dendröflexometer

all-in-one pocket to measure forest

User Manual

DOCUMENT:

User manual of dendröflexometer

Date:

21/06/2022

Contents

This instrument has been developed by REQUE and FERNANDEZ-MANSO (2003). The commercial exploitation of the dendröflexometer is protected by a patent of the University of Valladolid (number P-200100767).

1. What is dendröflexometer?

The dendröflexometer is an instrument used to measure the main dimensional variables of a tree and a forest mass. It is composed of a plastic housing in which a flexible and self-unwinding metal tape of 3 meters is collected with different scales on the upper surface and underside of the original tape. It combines, in a single economical instrument of small size, different classic forest measurement techniques (angular sampling, the Biltmore stick, the Christen rule).

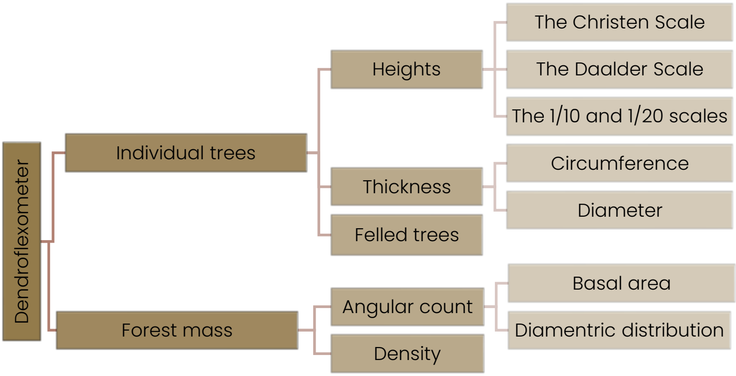
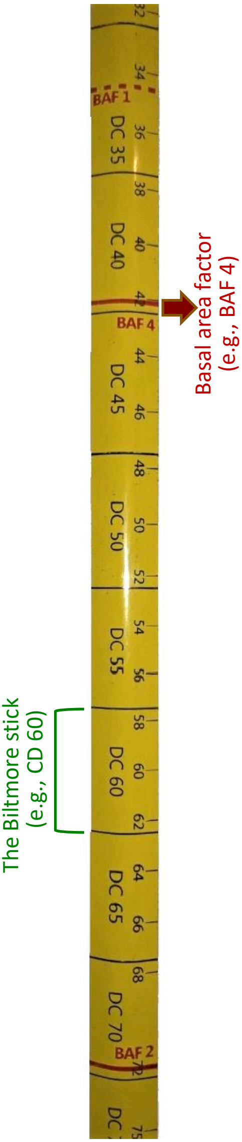


Illustration 1. Variables that can be measured with the dendröflexometer

The comparison of the most used devices in forest inventory is set out below, based, on the one hand, on the variable to be measured, and, on the other hand, on the price, accuracy, compactness and robustness factors, and the measurement speed. Each benefit is valued from 1 to 10.

Variable	Device	Price	Accuracy	Compactness	Speed
Diameter	Criterion RD1000	6	8	5	6
	Tree caliper	8	10	8	7
	Digital caliper	5	10	8	9
	Dendröflexometer	**10**	**9**	**10**	**8**
Height	Blume Leiss	8	4	5	5
	Suunto	8	4	8	3
	Vertex III	6	8	8	7
	Dendröflexometer	**10**	**4**	**8**	**5**
Basal area	Criterion RD1000	6	7	5	8
	Relascope	6	7	7	8
	Kramer	9	6	10	8
	Dendröflexometer	**10**	**6**	**10**	**8**

