PLANTATION GUIDELINE
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MEASURING TREES AND MONITORING PLANTATION GROWTH

IMPORTANCE OF MEASURING TREE GROWTH & DETERMINING YIELD

For any commercial tree grower, it is important to have at least a basic understanding of tree growth and current and expected stand volume. Such information is needed not only to predict future revenues (and thus to determine the viability of the tree growing venture) but also for valuation and sale purposes.

This Guideline covers only the basics of the large and rather specialist field of tree and forest measurement (usually termed mensuration), inventory and yield prediction. References are given at the end for those who wish to delve deeper into the subject.

TRAINING & EQUIPMENT

Selecting and training a good team is important with mensuration, as is the correct choice of method and instruments to obtain the required information. In a commercial plantation forestry business, many important decisions are taken on the basis of inventory results and thus it is vital that the work is closely supervised and results frequently cross-checked in the field.

SAMPLING

It is most important to understand that in commercial forestry, it is not feasible to measure every tree in one's plantation: this only is possible in small research plots.

Thus a sample normally has to be taken, which we hope represents the whole stand. Sampling is a complex area involving detailed statistical analysis, which is beyond the scope of this Guideline. What is crucial, however, is to ensure that the sample of trees being measured represents a reasonable cross-section of the whole area.

This is usually done by measuring trees (or plots of trees) situated systematically throughout the plantation, covering the various site factors (e.g. lower slopes, mid slopes and upper slopes) and the different species planted.

The easiest method is to take transects (lines) at regular intervals throughout the stand, with plots situated at a pre-determined distance along each transect. Each transect is normally done on a compass bearing. This takes away the bias factor, where there is often a tendency to measure only the best trees or areas in a stand and ignore the areas of poor growth or low stocking.

BASIC TREE MEASUREMENTS

Tree Diameter

Tree diameter (sometimes called girth) is a quick and easy measurement to take. Tree diameters are normally measured at breast height (dbh), which should always be 1.3m above ground level (NB. always ensure your measuring crew measure where 1.3m is on themselves as people differ in height!). The two most common instruments for measuring dbh are diameter tapes and callipers.

Diameter Tapes measure directly a stems' diameter (in cm or mm) with the tape being placed around the circumference of the tree. Some diameter tapes are 'rounded down' to the nearest cm class, others (used more for research purposes) can read to the nearest mm. Dbh tapes are either plastic-coated fibreglass or steel: the former can stretch as they wear and thus should be replaced as necessary. The steel tapes are expensive and not very hard- wearing.

There are some basic rules that must be followed when measuring dbh:

- The dbh tape must always be at right angles to the stem.
- Ensure that the dbh tape is not twisted.
- Remove any loose bark (or other obstacles) before dbh is measured.
- On a slope, always stand on the uphill side to measure dbh.
- The zero point on dbh tapes is the extreme edge of the steel rectangle or the point of the hook.

Callipers are also very common and offer a quick way of measuring tree dbh. They are made of steel or alloy and have one fixed and one moveable arm. The same rules for dbh tapes apply but with calipers, two measurements should be made on each tree at right angles to each other and the average recorded. The most common fault with calipers is excessive movement in the mobile arm and thus they must be regularly checked to ensure that the two arms are parallel.

Tree Height

In order to calculate tree (and stand volumes) accurately, tree height must also be measured. Tree height at a given age is also an important indication of site quality for a species.

There are two main measurements of individual tree height, namely ***total height*** which is the vertical distance from the base to the tip of the tree, and secondly, ***timber height***, which is the height from the base to a specified minimum stem diameter (often around 7cm).

There are also two expressions that refer to stand height (rather than individual tree height), namely, ***top height*** (sometimes referred to as dominant height) and ***mean height***. Top height is defined as the average total height of the hundred trees of largest diameter per hectare. To estimate the top height of a stand, a number of top height trees are measured from sample plots throughout the stand. The number of trees depends on the variability of the crop and the size of the stand. For a fairly uniform crop over 10ha, 10 trees will suffice, whereas 16 are recommended for a more variable crop.

