Original scientific paper

Efficiency of ultrasonic Vertex III hypsometer compared to the most commonly used hypsometers in Croatian forestry

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Abstract – Nacrtak

The article investigates the efficiency of the ultrasonic Vertex hypsometer in tree height measurements in relation to some of the most commonly used hypsometers in Croatian forestry. The whole measurement process consists of three steps: time needed to reach the measurement zone, time needed to determine the distance to a tree, and time needed to measure and read the height of a tree. Measurements were conducted with four hypsometers: Vertex, Blume-Leiss, Bitterlich's Spiegel Relaskop with a standard scale (RO) and Bitterlich's Spiegel Relaskop with a CP scale (with the horizontally /RCPH/ or vertically /RCPV/ positioned staff). Research results do not show any statistically important differences among the hypsometers in terms of time needed to reach the measurement zone. In measuring tree heights in a stricter sense (without the element of reaching the measurement zone), the least amount of time was required by the Vertex (28.4 cmin) on average. The Vertex is followed by the relaskop with a CP scale, the horizontally (57.4 cmin) or vertically positioned staff (86.1 cmin), then the Blume-Leiss (84.0 cmin) and finally the relaskop with a standard scale (106.8 cmin). The differences between the Vertex and other hypsometers are statistically significant. Despite a slightly higher price of the Vertex, its speed, precision, accuracy and simplicity of use, as well as the possibility of simple circular plot forest inventories rank it above all the other instruments.

Key words: *tree height, hypsometers, height measurement, time study, variance analysis*

1. Introduction – *Uvod*

Tree height measurements used in the estimation of site quality and the construction of height curves are important elements in forest management. According to Article 16 of the Forest Management Regulation (Anonymus, 1997), the one-entry volume table is determined for every tree species participating with over 10 % in the growing stock of each compartment or subcompartment on the basis of height curves and two-entry volume tables. Subcompartments are grouped according to management classes, site classes and ages, while the height curves are constructed on the basis of measured heights of 5–10 randomly selected trees from every diameter degree.

The establishment of labour standardization or standards is based on the time required to perform a particular task in given conditions. The majority of operations in forestry are standardized. According to labour standards in forest management (Meštrović and Fabijanić, 1995), depending on terrain conditions, one labourer can measure 110–150 heights in even-aged stands and 100–140 heights in selection stands. Terrain conditions may be optimal, medium favourable and unfavourable, and they may be defined by terrain slope and shrub cover. The types of hypsometers to which these standards refer are not prescribed by the Regulation.

In order to make labour analysis, all relevant data relating to the elements of labour being analysed must be available (Martinić, 1990). The use of time study in labour analysis involves splitting a working process in shorter work components and establishing the moment in which a particular task is completed (fixed points). At the moment in which a particular work component ends, the lapsed time is read from the chronometer and the duration of the next work component is measured (Poršinsky, 2005). Establishing the time needed to perform a part or the whole working process is one of the basic prerequisites for rationalizing work in a working process (Tomanić et al., 1978).

The procedure of tree height measurements with »classical« hypsometers (Blume-Leiss, Spiegel relaskop, Haga, Suunto) may be divided into several components: reaching the measurement zone, determining horizontal distances and measuring and reading heights. Better, more up-to-date instruments for tree height measurements have been produced recently. One of these is the ultrasonic Vertex III hypsometer, which integrates the second and third measurement component.

2. Aim of research – *Cilj istraživanja*

According to Baustian et al. (2001), the applicability of an instrument is determined by the time required to measure heights.

The set standards do not prescribe which hypsometer type should be used to measure heights. Therefore, the goal of this research was to establish the amount of time required to measure either a particular element or the entire height measuring process with some of the most commonly used hypsometers. The advantages and limitations of a particular hypsometer are also discussed.

The paper will focus on tree height measurements with the Vertex and its efficiency in relation to other hypsometers.

3. Material and methods – *Materijal i metode*

Research was conducted in Subcompartment 3b of the management unit »Sljeme«, which is part of the Teaching-Experimental Forest Site (hereinafter TEFS) Zagreb. The management unit »Sljeme« is situated on the northern slope of Mount Medvednica, north of the main Puntijarka - Rauhova Lugarnica - Stol divide within the »Medvednica« Nature Park. Subcompartment 3b takes up the northern exposition from 750 to 870 m above the sea. The terrain is more or less steep and intersected with ditches. Research focused on silver fir as a species with a distinct treetop (fir growth).

