DENDROMETER III instruction manual

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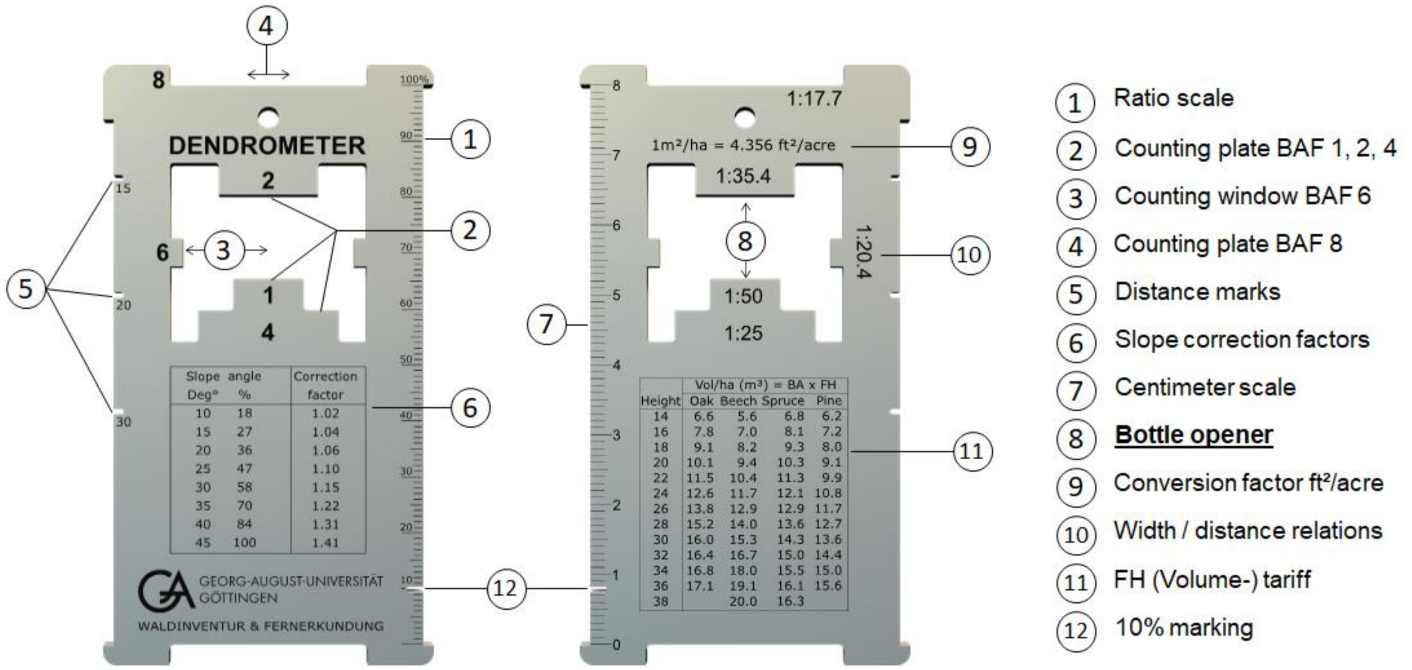

Figure 1. Front- and backside of the Dendrometer III.

1 Description of the Dendrometer

The Dendrometer III (from 2024) is a further development of the Dendrometer II, which was developed in the early 1980s by Prof. Dr. Horst Kramer at today's Chair of Forest Inventory and Remote Sensing at the University of Göttingen [1]. The main application of the Dendrometer is the estimation of stand basal area (BA/ha) according to the principle of angle count plots (according to Bitterlich "angle count sampling" = *ACS*) introduced by Walter Bitterlich in 1947/48 [2,3]. The "Göttingen bottle opener", once developed as an inexpensive device for students and for use in research projects, has proven over the last 40 years a useful pocket tool for many forestry and ecological applications. The new version of the Dendrometer is intended to continue the long tradition of this tool at the University of Göttingen's Faculty of Forest Science and Forest Ecology.

