TVET CERTIFICATE V IN FORESTRY

Forest harvesting

FORFH501 Harvest forest

Competence

Credits: 8 **Learning hours: 80 hours**

Sector: Agriculture and food processing

Sub-sector: Forestry

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Purpose statement

This module describes the skills and knowledge required to apply forest harvesting techniques. These skills are of great importance for sustainable forest exploitation.

The module will allow the learner to: Identify forest tools and equipment for harvesting, Carry out forest inventory, Apply forest harvesting techniques

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Learning Unit 1: Identify forest tools and equipment

LO 1.1: Select tools and equipment

Forest harvesting as an activity of cutting trees down and extraction; is one of the most important and cost-intensive operations in forest management. The different process steps of harvesting operations are felling, delimbing, debarking, bucking, off-road transport of the wood, and loading. Specifically in tropical countries, the resources, equipment, and machines that can be used are many and can be composed in complex systems. The climate conditions, soil properties, and human resources have to be considered in the choice of the equipment or machine used in each single process step of harvesting operations.

Smallholders or communities on the other hand are still relying on simple tools and equipment, animal-assisted skidding, and manual or motor-manual work in wood harvesting operations.

1.1.1. Types of forest harvesting tools and equipment

A. Mechanical tools and equipment:

Topic 1: Description of manual tools and equipment used in forest harvesting

These are used manual by hands of man-power and it includes for example: Panga, axes, Saws, tackle, Steel cables, log tongs, wedges, Cant-hook, and hammer.

Equipment	**Picture**	**Use**
1. Machette		It is a handtool used in debranching activities on felled trees during forest harvesting
2. Axe		Axe is a handtool used in cutting down trees and debranching in forest harvesting.
3. Handsaw		Handsaw (two man saw) is one of saws used in crosscutting activities during forest harvesting activities.

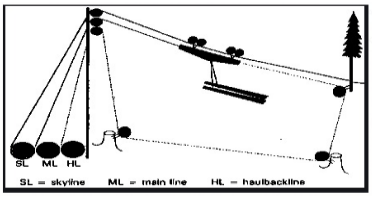
4. Tackle		Tackle is a hydraulic handtool used in logs extraction.
5. Steel cable		Steelcable is also tool that helps in pulling and transporting logs during forest harvesting.
6. Log-tong		It is a handtool used by two persons to transport logs during forest harvesting activities.
7. Wedges		Wedges (wooden/metal) are used in splitting logs and in sawing to avoid saws to be pinched
8. Cant-hook		A **cant hook** is a traditional logging tool consisting of a wooden lever handle with a movable metal **hook** at one end, used for handling and turning logs, especially in forest harvesting.
9. Hammer		A hammer is a tool consisting of a weighted "head" fixed to a long handle that is used for fixing wedges during forest harvesting.

B. Motorized equipment:

Topic 2: Description of motorized tools and equipment used in forest harvesting

Motorized equipment or **power tool/equipment** is a tool that is actuated by an additional power source and mechanism other than the solely manual labor used with hand tools. The most common types of power tools use electric motors.

Equipment	Picture	Use
1. Bulldozer		Bulldozer is used in forest harvesting especially collection of cut logs into a pile for easy transportation by logtrucks.
2. Crane		It is device mounted either on a logtruck or tractor for easing loading of logs.
3. Chainsaw		It is a motorized saw used for cutting trees.
4. Delimber		It's a kind of forest truck specialized in removing back and branches on cut trees.
5. Feller buncher		It is a forest truck used in tree harvesting activities
6. Forwarder		It is forest truck used in removing logs from cutting site to nearby roadside for easing transportation to logyard by logtrucks (Unloading)
7. Front end loader		It is a forest truck used in loading and off-loading logs in forest operations

8. Yarder		It is a system of transportation of logs by using cables, winches, pulleys and spar trees.

1.1.2. Criteria of selecting tools and equipment:

Topic 3: Discussion on criteria to consider for selecting tools and equipment used in forest harvesting.

A. **Average tree size:** tool or equipment to be used in harvesting for instance the big sized tree diameter can be felled effectively by chain saws and other felling, machines/feller buncher whereas axes can be used for small sized tree diameters.

B. **Location:** location can affect the selection of tools and equipment for example on steeper slope some equipment are not used like harvesting tractors but hand tools are suitable.

C. **Harvesting area:** when harvesting a large area heavy harvesting machinery like harvesting tractors are required.

D. **Environment risks:** When some risks are likely to occur some tool cannot be forgotten for preventing accident like cables and tackles for transport of logs (yarding).

Learning Outcome 1.2: Handle tools and equipment

Topic 1: Discussion on handling of tools and equipment used for forest harvesting.

Refers to the used of tools and equipment that require the following manufacturer's instructions or training from experts for accomplishing the task effectively. During handlings tools and equipment try your best to respect these:

1. **INSPECT YOUR TOOLS.** Never issue or use a damaged or defective hand or power tool. Always make sure they are in good working order before and after each use.

2. **PICK THE RIGHT TOOL**. Make sure you are using the correct tool for the task at hand. This also means using the right sized bits, blades and accessories on your power tools.

3. **WEAR YOUR PPE.** Issue personal protective equipment to your employees and make sure they wear them properly. This comprises of items like safety goggles, hard hats, etc.
4. **DON'T ALTER YOUR TOOLS.** Never remove guards or disable safety devices on power tools. Don't paint or cover up your tools as this could prevent you from noticing chips or cracks.
5. **HANDLE WITH CARE.** Tools are not toys. Never throw or toss a tool in the direction of or directly to a coworker. Never use electrical cords to lower or lift a tool to get it to a workspace.
6. **KEEP YOUR DISTANCE.** When working with hand and power tools be sure you have enough room to safely operate without coming into contact with other objects or coworkers.
7. **PICK UP AFTER YOURSELF.** Don't leave idle hand tools lying around the job site. They can lead to tripping or be accidentally knocking on someone's head.
8. **UNPLUG AND DISCONNECT.** Don't leave electric power tools plugged in when not in use, when making adjustments such as replacing blades and bits, or loading fasteners.
9. **KEEP YOUR WORKSPACE CLEAN.** A cluttered floor can lead to accidental trips or falls which can be extremely dangerous when working with hand and power tools.
10. **GET TRAINED UP.** Make sure you and your employees are thoroughly trained on the proper use of hand and power tools required for the task at hand.

Learning Outcome 1.3: Adjust tools and equipment

Topic 1: Explanation on adjustment on tools and equipment used for forest harvesting.

A. Adjustment techniques of mechanical and motorized tools and equipment:

When tool or equipment permits its adjustment what operator is supposed to do is nothing but to check whether each device is in its place or well fixed

B. Calibration standards

Calibration refers to the adjustment of tool and equipment for their good functioning.

C. SOP (standard operating procedures): refers to the use of tools and equipment according to manufacturer's specification in order not to damage them.

D. Adjustment of gauge: gauging instruments are the same as measuring instruments. So during their adjustment is done by checking whether they are well set for taking correct measurement.

Learning Outcome 1.4: Maintain tools and equipment

Topic 1: Discussion on maintenance of tools and equipment used in forest harvesting.

Harvesting tools and equipment require the following as maintenance, after their use they have to be cleaned, repaired when damaged, oiling to avoid rust and lastly they are kept in dry places.

1.4.1. Maintenance requirements

During maintenance activities, the following storage environment factors must be taken into consideration:

- **Light**: for avoiding too much cold that lead to humidity in storage environment.
- **Cleanliness**: to avoid dirty matters that can affect the quality of tools and equipment

1.4.2. Maintenance technique:

- **Sharpening**: it is an activity of increasing catting ability of a tool or equipment.
- **Oiling**: it is an application of oil onto the tool or equipment to avoid rusting.
- **Cleaning**: it is an activity of removing dirty material on tool or equipment.

- **Simple repairing:** it is like putting together or fixing parts of tools or equipment that do not allow it to be used appropriately.
- **Shaping**: when the cutting edge of tool or equipment is damaged it is reshaped for it to be straight and cut uniformly.
- Painting: as the paint is removed on tool or equipment it is better to repaint to avoid rust on metal that makes that tool or equipment.
- **Replacing**: it is like replacing damaged part of tool or equipment for it to work properly
- **Teeth setting:** teeth need to be set when they are not cutting as result of not being bent left and right so for this a setter is used to solve the problem.

