CWA Info Note 8:

Forest Inventory and Mensuration

This information note is one of a series produced by the Community Woodlands Association. It gives a brief introduction to the processes of forest inventory and mensuration, identifies various online resources and signposts to sources of more detailed information: other CWA information notes or external bodies.

Introduction

Forest inventory is the systematic collection of quantitative and qualitative data on forestry resources and forest mensuration is the process of measuring standing and felled timber. When measuring standing trees the key outputs are usually estimates of standing volume and growth rates, although assessments of timber quality are also important.

Forest managers have a range of reasons for measuring their timber resources:

- To facilitate management planning;
- To understand the likely long term sustainable harvest from the woodland;
- To predict the volume of timber arising from specific felling or thinning operations.

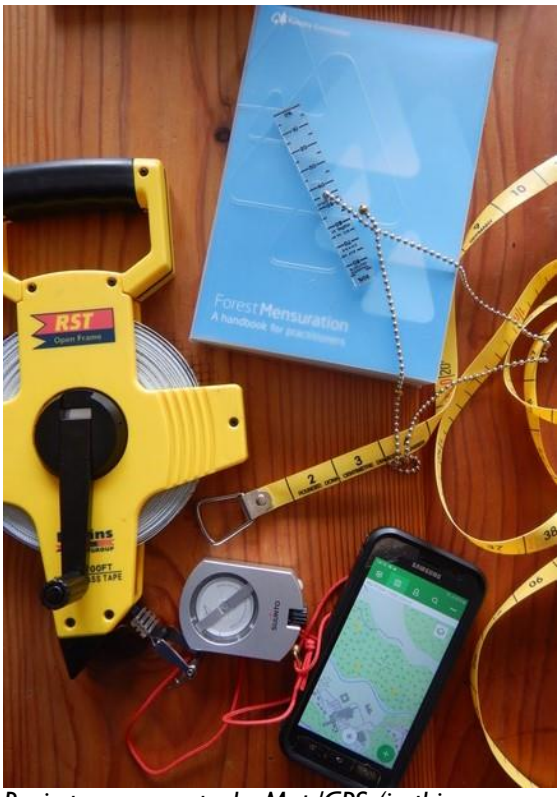
Generally, when selling timber the more accurate the information you provide to buyers or contractors, the more consistent their quotes will be, with less variation between them because of uncertainty about the crop.

Mensuration often takes place as part of a broader woodland survey. Once you have mapped your woodland and habitat types you are ready to gather more detailed information about the trees within each sub-compartment.

CWA info note 7 outlines the processes and requirements of woodland surveying and should be read in conjunction with this note

In some cases inventory work will need to be carried out by external contractors, but much can be done by volunteers; indeed, as with other aspects of woodland surveying, it can be an effective way of involving those who aren't interested in or able to do the more manual tasks around a community woodland such as path-building and tree-planting.

Mensuration can be done with simple tools and is relatively easy to learn. As always, with volunteers you either need to be confident about their existing skills or provide them with training to ensure the data they give you is accurate enough for your purposes.



Basic tree survey tools: Map/GPS (in this case a mobile phone setup with Viewranger), Suunto clinometer, 25m tape measure, Cruiser's Crutch relascope, Forest Mensuration handbook, girth tape. You should also consider safety glasses if working in dense stands, and paint or timber chalk may be useful to mark trees already measured.

A key caveat is that the outputs from mensuration are always estimates: trees are by nature very variable and it is impossible (short of felling the stand and submerging the trees in a large tank) to produce a truly accurate volume measurement. At best, mensuration figures should be treated as being accurate to

within plus or minus 10%, even when all protocols have been followed.

