Training module

Inventory techniques for Reduced Impact Logging

Integral Module

PREFACE

The application of Reduced Impact Logging (RIL) techniques is one of the important requirements for the certification of sustainable forest management.
However, considerable effort still has to be taken before the RIL practises will be operational on a large scale in the region.
Previous experiences have already demonstrated the necessity and feasibility of the training in Reduced Impact Logging (RIL) techniques in the Congo Basin.

Notwithstanding the considerable differences between the different countries of the Congo Basin we are of the opinion that by introducing the RIL practices in Gabon we can investigate at first hand the impacts of the conventional logging and demonstrate the advantages of RIL techniques for the enterprise and for the environment of all of central Africa.

This because Gabon still accommodates a rich and very much varied patrimony of fauna and flora, which is not only like elsewhere, seriously threatened by the logging and mining industries and by the progressing demography, but also still very much susceptible to methods that might avert these threats.
As the logging techniques in tropical countries can differ from country to country, and even from region to region and all the more as there are not yet sufficient data on RIL in Africa, it is still difficult to convince foresters of the advantages of the application of RIL.

The RIL training courses aim at teaching logging staff and workers these specific techniques and to optimize their skills.

The following modules have been composed to form a package of instruction covering most of the aspects of logging techniques under RIL methodology:

- Cartography
- Forest inventory
- Road planning
- Road construction
- Controlled felling
- Planning of skid tracks and tracing
- Planned extraction
- Log landing operations
- Post-harvest operations
- First aid in the forest
- Operational management in RIL

CONTENU

1. INTRODUCTION

Inventories

Forest inventories provide the information on which all budgets, management plans and construction and production plans are based. The level of accuracy with which data are recorded determines the efficiency of production and the reduction of impacts of forest harvesting on the environment.

To obtain environmental sustainability, all tree species are inventoried during the management inventory, which allows the calculation of the production capacity of the forest using a growth and mortality formula.
At the same time the fauna present is inventoried by a specialist who looks for signs of the presence of mammals, birds and reptiles.

The sustainability of the forest production should, amongst others, be assured by the protection of seed trees and future crop trees (FCT) of the commercial species. These need to be inventoried at 100% during a logging inventory.

2. CONTEXT AND OBJECTIVES

Forest managers can generally have three reasons to execute an inventory of the forest, depending on different goals for the results of the inventory. Suited to specific needs these three types can be distinguished as follows.

2.1 Exploration

The first goal of a forest manager is to know if a certain forest which is available responds to his expectations. To reach a decision whether or not to invest and on a medium or long term in a forest operation he will need an exploration prior to any other activity.

An exploration is the first encounter of the forest exploitant with the region where he hopes to work. The exploration will provide the preliminary information to determine whether, how, where and when the forest can be harvested. This activity also allows a zoning of the terrain in harvestable and unsuitable terrain. Based on this an inventory plan can be made.

Before starting this exploration it is essential to gather all available documentation available on prior inventories, such as maps, areal photographs, satellite images and data sets.
The exploration is carried out by a group of workers with the aid of a map of the region on a scale of 1:50.000, who are well aware of the species required and the needs for a successful exploitation, which means they can distinguish favourable and unfavourable terrain circumstances.

The prospectors will walk lines at regular intervals through the terrain to get an impression of the forest, the soil, the topography, hydrology and the densities of timber trees. They will also keep track of the proximity of human activities as these can have positive and negative consequences for the planned harvest.

Positive results for this exploration can lead to the decision of the forest developer to request the forest authorities the right to harvest timber in the area. The data from the exploration allow the elaboration of a map which identifies the harvestable areas (rich and poor) and the area which are not suitable for work (inhabited, under agriculture, swampy or otherwise inaccessible etc.).

A specific training for this exploration shall not be treated in this module, as workers qualified for the harvest inventory will also be perfectly capable to perform an exploration.

2.2 Management inventory

The second objective of a forest manager will be to collect data which will allow the formulation of a sustainable forest management plan. This data is produced through a management inventory.

This inventory will provide the exact and detailed information for the budgeting of activities, the elaboration of the long-term forest management plan, the elaboration of the medium term plans (5-year and annual plans), and in the longer run, the certification of sustainable forest management.

The management inventory will generally be done at 0,5 to 2 % of the concession and is performed following an inventory plan showing the inventory lines at regular intervals assuring the required intensity.

This work has to be done by specialists in forest flora of the region, who can distinguish seeds, fruits, leaves, young and adult plants of all species important for the continuity biodiversity and production. The inventory has to take place well before and harvesting operations take place in order to allow a planning at medium and long term.

The fauna needs to be inventoried before the lines for the management inventory are prepared in the field. This to avoid disturbance of the site biasing the outcome of a fauna inventory (chasing animals and disturbing tracks). The fauna inventory has to be executed by trained fauna specialists and cannot be done by normal company employees.

2.3 Harvest inventory

The third objective of a concessionaire is to know the exact number and location of trees and their volume for each harvestable species (above the minimum cutting diameter), and also of the **future crop trees (FCT)**. In addition to this information the developer t will want to know the terrain conditions which will influence harvesting operations. The information from this type of inventory will be used to make a marketing plan for the species and an extraction plan containing the number of roads, landings, trails etc. in the annual harvest area.

This module is principally for the instruction on methods and techniques to be used for the harvest inventory and mapping. It is not a specialist guide in the botanical identification of species. People interested in this training should already have extensive knowledge of the commercial species prior to the training.

The final pick is the final selection of trees to be felled. The criteria for the selection are formulated by the current market and determine species and qualities to be harvested. Harvestable trees that do not respond to the criteria laid out will be spared during felling. FCT, seed trees and protected species are marked with tape or with paint to assure they are spared from damage during felling and skidding.

3. TARGET GROUPS AND CAPACITIES TO BE TAUGHT

3.1 Target group 1: Specialists

General remark: **It is advisable to train the group members into polyvalent workers.**

Functions: Team leader, inventory clerk

Function profile:

- The management of an inventory team during the compartment line cutting work, the spotting of trees which can be harvested, trees to be protected, FCT, seed trees and the registration of terrain characteristics.
- Responsible for the elaboration of precise inventory maps which present all the data gathered
- Responsible for the safety of the team during the work in the forest

Knowledge and capacities needed:

- Good physical health
- Education level
- Managing capacity
- Good orientation in the forest
- Capable of using a compass
- Good knowledge of the harvestable species
- Able to measure tree DBH and height
- Judgement of the terrain
- Knowledge of mapping
- Basic capacities in the administration of First Aid.

Capacities to be learned trough this module:

- Systematic harvest inventory techniques
- Use of the GPS
- Use of a clinometer
- Use of a compass
- Distinction between harvestable trees, FCT, protected trees and seed trees
- Distinction of various qualities of harvestable and seed trees
- Increased knowledge of mapping
- Practical knowledge on First Aid

Function: Tree spotter

Function profile:

- Find harvestable, protected, FCT and seed trees
- Measure DBH and height of located trees
- Marking and numbering of the trees found
- Marking of protected, future crop and seed trees and monumental trees
- Identification of terrain characteristics

Knowledge and capacities needed:
- Good physical health
- Education level
- Orientation in the forest
- Good knowledge of harvestable species
- Judgement of the terrain conditions

Capacities to be learned through the training:
- Distinguishing between harvestable, protected, future crop and seed trees
- Distinguishing between different qualities of harvestable trees and seed trees
- Measuring DBH and height of trees
- Use of a clinometer
- Marking trees with knife and paint
- Precise appraisal of terrain conditions

Function: Compass man

Function Profile:
- Directing a team of line cutters in a preset compass direction
- Mapping of limits and lines opened
- Responsible for the safety of the team during the work in the forest

Knowledge and capacities needed:
- Good physical health
- Education level
- Orientation in the forest
- Use of the compass
- Knowledge of the staking work
- Judgement of the terrain conditions
- Basic knowledge of mapping
- Basic knowledge of First Aid

Capacities to be learned through the training
- Use of GPS
- Use of a clinometer
- Use of topofil instrument
- Increased knowledge of mapping
- Practical knowledge of First Aid
- Marking trees with knife and paint
- Precise appraisal of terrain conditions

Function: tree selector

Profile of the function:
- Leading of a tree selection team which will check the inventoried compartments at 100%
- The selection of trees to be harvested from the inventoried trees according to quality and species as dictated by company management.
- Marking of trees to be protected in such a manner that they are easily distinguished from the rest of the vegetation by fellers and skidder drivers.
- Checking of the other information provided by the inventory map elaborated by the inventory team

- Adaptation of the map of the compartment if needed
- Responsible for the safety of the team during the work in the forest