Learning unit 2: Carrying out forest inventory

Learning Outcome 2.1: Sample forest stands

2. 1.1: Sampling and exhaustive enumeration

Topic 1: Discussion on sampling and exhaustive inventory methods.

A. Sampling inventory

Sampling inventory is a method of forest inventory where the information is obtained on basis of samples not on the total forest area.

1. Random sampling

Is a sampling method in which all members of a group (population or universe) have an equal and independent chance of being selected.

2. Systematic sampling

A method of choosing a random sample from among a larger population. The process of systematic sampling typically involves first selecting a fixed starting point in the larger population and then obtaining subsequent observations by using a constant interval between samples taken.

3. Stratified sampling

The process of dividing a population into smaller subsets for sampling purposes. In statistics, stratified sampling is a method of sampling from a population.

In statistical surveys, when subpopulations within an overall population vary, it is advantageous to sample each subpopulation (stratum) independently. Stratification is the process of dividing members of the population into homogeneous subgroups before sampling. The strata should be mutually exclusive: every element in the population must be assigned to only one stratum. The strata should also be collectively exhaustive: no population element can be excluded. Then simple random sampling or systematic sampling is applied within each stratum. This often improves the representativeness of the sample by reducing sampling error.

B. Exhaustive enumeration (total inventory)

Exhaustive enumeration or inventory is a type of forest inventory type where all the information needed are collected from the whole forest area not on sample basis.

C. Inventory types basing the level of investigation or information needed:

Topic 2: Discussion on type inventories basing level of investigation or information need and cost of forest inventory.

Three broad classes of forest inventories can be considered based on the depth of the investigation:

1. **Reconnaissance inventory:** this class of inventory is based upon an exploratory investigation of the forest population. The information derived is primarily intended for preliminary management decisions. The inventory data are summarized on a regional or total area basis.

2. **Management inventory:** this inventory represents a low intensity investigation of a large tract of forested area; for example, a forest reserve. The information produced is primarily intended for broad-based management decisions, allowable cut calculations and long range planning.

3. **Operational inventory:** an operational inventory is based upon an intensive investigation of a relatively small area. The information produced is primarily intended for use in short term or "operational" planning, e.g. related to the harvesting of timber volumes within local cutting compartments or logging units.

D. Costs of a forest inventory

Forest inventory is generally a costly undertaking, hence explicit planning and real need is a necessary. There are three main factors, which influence the cost of an inventory: Type of information required; Standard of accuracy; Size of area to be surveyed and the minimum size of unit area in the forest.

a) Type of information Required:

General information on areas of the important forest types can be obtained relatively cheaply from aerial photographs. In contrast terrestrial forest inventory is very expensive particularly if various detailed information is sought. Hence, the intensity and quality of the selection of representative samples requires careful supervision.

b) Standards of Accuracy:

The greater the degree of accuracy required the greater the percentage of the forest that has to be sampled. The reduction of the standard error by half requires approximately four times as many samples.

c) Size of Area to be surveyed:

The cost per unit area for aerial photography will be less the larger the zone photographed. If individual estimates to a prescribed degree of accuracy are required then it is cheaper to have large blocks of forest rather than small ones.

2.1.2: Sample form:

Topic 2: Discussion on sample forms, sample size and factors influencing the sample size.

In forest invent inventory three geometrical forms are generally used such as **square**, **rectangular** and **circular** but the most preferred in current practices is circular for its following advantages:

1. Reduce the number of trees within plot
2. This form is easy than the rest of others two
3. It is easy to define

2.1.3. Sample size

The sample size determination is the act of choosing the number of observation to include in statistical sample.

Although there is no consensus, as a rule of thumb on the average there should be about **15-20 trees on the sample plot**. The table below suggests a reasonable plot size based on the stocking density of the stand.

2.3.4. Factors influencing sample size

1. **The density of stand for inventory:** when the number of trees are more per unit area it means small spacing between trees, the size of sample will reduce and on contrary to these it will increase.
2. **The shape of sample plot:** the shape of plot affects the size for example the square or rectangular form differs from circular form as result of same number of trees to include in sample plot; it means square and rectangular increase sample plot area for the empty corners without trees than circular form.
3. **Location of the land:** When the land location is uniform sample size will not be as lager as when it is not uniform it means when site contain small valleys or hills.
4. **Means:** when means is available sample size can be increased instead of working on small area as the cost of activities will be covered.
5. **Time in which inventory is supposed to be accomplished:** if there is limited time for inventory activities, the size of sample will be reduced as opposite to when the time is extended.
6. **Precision required:** if high precision is required, the sample size will be reduced thus sampling rate also is increased on contrary the size of sample will be increased and sampling rate reduced.

2.1.4. Sampling rate:

Topic 2: determination of sampling rate in forest inventory.

During forest inventory the whole forest is sampled but all samples are not supposed to be considered for economic and task minimization related issues, for these, some sample out a hundred samples are considered for data collection.

Practical exercise:

In Rulindo there is a national forest planted on **1.5ha**, species planted on that area is Eucalyptus saligna with a spacing of **2.5m X 2.5 m.** The forest is physiologically mature to be harvested, but to be sure of the volume to be harvested, sampling inventory must be done. Knowing that the sample plot will contain 20 trees and only 36 sample plots have been used in data collection you are asked to determine the sampling rate they have used during sampling inventory.

Answer:

- Number of trees on the area: $\frac{\text{Total area}}{\text{area of one tree}} = \frac{15000\ \text{m}^2}{6.25\text{m}^2} = 2400\ \text{trees}$
- Sample plot size: area of 1 tree **x** number of trees $=6.25\text{m}^2$ **x** 20 trees= 125m^2
- Possible samples that cover the area: $\frac{\text{Total area of the forest}}{\text{Area of the sample plot}} = \frac{15000\ \text{m}^2}{125\text{m}^2} = 120\ \text{samples}$
- Sampling rate used: $\frac{\text{number of sample plots used} \times \mathbf{100}}{\textbf{possible sample plots}} = \frac{\mathbf{36 \times 100}}{\mathbf{120}} = \mathbf{30\%}$

2.1.5. Safety and First Aid instructions

A. Safety or Personal Protective Equipment (PPE).

Topic 1: Discussion on Safety or Personal Protective Equipment (PPE) used in forest harvesting.

Personal Protective Equipment (PPE) are specialized clothing or equipment worn by employees for protection against health and safety hazards. Personal protective equipment is designed to protect many parts of the body, i.e., eyes, head, face, hands, feet, and ears.

PPE	PROTECTS	HAZARDS
Safety glasses	Eyes	Chemical liquid splashes, dust
Hard hat	Head	Falling materials
Ear protection	hearing	Excessive noise
Gloves	Hands	Corrosives, toxic materials
Respirator	Lungs	Toxic gases, vapors, fumes or dust
Clothing	skin	Toxic or corrosive materials
Foot wear	Feet	Corrosive and toxic materials

Accidents cannot be completely ruled out and therefore provisions must be made for first aid.

B. First aid comprises:

- The identification of the injury and assessment of its severity.
- Necessary first treatment of the injury on the spot.
- The call for further assistance including transport and medical facilities, if necessary.

Learning Outcome 2.2: Select mature trees

2.2.1. Characteristics of mature trees

Topic 1: Determination of mature trees during forest harvesting.

A. Diameter

Diameter of a stem is a length from the outside of the bole through the center to the opposite side of it. Diameter can be measured by using tape measure or caliper.

B. The diameter at breast height (dbh)

The standard position for diameter measurement at standing tree is at breast height. It is defined at 1.30 meter above ground in most countries, but there are some countries where diameter at breast height is measured at different heights.

C. Height

Tree height is defined to be the perpendicular distance between the ground level and the top of the tree. While, Tree length is the distance between the stem foot and the top along the stem

D. Age

The age of a tree can be determined by plant's whorls (branching point on stem) for conifers and counting growth rings. Maturity of a tree and hardness is determined by how many years the tree lasted.

Learning Outcome 2.3: Collect the data

2.3.1. Sample site description: Soil,

Topic 1: Description of site characteristics.

A. **Vegetation cover:** the type of vegetation on the site can determine fertility of the soil on that area and in turn affect the growing rate of trees.
B. **Slope:** the site slope also is one of elements that characterize the site it means sloped land or site have low fertility as compared to site with gentle slope. In calculation the slope of the site is obtained as follow: $\textbf{Slope}(\%) = \frac{\textbf{Vertical distance (VD)}}{\textbf{Horizonta distance (HD)}} \times \mathbf{100}$ **,** to get slope in degrees it's very simple, you find the **arc tan** of slope obtained in percentage **(%)**.