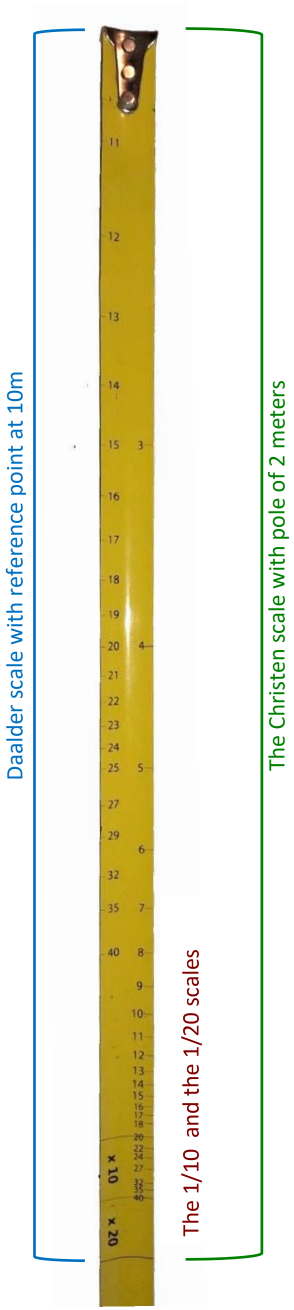


Dendröflexometer´s upper surface:

The graduated scales for the measurement of diameter and basal area which are present:

- The Biltmore stick scale allows measuring the diameter of the trunk at the normal height or at any other height. It returns two pieces of data, the diameter of the tree (measured at 1.30 m) and the diametric class to which it belongs (5 cm class width).

- The Angular count scale allows applying the statistical principle of angular counting of Bitterlich for determination of the basal area. The scale has been graduated for constants 1, 2 and 4 taking into account the exterior of the flexometer top plate and the interior.



Underside of the dendröflexometer

On the underside of the tape there are the graduated scales necessary for measuring the height of the trees with different techniques:

- **The Christen scale** is located on the right. It allows measuring the heights of the trees using a sight or reference mark of **two** meters. It is useful for trees under 12 m.

- **The Daalder scale** is located on the left. It allows measuring the heights of the trees according to Christen using a mark (fictitious pole) of reference of **ten** meters.

- **The 1/10 and 1/20 scales** are located at the bottom. They allow tracking down a signal on a tree which is equivalent to 1/10 (or 1/20) of the tree's height; thus, the height of the tree is determined by multiplying the indicated height by 10 (or 20, respectively).

- **The original flexometer scale** is located after the rest of the scales. It is graduated in centimeters and millimeters that allows measuring directly the perimeter of the tree trunk or any other length measurement (e.g., determine the normal height, measurement of logs, etc ...).

2. How to measure heights?

Three methods are proposed to measure heights based on geometric principles, which have the following advantages: they allow measuring the height of the tree from any distance; they are easy to use, independent of the inclination of the terrain slope and have sufficient accuracy for many applications.

2.1. The Christen scale

It consists of a graduated ruler of 33 cm in length. The use of a reference of 2 meters makes the designed scale lose precision for trees taller than 12 m. It is recommended to use the Daalder hypsometric scale or ruler for trees that exceed that height.

procedure

Measure on the trunk of the tree, with the tape measure of the dendröflexometer, a height of 2 meters in length and indicate its position. Once the height of 2 meters has been obtained, the operator must move away to a distance similar to the height of the tree, where its base and cyme are comfortably visible.

The Christen scale is placed parallel to the axis of the tree and in front of the eye, moving it away or closer to it until the total height of the tree is visualized within the limits of the ruler. Once achieved, **have a look at the height of 2 meters,** previously indicated, and read at the Christen scale the value in which it is cut by the look. That will be the height of the tree in meters.

