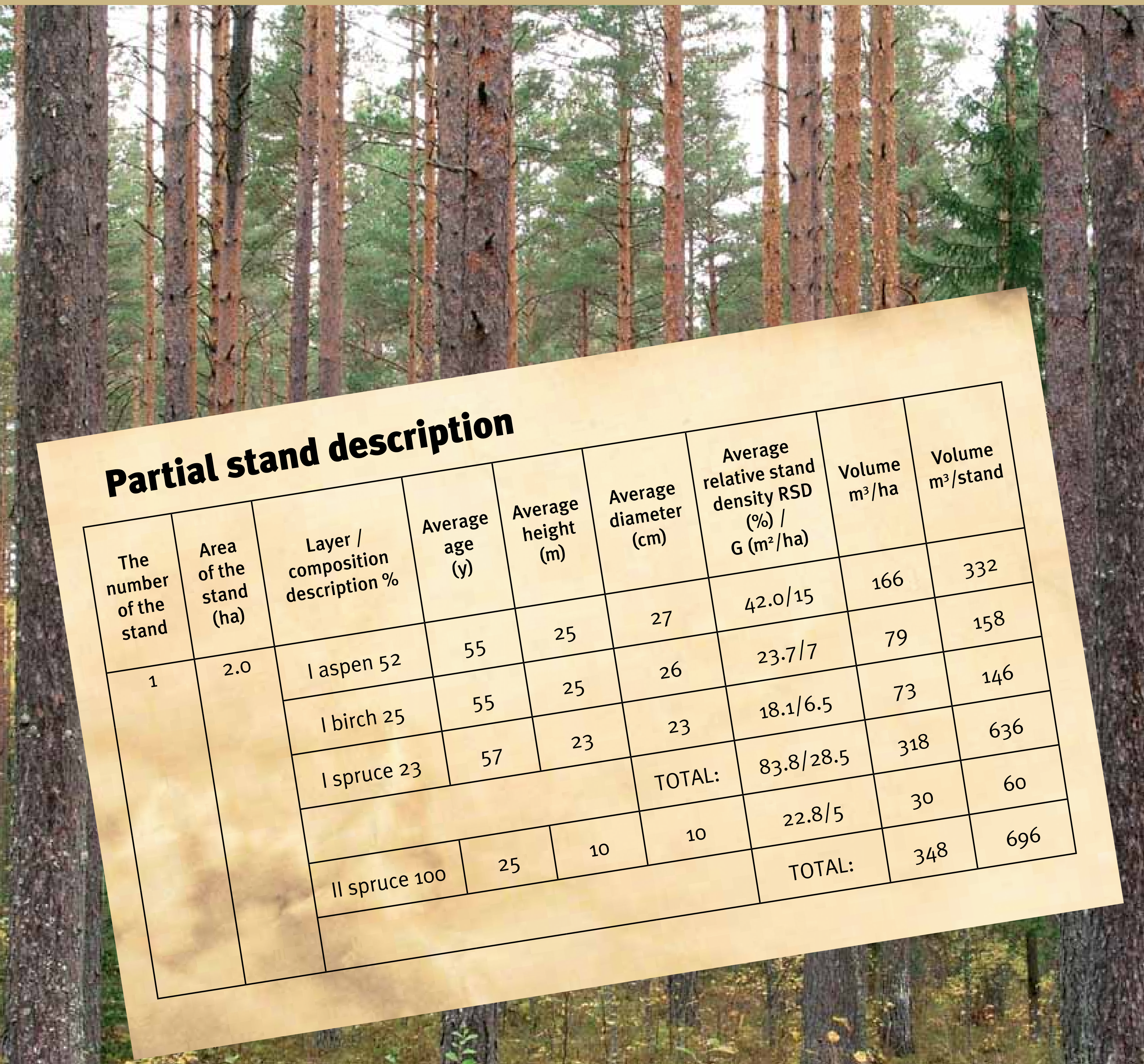
Jüri Järvis

FOREST MEASUREMENT WITH RELASCOPE

Practical description for fieldwork with examples for Estonia



Partial stand description

The number of the stand	Area of the stand (ha)	Layer / composition description %	Average age (y)	Average height (m)	Average diameter (cm)	Average relative stand density RSD (%) / G (m^2/ha)	Volume m^3/ha	Volume m^3/stand
1	2.0	I aspen 52	55	25	27	42.0/15	166	332
		I birch 25	55	25	26	23.7/7	79	158
		I spruce 23	57	23	23	18.1/6.5	73	146
					TOTAL:	83.8/28.5	318	636
		II spruce 100	25	10	10	22.8/5	30	60
						TOTAL:	348	696

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Consultants: Ahto Kangur, Allan Sims, Allar Padari, Andres Kiviste, Artur Nilson, Mart Vaus (Estonian University of Life Sciences, Institute of Forestry and Rural Engineering, Department of Forest Management);

Johannes Anniste and Peep Põntson from forest survey companies OÜ Metsabüroo and OÜ Metsaekspert respectively;

Priit Kohava (The Estonian Environment Information Centre);

Tiit Matson (from forestry consultancy company OÜ Forinfo).

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The relascope and relascope measurement was invented and introduced by Austrian forest scientist Walter Bitterlich (Bitterlich 1947, 1948). The method is widely used because it is simple, handy and quick. However, the method is less accurate when compared to cross-callipering forest measurement. It is used for the preliminary assessment of timber supply in a tree stand[1].