C. Exposition: It is a way of localizing the site according to certain factors.

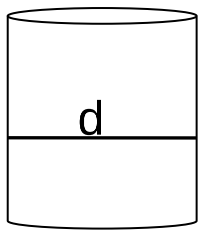
D. Geographical coordinates: it is special representation of the site, either of the two lines of latitude and longitude whose intersection determines the geographical point of a place

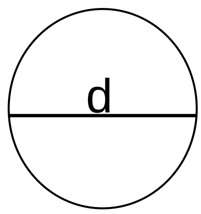
2.3.2. Tree growth parameters:

Topic 1: Discussion on tree growth parameters.

i. Diameter

Diameter of a stem is a length from the outside of the bole through the center to the opposite side of it.





A. Longitudinal/side view **B. Cross-sectional view**

(Different views of tree diameter)

Usually diameter is measured with bark so that a reduction needs to be applied if only the wood is of interest.

Sometimes instead of diameter, tree girth is measured. It is the circumference/perimeter of the stem.

$C = 2\pi r$ **$C = \pi d$**

Tree diameter and girth measurement are the most important tree variables because:

They are in most cases easily and directly measured from the diameter the basal area (which is closely correlated to tree volume) is directly calculated

The diameter distribution of a stand gives a good insight to the stands structure and potentially necessary silvicultural treatments

The diameter at breast height (dbh)

The standard position for diameter measurement at standing tree is at breast height. It is defined at 1.30 meter above ground in most countries, but there are some countries where diameter at breast height is measured at different heights.

Why dbh is preferred?

At breast height the instrument is easily handled (convenience and ease). Also on most trees the influence of buttress on the stem form is already much reduced at breast height. However, irregularities of tree stems do sometimes prevent the measurement of diameter at breast height.

The followings are some of the cases:

Trees on slope: measure dbh at the standard height above the floor/ground on the uphill side of the tree.

Leaning tree: measure parallel to the lean on the lower side of the lean

Buttress tree: if the buttress height is more than one meter then measure dbh from the point where buttress ends, otherwise measure normally. Abnormalities at breast height: swellings, knots, crooks, etc

Measure the dbh above or below the abnormalities and indicate the height at which diameter is measured. Sometimes measurement is done at equal distance above and below breast height and then dbh is estimated by taking the mean of the two readings.

Bifurcation: If a tree bifurcates above breast height then measure dbh as usual. But, if a tree bifurcates below breast height then measure dbh on each stem separately.

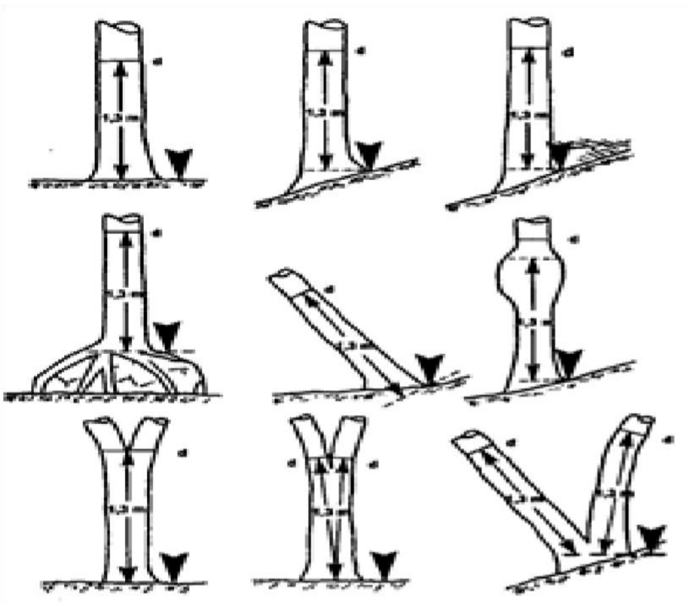


Figure: Positions of diameter measurement different conditions

Instruments used for measuring

Calipers and diameter tape are the most commonly used instruments. But also Biltmore stick can be used (very rare presently).

1). Caliper

Is the most efficient to measure dbh directly whenever there is direct access to the tree. It can be made of wood, metal or aluminum. It has two arms one fixed and a graduated bar/beam on which the second arm slides.

To measure with a caliper, hold it firmly and horizontally as well as perpendicular to stem axis at the same time. Usually two readings are taken perpendicular to each other rat breast height and then the average value will be recorded.

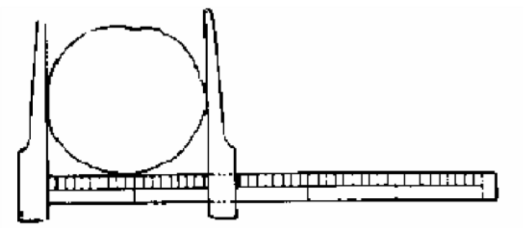


Figure: Tree diameter measurement with caliper

2). Diameter tape

There are diameter tapes from which the tree diameter can be directly read. Tree diameter can also be determined from circumference measurement which can be done by diameter tape or any tape since circular tree stem shape is assumed. $\mathbf{C = 2 \pi r = \pi d}$; $\mathbf{d = C/ \pi}$

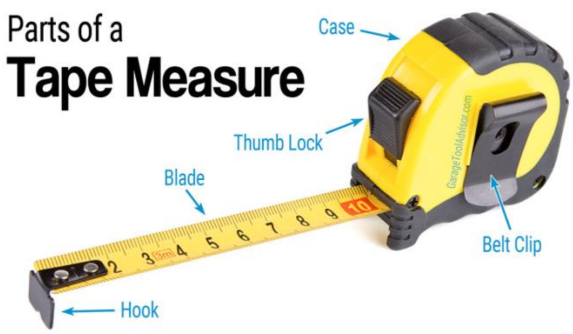


Figure: Taper measure.

Calipers Vs diameter tape

Tapes are easy to carry than calipers (especially in dense forest) Measuring with caliper is faster than with tape.

Bigger trees can be measured with tapes easily (calipers have an upper bound) tapes can be extended by joining them

Tapes are good to maintain consistency in measuring diameter regularly.

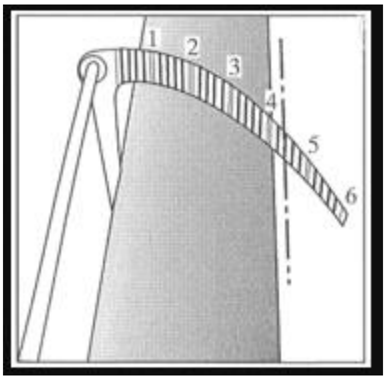
Measuring upper stem diameter

Upper stem diameter of a tree is measured for instance to describe the shape of a stem (derive taper curve). It is measured at various heights. Upper stem diameters are most easily observed on felled trees; however there are situations in which upper stem diameter need to be measured on a standing tree. Upper stem diameter is measured either at a fixed point (X meter) or at relative height (X% of height).

Methods

3). Using Finn caliper (Finnish parabolic caliper) Used to measure diameter up to 7m

Difficult to carry mostly beyond this height

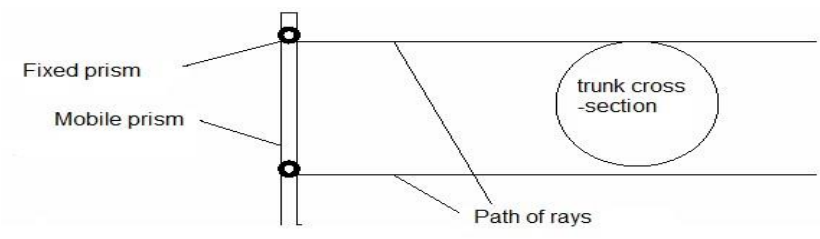


Upper stem diameter measurement with Finn Caliper

4). Optical caliper (parallel beams)

