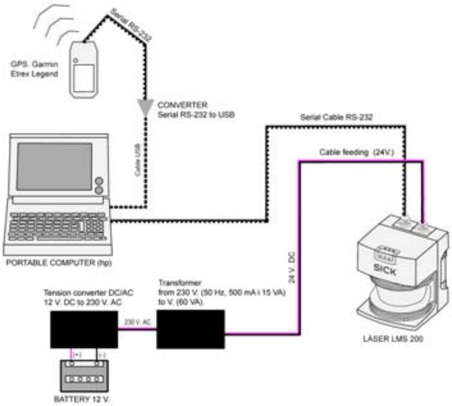

Figure 1. *Scheme of the experimental LIDAR system for field measurements, with the main components.*

Figure 2*. LIDAR system mounted on a tractor. the measurement data formats are also shown. Top: data in polar coordinates (distance and angle). Bottom: data in cartesian coordinates: x,y,z (z coordinate corresponds to tractor displacement axis).*

2.2 Field measurements

The system has been applied to characterize some common Spanish tree crops. The analyzed species were pear trees (*Blanquilla* and *Conference*), apple trees (*Golden* and *Red Chief*), vineyards (*Cabernet Sauvignon* and *Merlot*) and citrus (*Marisol, Oronules*, *Fortuna* and *Navelate*). Each field test consisted of several runs (measurements) with the LIDAR, on both sides of the row, as shown in figure 3, before and after the defoliation of the selected trees. In this way, the results of the LIDAR's measurements in both cases (trees with and without leaves) could be compared. As a result, 3D pictures of the crops could be re built from the cloud of points obtained from the scanner measurements. The volume of trees (figure 4) and LAI were measured manually. For LAI measurements, trees were divided in several volumes, as shown in figure 5, and separately defoliated, in order to dispose of much information about the distribution of leaves in the trees, and to look for correlations with the LIDAR results. Once in the laboratory, the one side area of the leaves was measured.

As far as plant volume is concerned, manually and LIDAR measurements are not coincident but there exists a straightforward relationship between both values, as is shown, as an example, in figure 10 for a *Blanquilla* pear orchard. The differences come from the uncertainty that is inherent with the concept of the volume of a tree and the method for its calculation (manually, by means of computer graphical methods...): what is understood as tree volume?

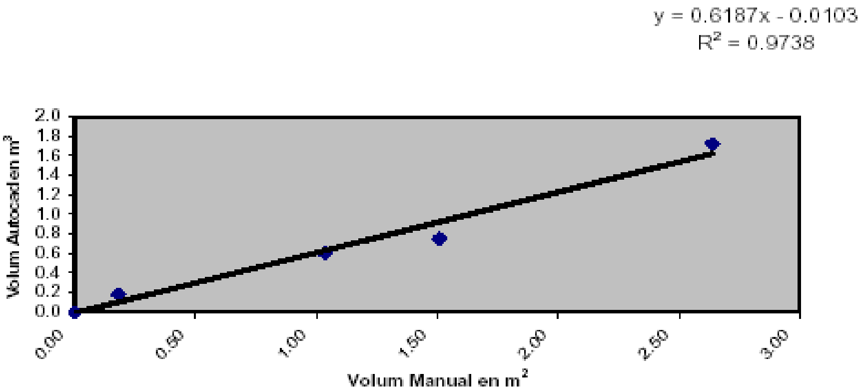

Figure 10. *Manually versus LIDAR measured volume of Blanquilla pear trees.*

On the other hand, two methods for the determination of LAI are being developed. The first one is based on the actual relationship between the LIDAR measured plant volume and its respective total foliate area (from which LAI can be obtained). As is shown in figure 11, there exists a straightforward relationship between both values.

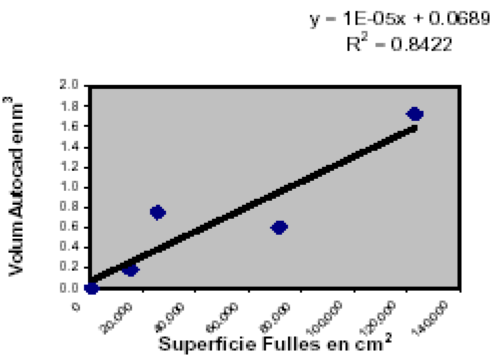

Figure 11. *Total foliate tree area versus LIDAR measured volume of Blanquilla pear trees.*

The second method is based on Beer's law, according to which the transmission of a beam of light across a plant is attenuated exponentially: $I(r)=I_o \exp(-\alpha r)$, where I_o and $I(r)$ are the original and the final (after a distance r) beam intensity, respectively, and α is an extinction coefficient related to the leaf area density and orientation. By this procedure the leaf area density (LAD) distribution along a plant is expected to be obtained, and so, the leaf area index. Figure 12 shows preliminary results for a fruit orchard.

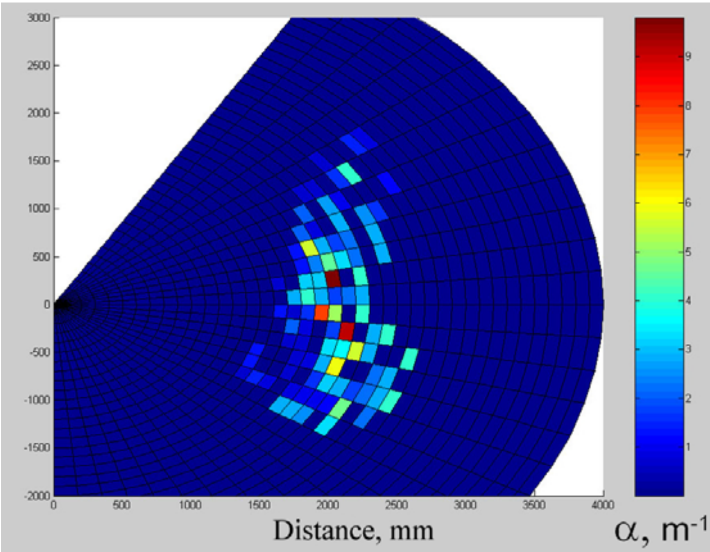

Figure11. *Mean distribution of the α factor (which is closely connected with the leaf area density) for a Blanquilla pear orchard, deduced from LIDAR measurements.*

4. Conclusions

The developed LIDAR-based measurement system is proving to be a valuable tool for the measurement of the physical and structural characteristics of the plants, such us tree volume and leaf area density and index. The obtained results will be used as support for the decision making related to the optimization of pesticide treatments for crop protection. Moreover, the developed system is expected to be of great interest, in general, for precision agriculture practices, in the two basic methods of implementing site-specific management for the variable-rate application of crop production inputs: *map-based* and *sensor-based*.

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