4.0 Assessing Tree Attributes

Individual Tree Attributes

- Measurement of the individual tree is basis for all forest resource assessment / inventory
- For tree attribute assessment purposes, a tree can be conveniently divided into four parts: roots, stump, stem (or trunk), and crown

4.1 Diameter Breast Height (DBH)

- Average stem diameter outside bark of the tree measured at breast height above ground level
- Breast height is 4.5 feet above ground on level or moderate slopes. On steep slopes, measure this distance on the uphill side of the tree.

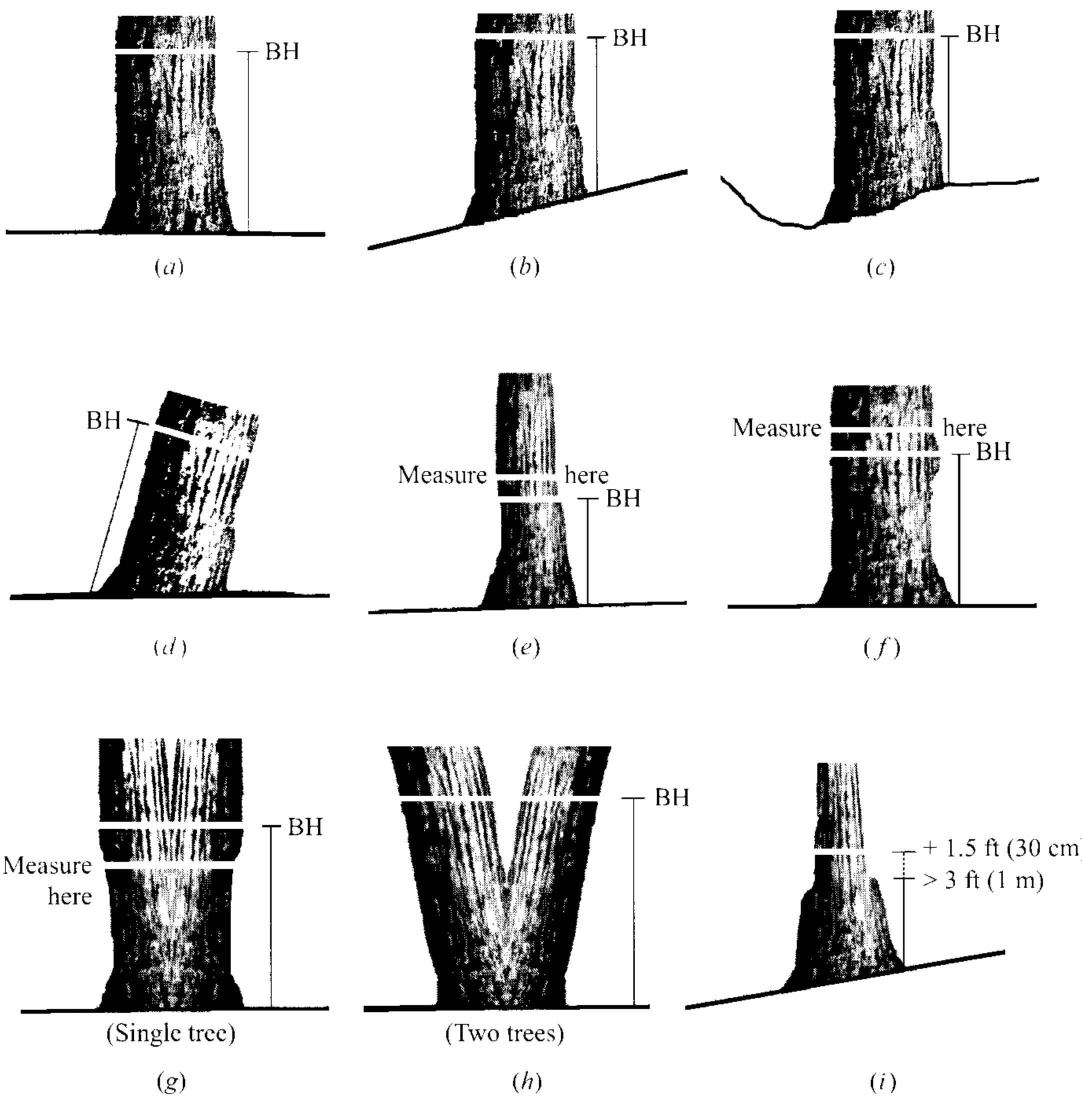


Illustration of how to measure Diameter Breast Height (DBH) on individual trees.

