A preliminary investigation of the operational use of a laser dendrometer for tree height measurement

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Abstract

The accuracy of tree height measurements using a laser dendrometer and a Suunto clinometer were compared for a small sample of eight Sitka spruce (*Picea sitchensis* (Bong.) Carr.) trees between 20 and 25 m in height. Measurements were taken at 15 and 30 m from the tree, and these were compared to the actual tree height measured after felling. Both the laser dendrometer and the Suunto produced estimates significantly lower than the actual height for measurements taken at 15 m from the tree, but at 30 m distance the actual and estimated heights (using both instruments) were not significantly different. Given the comparably high accuracy of the laser dendrometer and the traditional instrument, the gain in productivity from using the former which results from their being able to be used at any distance from the tree (without the need for a tape or range finder), as long as the tip and foot of the tree are in view, is a strong argument for recommending their use. However, further testing over a wider range of tree heights and species should be carried out.

Keywords: laser dendrometer, Suunto clinometer, tree height measurements

Introduction

Carrying out standing volume assessment and forest inventory can be time-consuming and expensive. As part of a research project on the development of a pre-harvest, wood procurement inventory procedure for a sawmill, the methodology and equipment used in tree height measurements were investigated. An aspect of the investigation was the comparison between a traditional tree height measurement instrument and one of the new laser based tools that have come on the market in recent years. This paper reports on a preliminary comparison of the two.

Testing of tree height measurement instruments

The accuracy of a full pre-harvest measurement system is dependent on the accuracy of each component within it (McHugh 1999). One of the basic components of a pre-harvest inventory procedure which was developed in he course of a larger research project (Malone 1998) is a stand-specific dbh/height model. This requires the height measurement of a number of standing trees in each stand by the sawmill wood procurement manager. In order to minimise the amount of time spent on inventory work, the actual number of heights to be measured was reduced to the minimum required to produce a sufficiently accurate dbh/height model (Nieuwenhuis and Malone 1999). Therefore, it is of utmost importance that the height measurements of the small number of sample trees produce

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accurate estimates. With this in mind, a test of height measuring instruments was carried out. Controlled tests of a wider range of similar equipment were carried out by Skovsgaard *et al.* (1998) and Williams *et al.* (1999).

Materials and methods

The height measurement instruments tested were the Suunto clinometer and the Impulse 200 (Laser Technology™) instrument. The latter is a new height measurement instrument that allows the user to measure tree heights at any distance from the tree (without the need for a tape) as long as the top and bottom of the tree are visible. Ten trees were chosen randomly for the test at a Sitka spruce clearfell site near Newcastle West, Co Limerick. Each tree was measured by two observers, each using both instruments at 15 and 30 m from the trees. Each height measurement was based on the mean of two readings. The trees were subsequently felled and the stem length was measured. The stump height was added to the stem length to determine the full total stem length. Two of the ten trees were subsequently omitted from the analysis as they had suffered stem breakage during the felling process.

The first step in the analysis was a comparison of the measurements obtained by the two people. No statistically significant difference was found between the two measurements so the data were pooled and the analysis was carried out on the mean of the two observations on each tree. In order to determine the accuracy of each height instrument/distance from the tree combination, a pair-wise comparison between actual height and estimated height was carried out using the 95% confidence interval. The objective was to compare the instruments and to determine the optimal distance from the tree at which to use them.

Results

The actual heights of the eight trees (measured after felling) and the values of the estimates based on the means of the two observations ranged from 20 to 28 m (Table 1). In most cases the estimates were consistently lower than the actual heights, especially for the measurements taken at 15 m.

Table 1. *Actual tree height and as estimated by the two instruments.*

Actual Height	*Impulse @15 m*	*Suunto @15 m m*	*Impulse @30 m*	*Suunto @30 m*
23.90	22.80	23.25	23.52	23.70
20.07	20.21	20.15	20.45	20.10
25.40	23.63	23.55	24.80	24.90
25.70	25.36	24.75	25.42	25.80
24.10	24.02	23.85	24.23	24.40
25.30	24.90	24.60	25.40	25.80
23.02	21.71	21.67	22.10	21.90
24.91	24.08	27.60	24.73	24.30

The results of the pair-wise comparison of the height measurement instrument /distance from the tree combinations (Table 2) showed that there was little difference in accuracy between the two height measuring instruments. However the results did show that at the greater of the two distances (30 m) from the tree, the accuracy of height estimation was higher than at the shorter distance. For trees between 20 and 25 m in height, it was clearly necessary to move more than 15 m away from the tree to get an accurate height measurement.