A random sample of fir trees was taken in the previously established directions of movement (designed in a map) and a variety of site conditions were included (terrain inclination, movement within the contour lines, up and down slope, stand density,

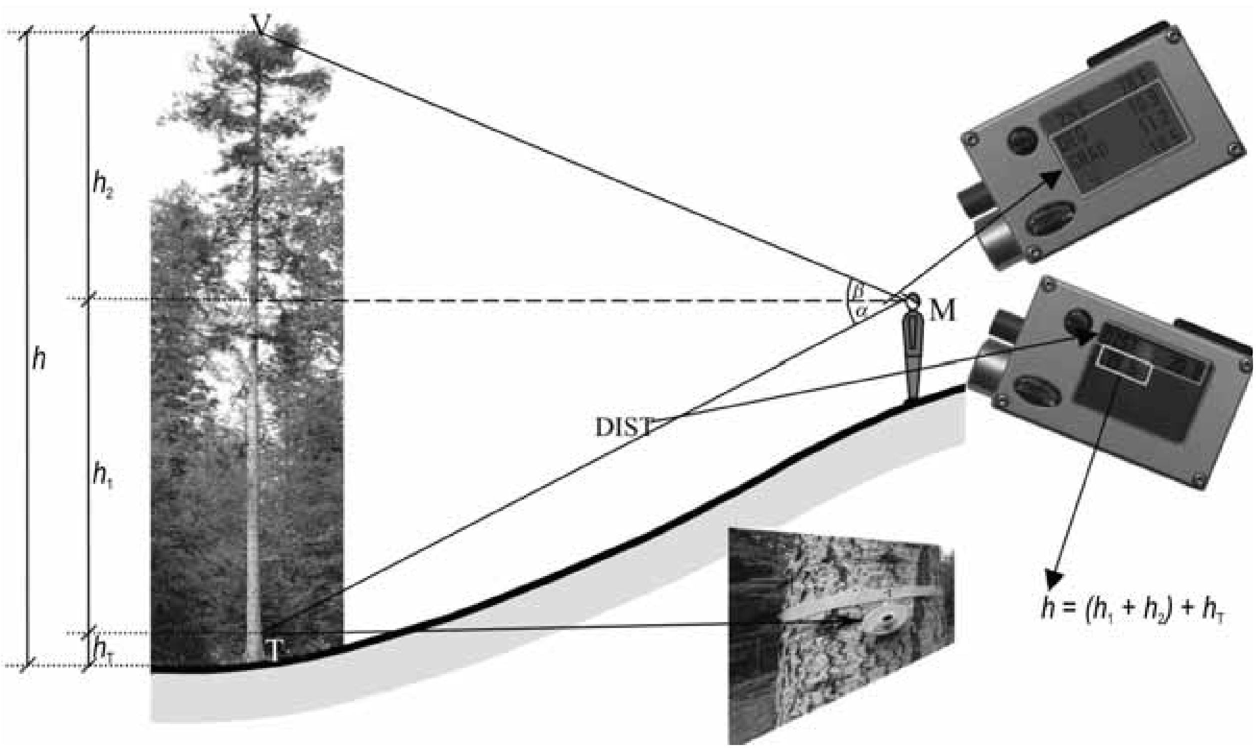

Figure 1 Tree height measurement process with the Vertex III hypsometer
Slika 1. *Prikaz postupka izmjere visine stabla visinomjerom Vertex III*

shrub coverage). All diameter classes were evenly represented. The sample consisted of 40 numbered trees, which were alternatively marked with red and yellow bands for easier identification in the terrain.

Four hypsometer types were used for measurements:

A) Vertex III (V)
B) Blume-Leiss (B)
C) Bitterlich's Spiegel Relaskop with a standard scale (RO)
D) Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally (RCPH) or vertically positioned staff (RCPV).

