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THE USAGE OF MOBILE LASER SCANNING TECHNOLOGIES FOR THE ESTIMATION OF FORESTRY AND FOREST INVENTORY INDEXES OF THE FOREST STANDS

Here are presented the results of the use of mobile scanning technology (using the GeoSLAM ZEB HORIZON scanner) for the evaluation of the main forestry and inventory indicators of forest stands. The diameters of stems were calculated with the use of ground scanning and resulting values were compared with the data of direct measurement of the inventory stem strengths in pine stands. Calculations were performed of forestry and inventory indicators of stands of experimental plots (calculated average diameter, average height, absolute density, stem volume stock) based on data from laser scanning and with the use of list methods of inventory. Discrepancies in different indicators were determined and analyzed.

Key words: 3D point cloud; dendrometric indicators of trees; comparative analysis; Geo SLAM; pine stands.

Modern digital technologies create prerequisites for the use of remote tools for the evaluation of forest resources. Especially relevant today is the determining of the quantitative features of forest biocenoses for their practical use. The use of remote sensing methods to obtain data on forests indicates their high efficiency. However the scale of the received/obtained data from remote sensing mostly are for the large areas. Instead the use of remote sensing for a separate subcompartment or for a separate plot (felling site) is impractical considering the costs. Alternative of remote sensing is the evaluation forest resources using laser scanning. At the same time laser scanning technology is gaining widespread adoption in recent times.

As part of the scientific project "Monitoring lasu - ocena stanu lasów w Polsce", the laser scanning of observation plots (the second level of monitoring) was performed using the GeoSLAM ZEB HORIZON scanner. In total, the experiment covered 32 permanent experimental plots of pine stands of different sizes. The obtained results of ground mobile laser scanning indicate that the optimal resolution, which guarantees reliable values of forestry and inventory characteristics of an individual tree, is 90–110 thousand points/sec, which is about a third part of the total power of the scanner. At the same time, the maximum duration of scanning should not exceed 20 minutes, which ensures the creation of files, the size of which is convenient for further processing. Such conditions ensure effective scanning and further processing of the "point cloud" of forest plots with an area of up to 1 ha. During scanning, a significant number of points are accumulated (point cloud that can be several million). At the same time, it is necessary to provide an appropriate scheme for moving the scanner.

The primary task of the project was the identification of trees on experimental plots using various algorithms of automated data processing. Specifically, today the question of developing software modules that would ensure automatic processing of the "point cloud" and receiving compiled forestry and inventory indicators of stands is relevant. With this in mind, we plan to obtain the main dendrometric characteristics of tree trunks (diameter, height, volume) from laser scanning and compare them with the data of traditional forest inventory measurements. For the analysis, the samples of measurements and laser scanning of 4 monitoring experimental plots in pure pine stands were used. From 165 to 286 trees were counted on each experimental plot.

It is commonly known that the volume of trunk directly depends on the diameter and the height. Therefore, firstly, we compare the obtained values of tree diameters from the results of ground laser scanning and traditional diameter measurement with a tree caliper in two perpendicular directions.

Using the designated software we obtained the value of the diameters at a height of 1.3 m in automatic mode. To identify the trees, we extracted a point cloud at a height of 1.3 m. and 5.0 m.

The Q-GIS software allowed us to compare the obtained point clouds which form the perimeter of the trunk at the mentioned heights. (Fig. 1)

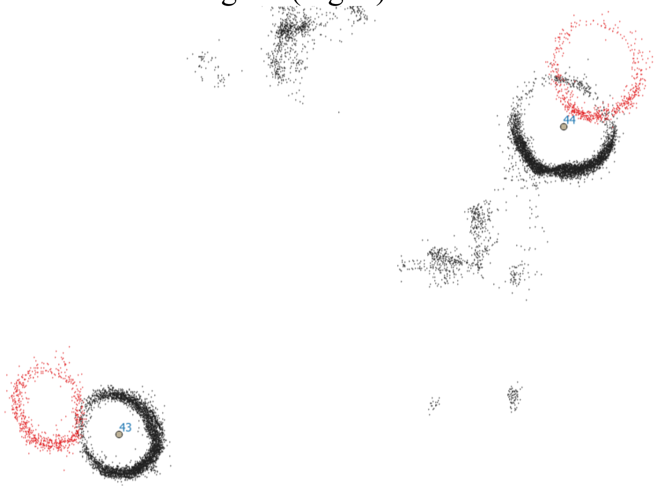

Fig. 1 A set of points of the perimeter of individual trees (trees numbered 43 and 44)