Needs determination of height before or after diameter measurement

It is independent of distance measurement

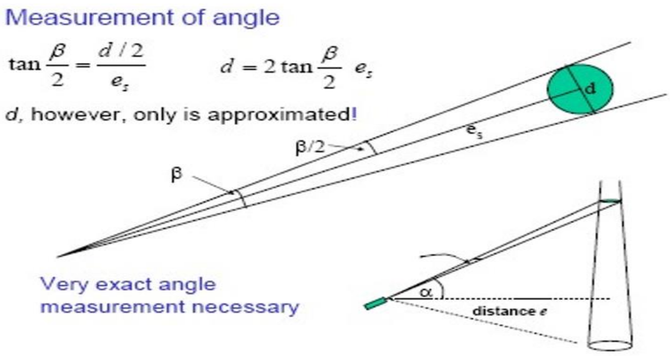


A B

Read diameter when the two images of the trunk coincides

Figure 1: Upper stem diameter measurement with optical caliper

Measuring upper diameter with angle measurement technique



Upper stem diameter measurement by angle measurement techniques

5). Measuring upper stem diameter with mirror relaskop

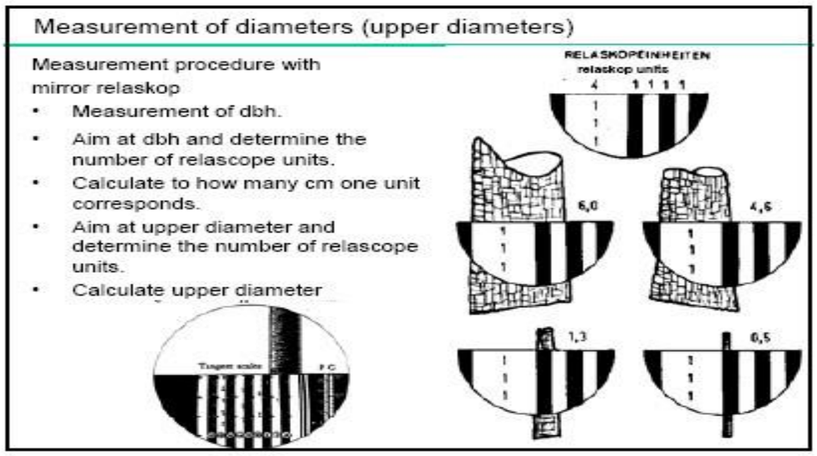


Figure 2: Upper stem diameter measurement using mirror relaskop

Tree cross-sectional area estimation

If the cross-section of a tree is determined using the diameter at breast height, then it is called basal area. It is denoted by “g”.

g = (π d2)/4

Basal area is commonly expressed in square meter (m^2)

Importance of basal area measurement:

The sum of the basal areas of all trees in crop is a useful measure of stocking. In a uniform plantation of a single species volume is closely related to basal area.

ii. Height

✓ Tree height Vs tree length

Tree height is defined to be the perpendicular distance between the ground level and the top of the tree. While, Tree length is the distance between the stem foot and the top along the stem

✓ Types of tree height:

1. **Total height:** the distance between the ground and top of the tree.
2. **Bole height:** the distance between the ground and the Crown Point.
3. **Merchantable height:** the distance between the ground and the terminal position of the last useable portion of the tree stem.
4. **Stump height:** the distance between the ground and the position where a tree is cut.
5. **Merchantable length:** is the distance between the top of the stump and the terminal position of the last useable portion of the tree stem.
6. **Dominant height:** is the average height of 100 thickest trees per hectare.

✓ Methods of tree height measurement

1. Direct method:

It involves climbing or using height measuring rods. It is rarely used and only for small trees.

2. Indirect method:

2.1). Using geometric principle

A christen hypsometer or ruler of a certain length (30cm for example) and a pole of constant length/height used to estimate/measure tree height.

✓ Biltmore Stick technique:

Place a pole of known length at upright position against the tree to be measured. Hold ruler (of known length) vertically and parallel to the tree to be measured.

Find the sighting position by moving back and forth and/or right and left so that the top of the ruler exactly aligned with the tip of the tree and the bottom of the ruler with the base of the tree.

Take ruler reading in line with the top of the pole. Then apply the following formula.

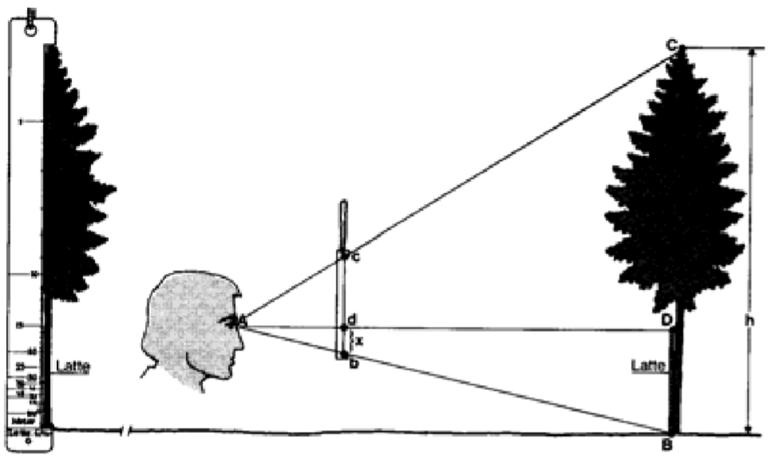


Figure 3: (Tree height measurement technique by geometric principles)

ΔABC ≅ ΔAbc

(BD/BC) ≅ (bd/bc); (bc/BC) = (bd/BD)

$$\text{Tree height (BC)} = \frac{\text{Known ruler length (bc) X Known length of pole (BD)}}{\text{Ruler reading on the pole (bd)}}$$

Advantages:

+ No distance measurement is required
+ Height reading is not influenced by slope

Drawbacks:

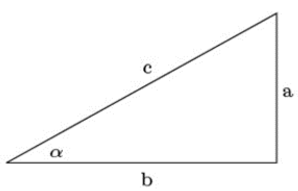
- In dense forest it is difficult to find suitable point of observation - Only with a steady hand can serious misreading be avoided.

2.2). Methods employing trigonometric principles

The followings are some of the instruments used to measure tree height based on trigonometric principles.

1. Sunto hypsometer
2. Silva hypsometer
3. Haga altimeter
4. Blume-leiss
5. Sunto clinometers: measure inclination angle in degree or percent

General steps (for the first 4 instruments mentioned above) Stand at a fixed horizontal distance from the base of the tree (usually 10, 15, 20, 25 meters, and so on) Sight at the top of the tree and read the value 'A' (top reading) Again sight at the bottom of the tree and read the value 'B' (bottom reading) Then the total height of the tree is top reading 'A' minus bottom reading 'B' Bottom reading +ve or –ve (above and below eye level)



Sin α = opposite / hypotenuse; (a/c)

Cos α = adjacent / hypotenuse; (b/c)

Tan α = opposite / adjacent; (a/b)

Case 1: If the observer is on a flat terrain

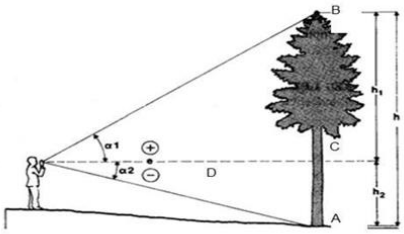
Tan α1 = BC / D BC = tan α1. D tan α2

= AC / D AC = tan α2. D

AB (height) = BC + AC

AB = tan α1. D + tan α2. D AB

= D (tan α1 + tan α2)



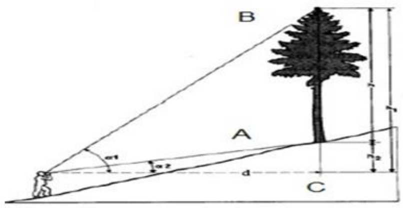
(Tree height measurement on a flat terrain.)

Case 2: upslope

AB = BC - AC

AB = tan α1. D - Tan α2. D

AB = D (tan α1 - tan α2)



(Tree height measurement on uphill terrain)

Case 3: down slope,

When the tree base is below the eye level of the observer

AB = AC + BC

AB = tan α1. D + tan α2. D

AB = D (tan α1 + tan α2)

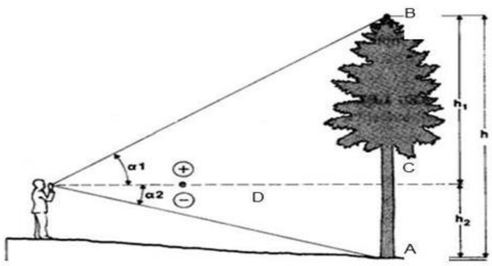
Clinometer method

It follows the same principles as above, but in this case we measure/read the inclination angle and then calculate height after knowing the horizontal distance between the observer and the tree.