2 Measurements with the Dendrometer

Most of the measurements that can be made with the Dendrometer are based on the intercept theorem or simple geometric principles. To carry out measurements with defined ratio scales (e.g. angle count plots), the Dendrometer is held at a fixed distance from the eye (50 cm). An adjustable cord stopper is provided for this purpose, which must be held directly next to the eye during measurements. For some other measurements, variable distances from the eye are possible. Users of the device should test themselves before use, e.g. by aiming at a boundary tree of the *ACS* from the measured tree individual critical distance (see 0).

2.1 Measurement of tree height

Due to its small size, the Dendrometer is of limited suitability for the measurement of heights for very tall trees, but an estimate can still be made. Height measurements are based on the geometric principle, for which a distance measurement is not required. The ratio scale used for this purpose is a miniature version of the well-known Christen hypsometer, which is based on the same principle.

> See Figure 2!

1. *find a position from which the top of the tree and the base of the trunk can be clearly seen (preferably 1 - 1.5 tree lengths away),*
2. *change the distance to the tree and/or the distance between the eye and the Dendrometer so that the tree fits completely into the right-hand recess (ratio scale),*
3. ***Option 1:*** *Read the relative height of a reference height previously measured and marked on the tree (e.g. 2m). The tree height results from: reference height / relative height read off.*
4. ***Option 2:*** *Note the position of the point that is aimed at over the 10% scale mark on the trunk and measure this height on the tree (then multiply the measurement by 10).*

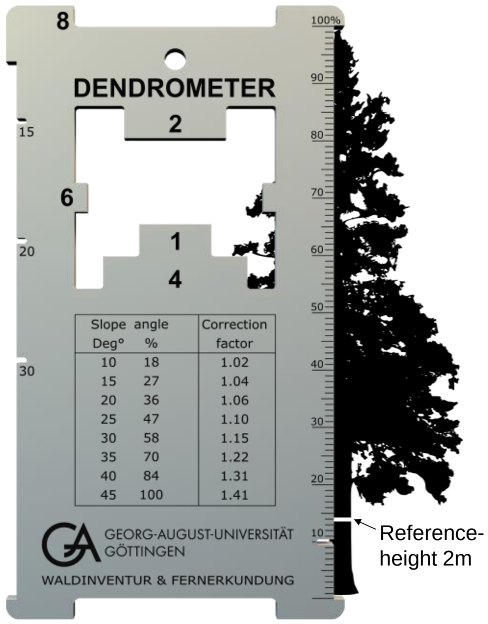

Figure 2. A measured reference height of 2m marked on the tree relates to 14% of the total tree height. Tree height is 2m / 0.14 = 14.3m. Observe the note on scale reading!

Note: Due to the small distance between the Dendrometer and the eye, it may be difficult or impossible to focus or read the scale directly. In this case, a "pointer" (e.g. thin branch) helps to first mark the scale value on the scale and read it of afterwards.

Tip: A longer reference base (e.g. 4 m high) can be used for large trees. The total tree height can also be divided into partial heights by first measuring the relative height of a visible reference point at a lower height (e.g. crown base or branch) from a greater distance. The height of this reference point can then be determined from a shorter distance. In this case, the two relative height readings must be multiplied.

Example: from a greater distance, the relative height of a prominent point on the trunk is read at 35% (0.35). From a shorter distance, the height up to this point is fitted into the ratio scale and the relative height of a marker attached to the tree at a height of 2m is read as 27% (0.27). The total height of the tree then results from 2m / (0.35*0.27) = 21.1m.

2.2 Distance measurement

There are three markings on the left-hand side of the Dendrometer which can be used to estimate fixed distances (15, 20, 30m).

1. *place a 2 m-high reference rod (e.g. ranging rod) at the tree (or mark the height on the trunk),*
2. *hold the Dendrometer vertically at a distance of 50 cm from the eye (cord stopper),*
3. *change your distance to the tree so that the lower end of the reference (or the base of the trunk) coincides with the lower edge of the scale and the upper end with the upper end of the reference rod or the respective marking on the trunk with the respective distance marking.*

Note: The accuracy of this measurement should not be overestimated, but it may be better than using a step measure. The distance to the tree can be used together with angle measurements to the top and base of the trunk to calculate the height (e.g. with smartphone apps and or with the aid of a clinometer). It is advisable to take a few test measurements from a known reference distance to get a feel for the accuracy or the view on the reference pole.