Simplified relascope is also called "simple relascope", "angle-counter", "angle-gauge" or "angle-template". So-called true relascope or mirror-relascope is a device that can automatically adjust its measured values according to the slope of the ground (*photo 1*).

Electronic relascope can be used instead of traditional mirror-relascope (e.g. Masser RC3, *photo 2*). Ground slope can be adjusted automatically by inserting slope angle value.

Measurement result must be adjusted when using simplified relascope on slopes with angle exceeding 8°.

Photo 1. Mirror relascope

Photo 2. Electronic relascope

Simplified relascope consists of a chain or non-stretching rope with precise length and rigid slab attached to it. The slab has one or more apertures with precise width (*photo 3*). It is also possible to create simplified relascope on one's own, provided that aperture width and chain/rope length have the greatest precision. Aperture width must remain within tolerance range of 0.1 mm and the length of the chain/rope within the range of 1 mm (Kohava 2002). Instead of a slab, a pen with round cross-section can also be used (*photo 4*). The combination of chain length and aperture size must be selected so that the chain attached to it is at least 50 cm long; otherwise the image of the aperture becomes blurred for observer's eye (*photo 9*).

Photo 3. Simplified relascope with 3 chains and 3 apertures

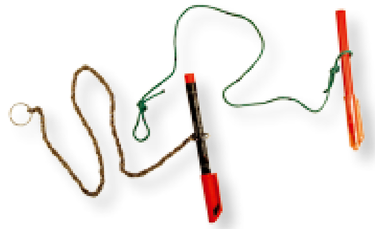

Photo 4. Self-made simplified relascopes

[1] Tree stand is a set of trees growing on one subcompartment. Subcompartment is the area in forest, outlined on the basis of similarities in forest management characteristics such as composition, height, diameter, age, or other parameters of tree species (Instruction for Forest Inventory 2009).

In case of relascope aperture-chain ratio of 1:50 the measurement result corresponds directly to the basal area of the stand (m2/ha). **Basal area of one tree** is the area of its imaginary cross-section area at the height of 1.3 m from its root collar. The trees are usually measured at the height of 1.3 m, which is also called **breast height**. **Root collar** is spot on the tree trunk where the stem passes into roots. Root collars are usually situated on the ground level, but can sometimes be remarkably higher. **Basal area of a stand** represents the sum of basal areas of all the trees growing in the stand. The basal area of a stand is usually expressed in square meters per hectare; its symbol is **'G'**.

Procedure of relascope measurement in a measurement point

1. Measurement point is a preselected point on the map and in the forest, where relascope measurement is to be performed. There must be more than one measurement point in the tree stand to be measured; otherwise the reliability of the measurements might suffer. The procedure of relascope measurement is the following: when standing in a measurement point, the measurer stands on the measurement point as exactly as possible. The chain of the relascope must be tense and straight, otherwise the distance between measurer's eye and aperture is shorter than required and the measured basal area becomes smaller. The measurer holds the end of the relascope's chain pressed against cheek underneath the eye (*photo 5*).

2. The measurer aims the relascope successively at all the surrounding stems in one stand element[2] around the measurer within the 360° range irrespective of their distance from the measurer. The tree stems must be targeted at the height of 1.3 m from root collars. Only the stems that seem larger than relascope's aperture/pens width (*photos 6 and 7*) must be counted. The slab or pen must be kept exactly perpendicular to the chain to avoid positive error.
   When counting trees in full circle, it is advisable to start counting from the nearest tree to remember from where the counting begins to avoid double-counting or missing the trees.
   If relascope with 1:50 ratio (aperture width 1 cm and chain length 50 cm) is used then the counted number of stems equals the basal area of trees in square meters per hectare (m²/ha).
   Those trees that seem to be narrower than the aperture/pen of the relascope are not counted (*photo 8*). If the measurer can not decide whether a tree is larger or narrower than aperture/pen, then he will count half of the tree or 0.5 m²/ha (*photo 9*). If higher measurement accuracy is needed, the distance to such tree from the measurement point and tree diameter at breast height (1.3 m) must be measured.
   The same ratio (1:50) is applied to define whether the tree must be counted as 1 or 0 m²/ha of basal area. For example, if the tree with the diameter of 20 cm covers the aperture at the maximum distance of 10 m (50 times the tree diameter) from relascope measurement point, then the tree is counted as 1 (m²/ha).
   A tree with a thickening at the measurement height must be measured above the thickening. Slanting stems must be measured with accordingly tilted relascope slab or pen.

Photo 5. The right holding of the relascope

Photo 6. The tree is counted as 1 (m²/ha of basal area)

[2] Stand element is a generation of a tree species in the stand with uniform growth.

3. In case of relascope measurement there is no circular sample plot because there is no certain radius. Thus these measurement points do not represent the centers of sample plots, but the centers of circular samples instead. For example, a tree with the diameter of 40 cm can be counted as 1 m²/ha at the distance of 20 meters (40 cm x 50 = 2000 cm = 20 m). If a tree has a diameter of 10 cm, then it can be counted as 1 m²/ha at the distance of just 5 meters (10 cm x 50 = 500 cm = 5 m).

Procedure of relascope measurement in a whole tree stand

1. The number of measurement points must be predetermined according to required measurement accuracy and confidence interval. In most cases confidence interval of 68% and accuracy of ±10% are used (*see tables 2 and 3*).
   In order to increase accuracy and confidence interval, the number of measurement points must be added. In case of significantly irregular allocation of trees in the forest stand it is recommended to use more measurement points than prescribed in the table. According to tables 2 and 3 the number of measurement points can be selected based on the need of accuracy and confidence interval (SMSIS Instruction for Fieldwork 2005). Pursuant to section 13 of the Instructions for Forest Inventory 2009, in case of argument arising from the measurement results it must be solved by repeating the measurement with double accuracy. This means that if the permitted error in case of the first measurement was ±15%, then it must be ±7.5% for repeated measurement.

