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USING STATIONARY AND MOBILE LASER SCANNER TO DETECT FOREST DEFOLIATION

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ABSTRACT:

We present results from a terrestrial laser scanner (TLS) and mobile mapping system (MMS) based investigation on forest defoliation caused by the European pine sawfly (*Neodiprion sertifer*) in a Scots pine dominated forest. The TLS and MMS results are compared with simultaneous visual estimation of the defoliation intensity as percentage of needle loss in the living crown. The capability of TLS of deriving changes on the standing tree biomass and defoliation degree was also confirmed by destructive, consecutive defoliation operations in laboratory. The biomass of the tree was measured simultaneously with the TLS measurements. The point cloud agreed with standing biomass with 92-99% coefficient of determination implying that terrestrial laser can be a powerful tool for biomass change reporting, and thus, usable for defoliation measurement.

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1. INTRODUCTION

The international interest in biomass detection is strongly related to forest health and carbon cycle monitoring (Sexton et al., 2009). The need for improved tools for, e.g., carbon monitoring applications, and the shortage of data for accurate biosphere and climate models has been internationally recognized. As the current knowledge on biomass, and particularly the changes related to it are almost entirely based on subjective ground measurements, remote sensing methods are called for. Airborne laser scanning (ALS) is a promising method in biomass detection (e.g. Lim and Treitz, 2004), because of its capability of direct measurement of vegetation structure (Zimble et al., 2003) and stand attributes (Hyyppä, 2004).

The environmental applications of terrestrial laser scanner (TLS) are constantly increasing Terrestrial laser scanner has been found to be an effective and low-cost monitoring method, and the information on TLS performance and range data accuracy is constantly increasing. Static measurements are however limited in range and area coverage. Laser scanner based mobile mapping systems (MMS) can be used to collect detailed data in a cost-effective manner from large spatial areas (Kukko et al. 2007). Vehicle mounted mobile mapping systems have also been deployed to gather information from changing biomass and defoliation (Rossel Polo et al., 2009).

1.1 The study site and Pine Sawfly hazard

This study was a part of ongoing monitoring campaign for forest defoliation caused by European pine sawflies (*Neodiprion sertifer*). The traditional monitoring methods have been based on field sampling (e.g., manual collection of different life stages) and subjective visual observation of tree condition. The test site was located in Outokumpu, eastern Finland, in a Scots pine (*Pinus sylvestris*) dominated forest. Reference data were collected from 20 field plots (consisting of 526 trees in total) in June 6-9, 2009. The visual assessment of defoliation was carried out simultaneously with tree-wise measurements in the field plots, and an additional visual assessment was done after defoliation by sawfly larvae (July 26-28) (see Lyytikäinen-Saarenmaa et al., for more details).

2. METHODS

2.1 TLS Laboratory case studies

We used a Leica HDS6000 which is a 685nm phase-based continuous wave terrestrial laser scanner with a 360°×310° field-of-view. The distance measurement accuracy is 4-5mm and the angular resolution is selectable from full 0.009° down to 0.288°. The scanner uses a silicon Avalanch Photo Diode (APD) as a photo detector.

The capability of TLS of deriving changes on the standing tree biomass and defoliation degree was verified by destructive, consecutive defoliation operations by two different laboratory case studies. In the first case study, one Scots Pine tree was defoliated in the laboratory in 7 steps. The biomass of the tree was measured simultaneously with the TLS, and defoliation was also estimated visually. Three simple tree-wise parameters were derived to represent the tree quality and defoliation: number of hits coming from the tree, ratio of tree hits (i.e., number of hits coming from the tree divided by the total number of hits), and the number of hits coming from the ground. These parameters were compared with the tree biomass measured with a 2-g accuracy for each step. The Pearson correlation coefficients derived were 0.996, 0.977 and 0.929, respectively, which implies that the number of points reflected from the tree represent accurately the standing biomass of the tree. The reason why the visual estimation of defoliation did not correlate that well with the number of laser hits is that trunks and branches affect the biomass but are ignored in the defoliation estimation. Therefore it can be expected that the visual estimation produces errors larger than those in terrestrial laser scanning.

In the second laboratory experiment (Fig. 1), five pine (*Scots Pine*) and spruce (*Norway spruce*) trees were measured with TLS from above and below. Here too the biomass of the tree was measured simultaneously with 2-g accuracy. The coefficient of determination with a linear regression model was 0.92 for total biomass and 0.98 for needle and branch biomass, which implies that the relative number of points reflected from the tree represent accurately the relative standing biomass of the tree.

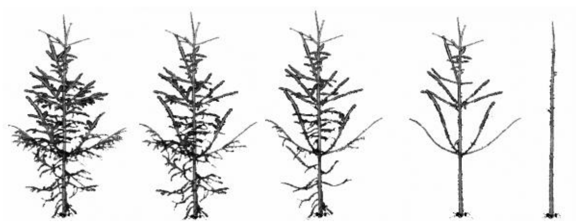

Figure 1: Defoliation time series from laboratory test derived from TLS scan files

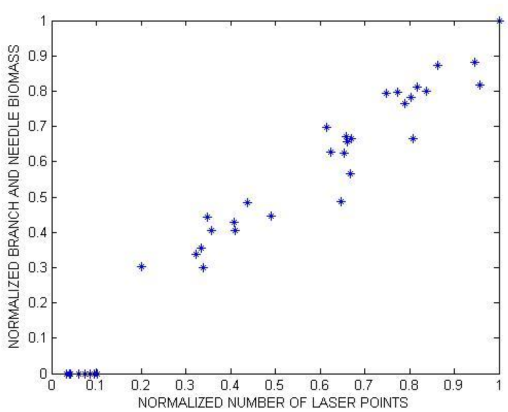

Figure 2: Normalized laser point number versus normalized total biomass of the trees from second laboratory experiment. R2=0.95.