2.3 Estimation of stand basal area

The main application of the Dendrometer is the estimation of the stand basal area (m²/ha) on the basis of the angle count plots (*ACS*) as proposed by Walter Bitterlich [2]. Trees around a sample point are included in the sample with a probability proportional to their basal area (trunk cross-sectional area at a height of 1.3 m). The maximum distance of a tree corresponds to a fixed multiple (c) of its *DBH* (see Table 1). Before carrying out the *ACS*, it must be clarified which basal area factor (*BAF*) is to be used (see 2.6).

> See figure 3!

1. *hold the Dendrometer vertically at a distance of 50 cm from the eye (cord stopper),*
2. *in a 360 degrees rotation on the sample point, count all trees whose diameter (aim at a height of 1.3m!) appears wider than the selected basal area factor (BAF),*
3. *boundary trees whose DBH appears to be exactly as wide as the BAF are either counted as ½ or checked more precisely to see whether they belong to the sample (see 2.4),*
4. *multiply the number of the such counted trees by the BAF used to obtain the stand basal area (m²/ha) (take 2.5 and 2.7 into account).*

Note: omitting trees during the *ACS* leads to an underestimation of stand basal area. It is therefore necessary to check whether trees are obscured, particularly behind larger trees that are close to the sampling point. To do this, take a step to the side (without changing the distance in the direction of view) and check whether any other previously obscured trees need to be recorded! If trunks at a height of 1.3 m are covered by other vegetation, they can also be targeted at a greater height. If a tree targeted, for example, at a trunk height of 4m is in the sample, it is also in the sample if targeted at a height of 1.3m. However, exclusion in the other direction does not work: if the trunk appears slightly narrower than the counting plate at a height of 4m, the tree may well be part of the sample when targeted at a height of 1.3m.

2.4 Checking of border trees

If the diameter of a tree appears to be exactly as wide as the counting factor, the sample point is on the edge of its inclusion zone (= the tree is on the edge of its individual sample plot). Since the maximum distance (= radius if its plot) of the tree is a fixed multiple of its *DBH* for a given *BAF*, it must be checked whether the tree is in or not (see Table 1).

A B C

Figure 3. Angle count with BAF 1: A is a counted tree; B is outside and C is a border tree.

To check whether a questionable tree is in or out:

1. *measure the tree diameter at 1.3m height (<u>as seen from the sample point</u>, not necessarily along the definition of measuring DBH!),*
2. *measure the distance of the tree (since a subsequent general slope correction is carried out, the slope distance),*
3. *the tree is counted if its distance is less than or equal to the corresponding multiple c of its DBH (or its DBH is greater than or equal to 1:c of its distance). If the tree is further away (or its DBH is too small), it is not counted.*

Table 1. Width-to-distance relation (1:c) of the corresponding BAF and constants a for the calculation of tree density (number of trees per hectare) follwing: $N/ha_i = a*DBH_i^{-2}$.

BAF	*1:c*	*a*
1	1:50	12732
2	1:35.4	25465
4	1:25	50930
6	1:20.4	76394
8	1:17.7	101859

2.5 Slope correction

Like all other area-related characteristics, the stand basal area (m²/ha) refers to the horizontal map plane. If an *ACS* is carried out on a slope, the result must be corrected to the smaller horizontal reference area.

1. *measure the mean slope angle α (in degrees) at the sample point (if indicated, as a mean value of two measurements up and down the slope)*
2. *multiply the result of the ACS by the correction factor 1/cos(α)!*

A table with correction factors for certain slope angles can be found on the front of the Dendrometer.

2.6 About the choice of basal area factor (*BAF*)

When selecting the basal area factor (*BAF*) to be used (which determines tree individual plot sizes), the visibility in the stand and the targeted average number of trees counted per sampling point should be taken into account. A small *BAF* (1) leads to large tree-individual sample plots and large trees can be far away (and possibly not visible). Large *BAF*s (6 or 8) are mainly for use in densely stocked forests with large trees (e.g. tropics/subtropics). *BAF* 1 would be suitable for stands with small medium tree dimensions but good visibility. *BAF* 2 or 4 are often a good compromise for typically stocked commercial forests.

