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ASSESSMENT OF GRADES AND QUALITY OF WOOD IN FOREST STANDS VIA LASER SCANNING

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Abstract: *The wood supply chain aims at providing the customer at the right time and at the right place with the demanded quantity of wood of a defined tree species. Quality and grade of the allocated wood is of particular importance hereby. The more this is adapted to the specific industrial requirements the higher is the recovery for the customer and thus lower the absolute quantity needed. In total the right estimation of wood quality as early as possible in the supply chain thus contributes to its resource and energy efficiency.*
With laser technology it is possible to analyze also the vertical structure of trees and stands. In a first instance the most probable diameter of a tree can be determined through crown size and height of a tree. For that purpose there exist numerous regression equations from forest growth models. Crown length, shape and dimension allow for interferences regarding the length of the branches and thus their diameter at the base and their height on the trunk. Branch diameters from 4cm upwards cause quality degradation of the round wood. All together this results in all the data necessary for the sorting: diameter at breast height, total tree height, and length of the knotless bole.
This method is under development and will further be enhanced by the use of terrestrial laser scanning. Research on this is part of the joint project 'FlexWood' funded within the European Union's Seventh Framework Programme. FlexWood aims at the design and implementation of a novel logistic system based on more accurate stand information allowing for an adequate use of harvesting systems in order to optimally supply industrial demand according to the specific requirements.

1. Introduction

The wood supply chain aims at providing the consumer at the right place and at the right time with a certain quantity *of a defined quality* of wood of one tree species. For the assessment of quantity and assortments there exist numerous long-standing inventory methods within a certain range of error (Smaltschinski, 2000). When it comes to quality, objective methods are scarce. Laser technolohy would provide a technical solution to support quality assessment of sorting trees within a stand. Amongst other partners, the Institute of Forest Utilization and Work Science (FOBAWI) and the Department of Remote Sensing and Landscape Information Systems (FeLis) of the University of Freiburg are working together on this issue in the European project FlexWood just launched.

What is the problem? Wood quality is determined by external and internal characteristics. Exterior features are the stem form, size and number of live and dead branches, the knot-free length of the stem or visibly noticeable injuries. Internal properties apply to the annual ring width, early and late wood, reaction timber, and internal defects such as fungi or insects.

Here, at first the external quality features are important, regarding how they can be judged via airborne and terrestrial laser scanning. In addition, already existing recordings of terrestrial inventories and of forest management were integrated in this research in order to not preclude the possibilities for improved multiphase sample inventories (de Vries, 1986). All recordings are in the same projection (Gauss-Krüger strip 3), to allow for simultaneous editing.

2. Material

The study area is located in the SW of Germany north of the city of Karlsruhe. Within the forest data of the actual inventory was available. In the test area Karlsruhe the accurate positions of the forest inventory plots of the forest inventory in Baden-Württemberg (Kändler U. BÖSCH, 2002) were calibrated by the Department of Remote Sensing and Landscape Information Systems, University of Freiburg, allowing the georeferenced LIDAR data to correspond with terrestrial measurements. The points of forest inventory form within the forest a regular grid of mesh size 100 x 200 m (Fig. 1).

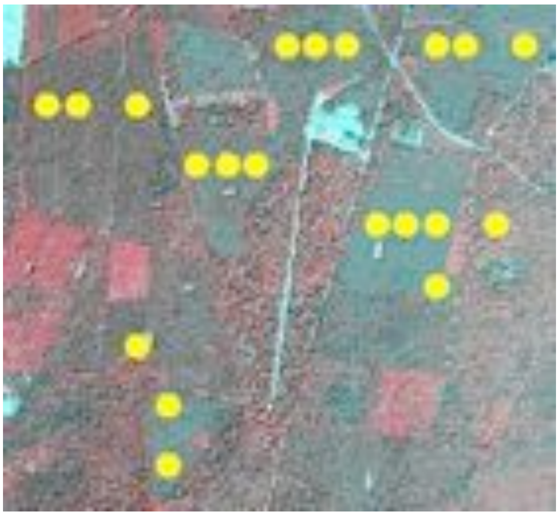


Fig. 1 Research area and plots of the forest inventory (yellow)

In addition to the tree data of the operating inventory, which only takes into account a proportion of all the trees in the sample plots circles, all trees were recorded including coordinates (Fig. 2).