The figure shows points at a height of 1.3 m in black, and points at a height of 5.0 m in red. Because trees can be warped - the overlap between points at different heights can have a certain offset. The absence of points at a height of 5.0 m indicates the absence of a tree. The obtained results indicate a 100% automatic identification of tree trunks. This confirms the expediency of using laser scanning to count the number of trees. However, such data is not very informational for practical use. Much more important and informative are the data on the values of the diameters of the recorded trunks.

A comparative analysis of the diameters of tree trunks shows that there is a certain difference between the diameters determined automatic determination using laser scanning data and the diameters measured with a tree caliper (Fig. 2).

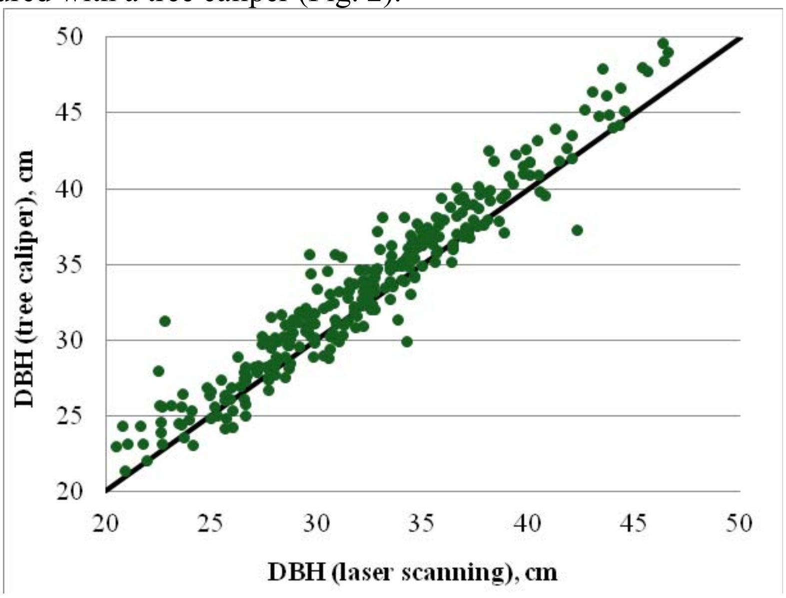

Fig. 2. Comparison of diameters on the fourth trial area

In general, we can see a trend indicating that the diameter values obtained using laser scanning data are slightly lower compared to the diameter values obtained by direct measurement. However, the deviations are not significant enough. Statistical analysis indicates the similarity of two samples of diameters according to Fisher's F-test. The accuracy of the experiment is 1.1-1.5%. The coefficients of variation between the diameters range from 0.877 to 0.965 and indicate a high direct relationship. The adequacy coefficients of the model range from 0.793 to 0.871. Such results indicate the correct choice of the algorithm for the automatic calculation of the diameters of tree trunks and the possibility of using laser scanning to obtain data on the diameters of tree trunks both at a height of 1.3 m and, if necessary, at different heights. This is also confirmed by the results of the calculation of the average diameter on the experimental plot. The obtained results indicate that the absolute deviation between the diameters is in the range of 1.2 to 2.0 cm in the direction of decrease, that is, laser scanners slightly lower the values of the diameters. In particular, the smallest deviation is observed in the fourth experimental plot - 1.2 cm in the decreasing direction (3.5%). The largest deviation was obtained on the second experimental plot - 2.0 cm. At the first and third experimental plot, deviations in average diameters are 1.5 cm and 1.7 cm, respectively. Analysis of the grouped values of diameters by thickness levels indicates that during laser measurement, a greater number of tree diameters are attributed to lower strength levels. Instead, the manual measurement of diameters with a tree caliper indicates that a greater number of trees are concentrated in higher strength levels. This results in an underestimation of tree diameters when determining them by laser ground scanning.