- Instruments: Dendrometers
  - DBH tape (or D-tape) is standard for this region
    - Most consistent method
    - Reliable to 0.1 in.
    - Slight positive bias
  - Caliper
    - Quick alternative to D-tape
    - Reliable to 0.1 in.
    - Gives different estimate from different sides of tree (out of round)
    - Ideal for small to mid-sized timber
  - Diameter fork (a.k.a. Sector Fork)
    - Determines diameter from a sector of a circular cross-section
    - One side of sector is fixed arm, the other a line of sight
    - Line of sight intersects a curved scale on which diameters are printed
    - Optimal for trees with DBH < 20”
  - Biltmore stick
    - Straight wooden stick, graduated for direct readings of DBH, based on principles of similar triangles
    - Parallax error is a problem
    - Reliable to 1 in.

- Tree DBH classes
  - Often expedient to summarize inventory data by diameter classes, e.g., 1 or 2-inch
  - Still measure to nearest 0.1 inch.
  - Example 1-inch classes:

…	3”	4”	5”	…
	2.6 – 3.5”	3.6 – 4.5”	4.6 – 5.5”	

- Basal Area (ba)
  - Cross sectional area of tree at breast height, always in square feet (stem circularity assumed)
    - $ba(sq.ft) = \pi r^2 = \pi\left(\frac{DBH(in.)}{2 \bullet (12 in/ft)}\right)^2 = 0.005454 DBH^2$
    - quadratic mean diameter: diameter of tree of mean basal area
      - $qmd = dbh_q = \sqrt{\frac{\overline{ba}}{0.005454}}$

Bark Thickness

Even though DBH is measured outside bark, a common objective is determining diameter inside bark (dib)

Reliable measures are essential, because the ratio of diameter inside bark to outside bark (dib/dob) at breast height is often used to estimate inside-bark diameters at inaccessible points on the stem

When using calipers for DBH:- bark thickness should be measured at the two exact points where the caliper touched the tree, added together the resultant then being subtracted from dob to obtain dib

When using a D-tape for DBH:- bark thickness should be measured radially from the wood surface to the contour of the tape at two or three locations around the stem – then bark thickness is found by the difference between the two concentric circles defined therein

Table 21. Mean Squared Bark Thickness Ratios for Top of 16-Foot Logs.[1]

Species	Bark Thickness Ratio Squared		
	Oregon	Western Washington	Alaska
Ponderosa pine	.820		
Western larch	.810		
Sugar pine	.780		
Concolor fir	.805		
Incense cedar	.699		
Douglas-fir			
25 to 50 years	.850		
over 50 years	.812		
Western hemlock	.891	.885	.86
Western red cedar	.903	.895	.88
Sitka spruce	.925	.937	.90
Lodgepole pine		.899	
White pine		.933	
Noble fir		.902	
Red alder		.890	
Alaska cedar			.90

1/ Ratios are merely guides since variation is found from area to area. Sources: Alaska, U.S.F.S.; Washington, Dept. of Nat. Res.; Oregon, Mason, Bruce & Girard, and Oregon State University.

2/ BTR = dib/dob

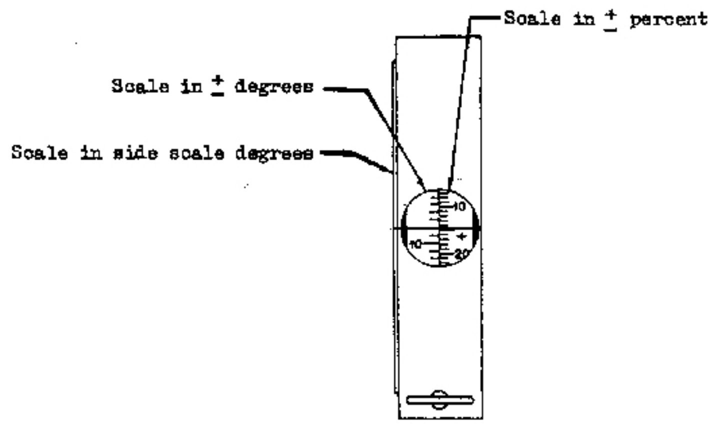
Source: Bell, J.F. and J.R. Dilworth. 2007 – Revised Ed. Log Scaling and Timber Cruising.