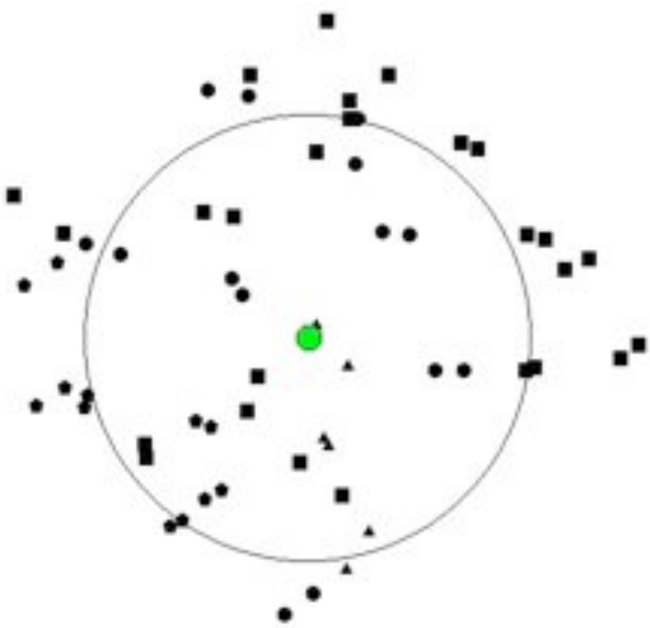


Fig. 2: Sample plot of the forest inventory with a radius by 12 m and the coordinates of the plot trees resp. additional measured trees outside the circle. Rectangle fagus sylvatica, circle

quercus robur, triangle carpinus betulus, pentagram prunus avium.

The company TopoSys GmbH conducted a flight mission in summer 2007 using the Harrier 56 system. It consists of a full-waveform laser system of the company Riegl (Riegl LMS-Q560) and a Rollei AIC camera. The Falcon II system has a laser recording just the first and the last pulse. The used line scanner records the following four channels: B-G-R-NIR (Fig. 3).

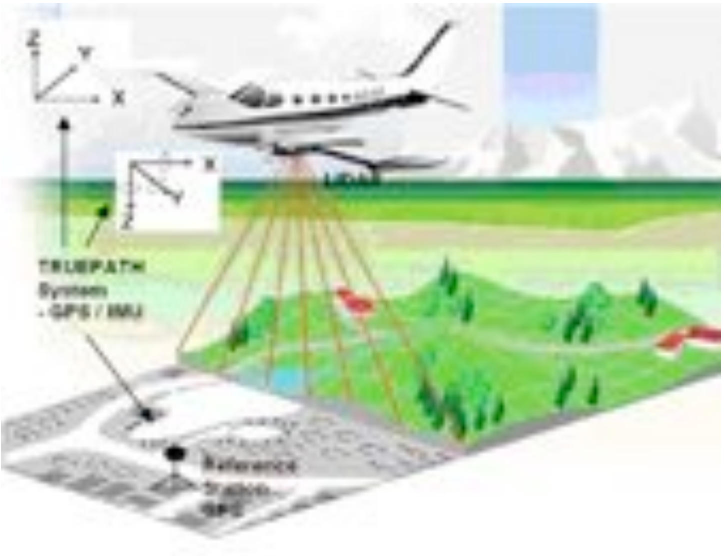


Fig. 3: Airborne Laserscanning

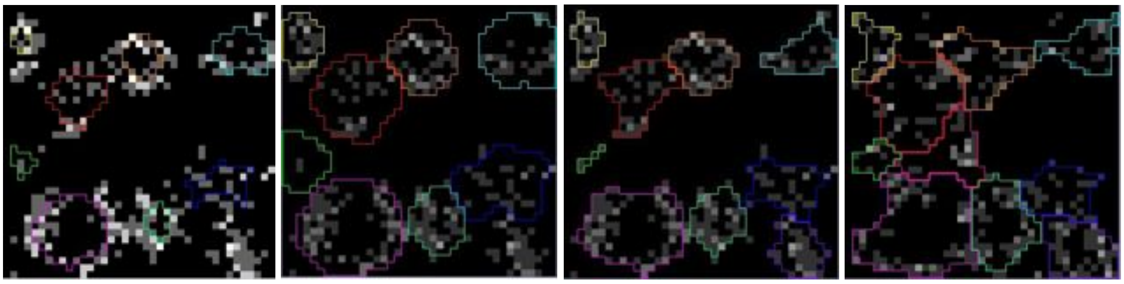
Furthermore, an additional terrestrial record with the laser scanner CX 3D, (Fig. 4) by Trimble has been performed. The scanner records a hemisphere, so that, beside external quality characteristics on the trunk, the heights of the trees on the plot could be estimated or measured. Per direction 50,000 data points are measured. The angle of progress of the directions can be defined according to the object of focus.