It is clear that the aspects of the distribution of trees by thickness levels have a direct impact on the sum of cross-sectional areas, and subsequently on the volume of the tree trunk. Thus, the analysis of the result of the calculation of absolute density (cross section area) indicates that deviations have the same tendency as the deviations in diameter. In all experimental plots, the deviations have a negative value, which indicates a tendency to underestimate absolute density by laser scanning. In general, the absolute values of the deviations range from 1.3 to 3.8 m^2 in the downward direction, which is 7-9%. The comparison of tree heights was performed based on the automated calculation of the heights of all trees and the simulated height values. This approach was used due to the method of field measurements and the cost of measuring the heights of all trees on the experimental plot. In particular, we measured the heights of 30 trees, taking into account the differentiation of trees by diameter. Based on the measurement of the diameters of tree trunks and their heights, modeling of the height values for all the trees of the experimental plot was performed. We use the three-parameter Chapman-Richards function as a model. Modeling of heights on the third experimental plot is shown in fig. 3.

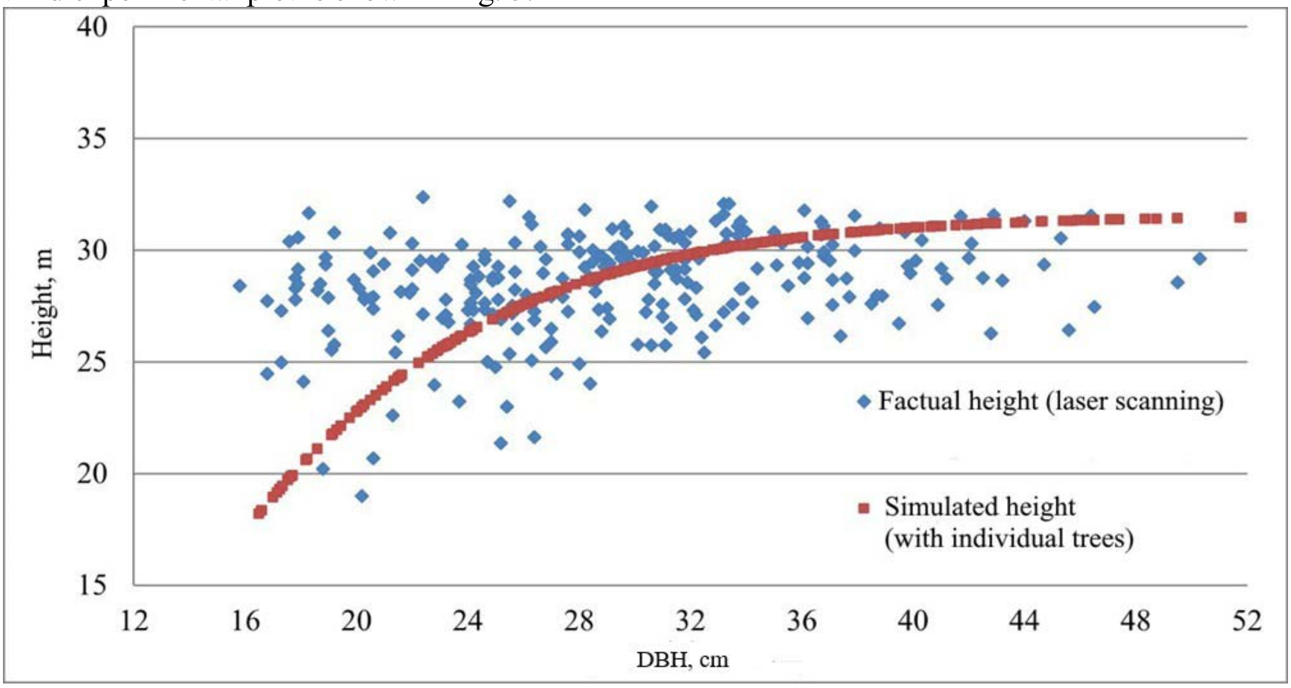

Fig. 3. Dynamics of tree height

In general, a tendency to a slight underestimation of the modeled height values in the lower thickness levels and a slight overestimation in larger thickness levels was found on all experimental plots. This will have a direct impact on the calculation of stem volume stock.