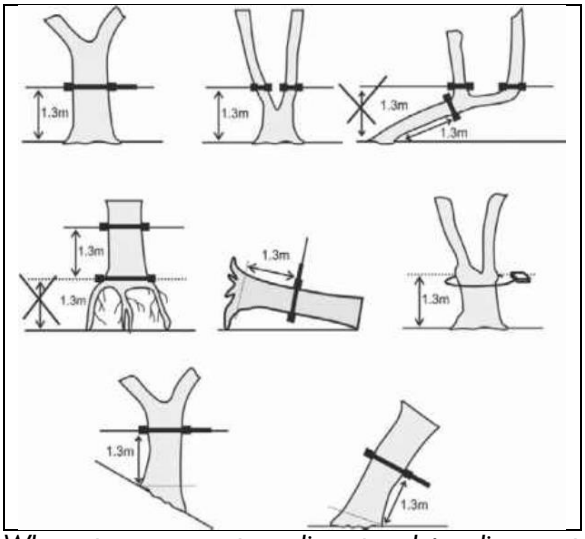
The outputs of mensuration are usually expressed as volume/ha. To estimate the total volume in a forest or a stand you must have accurate measurements of the stocked area: failing to account adequately for variables such as open space or rides, can result in over-optimistic inventory estimates.

Key metrics and conventions

The key measurements for standing trees are diameter (measured in cm) and height (metres) from which are calculated basal area (m^2) and standing volume (m^3). Knowing the age of a stand is necessary to calculate growth rates.

Forest Research have published tables to assist calculation of stand volumes from diameter and height data. These are available in Forest Mensuration, a handbook for practitioners (known to foresters as the Blue Book) which also contains detailed explanations of procedures and statistical methods.

Diameter



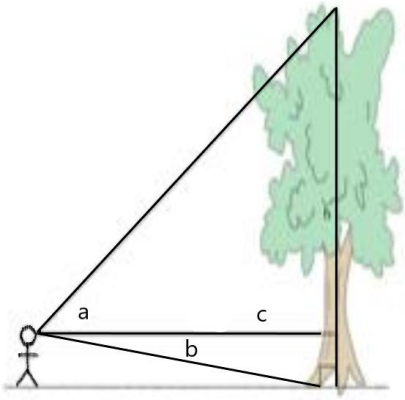
Where to measure tree diameter depending on tree form, slope, lean, forks, etc.

Tree diameters are conventionally measured at 1.3m above ground level, known as diameter at breast height (dbh). You can use a standard tape measure to measure the circumference and convert this to diameter, however it is quicker to use calipers or girthing tapes, which are calibrated to give the diameter of a tree trunk to the nearest centimetre.

Height

Tree height is measured from ground level to the tip of the leading shoot. The convention for selecting trees for measurement is to measure the height of the fattest tree in each sample plot (unless it is obviously damaged and missing its top section): this is not necessarily the tallest tree in the plot. The average of the trees measured is the 'top height' of the stand.

Tree heights can be measured directly using a hypsometer or calculated by measuring the angles to the top and bottom of the tree from a known distance away using a clinometer which expresses height as a percentage of a specified horizontal distance.



Where a & b: are clinometer readings (in %) to the top and bottom of the tree and c is the specified horizontal distance (metres) from you to the tree. If, as in the illustration, the base of the tree is below the horizontal level from your eye you should add a & b. e.g. if a= 115%, b=10% and c=20m then tree height is 20(115%+10%) = 25m. If the bottom of the tree is above your eye-line, subtract b from a.*

A simple method is to create a 45° angle using a stick held upright that is as long as your arm held out-stretched, horizontally. When you are far enough away from the tree that the top of the stick visually meets the top of the tree, your distance to the tree matches the height of the tree above the height of your arm.

In dense stands it can be difficult to see the tops of trees. If carrying out a pre-harvest survey you may be able to fell a tree to get an accurate measurement. Alternatively, you might be able measure a windblown tree or one on the edge of the stand but allow for edge trees being shorter than trees in the middle of a stand.