The Blume-Leiss hypsometer and the Bitterlich's Spiegel Relaskop with a standard and a CP scale have been widely used in Croatian forestry for a number of years. The Vertex III is a relatively newer, ultrasonic digital instrument for measuring heights, distances, vertical angles, slopes and current temperatures (Anonymus, 2002). To perform measurements, the instrument must be equipped with an external unit – the transponder. The principle of height measurements with the Vertex is very simple. The transponder is placed on a tree to be measured (Figure 1), at a calibrated height, (in our case it is 1.30 m). When the measurer (M) aims at the transponder (T) the instrument registers the angle (α) and the distance to the transponder (DIST), from which the horizontal distance and the height from the transponder to the isohypse (h_1) are calculated. When aimed at the tree top the instrument calculates the height from the isohypse to the tree top (h_2) using the previously established horizontal distances and the angle (β). The overall tree height (h) is the sum of the height at which the transponder is placed (h_T – registered in the hypsometer) and the heights h_1 and h_2.

The process of height measurements in the field is divided into three constituent elements (steps):

1. time required to reach the measurement zone
2. time required to determine the distance to the tree
3. time required to measure and read the heights of a particular tree.

In the height measurement process the hypsometer itself is used in the second and third step. Summarily, these two steps may be considered tree height measurements in the stricter sense.

Time required to reach the measurement zone begins when the height of the previous tree has been measured, and ends when the measurer reaches the position from which a tree height may be successfully measured. With an instrument that requires correction of the measured heights due to terrain slope, the measurer positions himself »in the isohypse« with the tree to be measured. Time required to measure the distance to the tree begins with the completion of the previous step, includes the measurer taking a position at a referent distance and ends with measuring the distance to the tree. Time needed to read the tree height begins with the completion of the previous step and ends with reading the measured tree height, or obtaining the elements needed to calculate the tree height.

The duration of any given element of tree height measurement was measured with the chronometer with the centesimal division (1 min = 100 cmin).

Measurements were made by two persons (measurer and assistant). The assistant positioned and held the staff or the transponder (depending on the instrument used), measured the tree breast diameter, simultaneously measured the time and entered the obtained data into the field manual. The measurer measured the heights (throughout all the tree steps) with the instrument at his disposal.

In order to avoid any possible bias the measurer might have due to longer experience with a particular instrument, measurements were made by forestry students in the final year who shared equal experience with every instrument. Before performing the actual measurements, the students had additional practice in using each instrument on an independent sample.

Tree heights were first measured with one instrument, then with another, then with another, etc.

The data relating to the time required to perform a particular measurement stage were entered in the developed Microsoft Excel 2000 database. All analyses and graphic presentations were made with the statistical package STATISTICA 6.0 (StatSoft, Inc., 2003).

In all statistical analyses the significance level of $p = 0.05$ was considered statistically significant. If a statistically significant difference among the instruments was found for any of the elements with the variance analysis, a multiple Post-hoc test (Schefee) was applied to determine which instruments differed statistically significantly (Sokal and Rohlf, 1995).

4. Results of research – *Rezultati istraživanja*

In the stage related to reaching the measurement zone the measurer roughly determined the position from which he could clearly see the top and bottom part of the tree. Depending on the instrument used, it took the measurer an average of 60-84 centiminutes to reach the measurement zone. Since all the instruments were used to measure the same trees in

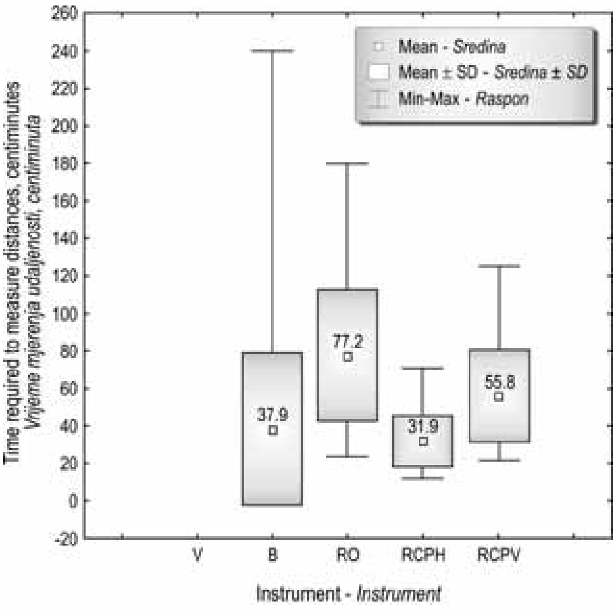

Figure 2 Times required to determine distances to a particular tree (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or the vertically /RCPV/ positioned staff)