1. If measured in percent:

$$Ht = \frac{(TR - BR)}{100} \times D$$

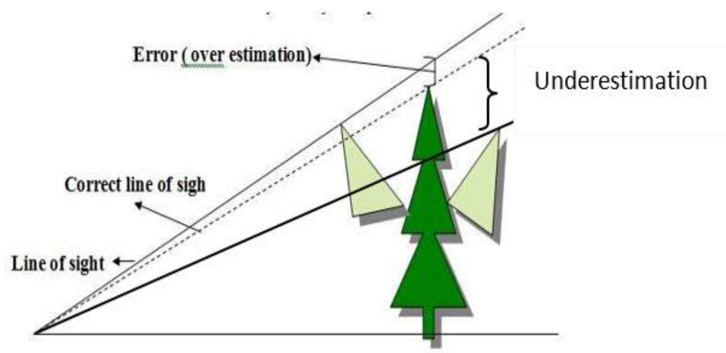
2. Or if measured in degree: H = D (tan α1 +/- tan α2)



(Tree height measurement using clinometers)

Possible sources of error in height measurement

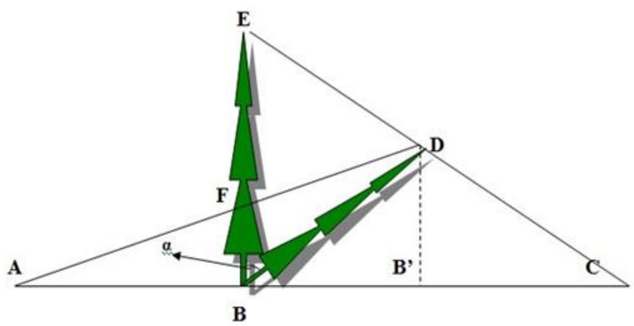
1. Error from failure to correctly identify the top of the tree



(Error during height measurement (failure to detect correct tree top)

2. Lean tree

When the leaning is away from the observer then the value will be under estimation and the vice versa.



(Error during measuring height of a leaning tree)

The correct length/height BD can be calculated after the angle of the lean is determined BD = DB' / cosα

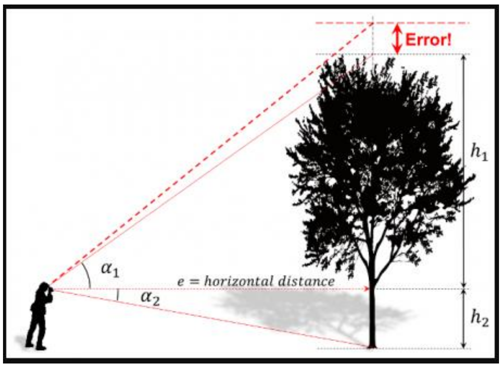
DB' is equal to the average of EB and FB

1. If the distance is not correctly measured If not reading is taken according to the scale if slope distance is measured instead of horizontal distance

Other important tree variables to be measured include:

Practical exercise on height determination:

Eucalyptus saligna is planted in school compound there; a forest technician has taken the following measurement related to the figure:



Data:

- Horizontal distance = 12m
- Height (h_2)=1.75m
- Alpha angle ($\boldsymbol{\alpha_1}$)=45^0

Question:

Trigonometrically find the tree height and angle $\boldsymbol{\alpha_2}$

Answer:

1. Tan $\alpha_1 = \frac{\text{Height (h1)}}{\text{Horizonatl distance(hd)}}$ <=>

   $\text{Height (h1)} = \text{Tan } \alpha 1 \times \text{horizontal distance}, \ \text{Tan}(45) = 1$

= 1$\times$ $12\text{m} = 12\text{m}$: height "**h1**"

The tree height=h1 +h2= 12m+1.75m=13.75m

2. Angle $\boldsymbol{\alpha_2}$⇔ **tan** $\boldsymbol{\alpha_2} = \frac{\textbf{opposite sides}}{\text{Adjecent side}}$ ⇔ $\boldsymbol{\alpha_2}$**=arc tan**$\frac{\textbf{opposite sides}}{\text{Adjecent side}}$= $\arctan \frac{1.75\text{m}}{25\text{m}}$=

   4^0 (4degrees)

= Angle $\boldsymbol{\alpha_2}$**=**4^0 (4degrees)

iii. Bark thickness

Bark is the outer sheath/layer of the tree. Some trees annually shed bark, while others have persistent bark. The inner bark transports photosynthates from the crown, while the outer bark has a major protective role. The bark protects the bole from insects and damage from physical abrasion. It is also important for fire resistance.

Bark thickness or width: Bark thickness is needed to convert diameter over-bark to diameter under-bark. Diameter under-bark is calculated as diameter over-bark minus two times the average bark thickness.

BT=DOB-2(ABT); where BT: Bark thickness; DOB: Diameter over Bark and ABT: Average Bark Thickness.

iv. Crown attributes

The tree crown is the top part of the tree, which features branches that grow out from the main trunk and support the various leaves used for photosynthesis.

The size of a tree crown is strongly correlated with the growth of the tree as the tree crown is the part of the tree, which contains the photosynthesizing tissue, absorbs radiation and produces energy to enable the growth processes.

Types of tree crown

1) Dominant

A dominant tree crown reaches over all other plants in the forest, including the crowns of other trees. This crown helps the tree catch the more direct sunlight than any other crown by pushing its branches and leaves not only upward but also outward, ensuring that as many leaves as possible have access to direct sunlight.

2) Codominant

A crown that is codominant shares access to sunlight with another tree. Slightly smaller in size than the dominant crown, the codominant tree crown receives sunlight at only the tips of its upper branches. Because of this, the tree does not grow to its full potential.

3) Intermediate

The last type of tree that receives any portion of direct sunlight features an intermediate tree crown. This crown grows only about as tall as the lower ceiling of the forest canopy, below the codominant tree crowns.

4) Overtopped

Receiving no direct sunlight in wooded areas, overtopped trees develop small crowns and are often lusher on one side or the other, surviving best where indirect sunlight is more present. Overtopped tree crowns feature sparse leaf presence and often a short stature.

V. Volume:

Stem volume measurement is function of a tree's height, basal area, shape, and depending on definition, bark thickness. It is therefore one of the most difficult parameters to measure, because an error in the measurement or assumptions for any one of the above factors will propagate to the volume estimate.

Volume is often measured for specific purposes, and the measurement and interpretation of the volume estimate will depend on the units of measurement, standards of use, and other specifications. For example:

i. **Biological volume** is the volume of stem with branches trimmed at the junction with the stem, but usually excluding irregularities not part of the natural growth habit (e.g. malformation due to insects, fungi, fire, and mechanical damage).
ii. **Utilizable or merchantable volume:** excludes some volume within irregularities of the bole shape caused by normal growth in addition to those irregularities not part of natural growth. For example, the volume contained in the swelling around a branch node may be excluded because this volume could not be utilized (by a nominated user).

Vi. Basal area: is the cross-sectional area of trees at breast height (1.3m above ground). It is a common way to describe stand density. In forest management, basal area usually refers to merchantable timber and is given per hectare or per acre basis.

Vii. Circumference: also known as girth is a measurement of the distance around the trunk of a tree measured perpendicular to the axis of the trunk.

Viii. Canopy biomass: a tree canopy refers to the upper layer formed by a mature tree crown and sometimes the term canopy is used to refer the extent of outer layer of leaves of individual tree or group of trees.

2.2.3. Biological rotation age or Stand revolution

Topic 1: Determination rotational age (MAI & CAI).

The point where the MAI and PAI meet is typically referred to as the biological rotation age. This is the age at which the **tree** or **stand would be harvested** if the management objective is to maximize long-term yield.

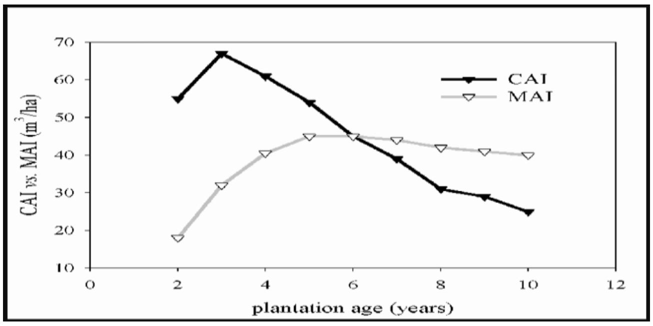


Figure 4: MAI (mean annual increment) and CAI (current annual increment)

a) Mean Annual Increment (MAI):

It is also known as mean annual growth, refers to the average growth per year a tree or a stand of trees has exhibited/experienced to a specified age. It is calculated as volume of stand over a period of time **(Y/t in years)** and expresses in **(m^3 ha^{-1} yr^{-1}).**

Practical exercise:

A forest stand has 15years after establishment and an inventory has been carried with 60m^3 as volume yield.