Basal area

Basal area is the cross-sectional area of the tree trunks in a stand at 1.3m above ground level, conventionally measured in m^2. Dead trees and those under 7cm dbh are not recorded. Basal area can be assessed with a relascope (see below) or calculated individually from diameter measurements, using the table below. Basal area/ha is the sum of the cross-sectional areas of all the trees in a hectare, expressed in m^2/ha.

dbh	BA	dbh	BA	dbh	BA
7	0.0038	22	0.0380	37	0.1075
8	0.0050	23	0.0415	38	0.1134
9	0.0064	24	0.0452	39	0.1195
10	0.0079	25	0.0491	40	0.1257
11	0.0095	26	0.0531	41	0.1320
12	0.0113	27	0.0573	42	0.1385
13	0.0133	28	0.0616	43	0.1452
14	0.0154	29	0.0661	44	0.1521
15	0.0177	30	0.0707	45	0.1590
16	0.0201	31	0.0755	46	0.1662
17	0.0227	32	0.0804	47	0.1735
18	0.0254	33	0.0855	48	0.1810
19	0.0284	34	0.0908	49	0.1886
20	0.0314	35	0.0962	50	0.1963
21	0.0346	36	0.1018		

Volume

Conventionally, this is defined as the volume of the main part of the trunk up to 7cm in diameter, including bark but excluding branches and the tree top.

The Blue Book contains species-specific stand volume charts which allow you to use a straight edge to read across from the measured basal area and top height for each plot or point to give the m^3/ha for the sample plot/point. The average of these plots is the estimated volume/ha for the stand.

An alternative method is based on multiplying the basal area per ha by "form height", which varies between species and can be predicted from top height. Again, this can be read from tables in the Blue Book.

Sampling intensity and methods

Measuring every tree is inefficient and would only be considered if felling a high quality stand of e.g. oak. Instead, a representative sample of the trees in a stand are measured. Sampling can be based on plots or points. There is a trade-off between effort and accuracy: generally the greater the sampling intensity the more reliable the volume estimate produced.

Your chosen sampling intensity will usually depend on your motives (a pre-harvest survey may need to be more detailed than one for general management planning) and on the crop itself (you would expect to spend more time measuring a high quality broadleaf timber stand than a wind-blown block of lodgepole pine).

When planning inventory work it is important that your sampling accounts for the variation within a stand (e.g. differential growth rates on slopes, wet areas where growth is checked) and that all component species are captured. Initial survey work will have divided the forest into sub-compartments. If these are fairly uniform in terms of species, tree sizes, ages and density it will reduce the number of sample plots or points needed. Conversely, for more complex stands a higher sampling intensity is required.

Sampling locations can be decided by laying a grid over the map and using perhaps 5 grid intersections in each sub-compartment at which to place a sample plot or point. Take the grid reference from the map and locate this in the woodland with your GPS device.

Alternatively walk a grid along a pre-determined bearing in the forest and place a plot every 100 or 200 paces. When you get to the edge of the sub-compartment, cross over 100 paces (for example) and come back on the parallel gridline, placing plots as you go. When you think you are done, check to see if you measured in sufficient plots to capture the variation in the stand.

Sample plots

Forest mensuration typically uses circular sample plots with a given radius. The most convenient plot size is 0.01ha (5.6m radius) as to convert sample results to per hectare values requires only multiplication by 100.

0.01ha plots are fine for simple and relatively dense stands of trees, but for more complex

stands or stands with fewer trees you will need larger plots (8m radius = 0.02ha, 12.6m radius = 0.05ha) to include sufficient trees to accurately capture the average size of trees in the stand. A good rule of thumb is that you should seek to average least 10 trees per plot.

Plot sampling is best undertaken by a two person team, with one measuring and calling out tree diameters and the other standing at the centre of the plot recording data.

Point sampling

A rapid way of estimating basal area in a forest is to use a tool called a relascope. There are various designs (the simplest of which is your thumb), all of which use a crosspiece or prism held at a known, fixed distance from your eye.