Table 2 provides an overview of the resulting plot radii or maximum distance of the trees (from *c*DBH/100*) depending on the *BAF* and *DBH* and helps to identify an appropriate *BAF*, considering the visibility in the stand. At the same time, it should be taken into account that the average number of trees counted per *ACS* is not too low (at best 10-15).

Table 2. Plot radii or maximum distance in meter depending on BAF and DBH (cm).

DBH	*BAF*				
	1	2	4	6	8
10	5	3.54	2.5	2.04	1.77
20	10	7.07	5.0	4.08	3.54
30	15	10.61	7.5	6.12	5.30
50	25	17.68	12.5	10.21	8.84
70	35	24.75	17.5	14.29	12.37
90	45	31.82	22.5	18.37	15.91
110	55	38.89	27.5	22.45	19.45

Note: the estimation of the mean stand basal area from several *ACS* is unbiased even if locally different *BAF*s were used (e.g. a mixture of sampling points with *BAF* 2 and 4). However, since the samples in this case were drawn from populations of differently sized plots, the use of a corresponding estimator (stratified sampling or estimation of a weighted error variance) is necessary to estimate the standard error!

2.7 Plots at the forest edge

If a selected sample point is close to the edge of the area to be described, this can lead to a distortion (restriction) of the inclusion probability of trees close to the boundary. An edge correction is necessary if the distance of a tree to the edge of the stand is less than the maximum distance up to which it is included in an *ACS* (see 2.4). Different correction methods are possible.

The mirage method:

1. *first carry out the ACS inside the stand, then*
2. *measure the shortest distance from the sample point to the edge of the stand (or an imaginary boundary line) and extend this distance outwards by the same amount,*
3. *from the temporary mirror point determined in this way, carry out another ACS and add the repeatedly enclosed trees to the first result.*

The "walkthrough" method [5]:

If it is not possible to step out of the stand (e.g. water surface), then

1. *for all trees in the line of sight (from the sample point) towards the edge of the stand, measure their distance from the sample point and extend this distance by the same amount,*
2. *if the end point is inside the stand, the trees are counted once; if the point is outside, they are counted twice.*

Note: Shifting of selected sample points at the edge of the stand (e.g. shifting them away from the boundary) is not correct from a statistical point of view and leads to a bias, as the specific conditions at the edge of the stand are not adequately taken into account!

3 Estimation of stand volume

On the back of the Dendrometer there is a form height table [4] for the most important economic tree species in Germany. A rough estimate of the standing volume (m²/ha) is obtained by multiplying the measured basal area by the stand form height factor corresponding to the average stand height. Therefore, an average stand height must be measured or estimated for application. The volume results from $V = BA/ha*FH$.

4 Estimation of tree density (trees/ha)

Performing the WZP allows a direct estimation of the stand basal area by just counting the included trees (and multiplying with *BAF*). Since the inclusion probability is proportional to the basal area of the trees (and does not refer to a uniform plot area), the estimation of the number of trees per unit area (*N/ha*) requires additional measurements on the included trees:

1. *for each included tree i, measure its DBH and calculate its cross-sectional area in m² as $g_i(m^2) = \pi/4*(DBH_i / 100)^2$,*
2. *calculate the number of trees/ha that each tree represents as BAF/gi,*
3. *sum the number of stems/ha over all trees of the ACS to obtain an overall result.*

Note: alternatively, the tree individual expansion factor can also be calculated from the size of the respective plot area: *$N/ha_i = 10.000 / \pi\, c^2\, BHD_i^2$. A transformation of this formulation is also given in Table 1.*

5 Mean tree diameter or diameter of mean basal area

The average diameter of the trees in a stand is calculated as a weighted mean, where the weighting factor of each DBH results from its stem number proportion. In forest planning, the average diameter of the trees is of lesser interest, but the diameter of the mean basal area D_g (quadratic mean diameter) is important in forest management (e.g. when dealing with yield models). For this purpose, the diameter of the mean cross-sectional area per tree g_m must be calculated, where $g_m = BA/ha / N/ha$, from which the corresponding diameter follows as:
$D_g = (4/\pi*g_m)^{0.5} *100$ (for g_m in m²).