Mean height refers to the mean total height of a stand and is assessed by taking the heights of trees randomly selected, irrespective of diameter, throughout the stand. Tree heights are measured as follows:

<u>Height Rods</u>: For trees up 6 metres or so, height is best measured directly with a height rod. This is usually a light pole with clear markings (depending on the accuracy required) that is placed against the tree's stem and read directly by another person.

This person must stand far enough away from the tree to be able to line up the top of the tree and then read from the markings on the pole. Care must be taken not to damage the tree stems when the height rod is placed alongside them. As the trees get taller than around 6m, however, height rods become too unwieldy to use and we have to then use other instruments.

<u>Clinometers</u>: The most common instrument is the hand-held clinometer (the most common brand is Suunto from Finland). The Suunto has a solid aluminium housing and a scale that rotates according to the angle of sight. Using a clinometer, a reading is taken at a known distance away from the tree - by sighting on the top of the tree and then on the base of the tree: the tree height is then calculated by adding or subtracting these two measurements (depending on whether one is above or below the tree).

When using a clinometer both eyes must be kept open (which takes some practice!). Use one eye to look through the instrument at the scale while the other sights the tree alongside the clinometer housing. An optical illusion is created and the horizontal sighting line will appear to project to the side of the clinometer housing. When this line is level with the tree's top (or base), the scale can then be read.

Suunto clinometers either have a percentage (%) scale or a 15 and 20 metre scale. The 15/20 instrument can only read from 15 or 20m distance from the tree (or multiples thereof) whereas the % one can read from any distance away (which must be measured). Some clinometers also have a built in rangefinder to quickly find the exact distance from the tree: otherwise, a long tape measure is required.

<u>*% Suunto*</u>: using the % Suunto, follow these procedures:

1. Back away from the tree (carefully!) to a point where you can see its top clearly and make a temporary mark on the ground.
2. Measure the distance from the tree (in our worked example let us say this is 25m).
3. With the Suunto sight to the top of the tree and read the % scale (e.g. +63%).
4. Then sight onto the base of the tree (e.g. –7%, which indicates that the base of the tree is below eye level).

5. The total reading is 70% (63+7).
6. To obtain total tree height, multiply this % figure (70% = 0.7) by the distance (e.g. 0.7 x 25m = 17.5m).

15/20 Suunto: using a 15/20 Suunto, follow the following procedures:

1. Measure a spot 15m or 20 away from the tree to be measured, where you can see the top clearly: mark the spot on the ground.
2. Using the Suunto, sight to the top of the tree and record the reading from the appropriate scale (the 15m scale is on the right, the 20m scale on the left as you look through it) (e.g. 17.25m).
3. Do the same sighting on the base of the tree (e.g. -1.5m, which indicates that the base of the tree is below eye level).
4. To obtain total tree height, add these figures (e.g. 17.25 + 1.5 = 18.75m).
5. The 15/20 Suunto can be used at distances of 30m and 40m but the readings on the appropriate scales must then be doubled.

The main problem with measuring tree height is often not being able to see clearly the top of the tree, especially in an unthinned, dense stand. The person using the clinometer must be prepared to frequently move around the stand in order to see the tree tops.

In stands with a lot of ground vegetation, in order to sight accurately on the base of the tree it is good practice to ask a colleague to stand against the tree and sight on where you expect his feet to be!

The Future

There is a range of sophisticated digital tools now available from specialist suppliers for measuring quickly and accurately tree diameters, tree height and distances. These electronic devices (clinometers, hypsometers, relascopes and rangefinders) are, however, beyond the scope of this basic Guideline.

Basal Area

The basal area (BA) of an individual tree is the cross-sectional area of a tree at 1.3m. BA is calculated as follows:

$$\textbf{BA (in m}^2\textbf{)} = (\pi \times \textbf{dbh}^2) \div 40{,}000$$

NB. Where dbh is measured in cm. and π = 3.142.

The BA of a stand is the sum of the BAs of all the trees in the stand. The usual way of estimating stand BA, however, is to measure the dbh of trees in sample plots throughout the stand and then scale this up.

Tree Volume

Tree volume is a function of tree height and basal area. A rough estimate of tree volume can be obtained from the following formula:

Tree vol. (in m3) = Total ht. x BA x FF

NB. Where FF = Form Factor (avg. FF for P. caribaea = 0.4; for E. grandis = 0.35).

