Structural Tree Modelling of Aboveground and Belowground Poplar Tree using Direct and Indirect Measurements: Terrestrial Laser Scanning, WGROGRA, AMAPmod and JRC-3D Reconstructor ®.

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Introduction

The IES-Action GHG-AFOLU aimed to quantifying the effect of land use changes on the overall cycles of greenhouse gases. A major uncertainty for budget estimates is related to the amount of biomass accumulated in above and belowground parts of the forests. In order to made a reliable estimate of these factors it is necessary an enormous amount of manual labour for forest inventories and destructive measurements.

In this context, laser scanning seem to be promising and fast method for forest inventories (Holopainen and Kalliovirta, 2006). According to Thies and Spiecker (2004), terrestrial laser scanning system is not yet ready for practical forestry use. Even though, the advances in terrestrial laser-scanning of trees during the last few years resulted in a variety of tree structure reconstructions that are based on the evaluation of three-dimensional clouds of points (Fleck et al. 2004; Pfeifer and Winterhalder, 2004; Gärtner and Denier, 2006; Bucksch and Appel van Wageningen, 2006). Moreover cloud point images could be used to create geometric models simulating the three-dimensional architecture of a tree, useful for example to characterize interception of light by dense or sparse canopies or to model the competition for nutrient and water efficiency of root systems (Danjon et al. 1999).

<u>The objectives of this research were:</u>
- To investigate the suitability of advanced technologies like 3D-Laser scanning to acquire fair and sound information's on structural and architectural characteristics of poplar stand;
- To compare direct and indirect measurement;
- To validate geometric models of above- and belowground tree structures using the software's WGROGRA (Kurth, 1994), AMAPmod v.1.8 (Godin and Guédon, 2001) and JRC-3D-Reconstructor ® (patented by JRC, IPSC, Nuclear Safeguards Unit).

Material and method

The study area was an intensive poplar plantation located about 10 km north-west of the city of Pavia within the "Parco Regionale del Ticino", Italy.

The poplar site is part of the CarboEurope network with the flux tower situated in the middle of a 120 ha even-aged plantation (*Populus x canadensis* clone I-214); the turnover times of the poplar stand was 14 years. On March 2005, the diameter at breast eight (DBH) of around 200 trees were measured in a one ha rectangular plot, characterizing the Eddy covariance fetch.

The vertical and horizontal stand structure was measured in a smaller circular plot (2000 m^2) near the tower.

Overall, 3 representative trees were selected on the base of their DBH and crown morphology.

<u>The indirect measurement</u> of the stand was made in April 2005 using a spot Zoller +Fröhlich GmbH Laser Measurement System LARA 53500 (Fröhlich and Mettenleiter, 2004); scans were

made in the super high mode (time of acquisition 15 min/scan) with a linearity error less than 5 mm.
We selected three 14's years old poplar trees and measurements of above- and belowground tree structures were carried out.
- *Aboveground measurements*: reference points (square targets) were positioned before the measurements in the scene and scans were made in four different points around each tree.
- *Belowground measurements*: Each root system, completely excavated using an Air-spade ®-2000, was scanned from ten different points of view.
The direct measurement of the selected trees was made on June 2005; trees were felled and measured (main architectural characteristics of stem and branches). Root systems were dried and weighted and volume was determined by multiplying those values with wood density.
3-D tree modeling: Filtering and registration of terrestrial laser scanning were made using the software JRC-3D Reconstructor ® and a 3-D information system was created for the above- and belowground structures (fig.1a). Unfortunately, due to hardware limitations, the laser scans were processed with a reduced resolution (sub-sampling) that inevitably influenced the level of detail.
Geometric modeling's of above- and belowground structures (fig.2b) were created using the software's WGROGRA and AMAPmod; to test the goodness of our geometric models they were compared with the laser scans using the inspection tool, provided by the software JRC-3D Reconstructor ®.

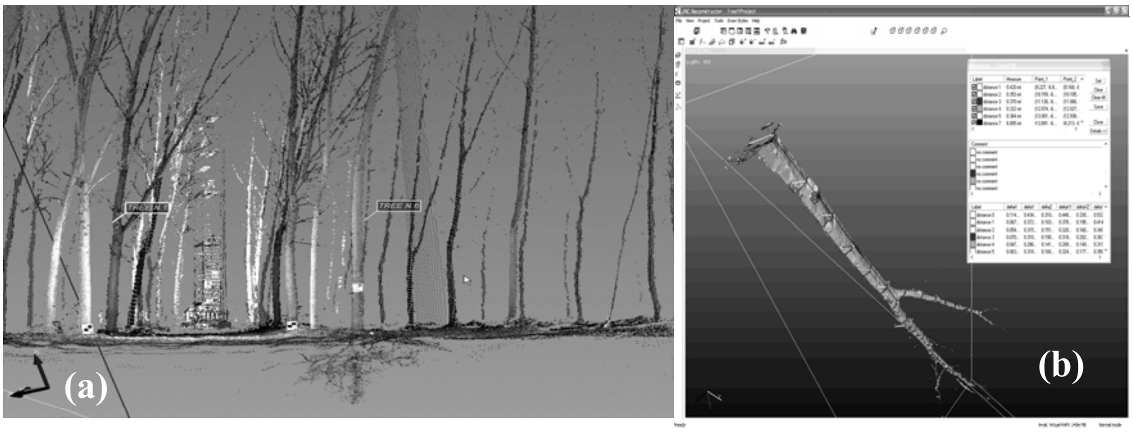

Fig. 1: Three-dimensional information system of aboveground and belowground structures (a) and analysis of stem and branches of a poplar tree (b)