Fig. 4 Trimble terrestrial laser scanner CX 3D

3. Evaluations

3.1 Evaluation Aerial Laserscanning (FELIS)

A vertical structure analysis was used for 3D modeling of the crown (Wang et al, 2005, 2008, Koch et al., 2004). This is based on a laser point cloud and a previously computed digital elevation model. The raw data points of the laser scanner can be normalized with the digital terrain model. They can then be assigned a voxel space. The number of normalized raw data points that fall within a particular voxel is the value of the voxel. The voxel space is divided into a series of 2D layers to reduce the complexity of the calculations.
The actual algorithm for the formation of the crown margins is based on the evaluation of each horizontal



(a) **(b)** **(c)** **(d)**

*Fig.5: H*ierarchical morphological based crown outline extraction *at several height levels. (a) 39m, (b) 38m, (c) 36m and (d) 35m.*

projection image. The basic principle of the algorithm is the monitoring of crown margins in the projection images from top to bottom (Wang et al. 2007, Weinacker et al. 2004). A hierarchical morphological opening and closing process with a set of predefined structural elements is carried out here (see Fig 5).
The crown contours from higher levels already evaluated are expanded according to their "cluster properties" in the current projection layer until they coalesce with neighboring regions. The "root node" of a tree is the region which is in the highest layer. A "pre-order" tree traversing process is carried out in order to "visit" all the regions that exist in the layers. Because the voxels have a certain height, 3D prisms can be reconstructed for each of the 2D crown regions in the different crown heights. The combination of these 3D prisms enables the generation of a prismatic 3D tree crown models for each tree (see Fig 6)

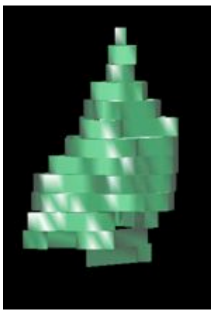


Fig 6: prismatic 3D tree structure model

3.2 Determination of crown surface and quality (FOBAWI)

The Institute of Forest Utilization and Work Science focuses on the applicability of the results presented so far for assessing the quality of standing trees. For a customized supply of wood to the enterprises of the

timber industry information about the wood quality is a priority in addition to species, quantity and variety, Here to date inventory results are very limited. Building on the results of FELIS opens the possibility to assess by remote sensing the quality of wood in the crown area.
For the sample plots of the single grid points FELIS made available the voxels of the tree crowns, more precisely of the shells of the tree crowns (Fig. 7).

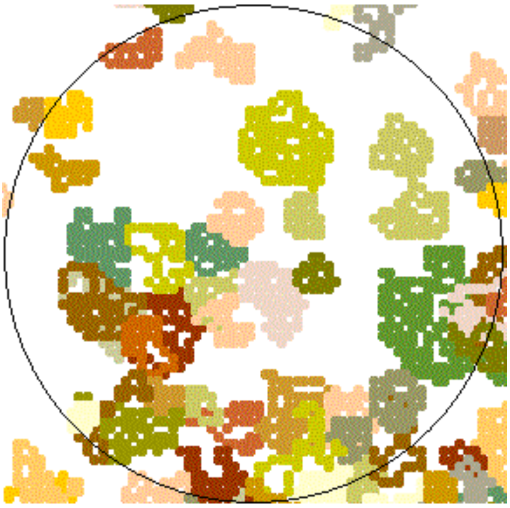


Fig. 7: horizontal projection of 3D points (voxels) of a sample of the operating inventory. Individual trees have different colors(FOBAWI).