Slika 2. *Prikaz vremenâ potrebnih za određivanje udaljenosti do stabla (V – Vertex; B – Blume-Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojega je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva)*

the same order, it is logical that no statistically significant differences were found among the instruments for this measurement stage ($F = 2.08$; $df = 4$; $p = 0.085$). Time needed to reach the measurement zone varied between 2 and 190 centiminutes, depending on trees. This depended on the distance between any two trees to be measured, on leaving the position of the previous tree measurement so that the next tree could be measured, on obstacles encountered while coming to the measurement zone (fallen trees, thick undergrowth, and similar), as well as the terrain configuration (movement of the measurer up/down the slope or within the isohypse).

After determining the position from which to measure the tree height, the measurer had to measure the distance to the tree to be measured. It should be emphasized that this element was not treated separately in the case of the Vertex, but was incorporated in the element 'height measurement'. Figure 2 shows variability of times required to determine distances to trees. Variance analysis of determining distances to trees revealed statistically significant differences among the instruments ($F = 18.00$; $df = 3$; $p < 0.001$). The results of Sheffe's post-hoc test are given in Table 1.

Table 1 Results of Sheffe's post-hoc test for determining distances to trees obtained with different instruments (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or vertically /RCPV/ positioned staff)

Tablica 1. *Rezultati Scheffeova post-hoc testa za određivanje udaljenosti do stabla između upotrijebljenih instrumenata (V – Vertex; B – Blume-Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojega je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva)*

Instrument *Instrument*	B	RO	RCPH
RO	**<0.001**		
RCPH	0.854	**<0.001**	
RCPV	0.078	0.022	**<0.001**

Note: The *p* values in bold are statistically significant.
Napomena: *Statistički su značajne p vrijednosti u tablici podebljane.*

After measuring the distances, the measurer performed the last step in height measurement: he measured and read the height. Figure 3 shows variability of times required to measure and read the height. Variance analysis of height measurement and reading revealed statistically significant differences among the instruments ($F = 15.63$; df = 4; $p < 0.001$). The results of Sheffe's post-hoc test are given in Table 2.

By adding up the time needed to determine the distance from the tree and the time needed to mea-

Table 2 Results of Sheffe's post-hoc test of determining distances to trees obtained with different instruments (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or vertically /RCPV/ positioned staff)

Tablica 2. *Rezultati Scheffeova post-hoc testa za određivanje udaljenosti do stabla između upotrijebljenih instrumenata (V – Vertex; B – Blume–Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojega je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva)*

Instrument *Instrument*	V	B	RO	RCPH
B	**<0.001**			
RO	0.996	**<0.001**		
RCPH	0.898	**<0.001**	0.712	
RCPV	0.981	**<0.001**	1.000	0.586

Note: The *p* values in bold are statistically significant.
Napomena: *Statistički su značajne p vrijednosti u tablici podebljane.*

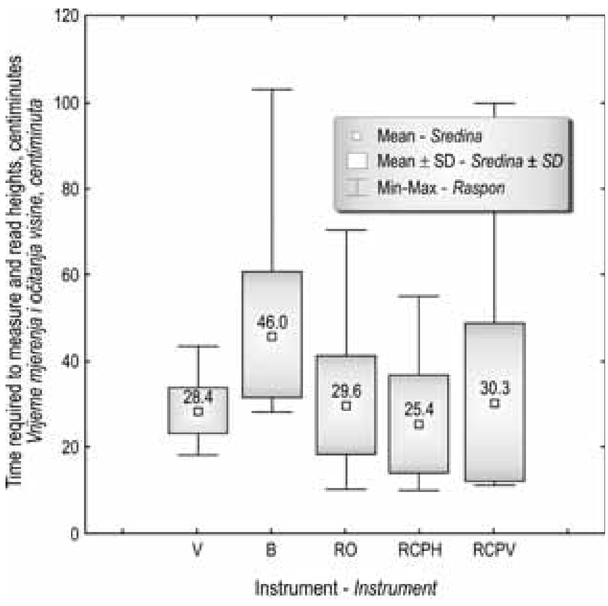

Figure 3 Times required to measure and read the heights (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or vertically /RCPV/ positioned staff)

