Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 6 (55) No.2 - 2013

STANDARD ERROR OF TREE HEIGHT USING VERTEX III

Maria Magdalena VASILESCU[1]

Abstract: *The idea to quantify the subjectivity at height measurement came with the large applicability of modern instruments. The aim of the study was to estimate the standard error of tree height using Vertex III in optimal conditions. In this way the error caused by accuracy of sight line was separated. A total of 104 users measured height of three studied trees. Mean, confidence interval of mean, absolute and relative deviations, coefficient of variation and mean error of one tree height measurement were computed for each tree. Results emphasize that the user error caused by the sight line at the top of tree is about 0.2 – 0.3 m.*

Key words: *standard error, height of tree, Vertex III.*

1. Introduction

There are different modern instruments for height measuring of trees as Suunto clinometer, Haglof Vertex hypsometer, Nikon Forestry 550 laser rangefinder. Tree height measurements are now possible even without clear sight through massive brush using laser technology.

It is known that Vertex III hypsometer allows an easy measurement of heights. Users guide for Vertex III provides technical specifications for heights 0–999 m, the resolution for height is 0.1 m, for angle is 0.1°, recommended distance to transponder is 30 m or more at good conditions, resolution for distance 0.01 m, accuracy for distance 1% or better if calibrated. The few functioning errors in case of measuring height and possibilities to solve them were analyzed by the manufacturing company. The most frequent faults in activities of height measurement using Vertex III with ultra sonic system are as follows: no distance shown in display, unstable distance value, incorrect distance value, cross hair will not go out, transponder will not start, no measuring values are presented, unrealistic values. The problems can be solved depending on causes. Transponder turned off, poor battery in transponder, disturbing noise in surroundings, poor calibration, too large angle, batteries placed incorrectly can be causes of errors. We have to start the transponder or change battery, measure from other spot, calibrate, increase distance to measuring object, turn batteries to right position to eliminate the faults [26], [27].

Therefore, in terms of using a calibrated instrument and according to users guide, only one error is brought by operator: the accuracy of sight line on the top of tree.

The aim of the study is to analyze the standard error of tree height measurement, given the error caused by sight acuity of the operator at the creation of line at the top of tree.

[1] Research Centre "Forest Engineering", *Transilvania* University of Braşov.

Tree height can be used on the models to estimate the volume of tree, stand volume [1], [3], [5-14], [16-18], [21], [23-25], to estimate biomass and carbon storage [2], or for the models to predict height or for the mechanical stability of trees [15],[22]. Therefore, it becomes a variable which requires accurate measurement.

2. Materials and methods

Three blue spruce (*Picea pungens* Engelm.) trees with different heights were chosen for measurement. To reduce the difficulties regarding the visibility of the top, the trees were chosen to be isolated and to have a clear terminal leadertypes from genus *Picea*. A total of 104 operators (N = 104) were trained for a right utilization of Vertex III hypsometer. After training they measured independently the height of the tree studied trees. The operators were distributed in five working groups. As a result we obtained five samples of values for each of the studied trees. Data were analyzed separately by trees, by samples and all grouped together.

Experimental distributions were studied [4], [19], [20] by computing the mean ($\bar{h}$), confidence interval of mean, absolute and relative deviations compared with mean, coefficient of variation and finally, standard error of one height measurement using equation 1 [11], [12].

$$s_h = \pm\sqrt{\frac{\sum\left(h_i - \bar{h}\right)^2}{N-1}} \qquad (1)$$

Standard error of a single measurement can be computed when we use many values obtained for the height (h_i) of the same tree.

3. Results and discussions

Obtained data for tree heights is shown for all trees in figure 1.