Age Determination

- Trees in temperate zones grow one distinctive layer of wood per year so age is found by counting these annual rings
    - Care is needed to avoid counting 'false' rings
- Tree Age:
    - Total Age: Elapsed time since germination of a seed or time since budding of a sprout or cutting
    - Breast-height age: Elapsed time since tree height exceeded breast height
- Tree Age measurement
    - Entire tree cross-sections are most reliable
    - Increment borer gives a non-destructive way to measure age
- Chiefly used for the determination of stand constitution (age structure)
    - Even-aged stands are those in which tree ages do not vary by more than 10 to 20% of the expected life-span (or rotation) of main species involved. Stand age can be expressed in no less than three ways
        - Total age – average of total tree ages as defined above
        - Breast-height age – average of tree breast-height ages (as above)
        - Plantation age – elapsed time since planting, irrespective of seedling stock ages
    - Uneven-aged stands are those with age ranges beyond 10 to 20% of expected life-span or rotation

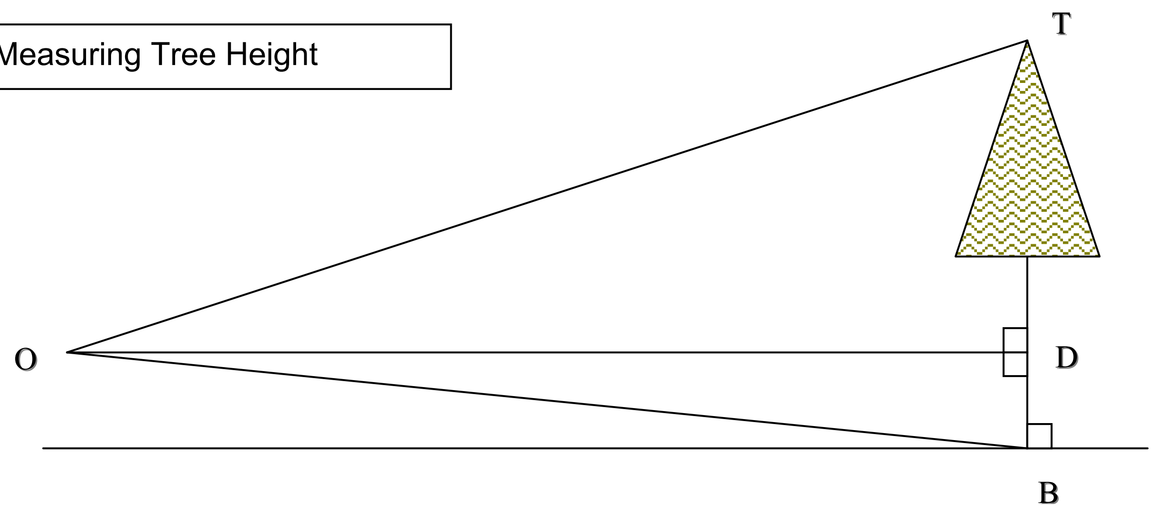
Tree Height

- Total height: distance from ground level to tip of tree
- Bole height: distance from ground to base of the live crown (crown point)
- Merch. height: distance from ground to some minimum top diameter
- Stump height: distance from ground to basal position on stem where tree would be cut (standard is 1 ft. for volume table construction and timber estimation)
- Crown length: distance from crown point (base of live crown) to apex of tree
- Merch. length: distance from top of stump to merch. height
- Instruments: Hypsometers
    - Direct measurements can be taken with a height pole (telescoping)
    - Indirect measurements use similar triangles (Merritt Hypsometer) or trigonometric principles (clinometer)



Looking into the eyepiece of the Suunto Clinometer (PCT/DEG scale)

Measuring Tree Height



Tree Height, H = TD + DB.

TD/OD = tan(∠TOD), therefore, TD = OD x tan(∠TOD)
DB/OD = – tan(∠DOB), therefore, DB = – OD x tan(∠DOB),

H = TD + DB = OD x tan(∠TOD) + [– OD x tan(∠DOB)], or,
H = OD x [tan(∠TOD) – tan(∠DOB)].