Slika 3. *Prikaz vremenâ potrebnih za mjerenje i očitanje visine (V – Vertex; B – Blume-Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojega je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva*

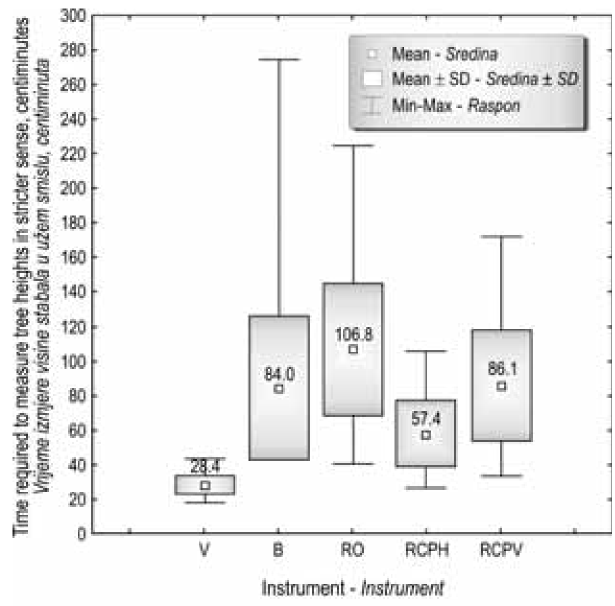

Figure 4 Times needed to measure tree heights in the stricter sense (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or the vertically /RCPV/ positioned staff)

Slika 4. *Prikaz vremenâ potrebnih za izmjeru visine stabala u užem smislu (V – Vertex; B – Blume-Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojega je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva)*

sure and read the height, a segment of the total time was obtained that relates to the use of a particular instrument, which we called the time of tree height measurement in the stricter sense. Figure 4 shows variability in the times of tree height measurement in the stricter sense. Variance analysis revealed statistically significant differences among the instruments (F = 39.56; df = 4; p <0.001). The results of Sheffe's post-hoc test are given in Table 3.

Table 3 Results of Sheffe's post-hoc test of measuring tree heights in the stricter sense obtained with different instruments (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or the vertically /RCPV/ positioned staff)

Tablica 3. *Rezultati Scheffeova post-hoc testa za izmjeru visine stabala u užem smislu između upotrijebljenih instrumenata. (V – Vertex; B – Blume-Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojega je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva)*

Instrument *Instrument*	V	B	RO	RCPH
B	**<0.001**			
RO	**<0.001**	**<0.001**		
RCPH	**<0.001**	**<0.001**	**<0.001**	
RCPV	**<0.001**	0.999	0.059	**<0.001**

Note: The *p* values in bold are statistically significant.
Napomena: *Statistički su značajne p vrijednosti u tablici podebljane.*

The total time required to measure a tree height is the sum of the times required to perform all the three measurement steps. Since the results of measuring the time needed to reach the measurement zone show no significant statistical differences (no influence of the instruments at this point), and since the share of this time in the total time depends on the distances between particular trees and terrain configuration, the results of the total time will not be presented here.

Since the arithmetic mean is under strong influence of extreme value, a median for tree height measurement in the stricter sense and its component elements was calculated as a mean that is independent of extreme values (Pranjić, 1986). The range was also calculated within which 50 % (the 25th and the 75th quartile) of all the measured values occur (Table 4).