   If higher measurement accuracy is expected, the confidence interval of 95% should be used. When confidence interval is increased from 68% to 95% or permitted error is reduced twice, the minimum number of measurement points grows four times (*tables 2 and 3*).

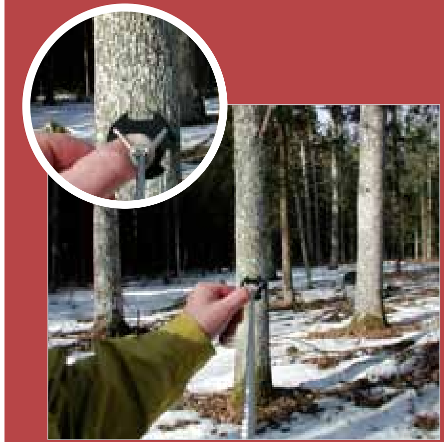

Photo 7. The tree is counted as 1 (m²/ha of basal area)

Photo 8. The tree is not counted because it seems thinner than the relascope's aperture

Photo 9. When it is difficult to decide whether the tree is seemingly thinner or thicker, 0.5 m²/ha will be counted

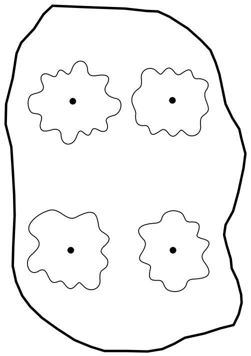

Figure 1

margin of forest stand

imaginary margin of the circle with floating radius

• measurement point

2. The number of necessary measurement points according to tables 2 and 3 must be determined when first (usually three) measurement points are measured based on gained results.
   The measurement points must be marked on the map to allow further verification. The points must be evenly distributed (*fig 1*). It is recommended to mark the measurement points to enable further control by interested parties, especially when the measurement is carried out for the purpose of determining transaction price. The points are marked with stakes inserted into the ground and marking tape attached to them. The number of forest stand and measurement point must be indicated on the marking tapes.

3. Relascope measurement must be carried out in every measurement point. Locations of measurement points must be found on the ground according to the distances shown on the map. It is necessary to measure the locations of the measurement points on the ground according to their locations on the map in order to ensure systematic positioning and even coverage of the area. It is important to use the measurement points indicated on previously prepared map to make sure that the measurement is taken randomly, and to prevent the measurer from subconsciously looking for thin areas for better visibility or easier measurement.

4. In every measurement point all the trees must be measured according to stand elements. **Stand element** is a generation of trees in the stand that has evolved evenly. Two or more stand elements can be formed by one tree species, for example, Norway spruce (*Picea abies*) can be found simultaneously in the upper and in the second canopy layer.

   The 1st layer (upper layer) is formed by the tallest trees irrespective of their species. The amount of timber volume is the highest in the upper layer. If the relative stand density (RSD) is less than 30% (also called as "relative stocking") in the upper canopy layer (see section "Method of calculation for relascope measurement"), then it is deemed as "**canopy layer of solitary trees**".

   The second layer of trees consists of trees that have 25–75% of the height of the upper layer, but are at least 4 m tall (§ 9 of the Instructions for Forest Inventory). Standing dead trees are counted as a separate stand element.

5. If the aim of the measurement is other than the determination of standing wood volume, e.g. assessment of basal area or stand density index before or after thinning, then all tree species can be counted together without distinguishing tree species.

6. In every measurement point the height and diameter at 1.3 m will be measured for one tree with estimated mean diameter in every stand element. Medium diameters and heights are easily measurable values that are necessary for later data analysis to perform rough calculation of roundwood assortment range and preparation of forest inventory report. **Forest survey report** consists in a description of forest stand parameters composed of data achieved from forest assessment or measurement. Average heights, diameters and ages of tree species are recorded in the forest inventory report.

Prevention of possible errors in relascope measurement

1. **Stems of further trees are not clearly seen due to thick understory- and natural regeneration layers** (*photo 10*). In this case relascope with larger aperture (1:35) must be used. Relascope with 50 cm long chain requires the aperture of 14.1 mm (*table 1*). When using relascope with 1:35 ratio, approximately twice as few trees can be counted from the same measurement point, compared to relascope with 1:50 ratio. Larger angle of the relascope now allows counting the trees that are closer to the measurement point. In case of relascope ratio 1:35 the number of counted trees must be multiplied by 2 and the number of measurement points used must be twice the number of measurement points indicated in tables 2 and 3.

Photo 10. Stems of further trees are not clearly seen

If the layer of bushes and smaller trees is too thick (*photo 11*) or tree crowns reach the ground, the relascope measurement cannot be used because of insufficient visibility. In this case other methods of forest measurement must be used instead.

Trees with very large diameter (over 30 cm) may remain unnoticed by the measurer because of their distance from the measurement point and even rather sparse undergrowth may be sufficient to conceal them completely.


Photo 11. Because of insufficient visibility relascope measurement can not be used

Table 1. Sizes of the apertures of relascope depending of the length of the chain (stick)

	Coefficient used in multiplication of the counting result		
	1	2	0.5
	Ratio between the aperture and the chain (stick)		
The length of the chain (stick)	1 : 50	1 : 35	1 : 71
50	10.0	14.1	7.1
70	14.0	19.8	9.9
100	20.0	28.3	14.1

Relascopes for professional use are usually made with longer chains or sticks (70 and 100 cm) and with several apertures for more convenient use (photo 3 and 15, table 1).