Table 2. *Comparison of actual tree height and estimated tree height for different combinations of instrument and distance from tree.*

Instrument	*& Distance*	*Bias* *m*	*SEE*[1]	*Difference from actual height (@ 95%)*
Impulse	15 m	-0.7075	.230549	Significant
Suunto	15 m	-0.8100	.244703	Significant
Impulse	30 m	-0.2150	.147793	Not significant
Suunto	30 m	-0.1775	.180573	Not significant

[1] SEE: standard error of estimate

An estimation of the residuals of each combination of distance and instrument (Figure 1, a & b) showed that both instruments under-estimated tree height almost every time when height was measured from a distance of 15 m from the tree. For measurements taken by both instruments at a distance of 30 m, the residuals were much closer to the actual

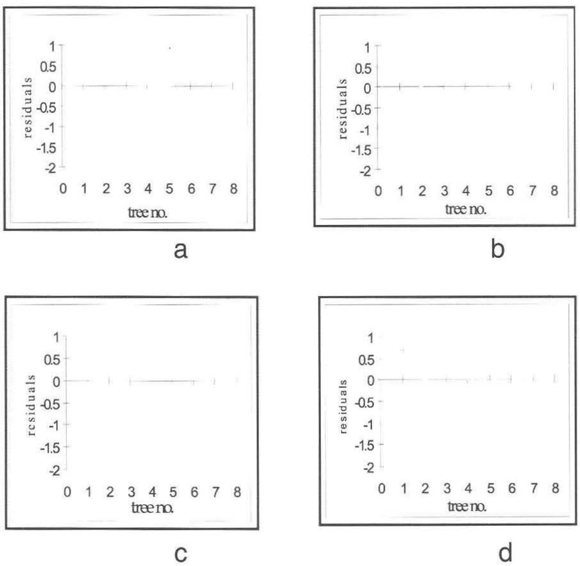

Figure 1. *Residuals (the difference between actual tree heights and height estimates) using (a) Impulse and (b) Suunto @ a distance of 15 m from the tree and (c) Impulse and (d) Suunto @ a distance of 30 m.*

measurements (Figure 1, c &d). These figures confirmed that the measurements from both instruments resulted in an under-estimation of height.

Discussion and conclusions

Laser dendrometers first became commercially available in 1991. Two manufacturers, Laser Technology Inc. (USA) and Jenoptik (Germany), dominate the market at the present (Skovsgaard *et al.* 1998). Although these instruments are expensive, they offer considerable potential to improve the efficiency of forest surveys (Hellström 1997).

Although only eight trees were included in this preliminary study, the results indicated clear, statistically significant differences. For this reason it was felt that, notwithstanding the small sample size, important conclusions could be drawn from the analysis and that reporting these to a wider audience was worthwhile.

The results showed that both instruments, under the right conditions, produced very accurate estimates of tree height. When the height estimates from the two instruments were compared with the actual heights, the height estimates taken with the Impulse 200 produced a slightly lower standard error than those taken with the Suunto. The distance from the tree significantly influenced the accuracy of the height estimates produced by both instruments. Significant differences were found between the actual and estimated heights taken at a distance of 15 m using either instrument. No such differences were found when heights were measured at a distance of 30 m from the trees. This is not surprising, for a number of reasons. First, as at the shorter distance it will be more difficult to see the actual tip of the tree. Second, small errors in pointing the instruments to the top and foot of the tree will result in larger differences in height estimates at closer distances as a result of the geometry involved. Third, the instruments were hand-held and not positioned on a support, resulting in a pivot axis that did not coincide with the axis of the instruments. This 'incorrect' operational use resulted in greater inaccuracies in the measurements at the 15 m distance because of the greater pivot angles involved.

It should be noted that measurements obtained with both instruments were for the vertical distance from the tip of the trees to the ground. The measurements obtained after felling the tree were for the distance along the bole. In the case of leaning trees, these two measurements are not expected to be equal and should not be compared to evaluate the accuracy of the instruments used. The standing trees selected for this study were however considered vertical for all intent and purposes.

In a controlled test carried out by Skovsgaard *et al.* (1998), two laser dendrometers and the Suunto were tested. Both laser dendrometers were found to give very precise readings but they did show some bias. The authors made the point however that this bias was statistically significant only because of the precision of the instruments, whereas a similar bias produced by traditional hypsometers might not be significant in a statistical sense because of the lower precision and so would remain undetected. In a study by Williams *et al.* (1999), of two dendrometers capable of measuring upper stem diameters and tree heights, it was found that increasing the distance from the tree at which the measurements were taken had a negative impact on the accuracy of the diameter measurement but no influence on the accuracy of the height measurements.

The main advantage of the laser instruments is the possibility to take the height measurement from any point where both the base and tip of the tree are visible, without the need to walk to the stem to establish the distance. Given the similar high accuracy compared to the traditional instruments, this gain in productivity, in itself, is a strong argument for recommending the use of these new instruments. However, in this project only one laser dendrometer could be tested on a small number of trees with a limited range of heights between 20m and 25m. It would be interesting and useful to test this and other laser instruments (including those with the added capability to measure upper tree diameters) on a larger sample of trees with a wider range of heights.

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