Table 4 Medians, the 25th and the 75th quartile of the times required to measure tree heights in the stricter sense and their component elements for a particular instrument. The values are expressed in centiminutes (V – Vertex; B – Blume-Leiss; RO – Bitterlich's Spiegel Relaskop with a standard scale; Bitterlich's Spiegel Relaskop with a CP scale, with the horizontally /RCPH/ or vertically /RCPV/ positioned staff)

Tablica 4. *Medijane, 25-i i 75-i kvartil vremenâ potrebnih za izmjeru visine stabala u užem smislu i njenih sastavnica za pojedini instrument. Vrijednosti su iskazane u centiminutama. (V – Vertex; B – Blume-Leiss; RO – Bitterlichov zrcalni relaskop sa standardnom skalom; Bitterlichov zrcalni relaskop s CP skalom, kod kojeg je za određivanje horizontalne udaljenosti upotrijebljena horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljena letva)*

Instrument *Instrument*	Determining the distance to the tree *Određivanje udaljenosti do stabla*			Measuring and reading the height *Izmjera i očitanje visine*			Tree height measurement in the stricter sense *Izmjera visine stabla u užem smislu*		
	Median	Q 25	Q 75	Median	Q 25	Q 75	Median	Q 25	Q 75
V				28.5	25.0	30.0	28.5	25.0	30.0
B	23.5	16.0	47.5	43.0	36.5	51.5	70.0	59.0	92.5
RO	74.5	52.0	94.5	26.5	22.0	35.5	99.0	85.5	127.5
RCPH	29.0	22.0	41.5	24.5	15.0	34.5	52.0	42.0	71.5
RCPV	49.0	37.0	69.5	28.0	18.0	35.0	81.5	60.5	110.5

5. Discussion – *Rasprava*

The differences in times required to measure the distance to the tree for individual instruments (Figure 1) were statistically significant between the relaskop with a standard scale (RO) and the Blume-Leiss, that is, the relaskop with a CP scale (the horizontally positioned staff - RCPH). The differences between the relaskops with a CP scale, between the horizontal and vertical staff are also significant (Table 1). The arithmetic mean of the trees measured with the Blume-Leiss (37.9 centiminutes) was strongly influenced by extreme values, when the maximal time needed to determine the distance to a tree was 240 centiminutes. This is indicated by the median, which is shorter than the arithmetic mean by 14.4 centiminutes compared to other instruments in which the difference is much smaller. The reason is that in measurements with the Blume-Leiss instrument it is necessary to position oneself exactly at the referent distance and see both the top and bottom of the tree. A denser canopy and an abrupt change in the slope (the tree bottom is hidden by the terrain) may cause changes in referent distances or the positions from which the heights are measured. In such cases it is more efficient (on an inclined terrain) to choose a position from which a desired distance may be taken with no difficulty, while the height may be reduced later. With other instruments, in determining distances to the trees, the difference between the arithmetic mean and the time median was much smaller.

In determining distances, the relaskop with a standard scale took the most time due to complicated handling with the instrument and the need to set it up at an accurate distance (as in the Blume-Leiss instrument).

Determining distances with the relaskop with a CP scale was simpler because the distance was assessed from the position taken by the measurer at his arrival in the measurement zone. At the same time the top and bottom of the tree were in view and no obstacles interfered sighting at the staff (undergrowth and similar). In the vertically positioned staff the amount of time was double (statistically significantly different) in relation to the horizontal staff. The reason was that in the vertically positioned staff the measurer had to aim at the staff (top and bottom) twice and read the values, while the horizontally positioned staff required only one sighting and reading. The actual distance was calculated on the basis of the staff length (or the part being sighted) and the read (added) percentages, that is, the number of relaskop units. Since the measurement was performed by two people, the assistant had enough time to calculate the distance to the tree while the measurer was reading the tree height. For this reason, in the relaskop with a CP scale the time required to obtain the distance (percentages or relaskop units) was considered the total required time. If heights were measured by one person, the time required to calculate the actual distance would have to be added to the time needed for the reading.

The accuracy of an instrument is even more important than the speed of measurement. Investigating the applicability of the Vertex III hypsometer in relation to the most commonly used hypsometers in Croatia (also used in this research), Lukić et al. (2005) concluded that all hypsometers measured heights equally well from a known distance and that the difference in height measurements of individual trees was almost exclusively due to badly determined distances to the trees. Using the Vertex-measured distances as referent values, the highest variability in determining distances to trees was obtained with the relaskop with a CP scale, and the horizontally or vertically positioned staff. The lowest variability was obtained with the Blume-Leiss. The heights of particular trees were burdened with errors made in determining distances to trees; however, the height curves constructed for each individual instrument (they almost overlap) indicate that positive and negative errors obtained in height measurements of individual trees were annulled (Lukić et al., 2005).