2. Stems of the trees are in clear view, but are sparsely located *(photo 12)* **or too thin** *(photo 13)*.


Photo 12. Sparsely located seed trees


Photo 13. Thin trees in a young stand

When using relascope with 1:50 ratio, the number of counted stems is low. Tables 2 and 3 can not be used for determination of required number of measurement points when the number of stems counted is less than 5. Low number of trees is usually counted in case of small average diameter of the trees in the tree stand. In order to increase the number of counted trees, relascope with aperture ratio 1:71 must be used as shown in *table 1*. Counted number of trees must be divided by 2 or multiplied by 0.5 to find out the basal area. Number of necessary measurement points must be determined according to tables 2 or 3, by using counted number of stems, not the calculated basal area.

3. **Improper use of relascope.** If relascope's chain or rope has stretched or unsuitable aperture is used, the measurement result will contain biased error. In order to avoid such errors, the aperture width and chain's length of the relascope must be inspected before measurement. When using relascope with only one chain or rope (*photo 14*), it is important to maintain right angle between rope and aperture plate when taking measurement, otherwise systematical error might occur. Therefore, it is easier to use relascopes with three chains (*photo 3*) or telescopic handle (*photo 15*). Relascope aperture must be chosen so that the length of rope/ chain/handle is not less than 50 cm. Objects that are closer than 50 cm are usually blurred for the human eye when simultaneously looking at the object at greater distance and vice versa (*photo 9*). The longer the aperture's distance from the observer's eye, the easier it is to compare aperture's width to the tree stem.


Photo 14. Relascopes with only one rope


Photo 15. Relascopes with telescopic handles

4. **Stems of trees remain hidden behind each other** (*photo 16*). The only instance that permits stepping aside from the measurement point is for the hidden tree. The distance from the tree that was hidden before must remain the same as it was from the measurement point. After measuring the hidden tree, the measurer must step back to the measurement point to proceed with the measurement.


Photo 16. Hidden trees from the measurer's viewpoint (from the measurement point)

Photo 17. The border of the forest stand is where the area with large trees ends. The measurement point from where the photo is taken is probably too close to the edge of the stand because the trees are thick.

Photo 18. In the middle of the photo there is the border between two stands, on the right thinned, on the left not-thinned. It is often not so easy to notice the border.

5. **The distance of the measurement point to the edge of the forest stand is too short** (*photos 17 and 18*). When measuring small or narrow stands, measurement error can occur when measurement points are too close to the margin of the stand. Sufficient distance from stand margin is 50 times of the diameter of the thickest tree in the stand (when using relascope with 1:50 ratio). For example, if the diameter of the thickest tree in the stand is 20 cm, then all measurement points must be located at the minimum distance of 10 m from the stand's margin. When using relascope with 1:35 ratio, the distance is 35 times the thickest tree diameter, when using relascope with 1:71 ratio, the distance from stand's margin is 71 times the diameter of the thickest tree.

6. **Forest stand is too narrow and it is impossible to place the measurement point to suitable distance from the stand's margin.** In this case, the measurement points must be located near the longer edges of the stand and the measurement is taken only in semicircular range (*fig 2*). For calculating measurement results the counted tree stems are multiplied by 2. Also, the number of measurement points must be twice of that indicated in tables 2 and 3. It is important to avoid measuring trees from neighboring stands. If relascope measurement is too complicated due to small size of the stand, it is recommended to use other measurement methods such as cross-callipering. Another advantage of cross-callipering method is gaining more accurate data irrespective of the size or shape of the forest stand.

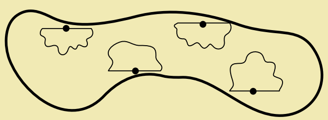

Figure 2

margin of forest stand

imaginary margin of the circle with floating radius

measurement point

7. **If the longer edge of the forest stand is adjacent to an open area like road, ditch or field, the so called edge effect will occur.** The edge effect means that due to better growth conditions, height of the trees, their diameter and number of stems per area unit differ from stand's average. Different availability of light and water is the main cause of such differences.
In order to take into account the edge effect, a proportional number of measurement points must be located near the stand edge and the measurement must be performed in semicircular ranges (*fig 3*). Proportional number means that the longer the stand edge compared to its perimeter, the more semicircular measurement points must be located near the edge.

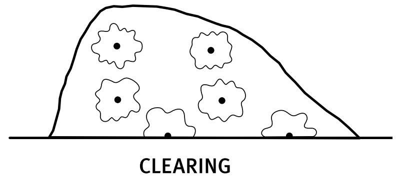

Figure 3

margin of forest stand

imaginary margin of the circle with floating radius

measurement point

8. **The exact surface area of the stand is not known.** The error of the stand size equals the error of the estimated volume of timber in the stand. The surface areas of the stands are often rounded to the accuracy of 0.1 ha. In case of small stands the error caused by rounding its area results in remarkable error in its calculated timber volume. For example if the area of the stand is 0.15 ha, but it is rounded to the nearest decimal which is 0.2 ha, then rounding causes increase of timber volume, calculated in view of stand area, by one third.