For most inventory work (and especially yield prediction), more detailed estimates of volume are required: these are logarithmic equations derived from accurate measure-

ments of many thousands of trees. They are considered, however, beyond the scope of this Guideline.

Stand Volume

The value that is of utmost interest to the forest owner (or investor) is stand volume. The maximum volume for a given species on a given site is determined not only by silviculture but also by age.

To calculate stand volume, an average tree volume is calculated which is then converted into an average volume per hectare by multiplying by the mean number of trees in each sample plot. The standing volume of the stand is estimated by multiplying the average volume per hectare by the stand's area.

FOREST INVENTORY

Forest Inventory is important for a number of reasons, in particular:

- To provide information for long-term planning.
- To provide data for immediate decisions on felling and thinning programmes.
- For valuation purposes.

It is important to note that a single (one-off) inventory provides only details of the current standing crop. To monitor growth rates, a recurrent or continuous inventory is required. This is discussed in the next section.

PERMANENT SAMPLE PLOTS (PSPS)

The most common form of continuous forest inventory is PSPs, which are located throughout the plantations and re-measured at regular intervals. PSPs have the following objectives:

- To provide information on stand growth for the efficient management of the forest.
- To estimate the potential productivity of the site.
- To quantify the effects of silvicultural treatment on growth and yield.
- To monitor changes in site productivity over successive rotations of tree crops.

Below are guidelines for establishing and assessing PSPs: a team of 4 people are usually needed, including the 'Booker' who oversees the operation.

Location and No. of PSPS: the PSPs should cover the range of species, age-classes and sites in the forest. For plantations in Uganda, roughly one PSP for each 15-25ha is a good guide.

Size of PSP Plots: the size of plot is determined by the spacing of trees in the stand: as a guide, each plot should be big enough to include 15-25 trees. Common plot sizes are as follows:

Circular plot radius: 8.0m (= 0.02 ha).
Circular plot radius: 11.3m (= 0.04 ha).
Circular plot radius: 12.6m (= 0.05 ha).

For well established (i.e. well stocked) Pine and Eucalpyt plantations in Uganda, the 8.0m radius plot is usually sufficient to give enough trees.

Mapping: the exact location of the PSPs must be clearly marked on a large-scale map (1:10,000 or larger). The compass bearing and exact distance from a clear reference point (e.g. the road junction at a compartment boundary) to the centre of the PSP must be marked on the map. For those with digital technology, each PSP's centre can be recorded using a GPS.