Times required to measure and read the heights with particular instruments (Figure 3) differ statistically significantly between the Blume-Leiss and other instruments (Table 2) as a consequence of the absence of a viewfinder on the Blume-Leiss instrument. In newer Blume-Leiss models, sighting is made easier with the viewfinder in the form of two concentric circles. Readings with the relaskop with a CP scale and the horizontally positioned staff show the lowest mean values of time required to measure and read the height. Smaller standard deviation, smaller value range in the Vertex (Figure 3), as well as the fact that time required to measure and read heights also contains time required to determine the distance to the tree place the Vertex before the relaskops. This is even more so in view of the fact that in reading the heights with the relaskop with a CP scale the actual heights are not read but the percentages in relation to distances. The actual height must be calculated later (similarly to determining the distance to a tree). Since measurements were performed by two persons, the assistant had enough time to calculate the height of the tree while the measurer was determining the distance to the next tree. In this case, in using the relaskop with a CP scale the time needed to read the height (percentages) was considered the total required time. If heights were measured by one person, the time required to calculate the actual distance would have to be added to the time required for the reading.

Special mention should be made of the Vertex viewfinder (cross hair sight), which clearly aims at the tree top without losing sight of the tree to be measured (as is the case in mirror relaskops).

The advantage of the Vertex in relation to other instruments is especially evident in the height measurement procedure in the stricter sense (Figure 4 and Table 3). In comparison with other instruments, measuring tree heights with the Vertex took statistically significantly less time at much lower variability. Using the Vertex to measure heights, Baustian et al. (2001) shortened the time of tree height measurements in sample plots by an average of 52 % in relation to the Blume-Leiss. Since the heights in this work were not measured in sample plots, our results cannot be compared with the results of Baustian et al. In our case, the measuring time was shortened by 66 % (height measurement in the stricter sense), or 40 % (total measuring time). The shorter measurement procedure was the result of the absence of one whole measurement element (determining the distance to the tree), which was included in the element of measuring and reading the heights.

The total time required to measure tree heights was strongly affected by the time required to reach the tree measurement zone. In this work, this time varied from 39.85 % in the mirror relaskop with a metric scale to 71.83 % with the Vertex. As shown in this work, this time was not affected by the instruments used but by the distances between individual measured trees and by the configuration of the terrain. Since the trees measured in this work were relatively close to one another (about 30 metres apart), it is clear that at longer distances between the measured trees the percentage would be even higher.

6. Conclusions – *Zaključci*

Time required to reach the measuring zone was not significantly affected by the instrument but by the distance between the measured trees and the terrain configuration.

There were statistically significant differences in the times required to measure trees in the stricter sense between the instruments. The least amount of time was required by the Vertex, followed by the relaskop with a CP scale, the horizontal and the vertical staff, the Blume-Leiss and the mirror relaskop with a standard scale. These times are the result of the simplicity or complexity of the measuring procedure. Thus, the least amount of time obtained with the Vertex is the consequence of two steps being integrated in one: determining the distance to the tree and measuring and reading the height, where distance measurement was at the same time (indirectly) sighting of the tree bottom. The Vertex is equipped with a high quality viewfinder which can clearly aim at the tree top without losing sight of the tree being measured (as is the case with mirror relaskops). On the other hand, the longer times needed by different instruments were the consequence of a complex procedure of tree height measurement, which refers particularly to the element of determining distances to trees. The latter procedure can be relatively »fussy« (the Blume-Leiss and the mirror relaskop with a standard scale) and precise (small standard deviation) or quick and imprecise (the relaskop with a CP scale).

Our research showed that the Vertex, apart from being precise and accurate, was also a fast height measuring instrument (compared to other instruments), especially in the time segment affected by the instruments (height measurement in the stricter sense).

In comparison with other instruments, the disadvantage of the Vertex is its higher price. However, its speed, precision, accuracy, and simplicity, as well as the possibility of simple and fast circular plot inventories place it above all the other tested instruments.