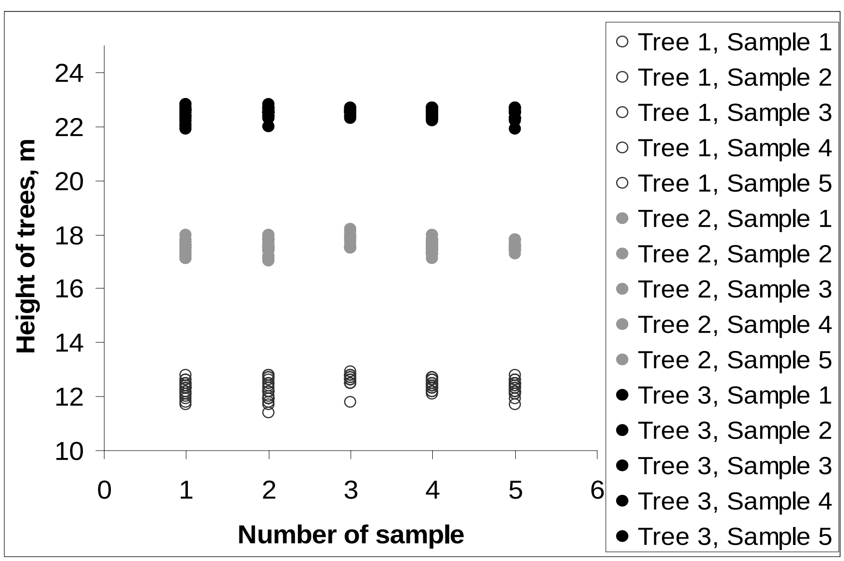

Fig. 1. *Distribution of height values for studied trees*

There is a better grouping of values in case of tree 3, this rising from three 1 to the tree 3. Trees were numbered by their height, 1 being the shortest and 3 being the tallest.

Mean height of trees was computed for every sample. Differences between these means and the average of all values (considered the reference height) are statistically not significant. Results are shown in figures 2-4. Confidence interval of mean (alpha = 0.05) is 12.35 ± 0.05 m (tree 1), 17.56 ± 0.04 m (tree 2), 22.47 ± 0.03 m (tree 3).

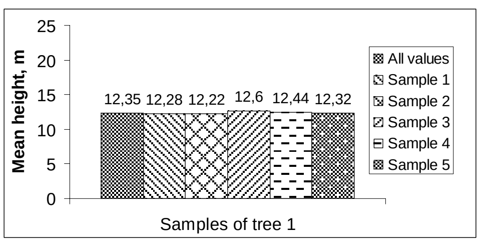

Fig. 2. *Mean height of tree 1 by samples*

Differences between means are between -0.13 and 0.25 m for tree 1 and between -0.08 and 0.18 m for second tree.

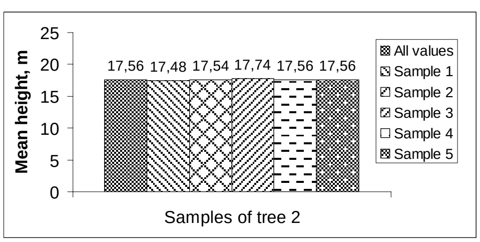

Fig. 3. *Mean height of tree 2 by samples*

The better grouping of individual values in case of the taller trees shown by the very small, statistically not significant differences between means (between -0.04 and 0.06 m) found in case of third tree. Relative differences between means range from -1.05 to 2.02 % for tree 1, from -0.45 to 1.02 % for tree 2 and from -0.17 to 0.26 % for tree 3. However, these are differences between mean values resulting from a large number of measurements for the same tree.

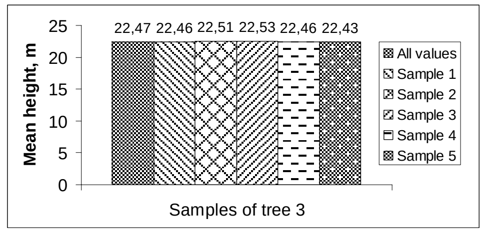

Fig. 4. *Mean height of tree 3 by samples*

The results regarding individual deviation of one measurement of height compared with mean of many measurements are interesting. Absolute and relative deviations (figures 5 and 6) were computed for a better accuracy and good capacity to comment.