Knowledge and capacities needed:
- Good physical health
- Education level
- Orientation in the forest
- Use of the compass
- Good knowledge of the harvestable species
- Finding the trees that are indicated on the compartment map
- Judgement of the terrain conditions
- Basic knowledge of mapping
- Basic knowledge of First Aid

Capacities to be learned through the training:
- Systematic inventory techniques
- Use of GPS
- Use of a clinometer
- Distinguishing between harvestable, protected, FCT and seed trees
- Distinguishing between different qualities of harvestable trees and seed
- Increased knowledge of mapping
- Precise appraisal of terrain conditions
- Practical knowledge of First Aid

3.2 Target group 2: Interested people

Managers (enterprise directors, logging managers, site managers), civil servants, researchers, teachers and NGO's

Presentation of the following subjects:
- Importance and extent of the inventory
- Team composition
- Capacities to be transferred to the team members
- Distinction between species of trees and whether these are harvestable, protected, FCT or seed trees.
- Distinguishing between different qualities of harvestable trees
- Use of the compass, GPS and clinometer
- Marking of tree with a knife or with paint
- Precise appraisal of the terrain conditions
- Treatment of inventory data
- Conversion of inventory data in inventory maps

3.3 Target group 3: Instructors

Function: RIL inventory Instructor

Function profile:
Teaching of inventory techniques to all levels of interested persons

Knowledge and capacities needed:

- Good physical health
- Education level
- Good teaching and guiding skills
- Orientation in the forest
- Use of the compass
- Good knowledge of the harvestable species
- Measurement of DBH and height of the found trees
- Judgement of the terrain conditions
- Basic knowledge of mapping
- Basic knowledge of First Aid

Capacities to be learned through the training:

- Systematic inventory techniques
- Use of GPS
- Use of a clinometer
- Distinguishing between harvestable, protected, FCT and seed trees
- Distinguishing between different qualities of harvestable trees and seed
- Increased knowledge of mapping
- Treatment of inventory data
- Conversion of inventory data into maps
- Practical knowledge of First Aid

4. PROGRAMME OF THE TRAINING

The training module was developed based on requirements mentioned in chapter 3 and consists of the following subjects, which will be elaborated upon in chapter 5.
The duration of the inventory training for target group 1 will be 10 days, the presentation of the techniques to target group 2 will take half a day. For the training of trainers on this subject twice the time is needed as for the training of the people from target group 1.

The use of safety helmets, boots, and visibility vests is compulsory during the stay in the forest.

4.1 Introduction and interpretation of the impact of the inventory and the importance of RIL techniques

Elements:
- Introduction, description
- Use of topofil, the compass, the clinometer and of the GPS
- Setting out the lines
- Mapping
- Identification and positioning of trees
- Measuring the trees
- Classification and quality of trees

Essentials:
- Blackboard or Flip over and markers
- Illustrations on posters or power point
- GPS
- Compass
- Clinometer
- Scribing knife, tape, tree tags

Location: meeting room

4.2 Use of topofil, compass, clinometer and GPS

Elements:
- Introduction, description of the different types of maps
- Use of topofil (to measure distance)
- Use of the compass in the terrain (for determining directions)
- Use of the clinometer (measuring slope and tree height
- Use of the GPS (location, direction and distance covered)

Essentials:
- Topofil
- Compass
- Clinometer
- GPS
- Map of road that needs to be traced

Location: Forest, on the baseline of the FMU at the boundary where the main road enters the FMU.

4.3 Line cutting

Elements:
- Introduction, description
- Use of the compass in the terrain
- Use of the clinometer
- Use of the GPS
- Correct measurement of distances
- Slope correction
- Species to be conserved
- Staking and marking the line
- Cutting the line
- Mapping

Essentials:
- Maps of the compartment
- Topofil
- GPS
- Compass
- Clinometer
- Paint or markers
- First Aid Kit

Location: Forest where there are no visible lines cut yet.

4.4 Enumeration (identification, localising, measuring)

Elements:
- Introduction, description
- Measuring techniques

Essentials:
- Compass
- Clinometer
- Scribing knife
- Tape, tags or paint
- Folder with inventory forms
- Measuring tape or callipers
- Slope correction form

Location: Forest (compartments or pockets lined and enumerated).

4.5 Cartography

Elements:
- Introduction, description of the different types of maps

- Elaboration by hand of maps using data from the inventory sheets
- Introduction of the data into a GIS system
- Interpretation of a map in the terrain

Essentials:
- Completed inventory sheets
- Maps

Location: Forest (compartments or pockets lined and enumerated).

4.6 Selection

Elements:
- Introduction, description of the maps
- Location of the trees
- Criteria for the grading of harvestable trees (export log, saw log, peeler log), of protected trees, FCT and of seed trees
- Tracing the trails from the tree to the main trail.
- Positioning of the marked peg on each fork in the trails
  - Updating the map of the pocket by hand
  - Applying numbers
  - Marking refused trees
  - Indication of conditions necessitating the deployment of tracked machines (weight, wet soil or slope)
  - Outlining the trails for the selected trees
- Marking of important trees for fauna, for biodiversity and for NTFP's which should be declared protected trees.

Essentials:
- Blackboard or flipchart and markers
- Illustrations on posters or in PowerPoint
- GPS, Compass and Clinometer
- Maps: inventory map of the compartment on A4, map of inventoried pockets on A4
- Tape, paint or markers

Location: Meeting room, Forest (inventoried compartment or pocket)

4.7 Calendar

4.7.1 Target group 1 Specialists:

- Team leader
- Inventory clerk
- Tree spotter
- Compass man
- Tree counter
- Selection verifier
- Verification prospector

Duration: 9 days

Personnel: 1 instructor, 1 compass specialist, GPS, clinometer, 1 expert prospector
Maximum number of participants: 8 persons

	1	2	3	4	5	6	7	8	9
Introduction et interpretation of impact									
Utilisation compass, clinometer and GPS									
Line cutting									
Counting									
Selection									
Mapping									
Exams, distribution of certificates									

4.7.2 Target group 2: Interested people

- Managers (enterprise directors, logging managers, site managers)
- civil servants
- researchers, teachers (University and Technical schools)
- NGO's

Duration: ¼ of a day
Personnel: 1 instructor
Maximum number of participants: 8 persons

4.7.3 Target group 3: Instructors

- Student instructors in RIL inventory

Duration: 20 days (2 whole days, the second he will assist the instructor of the centre)
Personnel: 1 instructor
Maximum number of participants: 2 persons

5. FURTHER ELABORATION ON THE SUBJECTS AND THEIR ELEMENTS

5.1 Introduction to and interpretation of the impact of the inventory and the importance of RIL techniques

To maintain environmental sustainability all tree species are inventoried during the management inventory, which will permit the calculation of the production capacity of the forest using formulas with growth and yield factors. In the same time the present fauna is inventoried by a specialist who observes and notes all sign of presence of mammals, birds and reptiles. The sustainability of production has to be maintained by the protection of seed trees and FCT during harvesting.

The negative impact of the harvesting operation on the environment can be reduced when the inventory team indicates sensitive spots in the field (water courses, biodiversity spots). Negative impacts of the inventory are limited to those caused by human presence, so by the prospectors staying on a site for a certain time; non bio-degradable waste, human parasite infestations, hunting / poaching.

The harvest inventory can only be done at 100%, which means that the whole area has to be covered, and all trees of interest are identified, measured, marked and positioned exactly on an inventory map at a scale of 1:2000. The topographical characteristics are also indicated which will allow to plan the secondary roads, side tracks, the log landings and the skid trails.

Ideally the inventory should to be finished at least a year but no longer than two years ahead of harvesting, to allow the construction and compaction of the roads in the compartments in question before they are to be used.

5.2 RIL techniques

The behaviour of the inventory workers has a great influence on the environment. They have to respect the following rules:

- Camp:
  - Toilet: all night soil has to be buried at a depth of 30 cm at a considerable distance from water courses (preferable 30 metres) so that human parasites will not infect the wild fauna.
  - Waste (plastic bags , lines and ropes which could potentially snare animals, and cans (sardines, vegetables, tomato paste), which potentially cut of trap animals) are to be collected in bags or boxes to be taken to the company's central site for disposal whenever the workers come out of the forest.
- Hunting :
  - Subsistence hunting could be allowed during the hunting season. It will then have to be checked thoroughly to ensure that no smoked, conserved or even fresh meat leaves the forest with the prospectors. A number of cartridges not exceeding the number of days in the forest

could be provided by management. The hunter will have to pick up and return any empty cartridges to justify the used ones. The hunter will have to be in the possession of a valid firearms licence.