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Sažetak

Djelotvornost ultrazvučnoga visinomjera/daljinomjera Vertex III u odnosu na najčešće upotrebljavane visinomjere u hrvatskom šumarstvu

Izmjera visina za određivanje boniteta sastojine i konstrukciju visinskih krivulja važna je sastavnica uređivanja šuma. Normama za radove u uređivanju šuma određeno je da jedan radnik, ovisno o uvjetima na terenu, može u jednodobnim sastojinama izmjeriti 110–150, a u prebornim sastojinama 100–140 visina. Pravilnik ne određuje tip visinomjera na koji se te norme odnose.

U radu je istražena djelotvornost ultrazvučnoga visinomjera/daljinomjera Vertex pri izmjeri visina stabala u odnosu na neke od najčešće upotrebljavanih visinomjera u hrvatskom šumarstvu. Cijeli je proces izmjere podijeljen u tri sastavnice: vrijeme potrebno za dolazak u zonu izmjere, vrijeme potrebno za određivanje udaljenosti do stabla i vrijeme potrebno za mjerenje i očitanje visine pojedinoga stabla. Izmjera je provedena s četiri visinomjera: Vertexom, Blume-Leissom, Bitterlichovim zrcalnim relaskopom s standardnom skalom (RO) te Bitterlichovim zrcalnim relaskopom s CP skalom (s horizontalno /RCPH/ odnosno vertikalno /RCPV/ postavljenom letvom).

Istraživanje je provedeno u odsjeku 3 b gospodarske jedinice »Sljeme«, koja se nalazi u sastavu Nastavno-pokusnoga šumskoga objekta (NPŠO) Zagreb. Istraživanja su provedena na običnoj jeli kao vrsti kod koje je izražen vrh stabla.

Na unaprijed određenim smjerovima kretanja, vodeći računa o obuhvatu različitih stanišnih prilika (nagib terena, kretanje u slojnici, niz padinu i uz nju, gustoća sastojine, pojavnost grmlja) uzet je nasumični uzorak stabala jele vodeći računa o ravnomjernoj zastupljenosti stabala u pojedinim debljinskim stupnjevima. Uzorak se sastojao od 40 obrojčanih stabala koja su radi lakšega uočavanja na terenu naizmjenično obilježena crvenim i žutim trakama.

Izmjeru su radi izbjegavanja pristranosti proveli mjeritelji (apsolventi Šumarskoga fakulteta) koji su sa svakim instrumentom imali podjednako iskustvo u izmjeri. Prije same izmjere mjeritelji su na nezavisnom uzorku dodatno uvježbali rad sa svakim instrumentom.

Izmjera je provedena tako da je najprije izmjerena visina stabala jednim instrumentom, nakon toga drugim itd.

Rezultati istraživanja pokazuju da pri vremenu potrebnome za dolazak u zonu izmjere nema statistički značajne razlike među visinomjerima. Pri izmjeri visina stabala u užem smislu (bez sastavnice dolaska u zonu izmjere) najmanje je vremena u prosjeku bilo potrebno Vertexu (28,4 cmin). Zatim slijedi relaskop s CP skalom, s *horizontalno (57,4 cmin) odnosno vertikalno postavljenom letvom (86,1 cmin), Blume-Leiss (84,0 cmin) te naposlijetku relaskop (sa standardnom skalom 106,8 cmin). Razlike između Vertexa i ostalih visinomjera statistički su značajne.*

Ukupno vrijeme potrebno za izmjeru visine stabla pod jakim je utjecajem vremena dolaska u zonu izmjere stabla. Ono u ovom radu iznosi od 39,85 % kod zrcalnoga relaskopa s metričkom skalom do 71,83 % kod Vertexa. To vrijeme, kao što je pokazano u ovom radu, nije pod utjecajem upotrebljavanih instrumenata, nego međusobne udaljenosti pojedinih mjerenih stabala i konfiguracije terena. S obzirom na to da su stabla mjerena u ovom radu bila dosta blizu jedna drugima (do 30 metara udaljena), jasno je da bi pri većim udaljenostima među mjerenim stablima taj postotak bio i veći.

Unatoč nešto višoj nabavnoj cijeni Vertexa, njegova ga brzina, preciznost, točnost i jednostavnost, kao i mogućnost jednostavnoga iskolčavanja kružnih ploha pri inventuri šuma stavljaju ispred ostalih instrumenata.

Ključne riječi: *visinomjeri, izmjera visina stabala, studij vremena, analiza varijance*

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