6 Estimation of crown ratio

The ratio scale can be used to estimate different relative heights or proportions. As shown in Fig. 4, the relative trunk length (here 57%) and from this also the relative crown length (43%) can be estimated. See notes on scale reading under 2.1!

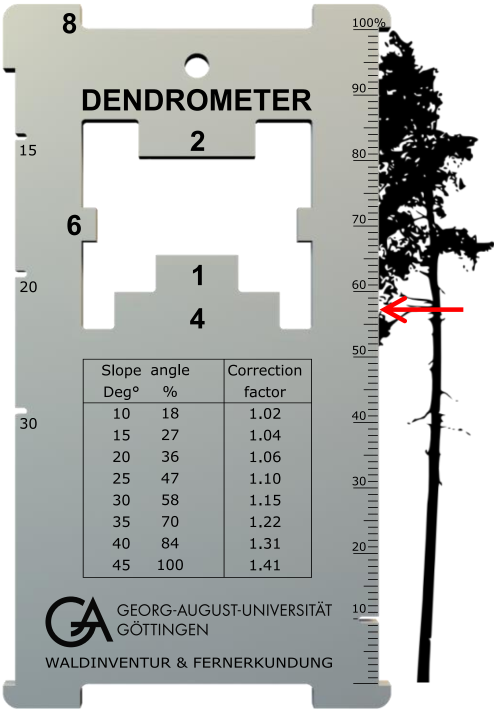

Figure 4. Measuring relative stem length or crown ratio using the ratio scale.

7 On Units of measurement

The stand basal area is estimated here in the unit m²/ha, but the result can be converted into the ft²/acre commonly used, for example, in the USA. The conversion factor is 1 m²/ha = 4,356 ft²/acre. 1 m³/ha corresponds to 0.4047 m³/acre or 14.29 ft³/acre.

All measurements made using the ratio scale are dimensionless and can be applied equally to absolute references in feet or meters (e.g. the height measurement described).

8 Maintenance of the Dendrometer

The Dendrometer is made of stainless steel, is largely corrosion-free and can be cleaned with any stainless-steel cleaner. The Dendrometer's scales are laser-engraved and remain visible for a long time.

! *The cord of the Dendrometer can lengthen or shorten over time due to the effects of weather or UV radiation. Regularly check that the cord stopper is at the correct distance of 50 cm!*

9 References

[1] Kramer, H., Akça, A., 2008. Leitfaden zur Waldmesslehre. 5. Auflage. J.D. Sauerländer's Verlag, Frankfurt am Main, 226 S.

[2] Bitterlich, W., 1947. Die Winkelmessung. Allgemeine Forst- und Holzwirtschaft, 58(11/12).

[3] Bitterlich, W., 1952. Die Winkelzählprobe. Forstwissenschaftliches Centralblatt 71(7/8): 215-225.

[4] Laer, W., Speidel, G., 1955. Die Wertklasse als Gütemaßstab in der Forsteinrichtung. Forstarchiv 26: 217-224.

[5] Ducey, M.J., Gove, J.H., Valentine, H.T., 2004. A Walkthrough Solution to the Boundary Overlap Problem. Forest Science 50(4): 427-435.

10 Details

Material: Stainless steel

W x H x L: 47mm x 85.6mm x 2mm

Weight: 53 g

Customs HTS / HS-Code: 9017.30 or 9017.80

Georg-August-Universität Göttingen
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Büsgenweg 5
37077 Göttingen
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The Dendrometer is produced in cooperation with GÖWE – Göttinger Werkstätten gGmbH. The purchase of a Dendrometer supports sustainable and meaningful social projects.

Where to buy: Unishop Göttingen:
http://unishop.uni-goettingen.de/

Further sources:

- *AWF-Wiki on angle count sampling*
- *AWF YouTube Channel „Monitoring of Forest Resources"*

Buy a Dendrometer

AWF YouTube Channel