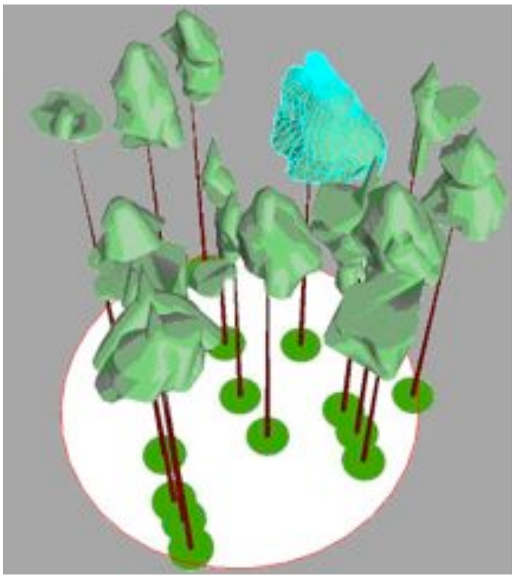


Fig. 8: Crown shapes derived from voxels of an inventory sample(FOBAWI).

The voxels of the crown shell can then be separated again into the individual height levels and the outer contour line can thus be determined. For that purpose the centers of the voxels were surrounded by a 25 cm buffer strip. The individual polygon rings of the crown were then meshed with each other, so that a closed space was created representing the crown surface (Fig. 8)
Each tree of this sample plot can be analyzed individually. It is presented here the example of the turquoise selected tree. From the crown dimensions the following values for the quality assessment and volume calculation can be derived (Fig. 9)

- The crown base height (~ length of knot-free trunk)
- crown length
- crown width per height level
- branch length > 4 m (a branch > 4 m has a diameter at the branch base of > 4 cm)

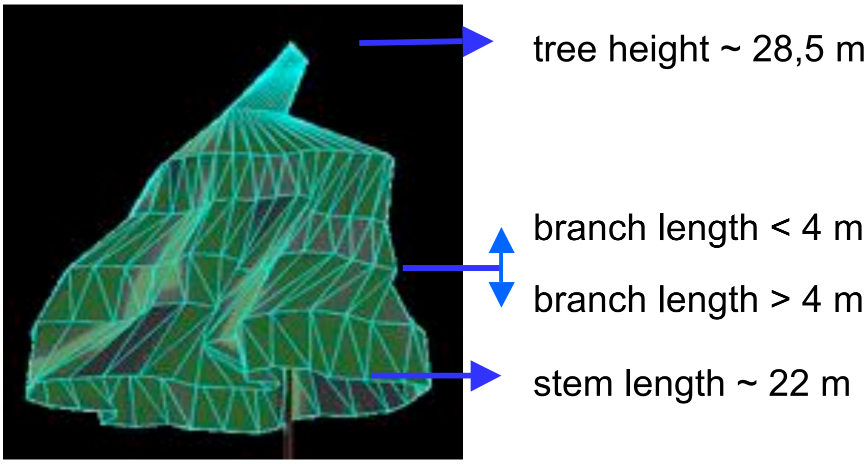


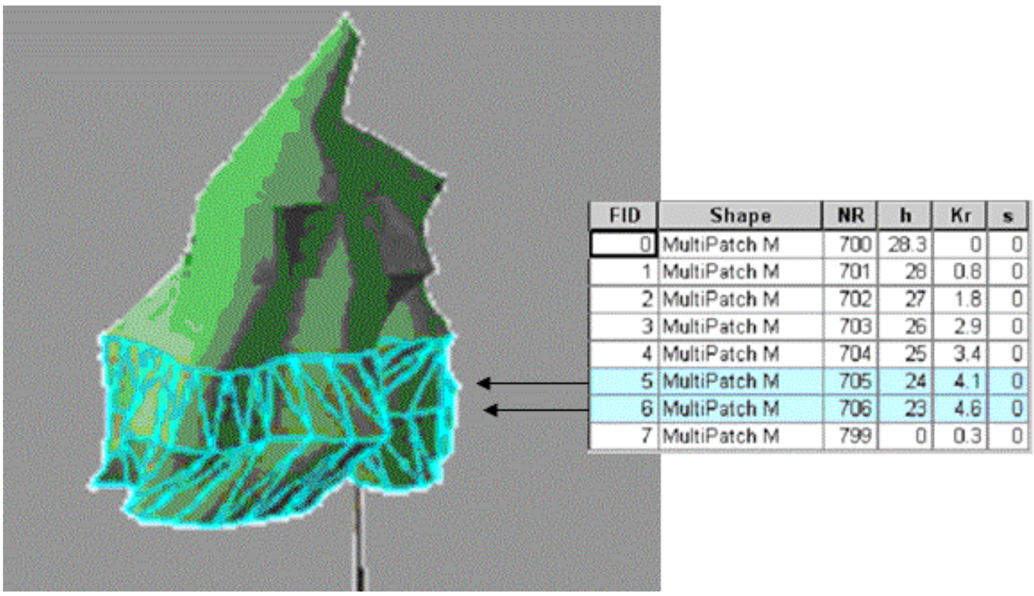
Fig. 9: values derived from the crown shape. Crown length = tree height – stem length