- Integrally protected animals can under no circumstance be hunted. The excuse of having shot in self-defence is acceptable (Wildlife will have to be avoided).

- Fishing : (with hook and decomposable nets : Yes; poison and explosives : No)
- A buffer zone will have to be indicated at crossings of inventory lines and water courses according the table below :

Width of the water course between both banks	**Width of the buffer zone**
< 5 metres	2 x 30 metres
6 – 10 metres	2 x 30 metres
11 – 20 metres	2 x 30 metres
21 – 30 metres	2 x 30 metres
> 30 metres	2 x 30 metres
Small streams	2 x 5 metres
Swamps , lakes	30 metres from the water's edge

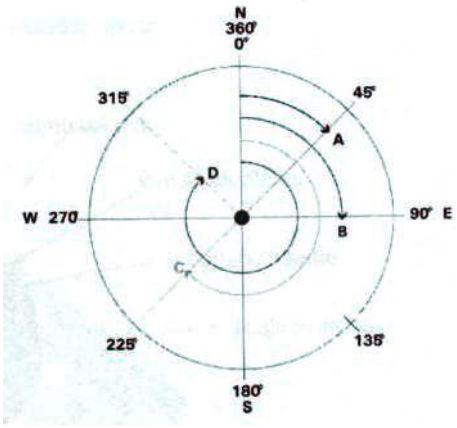
5.3 Use of compass, clinometer and GPS

5.3.1 The Compass

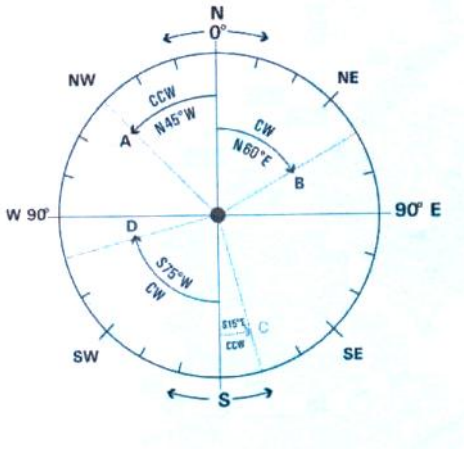
The compass indicates the North in the horizontal plane. Forming a complete circle the compass sis divided in 360 equal parts, the degrees. The degrees are numbered starting at the North (= 0º = 360º) following the circle clock wise

Reading the direction of the compass

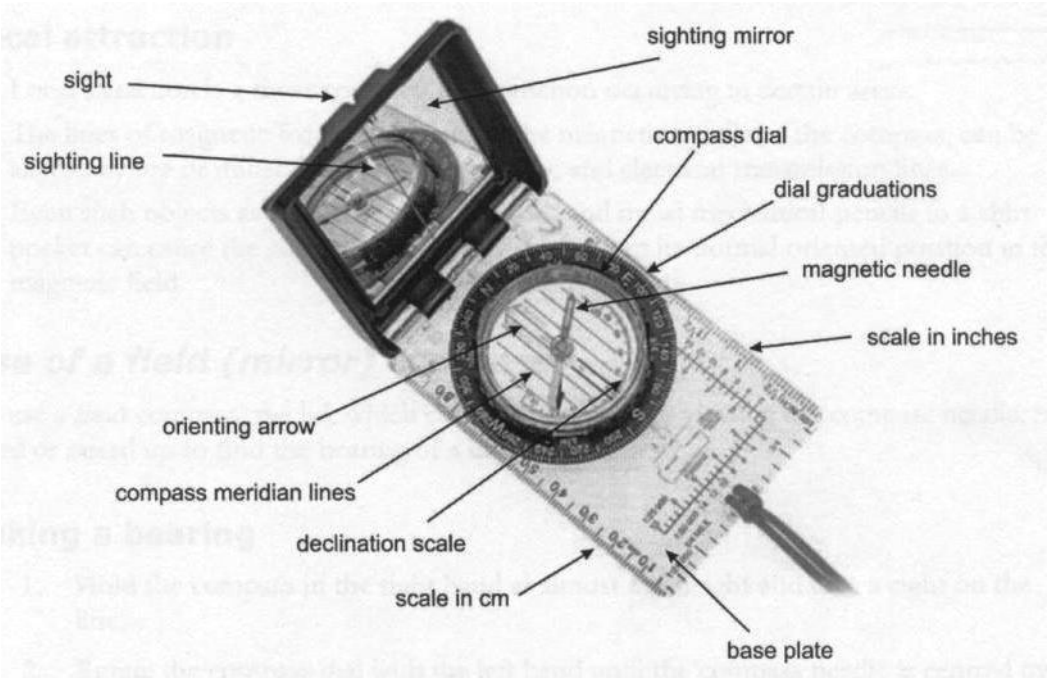
- The azimuth
  - Imagining that the user or a point on the map is in the middle of a circle, the direction from there is then measured following the needle clockwise from 0º to 360º. The direction of the azimuth is then marked as X º.



- The quarters of the compass
  - Les quarters of the compass are the right angles forming the quarters of the circle. There 90 degrees in a quarter and they always part from the north-south line. Angles within these quarters can be named differently from just the degrees. They are named for example: N45E or S30O.



Features of a compass:



- A dial to indicate the desired quarter of the compass
- A visor which allows aiming the compass directly at an object in order to read it bearing
- A aiming line to orient the compass toward a specific object (in the field or on a map)
- A compass needle (usually with a red point) which always points to the north which turns freely when the compass sis held horizontally.
- The needle is enveloped in a liquid which adsorbs vertical and horizontal movement.

Magnetic declination

- The earth functions like a big magnet. The source of this magnetism is not found in a specific place but distributed all over the earth.
- The direction of the compass needle is influenced by force fields on the earth's surface which force the needle to point to the magnetic north.
- The magnetic declination is the difference between the theoretic North (as on maps) and the magnetic north. The magnetic north changes with time and according to the position on earth.

True bearing and magnetic bearing

- The magnetic bearing of an object is the angle between the magnetic north, the compass and the object.
- It is possible to indicate on a compass what the bearing for the magnetic north is. By turning the dial for the declination to the magnetic north, all subsequent readings will be in true north.
- If the dial has not been adjusted to the magnetic north, all readings will be magnetic.

Local attractive force

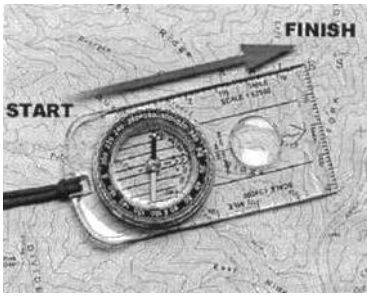
- Local attractive force is a common phenomenon in certain regions.
- The lines of the magnetic force field, which orient the compass needle, can be modified by mineral deposits, fencing and high tension electrical cables.
- Even objects like cutlasses, skidding cables or metal pens can deflect the direction of the compass needle. The same goes for using the compass in a car. A true reading may not be obtained.

Using the compass

- Taking a bearing :
  - Take the compass in the right hand at eye level and aim at the desired object.
  - Turn the movable dial of the compass to pass the indicator over the needle
  - Remove the compass from in front of the eye
  - Read the bearing from the compass
- Moving into a given direction :
  - Turn the dial until the arrow points in the desired direction.
  - Hold the compass level in font of your belly
  - Turn your body until the needle is flush with the arrow indicating your desired direction
  - Choose a reference point which is in line with your desired direction and aim at this point with the visor
  - While observing the reference point, also check the mirror regularly to check whether the needle in the mirror is still in line with the direction arrow.
- Finding your location in the forest :
  - Choose two reference points on the map
  - Aim at one of the points with the visor and read the bearing
  - Turn the dial until the magnetic needle aims to the N on the dial
  - Read the bearing on the scale
  - Place the compass on the map with the indicator touching the reference point

- Turn the compass until the orienting arrow is in line with the magnetic north
- Draw a line on the map from the reference point following the alignment of the compass
- If your compass is a flat transparent one with straight sides, this is easier as the corner of the straight side of the compass can be put on the reference point and while assuring that the direction in the field and on the compass are equal, the compass can be held parallel so a line can easily be drawn along the side of the compass.
- Repeat this process with the other reference point on the map.
- The intersection of the two drawn lines is your position in the forest

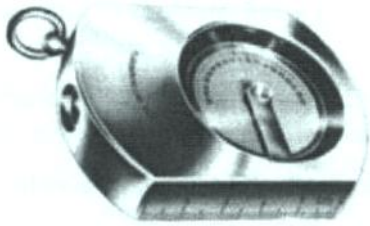
- Using the compass and the map :



- Place the compass on the map so that it links your actual position (departure A) with where you want to go (figure 8)
- Turn the dial until the “N” is aligned with the magnetic North on the map, when using a compass without a correction for the magnetic declination, and to the true North on a map when using a compass with magnetic declination (figure 9)
- Keep the compass in front of your belly with the visor straight ahead (figure 10)
- Turn yourself until the magnetic needle aims in the same direction as the arrow on the dial
- Look ahead to see if you can find a reference point in exactly that direction
- Move in that direction, while checking regularly that the alignment of the needle and the arrow continue to correspond. From time to time a reference point further ahead has to be sought out to allow walking straight ahead.