9. **Slope angle of the stand ground surface exceeds 8°.** The area of any forest stand is presented as horizontal projection. Surface slope with remarkably greater angle results in remarkable difference in its surface area and area of its horizontal projection. For that reason, it is easier and more reliable to use the original mirror relascope on slopes with higher degree. If the angle is smaller than 8°, the volume error caused by it is insignificant size. When the measurement must be conducted with higher than usual accuracy, then on slopes with angles exceeding 5°, adjustments must be made with regard to timber volume.

10. **There are hauling roads inside the forest stand.** In that case, the measurement points must be arranged randomly in relation to the hauling roads. Hauling roads are established during thinning and they can cover up to 1/5 of the surface of the stand area. Their impact on the stand's timber volume must be reflected in the measurement result. The easiest way to ensure randomly placed measurement points in relation to the hauling roads, is to place them on freely chosen lines that cut hauling roads at 45° angle.

Method of calculation for relascope measurement

Standard tables (also called “normal stand yield tables”) are used for calculating timber **volume** (V, m³) of stand elements (*table 4*). Standard tables indicate stand element’s stem volumes with bark within the area ranging from root collars to tree tops. The tables do not contain the volume of stumps and branches.

Several steps are required to calculate stand timber volume. At first the **relative stand density (RSD)** must be calculated for every stand element. Relative stand density (also called as “relative stocking”) stands for the ratio calculated by dividing stand element basal area (m²/ha) in a measurement point by the basal area indicated in standard table (m²/ha).

Relative stand density is usually expressed in percentage and thus the resulting ratio is multiplied by 100%. Basal areas are indicated in standard tables by tree species and height. Basal areas in the tables are given at RSD of 100%. The result represents the relative stand density in the measurement point and it is expressed in percentage. A stand with RSD 100% is called **normal stand**.

Division of calculated stand element relative stand density by 100% and multiplication by their corresponding normal stand volumes in the standard tables results in stand element volumes in solid cubic meters per hectare.

Timber volume of a stand is expressed in solid cubic meters per hectare (m³/ha) or in solid cubic meters per stand (m³/stand). For calculating timber volume per stand, the volume per hectare is multiplied by its area in hectares.

Example 1

There are three tree species growing in the first measurement point: aspen, birch and spruce. They form four stand elements: 1st layer of aspen; 1st layer of birch; 1st layer of spruce and 2nd layer of spruce. Basal areas and heights of every stand element are measured. NB! In current example the calculation is shown only for birch stand element, but the calculations should be repeated for all four stand elements.

Basal area of birch is measured by means of 1:50 relascope. Counted number of stems within 360° range was 9, thus the basal area G is 9 m²/ha. Also the height of a nearby birch tree having estimably mean diameter must be measured. The height of the birch tree is 25 meters. In standard table the birch column and the row corresponding to the height of 25 meters must be chosen.

Extract from the standard table

Height (m)	Birch and lime tree	
	Volume	The basal area at the RSD of 100% ($G_{100\%}$) m²/ha
24	323	29.2
25	344	30.0
26	365	30.7

In order to find relative stand density (RSD) for the stand element, the measured 9 m²/ha must be divided by 25 m high birch normal stand basal area (it is marked $G_{100\%}$). In standard tables, the value for birch $G_{100\%}$ is 30.0 m²/ha. SDI_{birch} = 9 / 30.0 = 0.3. To calculate its value in percentage, it must be multiplied by 100%. SDI_{birch} = 0.3 x 100% = 30%.

The volume of the birch stand element per hectare (V_{ha}) is calculated by dividing its relative stand density (RSD_{birch} = 30%) by 100%, resulting in 0.3. The result (0.3) must be multiplied by the volume of the stand element of normal stand at the relative stand density of 100% ($V_{100\%}$), i.e. 344 m³/ha. The result is 103.2 m³/ha. $V_{birch/ha}$ = 30% x 344 / 100% = 103.2 m³/ha.

NB! When counting tree stems by means of relascope, it is crucial to be careful, because every counted tree corresponds to several cubic meters per hectare. In current example, one counted tree corresponds to 11.5 m³/ha.

This counting procedure is repeated with every stand element in every measurement point. It is followed by the calculation of the average relative stand density and average roundwood volume per hectare for every stand element (*see Example 2*).

Example 2

Average timber volumes and stand element densities calculated on the basis of the data gained from all measurement points in the stand[3].

Birch stand element

The number of the measurement point in the stand	Number of trees counted with the relascope	Basal area G (m²/ha); when using the relascope 1:50 the value equals to the number of trees counted	The diameter of the estimated average tree near the measurement point (cm)	The height of the estimated average tree near the measurement point (m)	The basal area based on the standard table according to the height at the relative stand density of 100% i.e. $G_{100\%}$ (m²/ha)	Stand element's relative stand density (calculated on the basis of standard tables); RSD = G / $G_{100\%}$ x 100%	Volume on the basis of standard tables at SDI = 100% i.e. $V_{100\%}$ (m³/ha)	Volume per hectare V_{ha} (calculated on the basis of standard tables); V_{ha} = RSD / 100% x $V_{100\%}$ (m³/ha)	Age A (years)
1	9	9	26	25	30.0	30.0	344	103	55
2	15	15	25	23	28.3	53.0	302	160	57
3	3	3	25	27	31.5	9.5	386	37	53
4	0	0	–	–	0	0	0	0	–
5	8	8	27	26	30.7	26.1	365	95	54
AVERAGE VALUES OF THE STAND ELEMENT		G_{birch} = 7 m²/ha	Average diameter D_{birch} = 25.75 cm	Average height H = 25.25 m		RSD_{birch} = 23.7 %		V_{birch} = 79 m³/ha	Average age A_{birch} = 55 years

The average density of the birch stand element is RSD_{birch} = (30.0 + 53.0 + 9.5 + 0 + 26.1) / 5 = 23.7%.