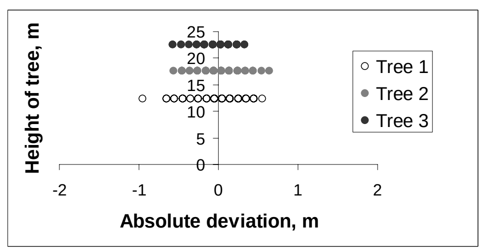

Fig. 5. *Absolute deviation of all values of height by trees*

We remark that individual deviations are between -0.95 and 0.55 m in case of first tree, between -0.56 and 0.64 m for second tree while for the third tree range from -0.57 to 0.33 m. As a result, the mean deviation is 0.23 m for tree 1, 0.17 m for tree 2 and 0.14 m for tree 3.

However, for a more precise assessment, individual deviation values were transformed into relative values. Mean relative deviation is lower for taller trees (figure 6). It ranges between -7.69 and 4.45 % for tree 1, or less for tree 2 (between -3.18 and 3.64 %) and tree 3 (between -2.53 and 1.46 %).

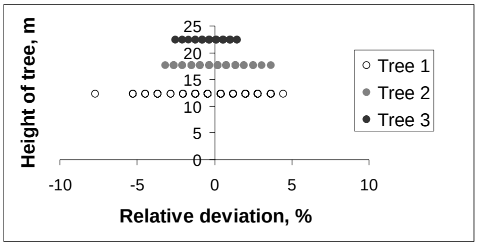

Fig. 6. *Relative deviation of all values of height by trees*

The mean value of relative deviation is 1.87 % in case of first tree, 0.99 % for second tree and 0.64 % for third tree.

Coefficient of variation was computed (figures 7-9) to verify the representativity of mean for each sample data set.

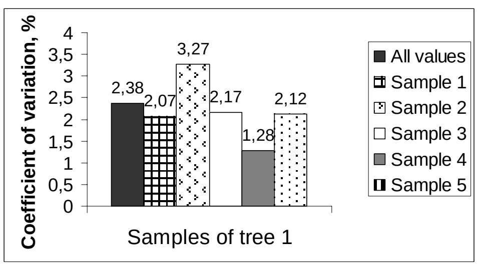

Fig. 7. *Coefficient of variation in case of tree1 by samples*

It is obvious that all samples are homogenous. The size of coefficient of variation for height values is 2.30 % in case of first tree and less, 1.29 % for second tree and 0.81 % for third tree. This completes previous results regarding the variation in situation of many measurements of height at the same tree.

This study gives the possibility to assess the error caused by an operator when he measures one height with Vertex III, even when he respects all rules from users guide.

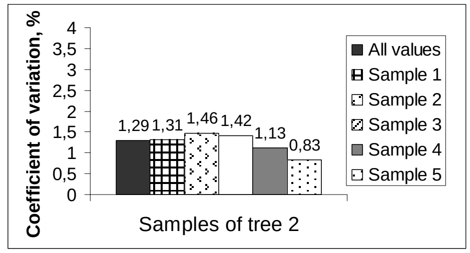

Fig. 8. *Coefficient of variation in case of tree 2 by samples*

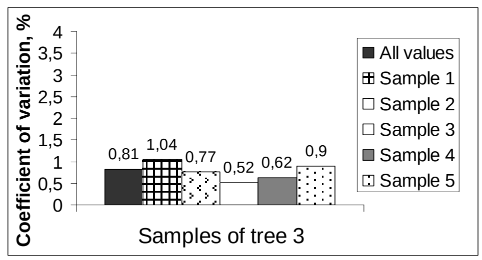

Fig. 9. *Coefficient of variation in case of tree 3 by samples*

Mean error of one measurement was 0.29 m in case of tree 1, 0.22 m for second tree and 0.18 m for third trees. The values were computed by applying equation 1. The source for this error is the visual acuity of the user which affects the accuracy in positioning the sight line at the top of tree.

4. Conclusions

Finally, the operator's subjectivity at the height measurement using Vertex III can be quantified by error estimation in case of positioning the sight line at the top of tree. This error is 0.3 m for the smaller trees (about 10 m height) and less than 0.2 m in case of taller trees (>20 m).

Acknowledgements

The author wishes to express the gratitude to the all 104 students from Faculty of Forestry in Brasov for the support during the measurements.