5.3.2 The Clinometer

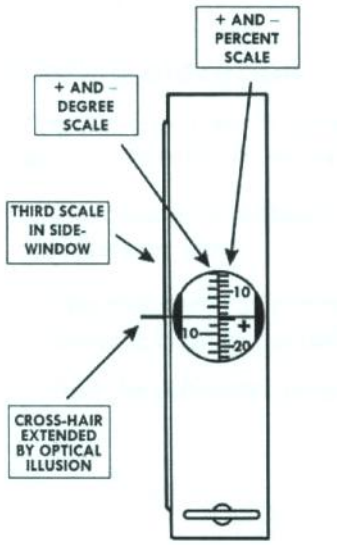
The clinometer is a devise that allows measuring the vertical angle in degrees and in percentages of a vision line above and below the horizontal. It allows determining with the aid of some formulas and techniques the following information:



a) The slope is important in forestry to correct distances moved in the forest into distances on the map (see also the conversion table in Annex X). This is very important when setting out boundary lines of a concession or inventory lines. In fact when covering a distance of 1000 metres in hilly terrain this will be less on the map when correcting for a slope. Omitting to apply the slope correction will create errors and may cause conflict or other problems. Knowing the angle of a slope will allow the forester also to judge whether a slope can be climbed by a loaded log trucks. If a slope is too steep an alternative route has to be chosen or the road made less steep by moving earth. Such decisions are important as it always concerns the more capital intensive part of the operation (machines)
b) Measuring the height of an object (in case of a tree) is important to calculate the length and volume of a tree when standing and to estimate the distance it will fall when felling it, so estimating the damage the felling may do to the forest or security measures to take.

Using a clinometer:

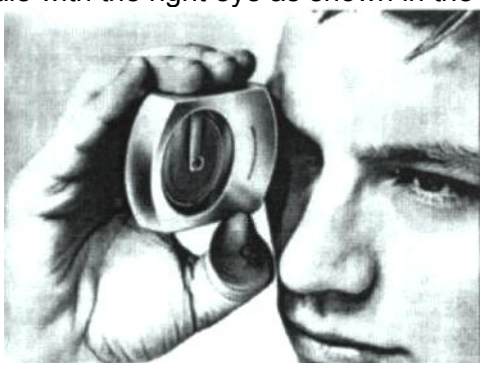
- Note that the clinometer has two scales :



  - The left scale indicates the angle from the horizontal at eye level in degrees

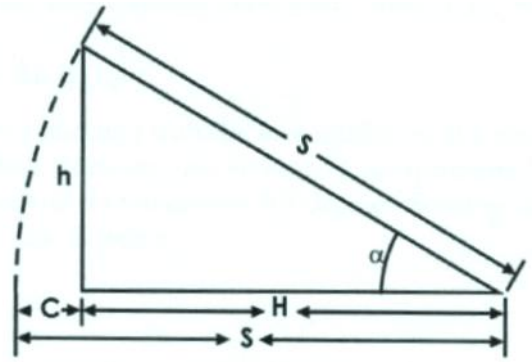
- The scale on the right indicates the height of a point from the same height as the eyes indicated as a percentage of the horizontal distance (from the observer to the tree).

- Using the clinometer step by step:
  1. Read the scale with the right eye as shown in the picture



  2. Keep both eyes open
  3. The hand holding the clinometer should not obstruct the view for the left eye
  4. The instrument should be kept in front of the eye so that the scale is visible trough the lenses and the round window points to the left
  5. The clinometer is pointed at the object
  6. Looking through the lens with the right eye you'll see the measuring scale and a horizontal line
  7. Aim with your left eye the object to be measured (such as a level pole or the crown of a tree)
  8. Because of an optical illusion the line seems to continue outside of the frame and can therefore be seen easily together with the scale and the object
  9. The instrument is then lifted or lowered until the horizontal line is aimed at the point to measure.
  10. When the horizontal line is aligned to the level pole or the crown of a tree you read the scale to find the angle in degrees or in percentage
  11. To measure a slope you need to point at an object (pole) which has the exact same height as you eye
  12. Take the measurement three times and calculate the mean value of these three.

- Calculating a height:
  Calculating the height difference between two points is easy as soon as the percentage of the slope and the horizontal distance are known:



S = slope distance
h = difference in elevation (S × sin α)
H = horizontal distance (S × cos α)
C = correction or (S - H)

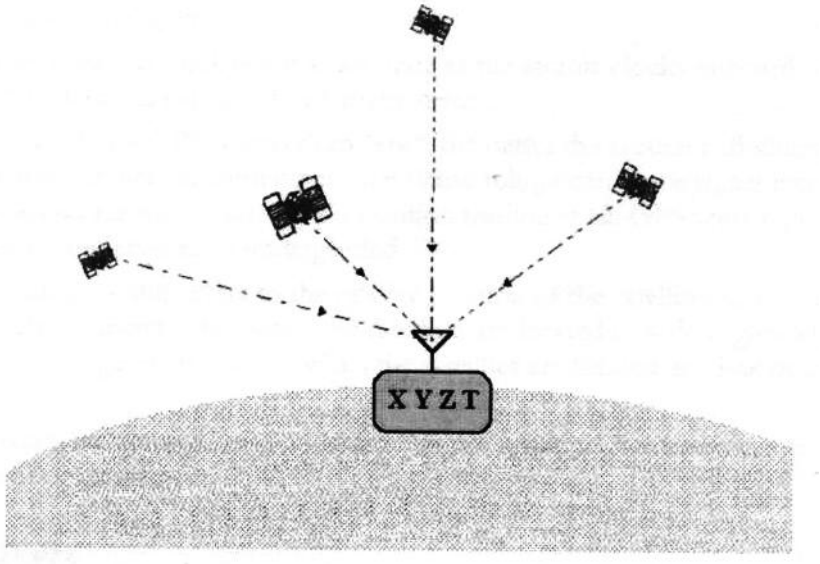
1. The horizontal distance is calculated by H = S x cos α or read in the slope correction table
2. The read percentage (h/H x 100%) is multiplied with the horizontal distance H and gives the height difference h
3. Add the height difference to the known height to know the height of a point

5.3.3 The GPS

The Global Positioning System (GPS) is in fact a constellation of 27 satellites which turn around the earth and communicate with receivers on earth or in the air.

The functioning of a GPS

- The GPS satellites turn around the earth and transmit information signals
- GPS receivers capture this information and calculate the position of the GPS user
- In fact the GPS receiver compares the moment a signal is received with a standard recapture time which is known for each individual satellite (as their position is always known exactly). Based on the time it takes the signal to come to the GPS a different distance can be calculated
- The position of the GPS devise is calculated using the information of several satellites as this allows for triangulation. These satellites are displayed in the screen of the GPS
- The GPS should receive signals of at least three satellites to be able to calculate an approximate two dimensional position (latitude et longitude) and the movement of the GPS along a track
- The GPS should receive signals of at least four satellites to be able to calculate an approximate three dimensional position (latitude, longitude and altitude) and the movement of the GPS along a track.



- As soon as the position of the GP user is known the devise can calculate other information such as the speed, direction and distance one moves in but also data like high tide in the neighbourhood, sunrise and sunset.

GPS satellite systems

- The 24 satellites which form the space part of the GPS system turn around the globe at an altitude of about 19000 kilometres.
- The turn around the earth twice in less than 24 hours
- They advance at speeds of around 11,000 kilometres per hour
- They operate on solar energy
- The GPS satellites emit two radio signals at low wavelength. These signals can travel in straight vision lines which means they can pass clouds, glass and clear plastic but not through solid objects such as buildings or mountains.