[3] This particular example includes a remarkably unevenly distributed stand that was deliberately chosen due to the wide variation in its range of characteristics, in order to show the calculation principles more clearly. If the variation in the characteristics of a stand exceeds standard guidelines, then different parts of the forest area are usually described as different stands, provided that they are large enough (0.1 ha for example).

The average volume of the birch stand element V = (103 + 160 + 37 + 0 + 95) / 5 = 79 m³/ha.
NB! In this example no birches were counted in the 4th measurement point. That means there were no birches near the 4th measurement point. However, the 4th measurement point must be taken into account in volume and basal area calculation because it represents 1/5 of the surface area of the stand. Hence, in computational terms, there are no birches in 1/5 of the stand area.

It is not recommended to calculate average volume for hectare based on average basal area and average height. This has frequently provided less accurate results, because the heights of the stand element may vary remarkably in different measurement points. Average volume of stand element must be calculated based on the timber volumes of all measurement points.

Average diameter of the birch stand element D = (26 + 25 + 25 +27) / 4 = 25.75 cm ≈ 26 cm.
Average height of the birch stand element H = (25 + 23 + 27 + 26) / 4 = 25.25 m ≈ 26 m.
Average age of the birch stand element A = (55 + 57 + 53 + 54) / 4 = 54.75 ≈ 55 years.

Despite having 5 measurement points, the average diameter D, height H and age A must be divided by 4 due to the fact that birches were found only in 4 measurement points out of 5.
In order to get timber volume for the whole stand, resulting volume per hectare is multiplied by the surface area of the stand. For example, if the surface area is 2 hectares, then the timber volume of the birch stand element in the stand is $V_{\text{birch in stand}}$ = 2 x 79 = 158 m³/ stand.

NB! If the basal area is determined at the accuracy of ±10%, then the roundwood volume determined based on standard tables may show greater variation. The reason for that lies in the nature of standard tables. In standard table the 100% volume of a tree species ($V_{100\%}$) is given as an average volume of the pure species stands in that particular geographical region. In every single stand in this region the stem forms and hence the stem volumes may vary significantly from the average. Stem forms may vary even more across different regions, which makes them region-specific.

That is also the reason why timber volumes gained by relascope measurement and harvester measurement usually vary from each other. The most accurate stand's timber measurement method is the harvester measurement, provided that it has been carried out properly.

In case of two layers of the same species in a stand the basal areas, densities, average diameters, heights, ages and volumes are provided separately per layer for the species.

Based on the volume of stand elements, stand elements percentage in the (canopy) layers is calculated and it is called **"layer composition percent"**.

Layer composition percent is a ratio expressed in percentage, indicating the ratio of timber volume in one stand element to gross timber volume in the same stand layer. Therefore, the gross timber volume of the layer, consisting of all the stand elements, is deemed as 100%. Layer composition percents are rounded to full percentages.

Based on layer composition percents of the species forming the layer, the **layer composition description** is written as follows: "1st layer: 52% aspen, 25% birch, 23% spruce".

2nd layer: 100% spruce.

Based on collected information, the stand description can be composed, which is similar to standwise forest inventory report. The report usually provides additional descriptive characteristics, such as site quality index, forest site type, annual growth rate, etc.

Example 3. Partial stand description

The number of the stand	Area of the stand (ha)	Layer / composition description %	Average age (y)	Average height (m)	Average diameter (cm)	Average relative stand density RSD (%) / G (m²/ha)	Volume m³/ha	Volume m³/stand
1	2.0	I aspen 52	55	25	27	42.0/15	166	332
		I birch 25	55	25	26	23.7/7	79	158
		I spruce 23	57	23	23	18.1/6.5	73	146
					TOTAL:	83.8/28.5	318	636
		II spruce 100	25	10	10	22.8/5	30	60
						TOTAL:	348	696

NB! The data in example 2 are mostly rounded to integers. Data describing other stand elements is retrieved from similar tables, but they are not included in this example.

NB! The volume in the table is indicated in full numbers without decimal points. With relascope measurement there is always an error in the results, which may sometimes reach from a few to dozens of percents, hence there is no need to use decimals in the volume values and calculated volumes simply represent the most probable values.

The goal of the relascope measurement may be other than the determination of the volume of timber in a stand. For example, measurement of basal area can be performed in order to plan thinning. Relascope measurement can also be carried out for the purpose of controlling the compliance of thinning with the prescribed rules. In these cases, it may be appropriate to count all tree stems together to get only stand layer's basal area. The relative stand density must then be calculated from the standard tables based only on tree species that have the highest estimated volume in the stand. Also, the height of the stand must correspond to the height of the dominant species (by timber volume).

Based on the volume of the tree species it is possible to estimate the approximate price of the stand. For that purpose, the timber volume must be divided into an assortment of round timber. For dividing the calculated timber amount into round timber assortment, it is advisable to use distribution tables (-formulas) of model trees. When choosing a model tree for timber division from distribution tables, it must have an average diameter and height of the stand element.

For calculation of the stand's monetary value, the costs of cutting, hauling and transportation of the timber must be subtracted from timber market value.