Question: find the mean annual increment of that forest

Answer: MAI= Y (m3)/T (yrs.) = $\frac{60\text{m3}}{15\text{yrs}}$= 4$m^3$/ha/yr.

b) Current Annual Increment (CAI):

Is calculated as variation in volume of stand over variation of time in years (over a fixed period of time).

CAI: where is $\frac{\mathbf{Y2-Y1}}{\mathbf{T2-T1}}$ and **Y:** is yield and **t:** is time and it is expressed in **(m^3 ha^{-1} yr^{-1}).**

Practical exercise:

A small woodlot has the growth period from age 5 to age 10, and the yield (volume of the woodlot), is 4m^3 at the beginning of the period and 19m^3 at the end.

Question: Find the current annual increment (CAI)

Answer: CAI= $\frac{\mathbf{Y2-Y1}}{\mathbf{T2-T1}} = \frac{\mathbf{19m3-4m3}}{\mathbf{10-5}} = \frac{\mathbf{15m3}}{\mathbf{5}}$ **= 3m^3/ha/yr.**

2.2.4. Filling format of data record and data entry

This refers start taking measurement when inventorying the forest either for example:

1. Diameter at breast height (DBH)
2. Basal area (BA).
3. Mean height (MH)
4. Bark thickness (BT)

During data filling format material can be used like pen, pencil and notebook while in recording electronic device are used like computer for easing data processing after screening them out for analysis.

Learning Outcome 2.4: Estimate forest volume

Topic 1: Discussion on stand measuring parameters.

2.4.1. Total volume of stand

a) Mean diameter: It is the diameter corresponding to mean basal area of a group of tree or stands. Sometimes used for arithmetic mean of the summated diameters.

b) Mean height: It is the height which when multiplied by the mean form factor and the mean basal area of a stand gives the arithmetic mean volume of the mean tree in the stand.

c) Average basal area of stand: The basal area of a stand of trees is the sum of the cross-sectional surface areas of each live tree, measured at DBH, and reported on a per unit area basis. Basal area is a measure of tree density, and widely used in forestry.

$$\text{Basal area (units}^2) = \pi\left(\frac{DBH}{2}\right)^2 \quad \text{or} \quad \pi\left(\frac{DBH^2}{4}\right)$$

2.4.2. Conversion forest volume

Topic 1: Discussion on conversion units (stere⇔cubic meter).

Abbreviations:

- **m³** : Cubic Meter (a unit of volume equal to a cube one meter long on each side)
- **St**: Stere (a metric unit of volume equal to one cubic meter) sometimes stere cannot contain $1m^3$ because of gaps during stere piling or logs characteristics.

Equivalence between stere and cubic mater.

- 1 stere en logs de 50 cm length is 0, 80 m^3 with piling coefficient of 1.25.
- 1 stere en logs de 33 cm length is 0, 70 m^3 with piling coefficient of 1.42
- 1 stere en logs de 25 cm length is 0, 60 m^3 with piling coefficient of 1.66

Practical exercise:

During tree felling, the following are measures taken on stem/trunk or merchantable height: du: 24cm, dl: 20cm and L: 2000cm.

Task: Determine the number of stere from that log

Answer:

- The log Volume: 3.14 x 2000 $(\frac{20^2+4(22^2)+24^2}{24})\text{x}1\text{cm}^3 = 761{,}973.33$ cm^3=0.76m^3
- Number of steres (with logs of 50cm): $\frac{\text{log volume}}{\text{real volume}} = \frac{0.76\text{m}^3}{0.80\text{m}^3} = 0.9 =$ 1 stere

2.4.3. Volume calculations

Topic 1: Determination of tree volume.

a) Newton formula: $\text{V} = (\frac{\text{gu}+4\text{gm}+\text{gl}}{6}) \times \text{l} \lll=\ggg \text{V} = (\frac{\text{du}^2+4\text{dm}^2+\text{dl}^2}{24}) \times \text{l}\pi$

b) Hubber formula: $\text{V} = \text{gm} \ \times \text{l}$

c) Smallian formula: $\text{V} = (\frac{\text{gu}+\text{gl}}{2}) \times \text{l}$

Where: **L:** Length, **gm:** Cross sectional in the middle, **gu:** upper cross sectional, **gl:** lower cross sectional areal.

Practical exercise:

Q3. During forest inventory, the following data have been taken for determining the volume of forest stand: /10mrks

1. **Mean height** has been obtained by using : **UR=90%, LR= -15%, HD=20m**
2. Upper diameter: **25cm**
3. Lower diameter: **30cm**
4. Area of forest stand: **1.8ha**
5. Sampling rate: **25%,** number of trees within a sample: **20trees** and spacing of **3mx3m**

Find:

1. Number of trees on the forest stand**:**

   Answer:

   i. **1.8ha = 18,000m^2; area of 1tree= (3x3) x 1m^2= 9m^2**

   ii. **Number of trees on site**$= \frac{\textbf{Total area of the site}}{\textbf{Area of 1 tree}} = \frac{\textbf{15,000m}^2}{\textbf{9m}^2} = \textbf{2000 trees}$

2. Area of 1 sample plot:

   Answer:

   Sample plot area: Number of trees to consider in sample x area of 1 tree

   = 9m^{2}x 20= 180m^2

3. Possible samples that can fit the site:

   Answer:

   Possible samples: $\frac{\textbf{Total area of the forest site}}{\textbf{Area of a sample plot}} = \frac{\textbf{18,000m}^2}{\textbf{180m}^2} = \textbf{100 samples}$

4. Number of sample plots (plots from which data are taken; not from all):

   Answer:

   Sample plots: possible sample x sampling rate

   = 100 samples$\times \frac{\textbf{25}}{\textbf{100}} = \textbf{25 sample plots}$

5. Using **Newton**, **Huber** and **Smalian's** formula find harvestable volume on the forest stand.

A). answer: Using Newton formula

i. Mean height: $\left(\frac{\mathrm{UR-LR}}{100}\right) \times \mathrm{HD} = \left(\frac{90-(-15)}{100}\right) \times 20 = 21\mathrm{m} = 2100\mathrm{Cm}$

ii. V of 1 tree=$\mathrm{l}\pi \times \left(\frac{\mathrm{du}^2+4\mathrm{dm}^2+\mathrm{dl}^2}{24}\right) \times = 3{,}14 \times 2100 \times \left(\frac{25^2+4\left(\frac{25+30}{2}\right)^2+30^2}{24}\right) \times 1\mathrm{cm}^3 = 1{,}250{,}112.5\mathrm{m}^3 = 1.25\mathrm{m}^3.$

iii. Volume at sample plot level= V of 1 tree x number of trees in sample plot= 20trees x 1.25m^3=25m^3.

iv. Volume of the forest stand= V of sample plot x possible sample that cover the area

= 25m^3 x 100 samples = 2,500m^3

B) Using Huber's formula:

Answer:

i. V of one tree: $V = (\frac{gu+gl}{2}) \times l$;

: gm x L ⇔ gm =$\frac{\pi dm^2}{4}$, ⇔ : dm= $\frac{du+dl}{2} = \left(\frac{25+30}{2}\right) \times 1cm = 27.5cm$

: Tree v is: $(\frac{3.14 \times 27.5^2}{4} \times 2100)cm^3$ =1,246,678cm^3= 1.25m^3

ii. Volume at sample plot level: V of 1 tree x number of trees in sample plot= 20trees x 1.25m^3=25m^3.

iii. Volume of forest stand: V of sample plot x possible sample that cover the area

= 25m^3 x 100 samples = 2,500m^3

C). Using Smalian's formula:

Answer:

1. V of one tree =$\left(\frac{gu+gl}{2}\right) \times l$ ⇔ gu= $\frac{\pi du^2}{4} = \left(\frac{3.14x\ 25^2}{4}\right)$

⇔ gl= $\frac{\pi dl^2}{4} = \left(\frac{3.14x\ 30^2}{4}\right)$

⇔ Tree v is: $\left(\frac{\left(\frac{3.14x\ 25^2}{4}\right)+\left(\frac{3.14x\ 30^2}{4}\right)}{2}\right) \times 2{,}100)cm^3 =$

$1{,}256{,}981cm^3$=1.25m^3

2. Volume at sample plot level: V of 1 tree x number of trees in sample plot= 20trees x 1.25m^3=25m^3.

3. Volume of forest stand: V of sample plot x possible sample that cover the area

= 25m^3 x 100 samples = 5000m^3

Learning Unit 3: Apply harvesting techniques

Learning Outcome 3.1: Select felling techniques

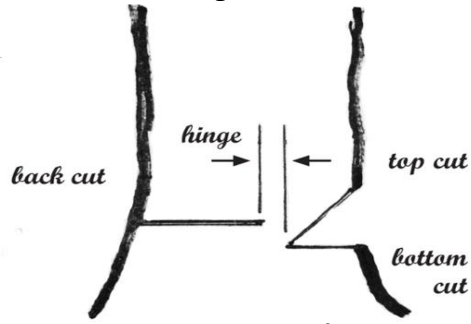
Topic 1: Discussion on tree characteristics before felling.