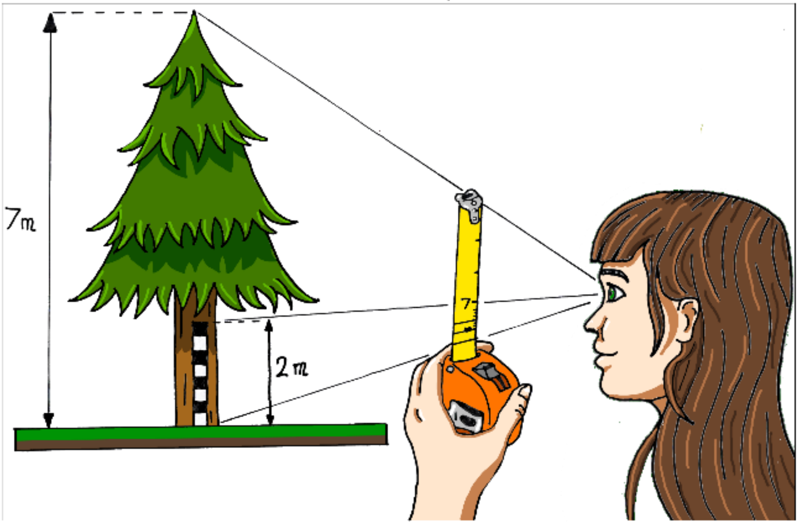


Illustration 2. Height measurement with the Christen scale. The tree is 7 m tall.

Some of the advantages of this method are:

- It is not necessary to take into account the distance between tree and operator.
- It is not necessary to take into account the inclination of the terrain.
- The height of the tree is obtained with a single reading.

2.2. The Daalder scale

The hypsometric rule is based on the principle of the Christen rule and it avoids the inconvenience of a lack of accuracy when measuring tall trees, as a consequence of the proximity of scale marks. Its use is recommended for trees over 12 m tall.

It can be considered as two complementary and consecutive Christen rules, one for 2 m range rod and one for 10 m range rod.

procedure

Measure on the trunk of the tree, with the tape measure of the dendröflexometer, a height of 2 meters in length and indicate its position. Once the height is obtained at 2 meters, the operator must move away to a distance similar to the height of the tree, where its base and cyme are comfortably visible. The procedure is performed in two steps:

The first step is to locate on the tree a point of 10 m high that will serve as a reference for the subsequent step. **To do this, using the Christen scale,** the dendröflexometer is moved away or closer to the eye until the beginning of the Christen rule coincides with the base of the tree and also the 2m mark with the 10 m mark of the ruler. The point needed will be located at the top end of the ruler. The location of that point on the tree is memorized.

In the second phase the Daalder scale is used, with the fictitious 10 m mark located in the previous step. We adjust the apex and the base of the tree with the extreme visuals of the Daalder scale (located on the left), and **the visual of the point at 10 m high will give us the total height of the tree.**

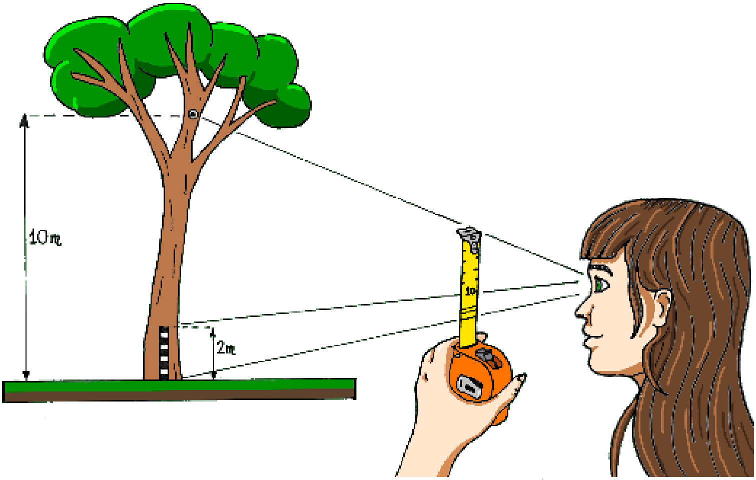


Illustration 3. Location of a point at 10 m.