*Table 2. The minimum number of sample points that must be taken for measuring the basal area for the relascope ratio 1:50 at given **absolute error***
Reliability 95%

G_{error} (m^2/ha)	G (m^2/ha) – is found for the stand according to the first measurement in the stand																																							
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1.0	19	23	27	31	35	38	42	46	50	54	58	61	65	69	73	77	81	85	88	92	96	100	104	108	111	115	119	123	127	131	134	138	142	146	150	154	158	161	165	169	173
1.5	9	10	12	14	15	17	19	20	22	24	26	27	29	31	32	34	36	38	39	41	43	44	46	48	50	51	53	55	56	58	60	61	63	65	67	68	70	72	73	75	77
2.0	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	36	37	38	39	40	41	42	43
2.5	3	4	4	5	6	6	7	7	8	9	9	10	10	11	12	12	13	14	14	15	15	16	17	17	18	18	19	20	20	21	22	22	23	23	24	25	25	26	26	27	28
3.0	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	12	13	13	14	14	15	15	15	16	16	17	17	18	18	18	19	19
3.5	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	8	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	13	14	14
4.0			2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	11	11
4.5				2	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9
5.0						2	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7
5.5								2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6
6.0											2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5
6.5													2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
7.0																2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4

Reliability 68%

G_{error} (m^2/ha)	G (m^2/ha) – is found for the stand according to the first measurement in the stand																																							
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1.0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1.5	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	11	11	11	12	12	13	13	14	14	15	15	15	16	16	17	17	18	18	18	19	19	20
2.0			2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10	11	11	11
2.5						2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7
3.0										2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5
3.5															2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
4.0																					2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3
4.5																											2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5.0																																		2	2	2	2	2	2	2	2

For the relascope ratio 1:35 twice as many measurement points must be taken as shown in the tables. For the relascope ratio 1:71 the same amount of measurement points must be taken as shown in the tables.
When finding necessary number of the measurement points for both the relascope ratios 1:35 and 1:71, the relascope's counting result must be used instead of the basal area.

*Table 3. The minimum number of sample points that must be taken for measuring the basal area for the relascope ratio 1:50 at given **relative error***
Reliablity 95%

G_{error} (%)	G (m^2/ha) – is found for the stand according to the first measurement in the stand																																							
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
5.0	307	256	220	192	171	154	140	128	118	110	102	96	90	85	81	77	73	70	67	64	61	59	57	55	53	51	50	48	47	45	44	43	42	40	39	38	37	37	36	35	34
6.0	213	178	152	133	119	107	97	89	82	76	71	67	63	59	56	53	51	49	46	44	43	41	40	38	37	36	34	33	32	31	30	30	29	28	27	27	26	25	25	24	24
7.0	157	131	112	98	87	78	71	65	60	56	52	49	46	44	41	39	37	36	34	33	31	30	29	28	27	26	25	24	24	23	22	22	21	21	20	20	19	19	18	18	17
7.5	137	114	98	85	76	68	62	57	53	49	46	43	40	38	36	34	33	31	30	28	27	26	25	24	24	23	22	21	21	20	20	19	18	18	18	17	17	16	16	16	15
8.0	120	100	86	75	67	60	55	50	46	43	40	38	35	33	32	30	29	27	26	25	24	23	22	21	21	20	19	19	18	18	17	17	16	16	15	15	15	14	14	14	13
9.0	95	79	68	59	53	47	43	40	36	34	32	30	28	26	25	24	23	22	21	20	19	18	18	17	16	16	15	15	14	14	14	13	13	12	12	12	12	11	11	11	11
10.0	77	64	55	48	43	38	35	32	30	27	26	24	23	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	12	11	11	11	10	10	10	10	9	9	9	9	9
11.0	63	53	45	40	35	32	29	26	24	23	21	20	19	18	17	16	15	14	14	13	13	12	12	11	11	11	10	10	10	9	9	9	9	8	8	8	8	8	7	7	7
12.0	53	44	38	33	30	27	24	22	21	19	18	17	16	15	14	13	13	12	12	11	11	10	10	10	9	9	9	8	8	8	8	7	7	7	7	7	7	6	6	6	6
13.0	45	38	32	28	25	23	21	19	17	16	15	14	13	13	12	11	11	10	10	9	9	9	8	8	8	8	7	7	7	7	6	6	6	6	6	6	6	5	5	5	5
14.0	39	33	28	24	22	20	18	16	15	14	13	12	12	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6	6	6	5	5	5	5	5	5	5	5	4	4
15.0	34	28	24	21	19	17	16	14	13	12	11	11	10	9	9	9	8	8	7	7	7	7	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	4	4	4
16.0	30	25	21	19	17	15	14	13	12	11	10	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	3	3	3
17.0	27	22	19	17	15	13	12	11	10	9	9	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3
18.0	24	20	17	15	13	12	11	10	9	8	8	7	7	7	6	6	6	5	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3
19.0	21	18	15	13	12	11	10	9	8	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2
20.0	19	16	14	12	11	10	9	8	7	7	6	6	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2
21.0	17	15	12	11	10	9	8	7	7	6	6	5	5	5	5	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
22.0	16	13	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
23.0	15	12	10	9	8	7	7	6	6	5	5	5	4	4	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
24.0	13	11	10	8	7	7	6	6	5	5	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
25.0	12	10	9	8	7	6	6	5	5	4	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2					