Horizontal distance OD is measured with a tape or pace.

Angles ∠TOD, ∠DOB are measured in percent w/clino, e.g.,
TOD% = 100 x tan(∠TOD), therefore,
tan(∠TOD) = TOD% / 100, so

H = OD x [TOD% / 100 – DOB% / 100], or

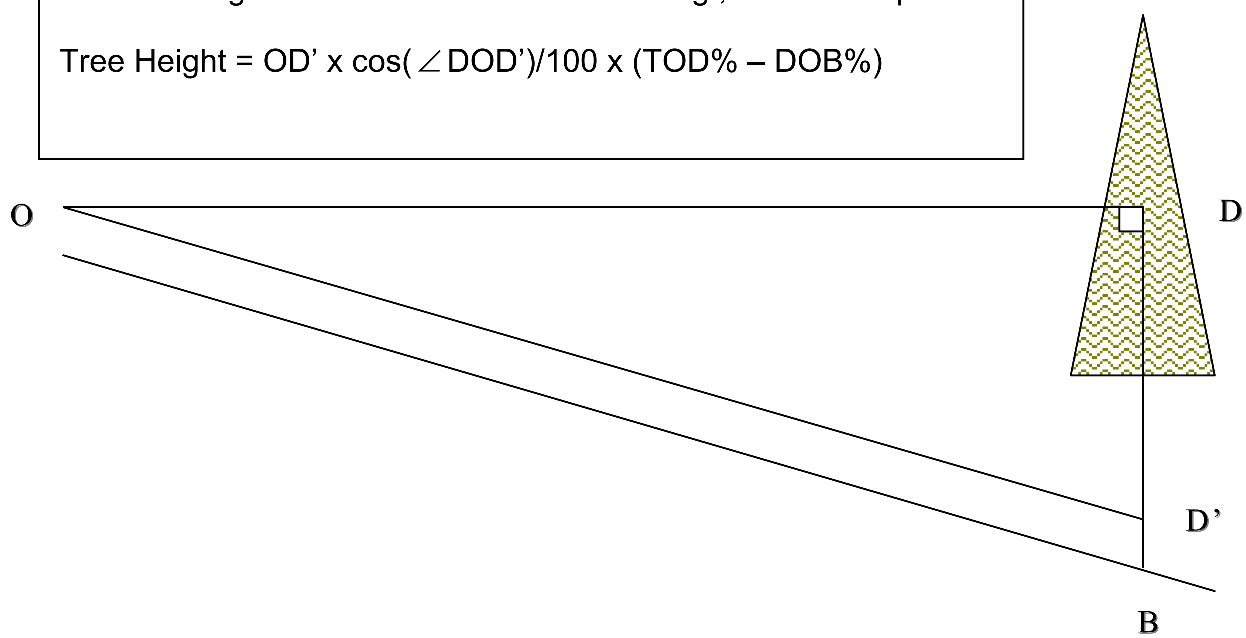
H = OD / 100 x (TOD% – DOB%)

Slope correction in Height Measurement

$OD/OD' = \cos(\angle DOD') \Rightarrow OD = OD' \times \cos(\angle DOD')$

Measure angle $\angle DOD'$ with clinometer in deg., then use equation:

Tree Height = $OD' \times \cos(\angle DOD')/100 \times (TOD\% - DOB\%)$

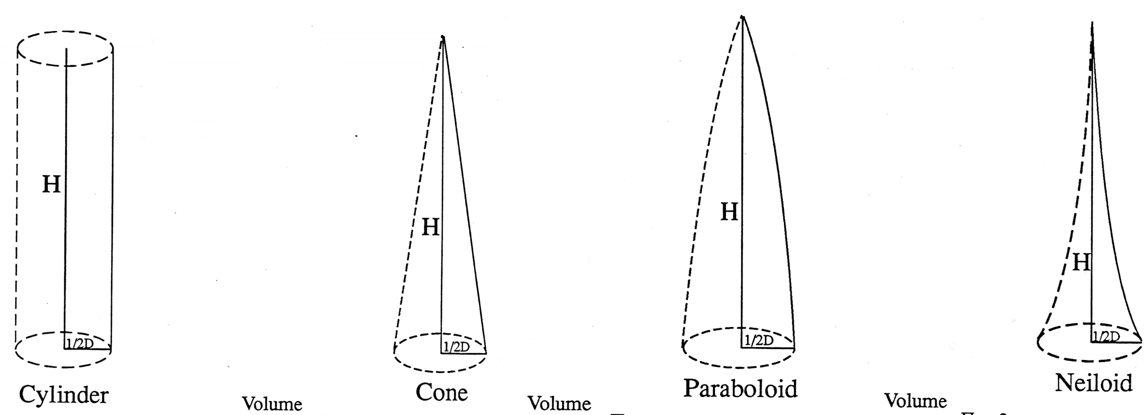


Growth Habit / Tree Form

Trees having their central stem axis interrupted in the upper portion due to frequent branching, like most broadleaved species, are said to have a *deliquescent* growth habit

Trees having a single, prolonged stem axis that is undivided to form a main stem, like most conifers, are said to have an *excurrent* growth habit

Tree "form" describes the "shape" of the tree stem, i.e., indicates a particular rate of taper



Cylinder
Volume $V = \frac{\Pi}{4} D^2 H$
Taper $d_i = K_1$

Cone
Volume $V = 1/3(\frac{\Pi}{4} D^2 H)$
Taper $d_i = K_2(H-h_i)$

Paraboloid
Volume $V = 1/2(\frac{\Pi}{4} D^2 H)$
Taper $d_i = K_3(H-h_i)^{1/2}$

Neiloid
Volume $V = 1/4(\frac{\Pi}{4} D^2 H)$
Taper $d_i = K_4(H-h_i)^{3/2}$

Form factor (denoted by f) –

Compares the volume of a stem (as a ratio) to a known geometric solid. Most often the solid of choice is a cylinder, leading to the *cylindrical form factor*

$$f_c = \frac{v}{gh}$$

Where v denotes the tree volume, g denotes basal area, and h denotes height

Form quotient (denoted by q) –

Ratio of stem diameter at a certain height above breast height to DBH. *Normal form quotient* is the ratio of the diameter at ½ tree height to DBH. *Absolute form quotient* is the ratio of diameter half-way between breast height and total height to DBH. Girard's form quotient is most often used in PNW. It is the ratio of diameter under bark at the top of the first 16-ft log to DBH:

$$q_G = \frac{dib_{17.3}}{DBH}$$

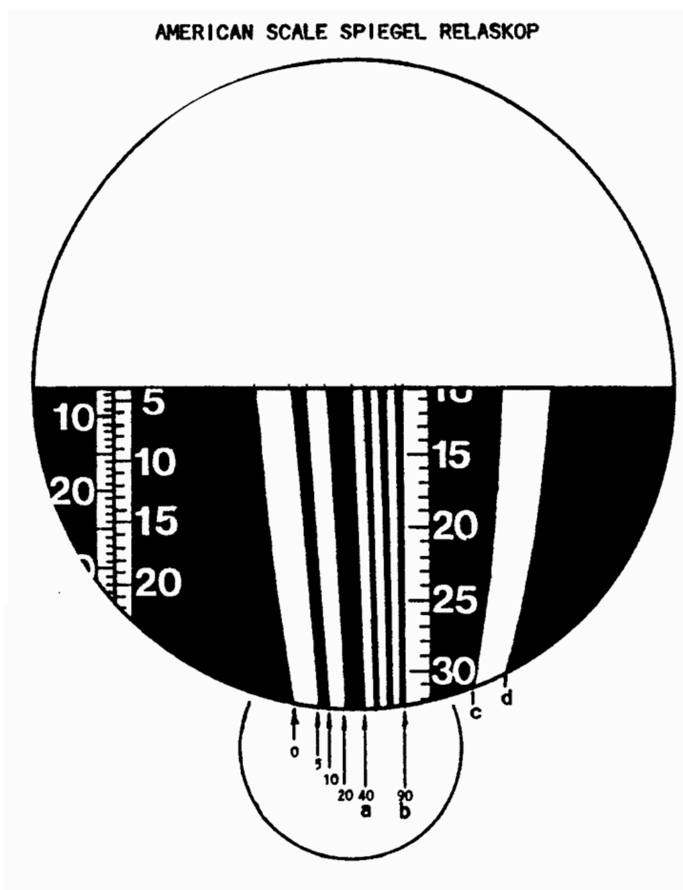
Girard's Form Class just puts this on a percent scale:

$$FC = q_G \times 100$$

Upper stem diameter(s) for form & taper determination

- Required for studies of tree stem form, taper, and volume
- Direct measurement, e.g., climbing with ladder & D-tape is most accurate
- Indirect measurement methods have been developed
    - Instruments: optical calipers, fixed-base range finders, optical forks
    - Optical Fork mimics a dendrometer fork using optics and the human eye
        - Instead of one fixed arm and one line of sight, two lines of sight are used
        - Lines of sight are tangent to the tree cross-section at the level of diameter measurement – eye is the vertex