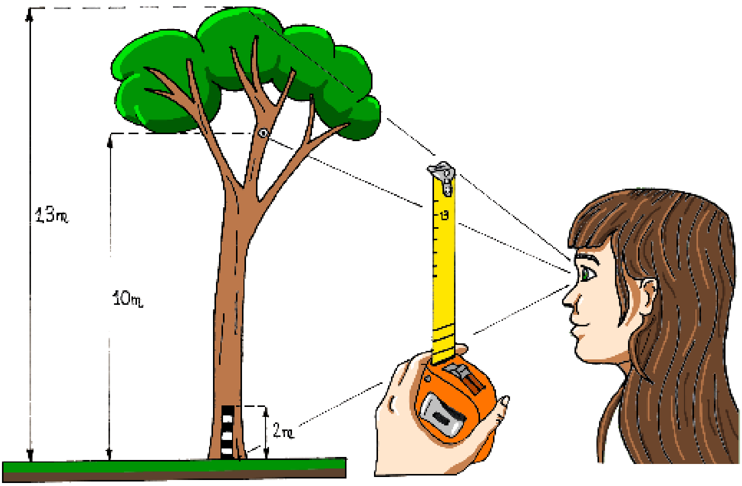


Illustration 4. Measuring the total height of the tree with the Daalder scale

2.3. The 1/10 and the 1/20 scales

This method is very simple and is not limited by the height of the tree. The accuracy of this rule, especially for tall trees, is greater than Christen's, due to the fact that there is no reading scale on the instrument. It is also known as the Workampff-Laue hypsometric rule method.

procedure

Stay at a distance from which you can comfortably see the base and apex of the tree. The dendröflexometer is placed adjusting the visuals within the limits of the ruler. Once the tree is framed, **a sign is replanted on the trunk at the height of 1/10** (or 1/20) having a look at the tree (in this step the support of a second operator is very useful).

The height of the mark is pointed out and measured on the trunk with any tool (tape measure, pole...). This height will be exactly one tenth (or twentieth) of the total height of the tree, which is calculated by multiplying by 10 (or by 20 depending on the scale used) the value obtained.

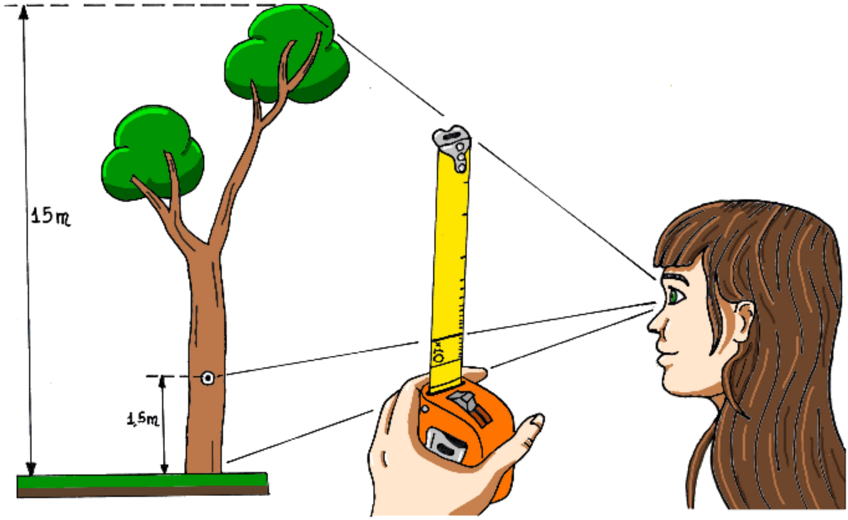


Illustration 5. Tree height measurement with the 1/10 scale of the dendröflexometer

3. Measure thickness

3.1. Normal circumference

Some of the main advantages of the dendröflexometer are related to its functionality as a tape measure. This functionality is used to measure magnitudes such as circumference or normal diameter but also to replant plots, measure distances, measure logs, etc.

procedure

The entire trunk is surrounded with the tape measure at the height of 1.30 m, checking that the tape remains perpendicular to the axis of the tree. The data obtained is the measurement of the normal circumference.

$$c_n = 2\pi r_n = \pi d_n$$

$$d_n = \frac{c_n}{\pi}$$

$$g = \pi r_n^2 = \pi \left(\frac{d_n}{2}\right)^2 = \frac{\pi}{4} d_n^2$$

$$g = \frac{\pi}{4}\left(\frac{c_n}{\pi}\right)^2 = \frac{c_n^2}{4\pi}$$

c_n = circumference or normal perimeter (measured at 1.30 m height)
d_n = normal diameter
r_n = normal radius
g = normal section of the tree

From this data it is possible to calculate others such as radius, diameter and section (area).