Sources of error in the GPS

Factor which can degrade the satellite signal and hence the accuracy, are the following:

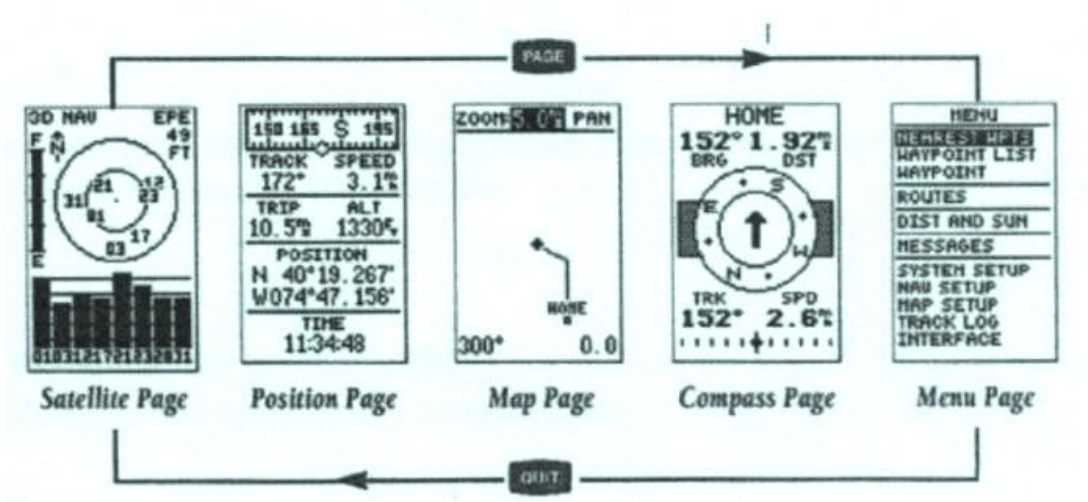
- The satellite signal slows down when passing through the atmosphere. The GPS uses a modulator which calculates a mean delay and then corrects for this. The error can be about 10 metres.
- « Multipath » of the signal indicates that the GPS signal is deflected of massif objects such as buildings or rock formations before reaching the GPS receiver. This increases the time it need from the satellite to the GPS and thus creates errors.
- The clock inside the receiver is not as accurate as the atomic clocks which are in the satellite. Clock differences can create errors up to a metre.
- The more satellites the receiver catches the more accurate the calculated position is. Buildings, mountains, electronic interference or even a tree canopy can block the reception of part of the satellites and create positioning errors, cause the GPS not to be able to calculate a position. GPS does not function inside, underground or under water.
- Satellite shade refers to the relative position of satellites at a given time. The ideal situation occurs when the satellites are distributed evenly at

large relative angles. Results are worse when the satellites are clustered or positioned in a line

- Other errors such as the choice of a wrong geodetic date can create an error between one and several hundred metres.

The GPS receiver

- Immediately after switching on the GPS receiver one has to verify if its almanac is up to date, and whether it updates automatically. Next it will look for satellites and subsequently perform a triangulation between the satellites to determine a position.
- The receiver has been conceived to capture stock and manipulate date within certain limits as well as visually present the data or transfer them to a computer.



- Most of the GPS receivers have difficulties receiving the signal through dense foliage cover, which limits the viable use to gaps in the cover.

Utilisation of the GPS

It is extremely useful to find the exact position of an object. This facility is often used in the forest. Some of the uses of this are:

- Collecting data on the position of objects to be positioned on a map later. This can vary from making new maps, to placing boundaries or positioning individual trees.
- Finding back something in the forest; this is particularly useful with places that are visited only every five years for instance such as permanent sample plots.
- Navigation, either by referring to information already in the GPS or by using coordinates from a map. This is particularly useful to take a route taken once before.

Waypoints

The GPS receiver will register a position when the button « waypoint » is pressed. A series of such points can be taken along a road in order to position this on a map. Taking points regularly will also allow tracing back a route. With the “goto” function a point can be selected and the GPS will then show (according to the user’s preference) a compass arrow pointing in the direction to take or a direct line on a map between the current position and the point.

Track
This modus registers a digital map with the road travelled. A big disadvantage is that this modus consumes a lot of power, and is therefore not always practical in the field. The tracks can be charged into a computer to be included on a map. (GIS).

5.4 5.4 Areas to exclude from harvesting

There are various reasons to exclude areas from harvesting (often called buffer zones) such as:

- Access (swamps, water ways, steep slopes, big rocks) to be determined by the inventory team
- Environmental protection (banks of water ways, mires, streams, habitat of threatened species, high biodiversity area, High Conservation Value Forests, fragile habitats, etc.) to be determined by biologists working on the sustainable management plan
- Cultural value (cemeteries, sacred trees or sacred groves) to be identified by sociologists working on the management plan
- Economic value (agricultural zones or areas reserved for use by villagers) to be determined by sociologists working on the sustainable management plan.

The areas have to be marked by staking out clearly well marked lines in the forest and by being positioned on the inventory map to be used during harvesting.

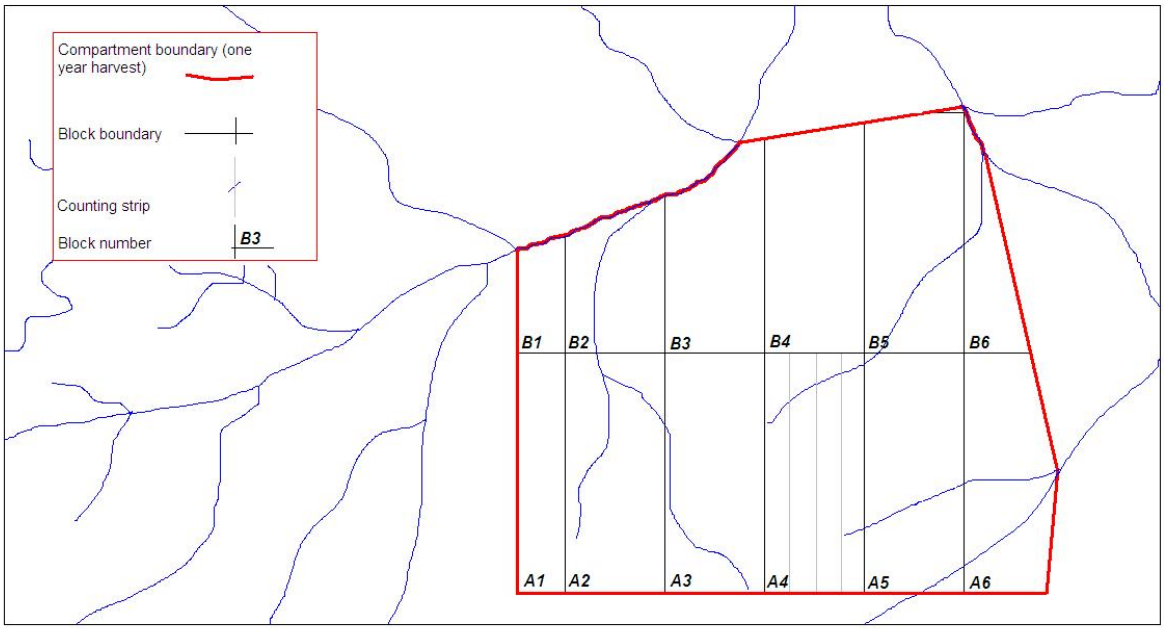


Figure 1 : Map showing the different levels mentioned in the text (compartment, block and inventory strips)

5.5 Opening lines and boundaries

5.5.1 Introduction and description

Opening lines or line cutting means the staking out of terrain and its subdivision in plots by means of lines cut in the forest undergrowth. A new concession will first have to be marked in the field with a boundary line. The width and markings to be used are defined by the national forestry authorities. Where a boundary crosses a road this boundary also has to be marked with signs and clear colour markings.

Ideally, the management inventory takes place before the harvest inventory. The inventory lines used for the management inventory do not correspond with those needed for the management inventory as it is only done at a fraction of the area (0,5 to 2%)

Concessions are usually divided in annual harvesting areas, which are sometimes regrouped in five to six 5-year blocks thus covering a rotation of 25 to 30 years.

The division of the concession is done based on information obtained through the management inventory, which indicates grossly where what species and volumes are to be found
According to the criteria for sustainable harvesting the surface of an annual cutting area is obtained by dividing the surface of the concession by the number of years of the rotation. In Central Africa this rotation is normally 25 to 30 years.

5.5.2 Method

The division of the concession in annual cutting areas is most often done in square or rectangular shapes of the same area. In hilly areas interspersed with outcrops and deep vales it is preferred to subdivide the terrain in harvesting pockets following natural features and trying to keep similar surfaces.
It is however preferable to keep a system of square or rectangular surfaces. The accuracy of inventory work done in irregular surfaces has proven to be questionable. Many trees remain unnoticed. Also working with irregular surfaces makes the mapping more difficult, especially if no GIS system is available.