2.2 TLS Field Experiment

Two sets of TLS measurements were carried out in the study site in June 25 and July 26-27 during the active period of the pine sawfly hazard. The first measurement was made at the early phases of defoliation and the second one after defoliation period. The scanning was performed from the centre of each field plot with similar scanning parameters and resolution at both dates. The trees that were directly visible (i.e., not obscured by other trees) were extracted from the resulting laser point clouds, and the change in the number of laser returns from each tree was compared to the visually estimated defoliation intensity given as percentage of the lost needle biomass of the living crown.

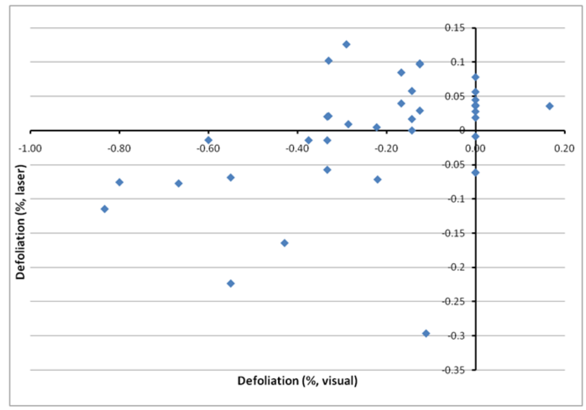

Figure 3: Visual and TLS-based measurement of forest defoliation (in percentages).

The change in laser returns from the tree canopy (in percentages) between the measurements in June 25 and July 26-27 is presented in Figure 3 and compared with visual observation. Clear trends of defoliation are visible in both visual and TLS-based analysis of the tree canopies. There are however several factors that affect the accuracy, e.g.,

- Deviation in change detection from TLS point clouds (e.g. mixed pixel effect with phase shift based laser scanners)
- The first visual estimation was carried out in June 6-9, i.e. two weeks before the first TLS measurements.
- The visual estimation of defoliation may be subjective, and it is not based on change detection rather than comparing the present situation with an ideal one (the crown is healthy by soil condition is taken into account).
- The ground-based TLS measurement is made in the upward direction, preventing some parts of the canopy from being measured. Airborne measurements facing downwards would improve the accuracy.

2.3 MMS Field Experiment

The mobile mapping system used in this study was a low cost approach combining pulse based laser scanner ibeo LUX and Novatel SPAN inertial measurement unit (IMU) + a GPS -unit. The ibeo scanner uses pulsed laser beam at 895-910 nm and has field of view 85° x 3.2° with 4 parallel beams. The scanner was mounted on the roof of a car (Fig. 4.) and the sample data was collected by driving along the test plots. GPS-IMU solution was post calculated using virtual reference station (VRS-GPS).

The MMS data (Fig. 5.) comparison to TLS data and visual interpretation was done with three sample plots. Change in laser returns from the canopy was determined comparing canopy returns to trunk returns as laser point density in target depends on vehicle movement. Early results from the data point out that defoliation trends were similarly visible as with TLS measurements. MMS data has however different error sources. Large laser footprint and shadowing effect from non-test sample trunks makes it difficult to detect small changes in test tree canopy biomass.

Figure 4: The MMS system mounted on car

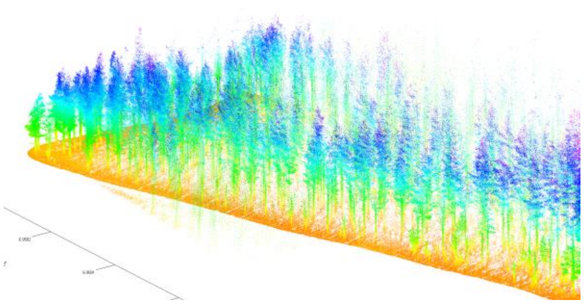

Figure 5: Point cloud derived from MMS data

3. CONCLUSIONS

The defoliation trend was visible in the TLS laboratory and field experiments, although correlation between point cloud and biomass was much better in laboratory experiments. Future tests will show whether the effect of the trunk is important. The results explain why airborne laser scanning (ALS) is effective for stem volume estimation, since the number of hits recorded by ALS is most probably highly correlated with the biomass, especially needle and branch biomass, which in turn correlated highly with the stem volume. Future tests are needed to verify this, but it can be assumed that a laser scanner measures tree height, crown area and biomass with a high accuracy. In this study we used mobile laser scanner parallel with TLS and visual defoliation estimation. First results from the MMS data point out potential of using mobile laser scanner as defoliation trends were visible in data and with mobile platform data collection can be done in very efficient manner.

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