3.1.1. Tree characteristics:

The followings are some of the cases:

Types stem	Picture	Description
1. Straight		Is a tree that shows verticality and not curved or bent aside
2. Forked/ bifurcated		A **tree fork** is a bifurcation in the trunk of a tree giving rise to two roughly equal diameter branches.
3. Bent/lean		Is a tree that do not show verticality in growth but it bends aside
4. Decayed		It is a tree that shows a progressive decomposition of tissues from outside to inside.
5. Twisted		It is a tree that shows twisted or spiral tissues from bark to inside
6. Trees with buttress		**Buttress roots** are large, wide roots on all sides of a shallowly rooted tree. Typically, they are found in nutrient-poor tropical forest soils that may not be very deep.

3.1.2. Tree felling cuts:



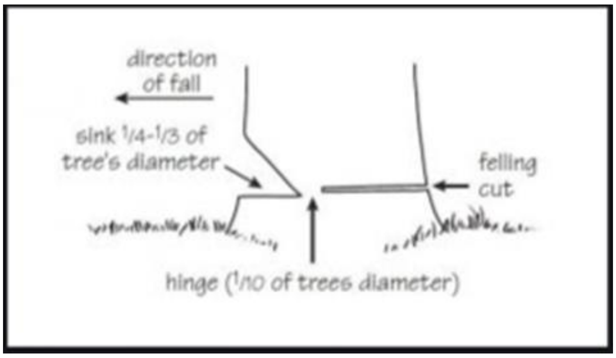


Figure 5: Directional cut/ felling notch

It is a part of tree cut for directing the tree to fall in planed

Figure 6: Backcut /fellingcut

3.1.3. Tree felling techniques for:

Topic 1: Discussion on tree felling techniques.

1. **Felling straight trees:** felling angles can be applied because these kind of trees don't have growing defects the most important is to determine felling direction.
2. **Felling forked:** these trees require to cut them with mechanized way using tackles, felling tractor or steel cable to avoid damage.
3. **Felling lean/bent trees:** these are trees which are not up straight but bent in one direction; to cut them down requires to cut them down using felling tool like tackle, steel cable or forest tractor for avoiding damage.
4. **Felling decayed trees:** to cut down decayed trees requires workers to be very cautious as they can be fallen abruptly; for these felling wedge, tackle, cables and felling tractor.
5. **Felling twisted:** these tree with spiral trunk requires to cut them down with felling tools because their stem are not strong and can fall quickly.
6. **Felling with buttress:** these trees are cut down using felling instruments because their roots are shallow and present on surface.
7. **Felling hang up trees:** requires to be careful for not being overstrike by abruptly falling tree; so you cut short logs from butt till the whole trunk fall on ground.

Learning Outcome 3.2: Examine tree dimensions

3.2.1. Concept definitions

a) **Trunk diameter: Diameter at breast height**, or **DBH**, is a standard method of expressing the diameter of the trunk or bole of a standing tree. DBH is one of the most common dendrometric measurements.

b) **Tree height: Tree height** is the vertical distance between the base of the tree and the tip of the highest branch on the tree, and is difficult to measure accurately. It is not the same as the length of the trunk. If a tree is leaning, the trunk length may be greater than the height of the tree.

c) **Trunk form:**

   1. Straight: it is growth characteristic where tree is up straight or show verticality.
   2. Forked: A **tree fork** is a bifurcation in the trunk of a tree giving rise to two roughly equal diameter branches.
   3. Curved: it is a tree trunk that do not show straightness but at many points along the trunk.

d) **Shape of Crown:** The crown of a woody plant (tree, shrub, liana) is the branches, leaves, and reproductive structures extending from the trunk or main stems. Shapes of crowns are highly variable. The major types for trees are the **excurrent** branching habit resulting in **conoid** shapes and **decurrent** (deliquescent) branching habit, resulting in **round** shapes. Crowns are also characterized by their width, depth, surface area, volume, and density. Measurements of crowns are important in quantifying and qualifying plant health, growth stage, and efficiency.

   I. **Regular:** It is a canopy of the tree that shows normal distribution of branches it means branches sideways of the trunk and allows light to pass through.

   II. **Irregular:** It is a type of tree canopy that show branches distributed uniformly around tree trunk.

   III. **Dense:** It is a type of tree canopy that do not allow light to pass through due to more branches

   IV. **Narrow**: It is type of tree crown with low branches that allow more light to reach the ground surface.

   V. **Weight distribution:** Weight distribution is affected by the side of trunk with more branches; these determine natural felling direction of the tree.

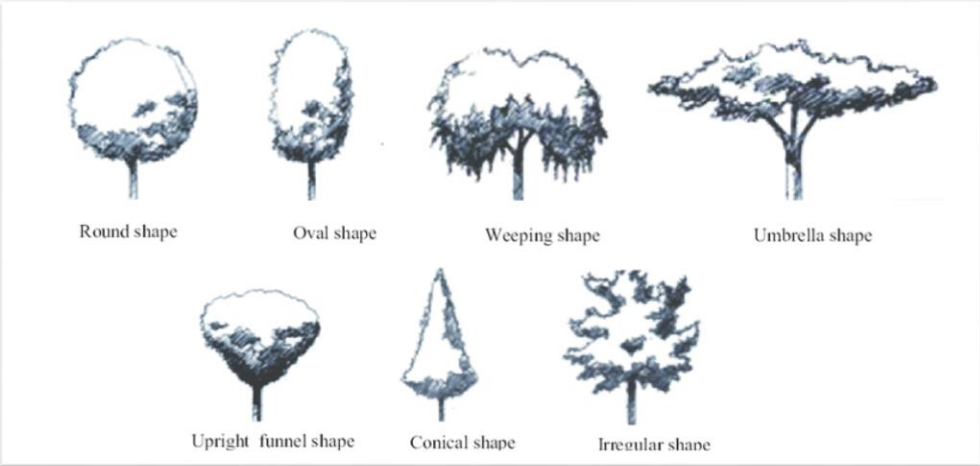


Figure7: Tree crown shape

e) Branching system:

i. **Length:** length of branches can be affect by species and management activities carried out.

ii. **Thickness:** It is affected by quantity it means the more branches the more branches diameter is reduced and vice versa.

iii. **Hardness:** It is determined by age of tree location of tree and the tree species.

Learning Outcome 3.3: Cut down the tree

3.3.1. Tree felling cuts:

Topic 1: Discussion on felling techniques.

a. Face cut/ directional cut

It is an operation that consist in making the first cut for directing the tree to fall in planned direction.

b. Back cut/ felling cut

It is an operation of making the second cut after the face cut for letting the tree to for in felling direction.

Cutting procedures

Preliminary activities

Any tree faller should ensure that they follow the five step tree felling plan.

1. Site assessment

Assess the stand for hazards relating to the trees, terrain, other operations, and power lines.

Assess the strength and direction of the wind and whether it will affect safety.

2. Individual tree assessment

Look for tree defects, decay, heavy lean, or any other characteristics of the tree that may affect the felling plan.

Note the ground condition and soil moisture.

Check the surrounding trees for interlocked branches, dead tops or branches that may fall into the work area.

Determine if you can fell it safely and plan the felling cuts.

Decide on the felling direction. This will help determine which side of the tree will be the safest for the escape route.

3. Preparation of the work area and escape route

Clear vegetation and obstacles from around the base of the tree.

Always think about your escape route before you begin any felling cuts. Where possible, the escape route should be at a 45-degree angle opposite the felling direction (see Figure below).

Be sure your escape route is clear of obstacles or hazards before beginning.

4. Fell the tree using safe felling techniques

Good felling technique is critical to safe, accurate, consistent results.