The most practical working method involves the division of the annual allowable coupe (AAC) into rectangular blocks of the same size, except there where the boundary of the concession or the compartment interferes. This is often the case where the AAC have been determined using natural boundaries such are rivers and streams.

Examples are:

- Squares of 1000 x 1000 metres = 100 ha
- Squares of 2000 x 2000 metres = 400 ha
- Rectangles of 500 x 2000 metres = 100 ha
- Rectangles of 500 x 3000 metres = 150 ha
- Rectangles of 1000 x 2000 metres = 200 ha, etcetera.

The choice is dictated by the size of the AAC, terrain characteristics and the number of workers to be employed in the inventory.

The following types of line can be distinguished:

- Principal or base line, outlining the compartments
- Counting lines directing the inventory workers during the inventory

5.5.3 Techniques

- The line cutting team consists generally of 1 team leader, one compass man, two chain men and 2 to 3 clearer (with cutlasses)
- The base lines are usually oriented North-South and East-West (magnetically for easy working)
- Every 100 metres the compass man takes a bearing in the opposite direction (+ or - 180° degrees to the direction taken before) to verify the precise direction taken
- The lines are opened to a width of 1 to 2 metres using cutlasses to remove the dense undergrowth. Pickets are placed at regular intervals
- Base lines should remain visible for at least two years
- The line cutting team also marks the characteristics of the terrain (slope, water courses, swamps) on the map
- The pickets are placed every 50 or 100 metres and the distance from the base point is written on them in industrial crayon or with a marker on ribbon.
- The clinometer is used to verify the slope and correct the distance between with the pickets
- The distance between pickets is always measured at soil level and not in the middle or at the top of the picket as these are hardly ever planted exactly straight
- The GPS position is taken in the south-west corner of each inventory block
- Along paths through the blocks the number of the compartment and the block are written on trees in side the compartment bordering the path
- The production per team, depending on the terrain conditions, is about 2 kilometres per day.

Enumeration lines divide the block in inventory strips with a width of 100 to 200 metres.

- **It is advised not to distance the lines more than 100 metres apart to assure a good positioning and communication between the prospectors and to assure the whole area to be covered.**
- The width of the lines should not be more than 1 metre
- Along these lines pickets should also be placed with the distances marked on them.
- The prospectors position themselves a equal distances on the base line and advance in battle array while identifying and measuring the trees
- They shout the species and size to the clerk who positions and notes the trees on the map
- Every so often the team has to align to assure working parallel to the baseline
- The production per team is, depending on the terrain circumstances, about 3 to 4 kilometre per day (a strip of 100 metres thus means 30 to 40 hectares).

5.6 Enumeration (identification, position and measuring of trees)

5.6.1 Introduction and description

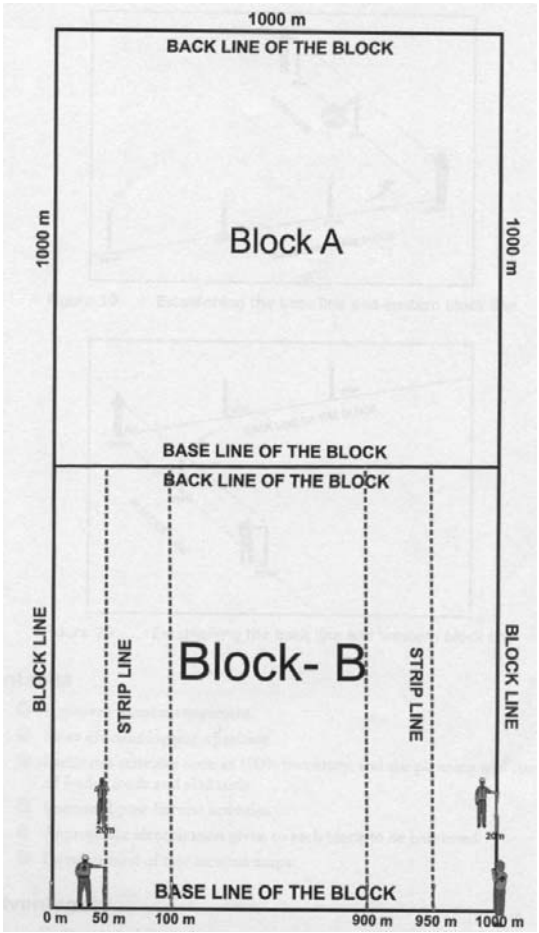
The criteria for the selection of trees for the inventory are:

1. Species
2. Classification (commercial, seed tree, protected species)
3. Minimum diameter (DBH)
4. Quality – shape of the trunk (straight, bent, twisted or hollow)
5. Position / accessibility in the terrain (slope, swamp etc.)

The measurement of exploitable trees during the inventory allows the selection of trees with a diameter superior to the minimum authorised by law or determined in the management plan. It also allows identifying the **future crop trees**. Finally, the inventory allows to estimate the volume of the trees (and thus per compartment) bases on volume tables which link volume to diameter (these tables are specific to certain forest areas).

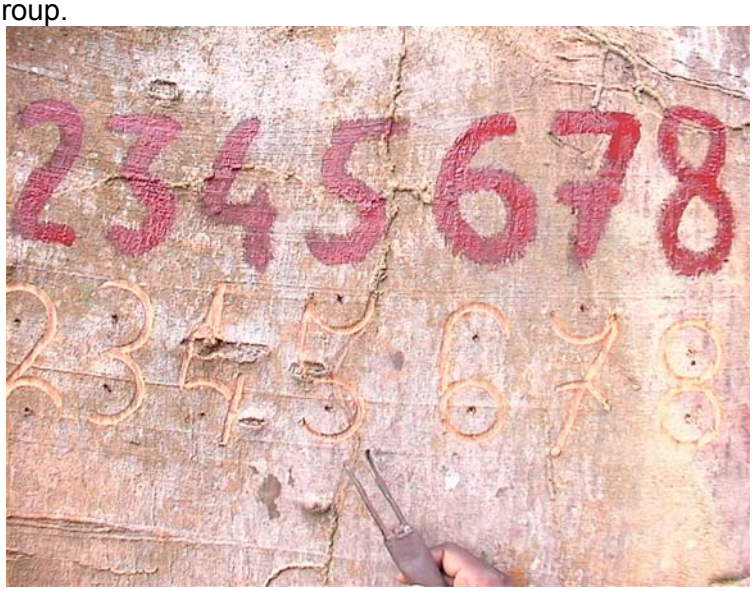
5.6.2 Enumeration technique

Enumeration technique: the enumeration team generally consist of 1 team leader and six (9) prospectors who cover a strip of 125 (200) metres wide. The ones on the left and the right walk on the line separating the enumeration blocks and hence need to cover only 12,5 metres. These are also responsible for the noting of distances on the poles and the alignment of the prospectors. The other members of the team each work a strip of 25 metre wide.



5.6.3 Numbering of the inventoried trees

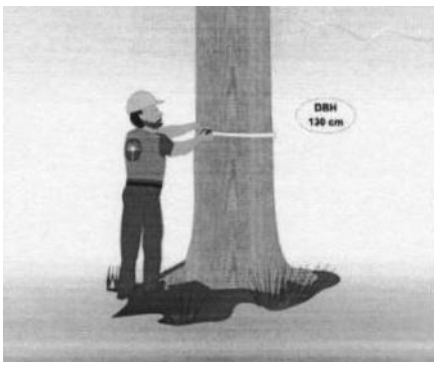
Only trees that are inventoried for harvesting in the current rotation are to be numbered. This inventory number has to be put on a clearly visible place preferable at eye height in paint, aluminium tags or in the bark with the scribing knife. Putting the number on a piece of ribbon to tie to the tree is not efficient as some animals (primates, elephants) will take the tape off and play with it. The numbered trees are listed in a book or in a table with Number – Species – Diameter group.

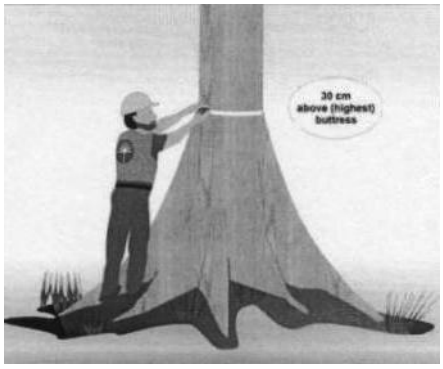


Numbering the tree with paint and the scribing knife

5.6.4 Measuring technique

The general rule in West and Central Africa is to measure the circumference of the tree at breast height (DBH), which is 1,30 metres of the ground or, in case of very pronounced buttresses, at 30 cm. above the buttresses.