Based on the following two formulas (Nagel, 1997), at first the diameter of the trees can be determined from these data:

$$(1)\ CrownDiam = (a_0 + a_1 d)(1 - \exp(-(\frac{d}{a_2})^{a_3})$$

$$(2)\ CrownLength = h\exp(-abs(a_1 + a_2\frac{h}{d} + a_3 d + a_4\ln(h100))$$

The equations have been determined by ground measurements of vertical alignments of crowns. The crown diameter, crown length and tree height can be derived according to Fig 11.
These values are to be used in both formulas, with an iteratively determinable upper and lower value for the tree diameter. Fig. 10 shows again the selected tree.



FID	Shape	NR	h	Kr	s
0	MultiPatch M	700	28.3	0	0
1	MultiPatch M	701	28	0.8	0
2	MultiPatch M	702	27	1.8	0
3	MultiPatch M	703	26	2.9	0
4	MultiPatch M	704	25	3.4	0
5	MultiPatch M	705	24	4.1	0
6	MultiPatch M	706	23	4.6	0
7	MultiPatch M	799	0	0.3	0

Fig 10: Geometry and attributes of the spatial data set tree crown. The selection of the attribute crown radius (Kr) > 4 leads to the height levels of 23 and 24 m. Here branches with diameters> 4 cm can be expected.

The tree itself is a 3D-Shapefile, which was calculated in ArgGis 9 as a spatial data set. This generally consists of the geometries themselves linked with the attribute data describing these geometries. Any selection of the geometries generates a parallel selection in the object data and vice versa. Regarding conifers it can generally be assumed that a branch with a length of 4 m is about 4 cm at the base of the branch. In Fig. 11 these relationships are illustrated by the example of the selected tree. In the attribute table, all crown radii larger than 4 m were selected, which then appear in the selected geometries.