All trees over 200mm at the stump must be felled using a scarf and back cut.

The degree of forward or back lean will determine how many wedges and/or whether a pull rope will be necessary and how much power may be required to pull the tree over.

5. Retreat and observe

Remember to finish the felling cut on the safe side of the tree and use your escape route as soon as the tree begins to fall.

Watch for falling material and be far enough from the base of the tree to avoid a kick back, butt swing, or bounce.

Avoid walking directly behind the tree.

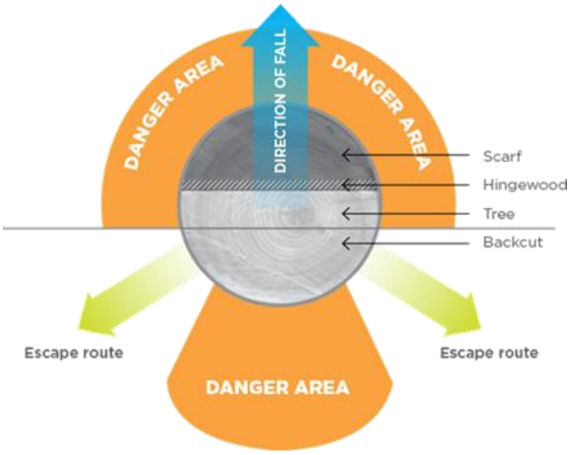


Figure8: Escape route positioning

Cutting operations

Topic 1: Implementation of felling techniques.

1. **Site assessment:** concerning the plan of felling direction as place the tree can not cause any damage to the working environment and gather felling instruments.
2. **Individual tree assessment:** checking whether there no decayed branches that can strike and cause the injury to worker.
3. **Preparation of the work area and escape route:** concerning the removal of all the obstacles that can interfere felling activities like stone, cut branches and undergrowth.
4. **Fell the tree using a safe felling techniques:** start making face cut or in felling direction then after back cut or felling cut as well as leaving the hinge in between two cuts.
5. **Retreat and observe:** concerning withdrawal from danger zone or implanting escape way.

Learning Outcome 3.4: Log the felled trees

3.4.1. Tree logging operations

Topic 1: Discussion on tree logging activities.

1. **Limbing /Delimbing:** it is a forest operation that consists of removing branches or limbs from felled tree.

Tree delimbing with a chainsaw

2. **Topping:** it is an activity of removing the crown of felled tree to be used or transported.
3. **Log measurement:** measurement reflect the market size demand and the end use of logs because logs to be used for plywood, pulpwood and those for charcoal defer in dimensions.
4. **Bucking/ Cross cutting:** it is an operation that consists in cutting the stem or trunk into short lengths basing on the market demand and also end used.

5. **Debarking:** it is an activity of removing bark from log or the whole trunk of felled tree for quick drying or to be used specifically.

Learning Outcome 3.5: Transport the logs

3.5.1. Skidding techniques

Topic 1: Discussion on logs transport techniques.

A. Manual:

Human powered transport is the transport of wooden products using human muscle-power, in the form of walking and swimming. Modern technology has allowed machines to enhance human-power. Human-powered transport remains popular for reasons of cost-saving, leisure, physical exercise and environmentalism.

B. Animal traction

Animal traction, animal powered mechanization, and animal draft are terms which describe the use of animals to pull timber products, and other loads. The most common draft animals (animals used for pulling heavy loads) are cows, horses and mules, but donkeys, camels, domestic water buffalo, yaks, reindeer and even elephants are used for traction in some parts of the world. The kind of animals used and the kind of work performed depend largely on people's resourcefulness in raising and training animals and devising hitches that allow them to pull.

C. Mechanized

Mechanized transportation is another type of transportation of forest products by using other means than human powered muscles.

C.1. Landway transportation of logs:

Landway uses roads and pathways as working infrastructures for transportation of forest products where logtrucks and wheeled tractors are used.

C.2. Waterway transportation:

Flotation and transportation by boat or ship. Timber Flotation is a form of water transport of logs that uses the buoyancy of the wood. Flotation a form of water transport of logs that uses the buoyancy of the wood. As an industrial process, timber transport is the final stage of logging operations; its purpose is to deliver prepared timber to points of consumption or transfer to another type of transportation. Flotation is an extremely cheap form of large-scale timber transport; in some areas it is the only kind available.

By using boat or ship, logs can be packed onto the ship or boat on other hand logs in raft or barge also can be pulled by these boats or ships.

C.3. Aerial or airway transportation

It is a transport method by using helicopters and balloon. **Helicopter transport** is a method of transport that use helicopter to remove the cute trees from forest by lifting them on the cable attached to helicopter. This method helps to reduce environment impact of transport. It increases also productivity in these remote areas.

Balloon transport is inflammable flexible filled with gas such helium, hydrogen, oxygen or air. Modern balloon can be made from materials such as rubber (coutchou, latex).

3.5.2. Piling procedures and factors

Topic 1: Discussion on piling techniques.

A. Log form

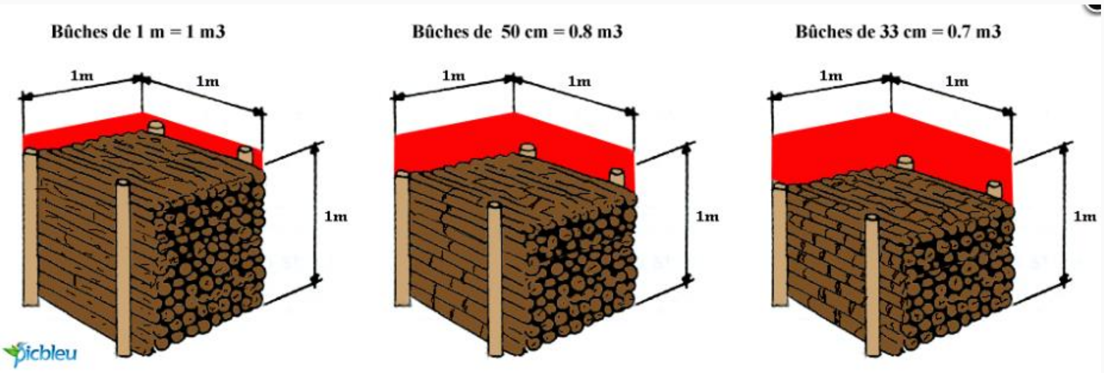
Stere is a unit used to measure volumes of stacked timber equal to one cubic meter. In piling of logs are stacked into steres of $1m^3$. It means 1m length, 1m large and 1m height. Logs form can affect the volume in stere it means straight logs increase while curved logs decrease the volume in stere and these referred to us piling coefficient.

Piling coefficient is defined as the ratio between the apparent volume (1 cubic meter or box into which logs are stacked) and real volume (the volume of logs as well).

$\frac{\mathbf{AP}}{\mathbf{RV}} = \mathbf{PC}$ **AP:** apparent volume, **RV:** real volume and **PC:** Piling coefficient

Equivalence apparent volume and real volume basing on length of log cut.

1. 1 stere en logs de 50 cm length is 0, 80 m^3 with piling coefficient of 1.25.
2. 1 stere en logs de 33 cm length is 0,70 m^3 with piling coefficient of 1.42
3. 1 stere en logs de 25 cm length is 0,60 m^3 with piling coefficient of 1.66



Normally 1 stere is not equal to 1m3 of firewood because of forms and size of logs, piling skills of works.

B. Size

Logs used in stere must meet the market demand. In ordinal stere piling the size of logs used is 1m length.

C. Slope

During logs piling, the slope of the site must be taken into account but normally a gentle slope is preferable

References:

Zerihun Astra (MSc) and Yemiru Tesfaye (PhD). (2013). Forest inventory and management in the context of SFM and REDD+ **(page 1-40).**

https://www.forestcarbonpartnership.org/sites/fcp/files/fcpdocs/2015/October/Forest%20Inventory%20%26%20Management_Manual.pdf

Forest harvesting Code of practice 2007 (PN11174) **(page 5-22).**

Forest harvesting module FORFH501 (**Original published version updated:** March, 2013)

https://worksafe.govt.nz/topic-and-industry/tree-work/safe-manual-tree-felling/ **(accessed on 6/6/2020)**

https://fennerschool-associated.anu.edu.au/mensuration/volume.htm **(accessed on 7/6/2020).**

https://www.woodstock-bois.fr/mesures-bois-de-chauffage-equivalent-stere-m3/ **(accessed on 7/6/2020).**