Illustration 6. Measurement of the circumference with dendröflexometer

3.2. Diameter with the Biltmore stick

The Biltmore stick allows measuring diameters (usually at 1.30 m) and classifying them within a range or diametric class.

procedure

Superimpose on the normal diameter of the tree (at the height of 1.30 m) the Biltmore stick and be located at a distance of 65 cm (approximately the length of the arm), which is the distance for which the scale of the dendröflexometer was calibrated.

The scale is adjusted so that, on the left, the origin is aligned with the left side of the tree and, without moving the head, the line of sight is moved to the right side of the trunk. With the reading of the scale or the stick at the point where the line of sight crosses it, two data are obtained: the normal diameter of the tree and the diametric class.

The stick is graduated to return 5 cm diametric classes, from CD10 (7.5 – 12.5 cm) to CD 120.

Illustration 7. Measuring the diameter of the tree with dendröflexometer

3.3. Measurement of felled trees

Utilities such as tape measure of the dendröflexometer allow us making many measurements on the felled and chopped trees: diameters and sections at different heights, lengths, forest scaling of logs, etc.

In the classical methodologies of study of type trees and trunk analysis, the dendröflexometer can be used as a measuring instrument.

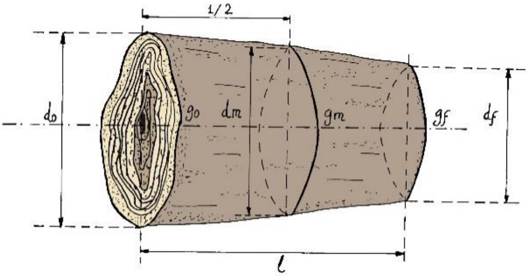


Illustration 8. Measures that can be carried out on the felled tree

FOREST SCALING OF THE FELLED TREES

HUBER formula: a diameter measurement

$v = \frac{\pi}{4} * d_m^2 * l = \quad v = g_m * l$

SMALIAN formula: two diameter measurements

$v = \frac{\frac{\pi}{4}*d_o^2+\frac{\pi}{4}*d_f^2}{2} * l \quad v = \frac{g_o+g_f}{2} * l$

NEWTON formula: three diameter measurements

$v = \frac{l}{6}(g_o + g_f + 4g_m)$

v = trunk volume
d_m = diameter of the half of the length
d_o = diameter of the section at the base
d_f = upper section diameter

l = trunk length
g_m= mid-trunk section
g_o= section at the base
g_f= upper section

4. How to measure dasometric variables?

4.1. Basal area

Measuring the basal area with a dendröflexometer is easy and fast. It is done by applying the Bitterlich angular counting statistical principle, from which the basal area of a forest stand (G, in m^2/ha) can be estimated. The scale has been graded for basal area factors (BAF) 1, 2 and 4.

procedure

It begins by choosing an angular constant appropriate to the density of the stand, so that the number of trees counted is between 7 and 15. The outside or inside of the top plate shall be used according to the distance to the eyepiece to be used.

