1992 (6.9 mm).

Table 2. The Accuracy of diameter measurements (mm) by tree species, bias and standard error proportioned to the mean diameter in parenthesis.

Method	n	bias	S_E
TLS			
Pine	16	0.11 (0.05)	6.14 (2.88)
Spruce	35	3.07 (2.08)	7.64 (5.18)
Birch	21	0.20 (0.09)	9.78 (4.53)
Other deciduous	10	-7.08 (-3.21)	11.23 (5.09)
Laser-camera			
Pine	26	0.96 (0.49)	8.26 (4.25)
Spruce	51	0.94 (0.68)	8.16 (5.92)
Birch	25	-0.44 (-0.20)	10.45 (4.64)
Other deciduous	18	0.44 (0.27)	7.72 (4.62)
Laser-relascope			
Pine	26	10.81 (5.44)	16.36 (8.24)
Spruce	47	8.53 (6.47)	16.37 (12.42)
Birch	25	8.44 (3.75)	20.56 (9.14)
Other deciduous	21	8.81 (5.13)	18.60 (10.83)

Conclusions

- The TLS and Laser-camera were determined to be accurate methods of measuring dbh.
- These methods also enable the measurement of other characteristics, such as diameters at multiple heights, which can improve volume or tree quality estimates.

- TLS
  - It was impossible to get an observation from every tree, because there was only one scan per plot. That problem should be fixed with more scannings before accurate plot level estimates could be calculated.
  - Gives totally new possibilities for the measurement of forest stands. TLS can provide a wide range of objective measurements of different stand characteristics.

- Laser-camera and Laser-relascope
  - The Laser-camera's principle for diameter measurement has been significantly improved from its previous prototype, the Laser-relascope.
  - The Laser-camera is easy to use, the price would be reasonable, and the diameter measurements are accurate.

- In general, there is a need for devices that make forest field inventory easier. New laser-based methods are promising for this. Still, further studies are needed in order to develop these methods to be able to displace traditional methods in practical work.

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