Different notions:

- The minimum harvesting diameter (MHD) per species is measured at breast height and in case of buttresses at 30 cm above the buttresses. This diameter is determined by the national government and is compulsory.
- The management diameter is determined based on the analysis of inventory data, and species growth and mortality rates. This diameter is determined by the management plan.

The tools normally used are:

- Aluminium callipers reaching a maximum diameter of 1,50m.
- The pi tape with two scales: in centimetres to measure the circumference of a tree and one which converts the circumference in diameter.
- To measure above the buttresses a special board with a decimetre scale mounted on a pole exists. This allows a rough estimate of the diameter above the buttresses.

The height is measured preferably by sample, so more than one tree per DBH and not per single tree nor for all trees found.

5.6.5 Future crop trees having a DBH of over 50 cm.

All trees of commercial species having a diameter at breast height of more than 50 cm and less than the prescribed minimum felling diameter are considered FCT and can be inventoried.
Those positioned in the falling direction of harvestable trees are to be marked as such on the inventory sheet. These trees are later sought out before felling by the selection team and marked with a ribbon or with paint to enhance their visibility so fellers can avoid them during felling. Future crop trees which are found at less than 5 metres from planned skid trails also have to be marked by the selection team so they can be avoided during skidding.

5.6.6 Seed trees

Seed trees are to be selected from the harvestable trees by the inventory team leader. These trees have to be of good health and form. They can be of a diameter slightly below the minimum harvesting diameter (MHD, MD).

5.6.7 Trees of protected species

Protected species are mentioned in the **CITES** list or in national legislation. In Africa the only tree on the CITES list is Kokrodua (Pericopsis Elata). This tree can not be harvested and exported from Ghana. In other countries it can be harvested and exported but only with the appropriate CITES documentation.
Species that produce non-timber-forest-products (NTFP) will have to be spared during harvesting, though some species produce both NTFP's and timber. When these species are found and villages are nearby, it has to be examined first whether harvesting these trees will negatively affect the communities. The analysis should be described in the management plan and an eventual compensation plan drawn up.
Species protected nationally can be of any species which is judged rare or threatened. In most countries of Central Africa the Ebonies (Diospyros spp.) have been awarded a special status.
These trees need to be marked on the inventory map, and before harvesting starts these have to be marked with tape or paint so they can be spotted and avoided.

5.7 Topographical characteristics

5.7.1 Hydrology

The line cutters, prospectors and clerks have to mark the following features accurately on their map:

- Water courses crossing their line or strip, mentioning the width and the direction of the flow
- The state of the banks
- In case of swamps the entire outline and the soil type (sandy, peaty)

5.7.2 Soil

The soil characteristics need to be identified and noted: sand, peat, clay, laterite, gravel stones, rocks.
The presence of gravel and laterite is important for the construction and maintenance of roads
Peaty areas (mires) and rocky areas should be avoided during road construction.

5.7.3 Slopes

While opening the lines and during counting the slopes have to be measured with the clinometer and the distances corrected so the poles are placed at the correct distance from the baseline.
On the inventory sheet the slope are mentioned with an arrow indicating up-slope:

- > = slight incline, no need to level off slopes or to cut out flank roads
- >> = steep slope, necessary to level off or to cut roads into the slope
- >>> = impassable slope, to be avoided

5.7.4 Vegetation

Changes in the type of vegetation are to be noted on the inventory sheets. Distinctions can be made between:

- Dense forest with little undergrowth
- Dense forest with dense undergrowth
- Light forest
- Forest with big gaps or openings
- Tree savannah
- Savannah
- Plantations
- Agricultural land / fallow
- Bare earth, rocks

5.8 Mapping

5.8.1 Introduction

Maps with zoning, with the results of exploration, with infrastructure and with the inventory results form the documentation to be used in the formulation of the sustainable management plan and the budgeting of activities.

5.8.2 Description of the different map types

The following maps are needed for the correct execution of the harvest inventory:

1) **Maps of the Concession and its subdivision** (scale 1: 50.000, on national maps or in a GIS, scale and type in relation to the area of the concession. These maps should show:

- Topography
- Hydrographical network
- Height curves
- Boundaries of he concession and the subdivision
- Road network and other infrastructure (built or planned)

2) **Map outlining the inventory in the compartment** (scale 1: 50.000, printed from the GIS of drawn by hand, size A4, showing:

- Topography
- Hydrographical network
- Boundaries of the compartment
- Numbered baselines
- Subdivision in inventory blocks
- Identification (numbering) of each line.

3) **Enumeration sheet per block or per inventory strip** (scale 1: 1.000 – 1: 1.200, filled out by hand by the inventory clerk, size A4 showing:

- Grid showing the block with a scale of 1 to 500 m
- Identification and position of the trees (harvestable, FTC, protected trees)
- Summation of the counted trees (next to the grid or on the other side of the sheet) per species and per DBH class
- Topographical and hydrographical characteristics and slopes
- The inventory and slope, topographical and hydrographical data are entered into the GIS system or directly on an inventory map of the compartment

4) **Inventory map of block of pocket** (scale 1: 3.000 – 1: 4.000, printed from the GIS or drawn by hand, size A4), showing:

- Inventory of the trees, numbered per compartment with a symbol show species, inventory number and diameter, for each harvestable, FCT or protected trees encountered.
- Summary of counted trees (on the back side)
- Slope, topographical and hydrographical characteristics taken from the inventory sheets
- Buffer zones

5) **Inventory map of the compartment** (scale 1: 7.500, printed from the GIS or drawn by hand), showing:

- Topography
- Hydrology
- Boundaries of the compartment
- Division in inventory blocks
- Slope, topographical and hydrographical characteristics taken from the inventory sheets
- Identification of the blocks
- Inventory of the trees, numbered per compartment with a symbol show species, inventory number and diameter, for each harvestable, FCT or protected trees encountered.
- Existing roads and skid trails
- Buffer zones

6) **Map of the subdivision of the compartment** (scale 1: 30.000, printed from the GIS or drawn by hand, size A3), showing:

- Division in sub-compartments, their boundaries and numbering (in 25, 50 or 100 hectare) of the compartment
- Division and outline according to terrain circumstances (streams, hill tops) of the compartment in pockets of 10 to 100 hectares and their numbering
- Hydrology
- Existing roads and skid trails
- Inventory of the trees, numbered per compartment with a symbol show species, inventory number and diameter, for each harvestable, FCT or protected trees encountered.

For the final selection of the harvestable trees the following maps are used:

6) **Map of the subdivision of the compartment** (scale 1: 30.000, printed from the GIS or drawn by hand, size A3), showing:

- Division in sub-compartments, their boundaries and numbering (in 25, 50 or 100 hectare) of the compartment
- Division and outline according to terrain circumstances (streams, hill tops) of the compartment in pockets of 10 to 100 hectares and their numbering
- Hydrology
- Existing roads and skid trails

4) **Inventory map of block of pocket** (scale 1: 3.000 – 1: 4.000, printed from the GIS or drawn by hand, size A4), showing:

- Inventory of the trees, numbered per compartment with a symbol show species, inventory number and diameter, for each harvestable, FCT or protected trees encountered.
- Summary of counted trees (on the back side)
- Slope, topographical and hydrographical characteristics taken from the inventory sheets
- Buffer zones

When the selection has been finalised map 4: Inventory map of a compartment or pocket is changed into:

Selection map (of the pocket) printed from GIS or drawn by hand to a scale of 1: 3.000 – 1: 4.000, size A4), showing:

- Final inventory of the harvestable trees, numbered per compartment with a symbol show species, inventory number and diameter.
- Traced skid trails
- Indication of the type of machine needed for the work (based on terrain)
- Summary of selected trees (next to drawn map or on the back side of the sheet)
- Slope, topographical and hydrographical characteristics taken from the inventory sheets
- Buffer zones

This map serves as a working map during harvesting. Copies of it are distributed to fellers and skidders.