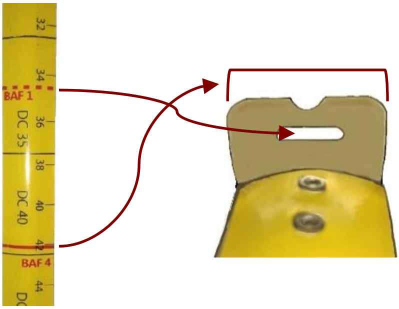
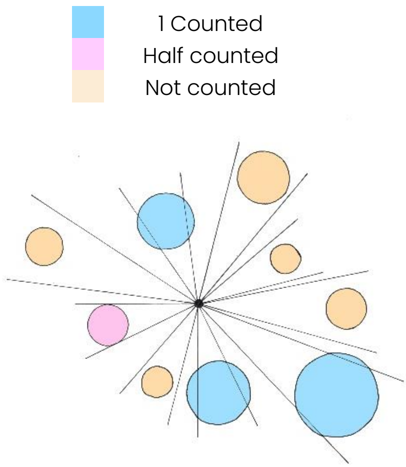


Illustration 9. Bandwidth to be used according to the chosen distance to the eyepiece.

For BAFs with greater distance to the eyepiece, which correspond to those printed with continuous lines on the dendröflexometer, the outside of the plate shall be used.

For BAFs with a shorter distance to the eyepiece, those with a dashed line, the inside of the plate will be used.

A look is directed at the height of the normal diameter and, turning around, the feet are counted following the following criteria:



a. If the normal diameter is greater than the reference amplitude, one is counted.
b. If the normal diameter is equal to the reference amplitude, half is counted.

c. If the normal diameter is less than the reference amplitude, it is not counted.

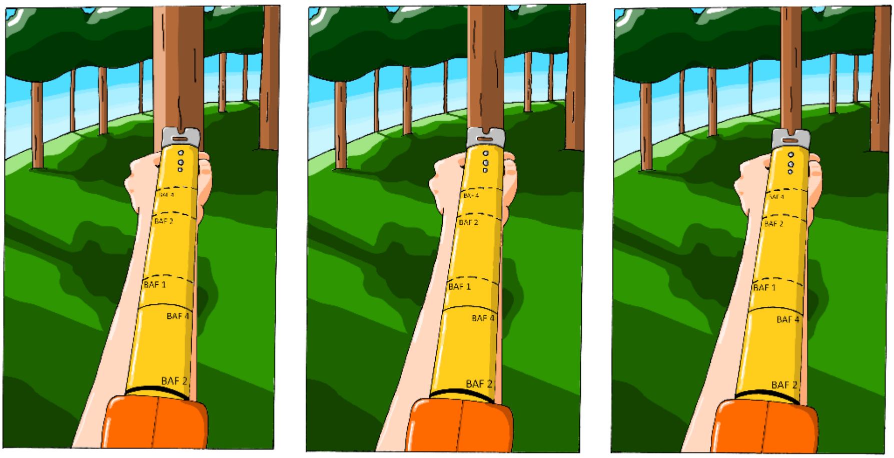


Illustration 10. Left: Tree is counted (sum 1). Center: Half tree is counted (sum 1/2). Right: Tree is not counted (sum 0).

Whenever **the terrain is flat,** the value of the basal area (G) will be the product of the number of trees counted by the constant used (BAF). For example, if 9 feet have been counted with a BAF=2, then the G is 18 m^2/ha.

In the case of **sloping land,** the BAF needs to be corrected. To correct this, the obtained basal area is multiplied by the secant of the slope of the land (sec α ; 1/ cos α)

In the case of the previous example, if the slope of the land is 40% (21.8°), we have to multiply the value by 1.077. The result of the basal area in that sloping stand will be 19.39 m2/ha.

$$G\left(\frac{m^2}{ha}\right) = N * BAF$$

$$BAF = 2500\left(\frac{a}{b}\right)^2$$

G= basal area
N: number of counted feet
BAF= basal area factor
a= bandwidth
b= distance to the eyepiece

CORRECTION TO BE APPLIED ON SLOPING LAND

Inclination		Correction
%	°	*sec* (°)
10	5.71	1.005
15	8.53	1.011
20	11.31	1.020
25	14.04	1.031
30	16.70	1.044
35	19.29	1.059
40	21.80	1.077
50	26.57	1.118
60	30.96	1.166
70	34.99	1.221
80	38.66	1.281
90	41.99	1.345
100	45.00	1.414

4.2. Diametric distribution by angular sampling

To obtain the diametric distribution table of forest stand studied (number of trees per diametric class) it is necessary to measure the diameter of all the trees included in the angular count.