Reliability 68%

G_{error} (%)	G (m^2/ha) – is found for the stand according to the first measurement in the stand																																							
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
5.0	79	66	57	49	44	40	36	33	30	28	26	25	23	22	21	20	19	18	17	16	16	15	15	14	14	13	13	12	12	12	11	11	11	10	10	10	10	9	9	9	9
6.0	55	46	39	34	31	27	25	23	21	20	18	17	16	15	14	14	13	12	12	11	11	11	10	10	9	9	9	9	8	8	8	8	7	7	7	7	7	7	6	6	6
7.0	40	34	29	25	22	20	18	17	16	14	13	13	12	11	11	10	10	9	9	8	8	8	7	7	7	7	7	6	6	6	6	6	5	5	5	5	5	5	5	5	4
7.5	35	29	25	22	20	18	16	15	14	13	12	11	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	5	5	5	4	4	4	4	4	4
8.0	31	26	22	19	17	15	14	13	12	11	10	10	9	9	8	8	7	7	7	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	3
9.0	24	20	17	15	14	12	11	10	9	9	8	8	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3
10.0	20	16	14	12	11	10	9	8	8	7	7	6	6	5	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2
11.0	16	14	12	10	9	8	7	7	6	6	5	5	5	5	4	4	4	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
12.0	14	11	10	9	8	7	6	6	5	5	5	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
13.0	12	10	8	7	7	6	5	5	5	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2						
14.0	10	8	7	6	6	5	5	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2												
15.0	9	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2																
16.0	8	6	6	5	4	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2	2																				
17.0	7	6	5	4	4	3	3	3	3	2	2	2	2	2	2	2	2	2																							
18.0	6	5	4	4	3	3	3	3	2	2	2	2	2	2	2	2																									
19.0	5	5	4	3	3	3	2	2	2	2	2	2	2	2																											
20.0	5	4	4	3	3	2	2	2	2	2	2	2																													

For the relascope ratio 1:35 twice as many measurement points must be taken as shown in the tables. For the relascope ratio 1:71 the same amount of measurement points must be taken as shown in the tables.
When finding necessary number of the measurement points for both the relascope ratios 1:35 and 1:71, the relascope's counting result must be used instead of the basal area.

Table 4. The standard table (normal stand yield table)
The volume of timber in the forest stand V (m^3/ha) and the basal area G (m^2/ha) at the relative stand density of 100% according to the stand average height H (m)

Height (m)	Scots pine (*Pinus sylvestris*), other pine and larch species		Norway spruce (*Picea abies*), fir species, Douglas fir		Silver birch (*Betula pendula*), small-leaved lime (*Tilia cordata*)		European aspen (*Populus tremula*), black alder (*Alnus glutinosa*), grey alder (*Alnus incana*)		English oak (*Quercus robur*), European ash (*Fraxinus excelsior*), Norway maple (*Acer platanoides*), Scots elm (*Ulmus glabra*), European white elm (*Ulmus laevis*)	
	Volume $V_{100\%\ ha}$	Basal area $G_{100\%\ ha}$	Volume $V_{100\%\ ha}$	Basal area $G_{100\%\ ha}$	Volume $V_{100\%\ ha}$	Basal area $G_{100\%\ ha}$	Volume $V_{100\%\ ha}$	Basal area $G_{100\%\ ha}$	Volume $V_{100\%\ ha}$	Basal area $G_{100\%\ ha}$
6	84	18.9	69	15.8	53	12.2	56	14.2	49	13.1
7	102	21.3	85	17.5	59	13.1	64	15.4	60	14.4
8	119	23.3	101	19.1	67	14.1	74	16.7	72	15.7
9	137	25.0	117	20.5	76	15.1	86	17.8	85	16.9
10	155	26.5	134	21.9	86	16.1	98	19.0	99	18.1
11	173	27.8	152	23.2	97	17.1	112	20.2	113	19.2
12	190	28.9	170	24.5	110	18.1	126	21.4	128	20.3
13	208	29.9	188	25.7	123	19.1	142	22.6	143	21.4
14	225	30.8	207	26.8	138	20.1	159	23.7	160	22.5
15	243	31.6	226	27.9	153	21.0	177	24.9	176	23.5
16	260	32.3	246	29.0	170	22.0	195	26.0	194	24.5
17	278	32.9	267	30.0	187	23.0	215	27.1	212	25.5
18	295	33,5	288	31.0	205	23.9	235	28.2	230	26.5
19	313	34,0	310	32.0	223	24.8	256	29.3	249	27.4
20	330	34.4	332	33.0	242	25.7	278	30.4	269	28.4
21	347	34.9	355	34.0	262	26.6	301	31.5	289	29.3
22	364	35.2	379	34.9	282	27.5	324	32.6	310	30.2
23	381	35.6	403	35.9	302	28.3	348	33.6	331	31.1
24	398	35.9	428	36.8	323	29.2	372	34.6	353	32.0
25	415	36.3	454	37.7	344	30.0	397	35.7	375	32.8
26	432	36,6	480	38.6	365	30.7	422	36.7	397	33.7
27	449	36.8	507	39.5	386	31.5	448	37.7	420	34.5
28	466	37.1	535	40.4	408	32.2	474	38.7	444	35.4
29	483	37.4	564	41.3	429	33.0	500	39.6	467	36.2
30	499	37.7	594	42.2	450	33.7	527	40.6	491	37.0
31	516	37.9	624	43.1	471	34.3	554	41.5	516	37.7
32	533	38.2	655	44.0	492	35.0	580	42.5	541	38.5
33	549	38.5	687	44.8	512	35.6	608	43.4	566	39.3
34	565	38.8	720	45.7	532	36.2	635	44.3	591	40.0
35	582	39.0	754	46.6	552	36.7	662	45.2	617	40.7

The standard tables contain timber volumes with bark starting from root collars until tree tops, but do not contain volumes of the branches, roots and stump parts that remain beneath the root collars.

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