- $\sin\left(\frac{\alpha}{2}\right) = \frac{r}{L}$
- $r = L \bullet \sin\left(\frac{\alpha}{2}\right)$
- $d = 2r = 2L \bullet \sin\left(\frac{\alpha}{2}\right)$
- Relaskop is an example of an optical fork
- Base unit of measurement is the Relaskop Unit (RU)
- 1 RU corresponds to sector angle α = 0.28938°
- $d = 2r = 2L \bullet \sin\left(\frac{\alpha}{2}\right) RU = 2\sin\left(\frac{0.28938}{2}\right) L \bullet RU = 0.0050505 L \bullet RU$
- The relaskop instrument automatically corrects for slope
- There are six (6) individual single RU stripes
- Each large pair of light / dark stripes equals 6 RUs (see next Figure)



Looking through the eyepiece of the American scale Spiegel Relaskop (your “window” to the world).

Crown Parameters

Tree foliage drives growth of the tree, stand dynamics, and the growth of the forest

The use of crown dimensions as a surrogate for the amount of foliage has become an integral part of forest measurement and many forest growth and yield studies

Crown dimensions are also useful for estimating (predicting) wildlife habitat quality

Crown Diameter / Area

Crown diameter is useful in tree and forest health monitoring

Crown diameter can be used to estimate DBH and therefore volume such as is used in aerial-photo volume equations

Crown area is used in estimating Crown Competition Factor (CCF)

Crown diameter as measured from the ground is usually measured in several directions, then averaged

- Averaging four directions (N-S, NE-SW, E-W, SE-NW) works best
- For crowns that have raised above ground level, the vertical projection of the crown onto the land surface is used
- Measuring crowns on aerial photos is much easier, but biased downward

Crown cross-sectional area is usually calculated from average crown diameter and plugging that into the formula for the area of a circle

Crown Surface Area / Volume

Crown surface area for conifers and young hardwood tree species is well approximated by assuming crown shape to be a cone – this assumption leads to the formula for surface area, $S = \pi D_b \left(\frac{L}{2} \right)$, and the formula for volume, $V = \pi D_b^2 \left(\frac{l}{12} \right)$

where S = crown surface area (ft^2 or m^2),
V = crown volume (ft^3 or m^3)

D_b = diameter at crown base (ft or m)

L = length on a slope from crown apex to base of crown (ft or m)

l = crown length (ft or m)

Live Crown Ratio (LCR)

LCR is often used as a surrogate for amount of crown to indicate tree vigor

LCR can also be used as an indicator (w/ other attributes) as an index to stand density

LCR is the proportion of total tree height that is supporting branches with live foliage and is calculated by

$$LCR = \frac{Crown\ Length}{Total\ Height} = \frac{Total\ Height - Bole\ Height}{Total\ Height} = 1 - \frac{Bole\ Height}{Total\ Height}$$

Summary Points

1. Although the most important portion of a tree in terms of usable wood is the bole, a tree can be considered to consist of four parts: *roots, stump, stem,* and *crown.*
    - Roots are extremely difficult, hence expensive to measure, no standard methods exist, the best method depending on the interaction between the species of tree, soil conditions where it is found, and how close its nearest tree neighbors are
2. The stump, stem, and branches are all covered with bark, whereas useable wood volume does not include bark, estimates of bark thickness and volume are necessary
3. Whole-tree stem dimensions are typically characterized by *DBH* and *Height*
4. More detailed stem dimensions can be measured using devices to characterize upper stem diameters from which stem form can be derived
5. Dimensions of the crown are important since the crown is the "growth" factory of the tree, influences precipitation throughfall, impacts thermal cover quality, etc.