The determining factor of the economic activity of forest enterprises is the volume stock. The most accurate way of determining the stock is to add up the volumes of all trunks. We calculated the trunk volume of individual trees based on laser scanning data and measures/simulated dendrometruc indicators. A comparative analysis of the results obtained indicates certain differences between the volume of trunks of individual trees. The smallest deviations were found on the third experimental plot, which is shown in fig. 4.

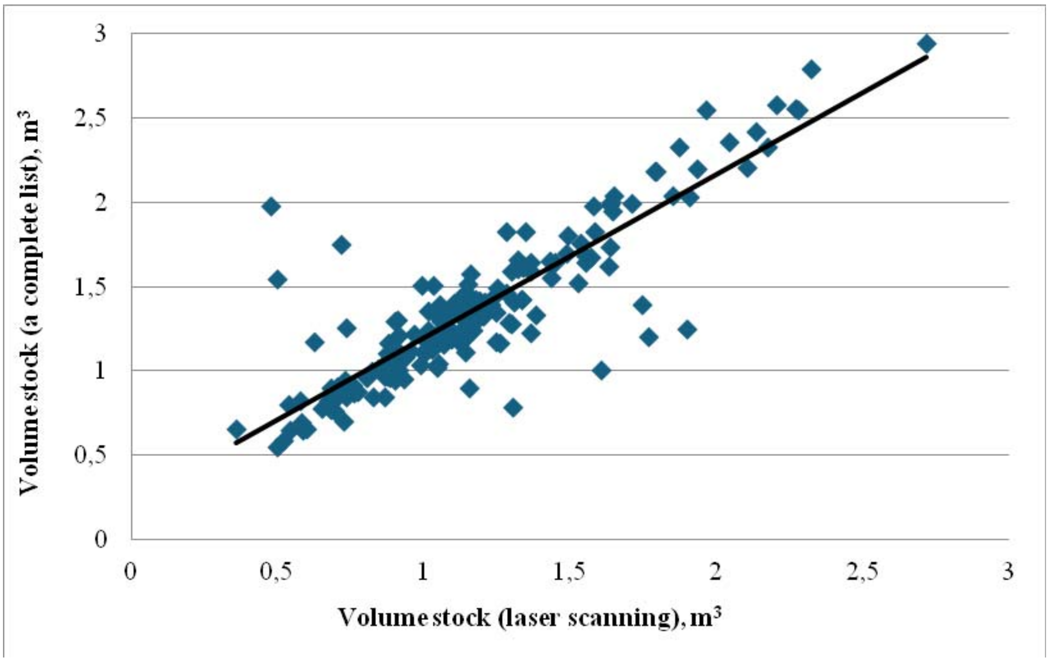

Fig. 4. Comparison of values of trunk volumes

In general, we observe a general tendency to underestimate the volumes of tree trunks using laser scanning materials. However, the research results indicate the presence of a very high correlation in all experimental plots. The correlation coefficient ranges from 0.907 to 0.963. The absolute values of deviations by reserves are 10.5-32.1 m^3 which is relatively 5.8-12.7% downward.

Thus, the research results indicate that it is expedient to use laser scanning for the assessment of forestry inventory characteristics. At the same time, it is necessary to improve methodical approaches to calculating individual indicators to increase accuracy. The technology of ground mobile laser scanning can provide fast and relatively cheap data acquisition on the qualitative and quantitative characteristics of both an individual tree and a stand as a whole.

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