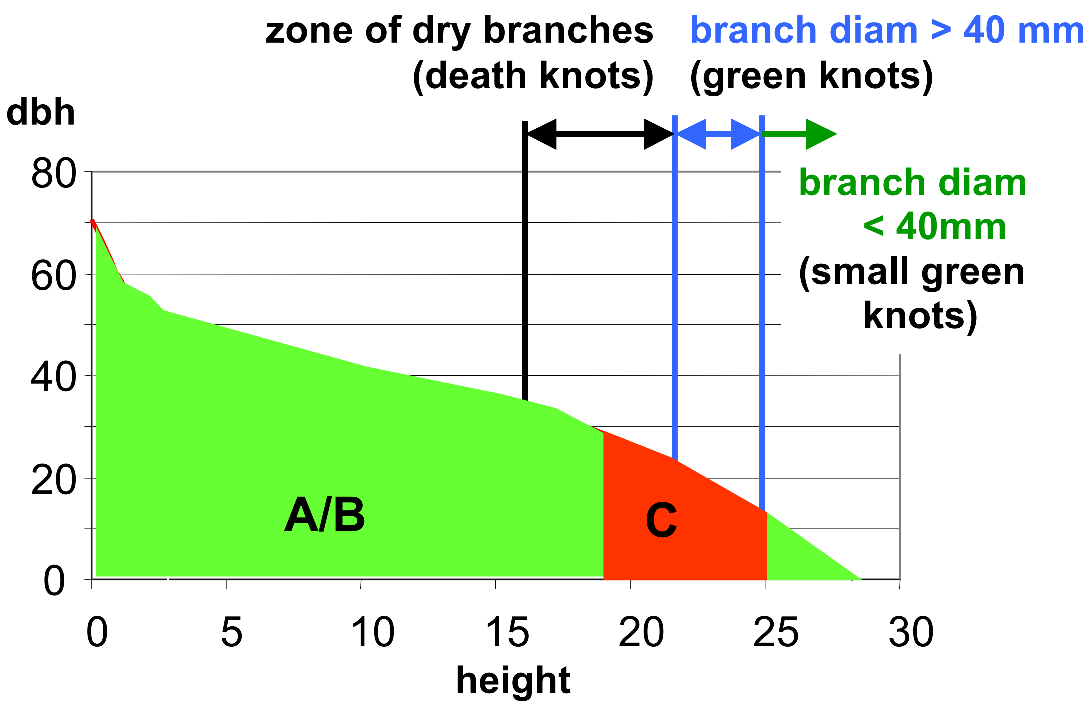


Fig. 11: Taper curve of a tree with the quality levels A (very good), B (good) and C (bad)

Branch diameter of 4 cm at the base result in the sorting of low grade (C). Based on these data sorting can now be made from the air. Important input data are the length of the stem free of knots (~ height of the crown base), the length of the stem with quality C, the total tree height and the diameter at breast height (1.3m).

To get the length of the knot-free stem in the case of larger crowns, a deduction has to be applied accounting for dead branches below the crown base. With these data, sorting with quality determination is possible with the use of the software Holzernte (Hradetzky u. Schöpfer, 2001) of the Baden-Württemberg Forest Research Institute. The sorting itself is shown in Fig. 11.

3.3 Terrestrial Laser Scanning

Airborne laser scanning can only be used for the determination of the tree quality within the canopy by the approaches described. Terrestrial shots are needed for the determination of stem shapes, stem lengths or other external features. Here attempts are shown how terrestrial laser scanning can be used for the determination of the length of the utilizable log or to get a detailed presentation of the stem. (Fig. 12, right). Besides the trunk length other measurements like the diameter at breast height or at other heights and – given good visibility – also the tree height are possible. The recordings have been shot and made available by the company Trimble using their CX 3D laser scanner.

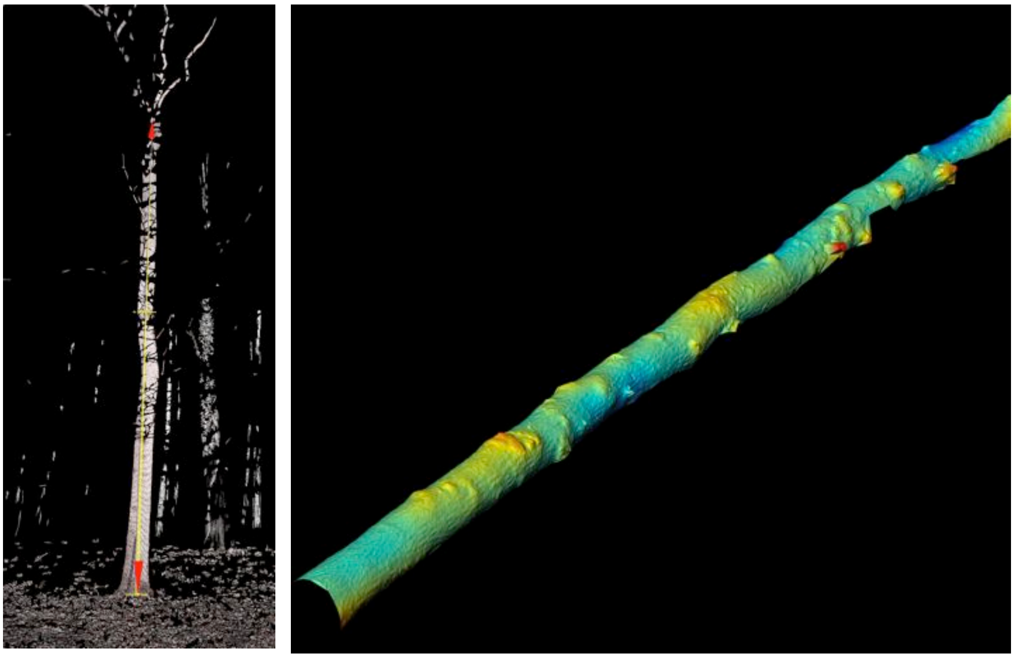


Fig.12: Terrestrial laser scanning images. Left: measurement of trunk length. Right: analysis capabilities of the trunk surface with overgrown branches and other characteristics.

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