5.9 Health and Safety

5.9.1 Safety

The inventory team is subject to diverse risks and dangers while staying in the forest day and night. Several safety rules are to be respected to increase safety:

- When choosing for the placement of the camp observations of the terrain have to be made of especially the canopy to spot any overhanging dead branches that may fall
- The camp has to be site sufficiently far from streams to avoid the risk of flooding which could cut people off from food and equipment
- Water from streams is not to be drunk unless clean and clear. It is however always best to filter and boil water from streams
- The soil of the camp, especially below and surrounding the beds, tarpaulins and tents has to be cleaned of all rubbish or vegetation which could attract and hide vermin or other harmful animals (ants, rodents or snakes)
- When there is an indication of the presence of big game (such as elephants, buffalos or gorillas the team has to turn back and wait until the animals move away

5.9.2 Health

- Every team needs to have a first aid kit which contains material for the treatment of pains, cuts, stings, bites and the stabilisation of broken bones. It should also contain medicines for the treatment of malaria, diarrhoea and fever.
- Every team has to have members trained in the application of first aid. This training and a procedure for emergencies ensures that people know how to react in an emergency, and how the immediate evacuation is to be done in case of need.
- Teams should have a satellite phone or radio to be used in emergencies.
- Toilets should be dug sufficiently far away from streams to avoid pollution and be deep enough to avoid flooding in case of heavy rain.
- The toilets have to be filled with earth when camp is abandoned.
- If toilets are not dug, any excrement has to be immediately buried sufficiently deeply.
- Bodily hygiene is very important when living in the forest. A good site has to be chosen so that there is access to clean water for washing near the camp.

5.10 Structure of the training

Introduction and description:

- Lecture 2. Objectives

Theoretical training:

- In the classroom
- Black board
- Lecture 5.1 – 5.6
- Seats for all students
- Question round.

Practical training:

- Use of the clinometer
- Use of the compass
- Use of GPS
- Use of the topofil
- Use of the scribing knife
- Line cutting and pole placing (pegging)

Conditions:

- Part of the concession has to be available and be reserved to perform the inventory training at no further than 1 hours from base camp

Objectives for the trainer:

- Explanation of the importance of each action of the inventory concluding with a question round and open discussion
- Execution of all training activities with the group of students

Materials:

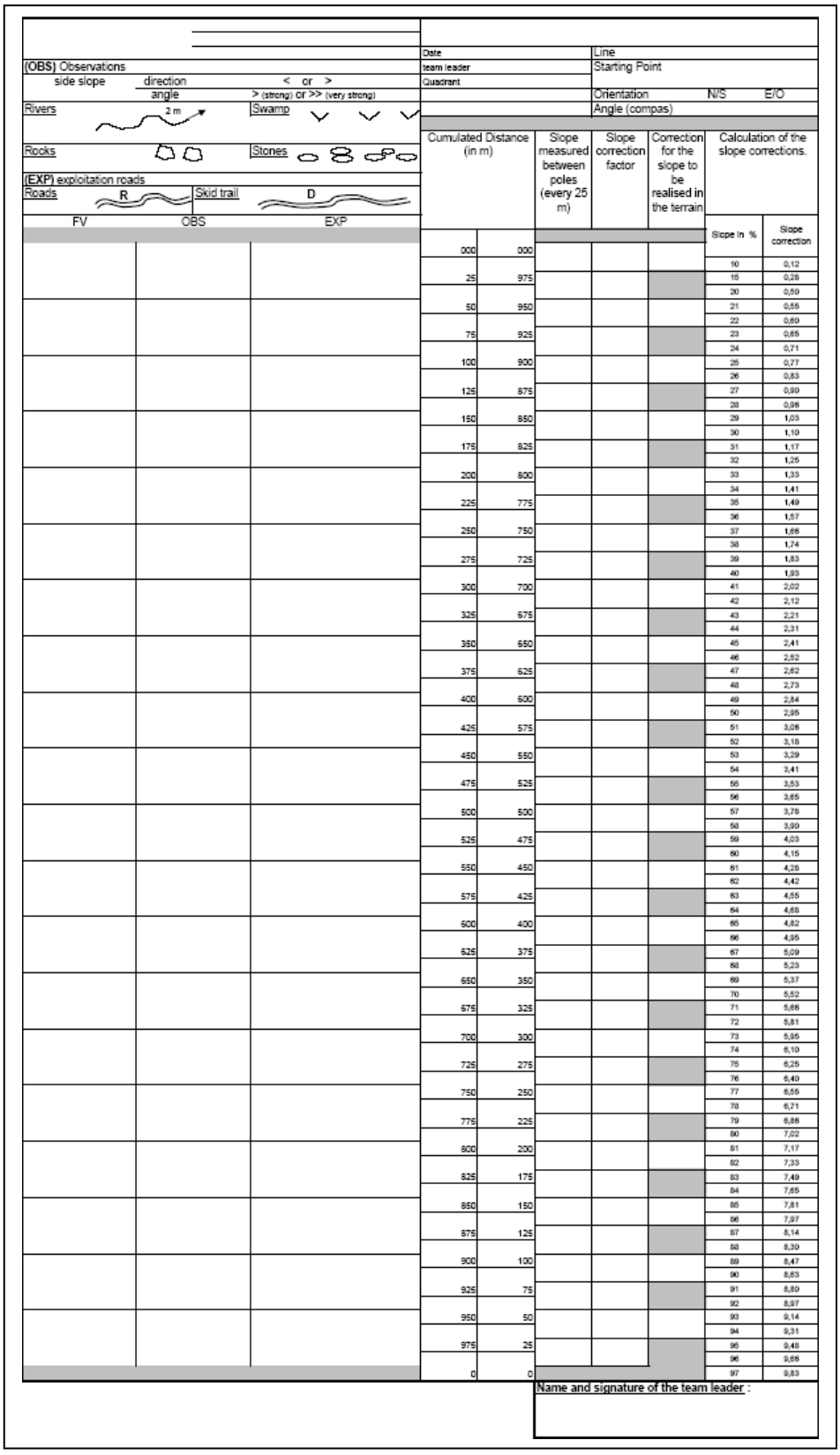
- Compass, clinometer, GPS, topofil, tape markers, scribing knifes, paint, cutlasses, inventory sheets, maps (see 5.2 mapping)

Personnel:

- 1 Instructor

Duration: 6 days

6. ANNEX 1: CONVERSION TABLE FOR CLINOMETER READINGS.



(OBS) Observations
side slope direction angle < or > > (strong) or >> (very strong)
Rivers 2 m Swamp
Rocks Stones
(EXP) exploitation roads
Roads R Skid trail D
FV OBS EXP

Date
team leader
Quadrant
Line
Starting Point
Orientation N/S E/O
Angle (compas)

Cumulated Distance (in m)		Slope measured between poles (every 25 m)	Slope correction factor	Correction for the slope to be realised in the terrain	Calculation of the slope corrections.	
					Slope in %	Slope correction
000	000				10	0,12
25	975				15	0,28
					20	0,50
50	950				21	0,55
					22	0,60
75	925				23	0,65
					24	0,71
100	900				25	0,77
					26	0,83
125	875				27	0,90
					28	0,96
150	850				29	1,03
					30	1,10
175	825				31	1,17
					32	1,25
200	800				33	1,33
					34	1,41
225	775				35	1,49
					36	1,57
250	750				37	1,66
					38	1,74
275	725				39	1,83
					40	1,93
300	700				41	2,02
					42	2,12
325	675				43	2,21
					44	2,31
350	650				45	2,41
					46	2,52
375	625				47	2,62
					48	2,73
400	600				49	2,84
					50	2,95
425	575				51	3,06
					52	3,18
450	550				53	3,29
					54	3,41
475	525				55	3,53
					56	3,65
500	500				57	3,78
					58	3,90
525	475				59	4,03
					60	4,15
550	450				61	4,28
					62	4,42
575	425				63	4,55
					64	4,68
600	400				65	4,82
					66	4,95
625	375				67	5,09
					68	5,23
650	350				69	5,37
					70	5,52
675	325				71	5,66
					72	5,81
700	300				73	5,95
					74	6,10
725	275				75	6,25
					76	6,40
750	250				77	6,55
					78	6,71
775	225				79	6,86
					80	7,02
800	200				81	7,17
					82	7,33
825	175				83	7,49
					84	7,65
850	150				85	7,81
					86	7,97
875	125				87	8,14
					88	8,30
900	100				89	8,47
					90	8,63
925	75				91	8,80
					92	8,97
950	50				93	9,14
					94	9,31
975	25				95	9,48
					96	9,66
0	0				97	9,83

Name and signature of the team leader :

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8. ABBREVIATIONS

AAC	Annual Allowable Coupe
ARCView	Mapping software
CFAD	Concession Forestière sous Aménagement Durable: Forest concession in Gabon
CITES	Convention on International Trade in Endangered Species
DBH	Diameter at breast height
FTC	Future Crop Tree
FMP	Forest Management plan
GPS	Global Positioning System
GIS	Geographic Information System
MD	Management diameter
MHD	Minimum Harvesting Diameter
NGO	Non Governmental Organisation
RIL	Reduced Impact Logging
SMP	Sustainable Management Plan
SFM	Sustainable Forest Management