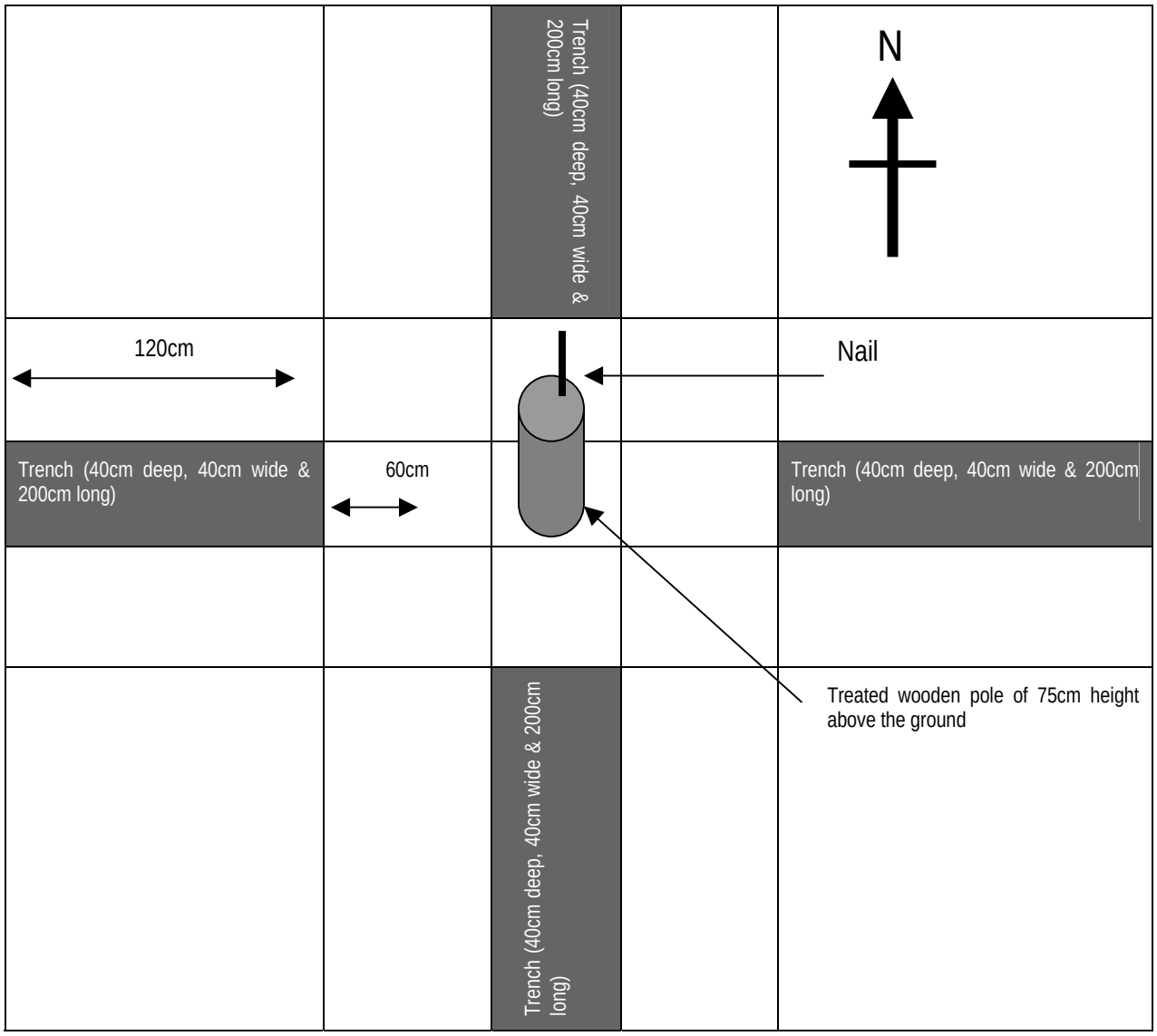
Centre Posts: a treated, wooden post should be put into the centre of the plot with 4 trenches dug along N-S and E-W axes. A nail knocked into the top of the centre post is useful for measuring the plot radius with a tape measure.

Marking Trees: all trees within the plot boundary should be marked with permanent enamel paint at 1.3m height. All trees must be carefully checked from the centre post, to ensure that they are within the plot. The trees should be counted (and marked) in a sweep from the North in a clockwise direction. As soon as the trees in the PSP are large enough, numbers should be painted onto their stems. This can be difficult with Eucalypts, for example, which shed their bark regularly. Numbered, metal tags are sometimes used instead of paint (though the disadvantage of such tags is that they have to be nailed onto the trees and are often stolen).

Measuring Trees:
The trees are measured in order – sweeping from the North. The Booker must stand behind the centre-post and direct which order the trees are measured in. When two trees are in line, the closer one is measured first. All dbhs are measured preferably with non rounded-down dbh tapes. A sample of height trees are also measured: in an 8.0m radius plot (=1/50th hectare), the total height of the two trees of largest dbh should be measured in each plot (this gives us the Top or Dominant Height). Height should be measured to the nearest 0.25m if using a Suunto.

Data Confirmation: if a PSP is being re-measured, it is advisable to have the data on hand from the previous measurement. In this way, problems can be picked up immediately (e.g. if more trees than before are recorded or if a tree has appeared to have reduced in dbh). Increasingly inventory crews worldwide are using hand-held computers to eliminate such errors.

Other Information: Any other observations on tree conditions should be recorded at the time of measuring PSPs, for example, relating to tree health. Because of the long-term nature of PSPs, it is essential that the data is stored both on paper and digitally. PSPs should be re-measured every year.



EQUIPMENT SUPPLIERS

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FURTHER INFORMATION

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