Top image: Using a notch or gap type relascope
Bottom image: How a prism type relascope works

Stand at the centre of an imagined circle and starting from a fixed point, look at the width of each tree trunk 1.3m above ground level, visible from the circle centre. Any tree appearing bigger than your thumb or the notch, or overlapping in the prism, counts as 1. If one tree is at all hidden by another tree you may need to stand a bit to one side to clearly see each side of the trunk, but then return to your plot centre to assess the next tree. Stop when you have completed a sweep around the full circumference of your imagined circle and your tally of trunks is then multiplied by the relascope "factor" to give an estimate of basal area for that bit of the forest. Purpose built relascopes are already calibrated to a specific factor: if using your thumb you will need to calibrate it!

Relascope sweeps can be done on your own and are quicker but perhaps a bit less accurate than measuring diameters, so you should do more of them than you might have done plots.

Principles of stand growth, yield models

Forest management requires an understanding not just of the current standing volume but also of the growth rates and a stand's future volume or vulnerability to windthrow.

Forest Research has been measuring and modelling stand growth for different plantation species under a range of simple management regimes since 1920. The latest (2006) version is available through the Forest Yield modelling software package: a licence costs £50+VAT although the supporting handbook can be downloaded for free. As with the Blue Book, archived older versions of the table are available as pdfs from the FR website (see resources section for links).

Trees grow each summer, increasing in girth and height, but whilst this growth is predictable, it is not consistent: the annual addition in volume is low when the trees are young, increases rapidly during the juvenile stage (e.g. 15-40 years for Sitka) then gradually slows in maturity. Meanwhile, competition between trees leads to mortality and stocking densities naturally reduce from many thousands of seedlings to a few hundred (or less) mature trees per hectare.

One slightly counter-intuitive aspect of modelling tree growth is that the total annual increment of a fully stocked stand is largely independent of stocking density: the growth accrued by a given stand will be essentially the same whether there are 2,000 or 3,000 trees per hectare. Foresters therefore focus on the

annual increment and productivity of stands, rather than that of individual trees.

Yield class (YC) is an index of the potential productivity of even-aged stands of trees used in UK forestry. It is measured in units of m^3/ha/year, conventionally expressed in increments of 2, and can be estimated from the top height and age of a stand using FR's tables and charts: knowing the YC of a stand allows you to make projections of future growth.

Note that Yield Class can be assessed for mixed species stands (the different species will usually have different YC) but the YC of very young or mixed-aged stands cannot be determined with any reliability.

Felled timber measurements

It can be useful to know how to measure the volume of single, felled trees or stacks of logs. For single logs this can be calculated from measurements of the length and mid-diameter of the log. For stack volumes you will need to measure the length of the logs and the cross-sectional area of the stack (dividing the face of the stack into rectangles and triangles and measuring length and height of these sections). You should then apply a conversion factor of 0.7 for straight logs and 0.6 or lower for irregularly shaped logs to allow for the spaces in the stack.

Selling timber by weight

The mensuration procedures detailed above estimate timber volumes, however, timber is usually sold by weight. The Blue Book contains conversion factors for various species, e.g. for Sitka spruce the volume:weight conversion figure given is 1.08m^3/tonne, so a cubic metre will weigh 0.92t Note that this is "green" weight, and the actual weight of a cubic metre of timber will depend on the extent to which logs dry out between felling and weighing.

Resources

Community Woodlands Association (advice and support for community woodlands)
http://www.communitywoods.org

Making Local Woods Work (advice, tools and resources for woodland social enterprises)
https://makinglocalwoodswork.org

Forest Research publications
https://www.forestresearch.gov.uk/research/forest-mensuration-a-handbook-for-practitioners/
https://www.forestresearch.gov.uk/research/forest-yield/

Archive versions of Forest Research publications
https://www.forestresearch.gov.uk/research/archive-forest-mensuration-handbook/
https://www.forestresearch.gov.uk/research/archive-forest-management-tables-metric/

Resources for schools / students
RFS https://www.rfs.org.uk/learning/forestry-knowledge-hub/tree-biology/mensuration/
OWL Scotland TreeMeasuring2018.web3.pdf (owlscotland.org)

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