Results

Considering the characteristics of the stand (plantation), the indirect measurement of aboveground structure was particularly simple and fast (half day, 12 scans) and there weren't problems due to the occlusion of laser beam from understory or dominated trees. The registration of the scans was accurate thanks to the square targets positioned in the scene before the measurements and to the possibility to translate and rotate manually each scan in a 3-D virtual space, using the software JRC-3D Reconstructor ®. Moreover the software tools permitted to extract geometric features of selected plants (topology) and to slice and export (*.dxf) the aboveground and belowground sections of the poplar trees. A good fitting ($r^2 \cong 0.8$) was found between direct and indirect measurements of stem sections. Indirect measurements of branches were less significant ($r^2 \cong 0.6$) because of (1) the scans sub-sampling, (2) the smaller diameter of the objects and (3) the distance of these from laser beam source.

The root systems (fig.1a, fig.2a) occupied a volume of soil ranging between 15 to 27 m^3; they were characterized by a central conical taproot and by several lateral branches. First-order plagiotropic branches (Intersection angles $\geq 70°$) are in the upper and middle parts of the taproot whilst geotropic (Intersection angles $\leq 30°$) are in the lower part. The taproot length ranged between 1.3 to 1.5 m; probably, taproot length is related more to the 2-year-old unbranched seedlings, used during the plantation of the stand, than to the soil matrix.

WGROGRA and AMAPmod were used to create geometric models of selected trees, based on the structural information's collected during the direct and indirect measurements. In order to test the goodness of our geometric models, they were imported in the 3-D information system and a comparison was made with the cloud of point images using the inspection tool provided by the software JRC-3D Reconstructor ®.
The software reported an error of about 10 cm for the stem and from 10 to 40 cm for the branches. The information's were used in an iterative process to modify and ameliorate our geometric models.

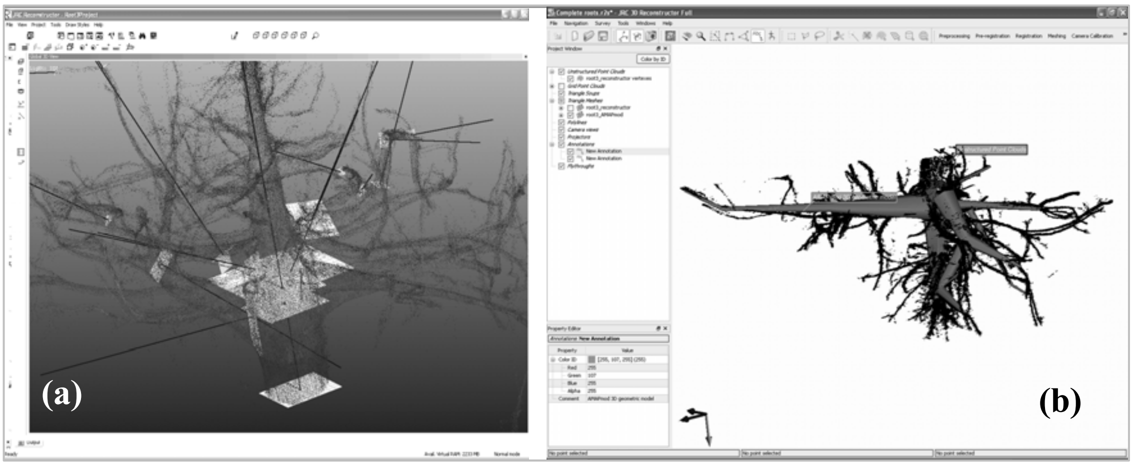

Fig. 2: (a)Topology of poplar root system extracted from point cloud image and (b) verification of a preliminary AMAPmod model (*.MTG) using a laser scan image and the JRC-3D Reconstructor®

Conclusion

We gathered high-resolution land cover information's of our test site using a terrestrial laser scan. The method was able to acquire fair and sound information's on structural and architectural characteristics of poplar trees. In fact, the three-dimensional information system of the poplar stand, created using the JRC-3D Reconstructor® software, has permitted to measure, from point cloud images, morphology of stems and branches, stand basal area, height of trees and to map topology of aboveground and belowground structures with an acceptable level of accuracy. Moreover it represented a source of information's that was used in combination with other software's (WGROGRA, AMAPmod) to validate geometric models of trees.
Although, the use of terrestrial laser scanning could be difficult in those stands, characterized by a complex horizontal and vertical structure, we believe that the use of this method on tree modelling activities or to detect forest volume and stand structure on large area at one time or in different decade should be more investigated.

Acknowledgements

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