Diametric classes of 5 cm are generally used.

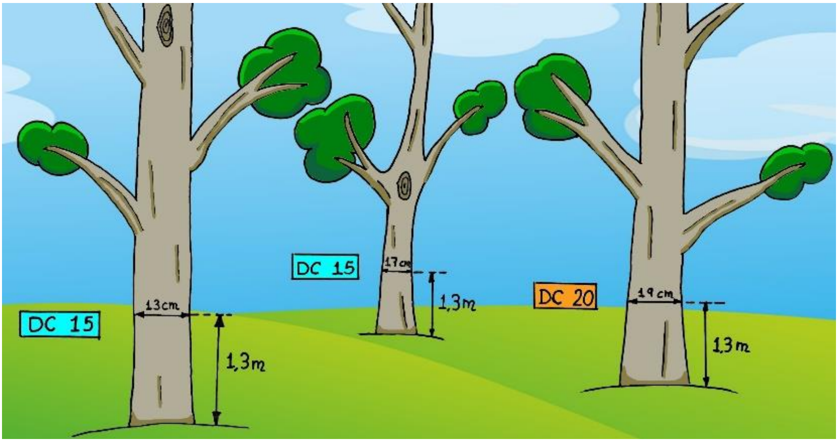


Illustration 11. Diameter measurement to obtain the diametric distribution.

$$N = BAF \sum_{i=1}^{m} \frac{n_i}{g_i(m^2)}$$

N: number of trees per hectare.
BAF: basal area factor used.
n_i: number of feet of diametric class and counted in angular count sampling.
g_i= basal area of the tree with class mark diameter

4.3. Density (feet/ha)

It is possible to calculate the density of the mass by means of a sampling in which the area of the plot is variable and the number of trees is fixed.

procedure

The 6 trees closest to the center of the plot are determined. The distance from the center of the plot to the center of the sixth tree is measured, this being the length of the radius of the plot (r_6).

The density estimation is based on the fact that a plot of surface equal to πr_6^2 (m^2), contains the 5 trees and half of the sixth tree closest to the center of the plot. Subsequently, expanding the stocks of the plot to the hectare the density per ha is obtained.

$$\frac{N}{ha} = \frac{10000}{\pi r_6^2} * 5{,}5$$

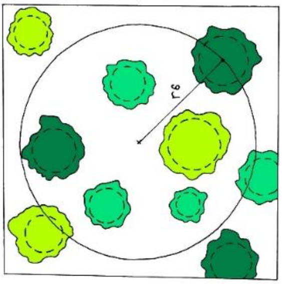


Illustration 12. Distance from the center of the plot to the sixth tree

DENSITY ACCORDING TO THE DISTANCE TO THE 6TH TREE

Distance to 6th tree (m)	Density (feet/ha)
2.0	437.,8
2.5	2801.1
3.0	1945.2
3.5	1429.1
4.0	1094.2
4.5	864.5
5.0	700.3
6.0	486.3
7.0	357.3
8.0	273.5
10.0	175.07
12.5	112.0
15.0	77.8
17.5	57.2
20.0	43.8

Similarly, it is possible to obtain a timely estimate of the basal area. For this it is necessary to know the diameters of the 6 trees closest to the center of the plot. The calculation is based on the fact that a known surface plot contains a basal area that can be calculated. Subsequently, the data is expanded to the hectare:

$$Gha_i = \frac{10000}{\pi r_6^2}\left(\sum_{j=1}^{5} g_j + g_6/2\right) = \frac{2500}{r_6^2}\left(\sum_{j=1}^{5} d_j^2 + d_6^2/2\right)$$