References

1. Avery T. E., Burkhart H., 1983. Forest measurements. Third edition. McGraw-Hill, New York.
2. Feldpausch T. R., Lloyd J., Lewis S. L. et al., 2012. Tree height integrated into pantropical forest biomass estimates. In: Biogeosciences, 9: 3381-3403.
3. Forslund R., 1982. A geometrical tree volume model based on the location of the centre of gravity of the bole. In: Canadian Journal of Forest Research, 12(2):215-221.
4. Giurgiu V., 1972. Statistical methods in silviculture (in Romanian). Ed. Ceres, Bucharest.
5. Giurgiu V., 1979. Forest biometry (in Romanian). Ed. Ceres, Bucharest.
6. Giurgiu V., Decei I., Armăşescu S., 1972. Biometry of Romanian trees and stands (in Romanian). Ed. Ceres, Bucharest.
7. Giurgiu V., Decei I., Drăghiciu D., 2004. Methods and tables of forest mensuration (in Romanian). Ed. Ceres, Bucharest.
8. Hamilton G. J., 1988. Forest mensuration handbook. HMSO Books. Forestry Commission Booklet 39.
9. Husch B., Beers Th., Kershaw J., 2003. Forest mensuration. John Wiley & Sons, New Jersey.
10. van Laar A., Akça A., 1997. Forest mensuration. Cuvillier Verlag, Göttingen.
11. Leahu I., 1994. Forest mensuration (in Romanian). EDP, Bucharest.
12. Leahu I., 2007. Forest mensuration (in Romanian) Transilvania University Press, Braşov.
13. Ozcelik R., Wiant H. Jr., Brooks J., 2006. Estimating log volumes of three tree species in Turkey by six formulae. In: Forest Product Journal, 56(11/12): 84-86.
14. Parent D., Moore J., 2003. A stand volume equation for cruising small-diameter material. In: Journal of Forestry, 101(5): 5-6.
15. Peltola H., 2006. Mechanical stability of trees under static loads. In: Am. J. Bot., 93(10): 1501-1511.
16. Philip M., 1994. Measuring trees and forests. Second edition. Cab International, London.
17. Steinhilb H. M., Winsauer S., 1976. Sugar maple: Tree and bole weights, volumes, Centers of gravity, and logging residue. www.ncrs.fs.fed.us/pubs/rp/rp_nc132.pdf
18. Soares C. P. B., da Silva G. F., Martins F. B., 2010. Influence on section lengths on volume determination in Eucalyptus tree. In: Cerne. Lavras 16(2): 155-162.
19. Tereşneu C., Ionescu M., 2011. Informatics for topography and cadastre (in Romanian). Ed. Lux Libris, Braşov.
20. Tereşneu C., 2012. Automation of geodetic data (in Romanian). Transilvania University Press, Braşov.
21. Tomusiak R., Zarzynski P., 2007. The old trees trunk's volume determination with use of theodolite. In: Rocznik Dendrologiczny, 55:9-16.
22. Urata T., Shibuya M., Koizumi A., Torita H., Cha J. Y., 2011. Both stem and crown mass affect tree resistance to uprooting. In: J For Res., 17: 65-71.
23. Wiant H. Jr., Spangler M., Baumgras J., 2002. Comparison of estimates of hardwood bole volume using importance sampling, the centroid method, and some taper equations. In: Northern Journal of Applied Forestry, 19(3): 141-142.
24. Yavuz H., 1999. Comparison of the Centroid method and four standard formulas for estimating log volumes. In: Tr. J. of Agriculture and Forestry, 23: 597-602.

25. Yousefpour M., Fadaie Khoshkebijary F., Fallah A., Naghavi F., 2012. Volume equation and volume table of Pinus pinaster. In: Ait. International Research Journal of Applied and Basic Sciences, 3(5): 1072-1076.
26. *** Users guide Vertex III and transponder T3, September 2005. http://www.forestry-suppliers.com/Documents/176_msds.pdf.
27. *** Users guide Vertex III V1.5 and transponder T3, April 2007. http://www.haglofcg.com/index.php?option=com_docman&task=doc_view&gid=93&Itemid=125&lang=en.