Improving Capacity in Forest Resources Assessment in Kenya (IC-FRA)

Field Manual for Biophysical Forest Resources Assessment in Kenya

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Cover caption: Front page photograph by P. Hyvönen: Natural forest in Nakuru National Park.

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Abbreviations

ASALs	Arid and Semi-Arid Lands
DBH	Diameter at the breast height (1.3 m)
DEM	Digital Elevation Model
DRSRS	Department of Resource Surveys and Remote Sensing
ERMIS	Environment Research, Mapping and Information System
FAO	Food and Agricultural Organization
FIS	Forest Information System
FRA	Forest Resources Assessment Programme
GHG	Green House Gas
GIS	Geographic Information Systems
GPS	Global Positioning System
ILUA	Integrated Land Use Assessment
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
LDS	Litter, woody Debris, and Soil
METLA	Finnish Forest Research Institute
NFA	National Forest Assessment (Project)
NFI	National Forest Inventory
NFMA	National Forest Monitoring and Assessment
NGO	Non-governmental Organization
NWFP	Non-wood Forest Product
PDA	Personal Digital Assistant, mobile device
PSP	Permanent Sample Plot
REDD	Reducing Emissions from Deforestation and Forest Degradation
SFM	Sustainable Forest Management
SOC	Soil Organic Carbon
TOF	Trees Outside of Forests
UoE	University of Eldoret
UTM	Universal Transverse Mercator

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This Field Manual is based on the experiences and the field manual of the Integrated Land Use Assessment (ILUA) of FAO. We sincerely thank Lauri Vesa, Anne Branthomme and Dan Altrell (from FAO FOMR) for providing us their valuable information.

This Manual will go a long way in harmonizing field data collection methods for forest resource assessments in Kenya and is a basis for developing an efficient forest monitoring system.

Definitions

Abiotic: Refers to the non-living parts of an ecosystem, such as soil particles bedrock, air, and water.

Afforestation: The establishment of a forest or a stand of trees in an area which had no forest before or where the preceding vegetation or land use was not forest. (Reforestation is establishing a forest where one has been removed).

Agroforestry: A collective name for land-use systems and practices in which trees and shrubs are deliberately integrated with non-woody crops and (or) animals on the same land area for ecological and economic purposes.

Biotic factor: Any environmental influence of living organisms (e.g., damage by animals) in contrast to inanimate (i.e., abiotic) influences.

Bole height: Bole height refers to the distance along the main stem of a tree from the base of the tree above the stump to the point where utilization of the stem is limited by defect or small size of the diameter.

Breast height: Breast height is the height at the point 1.3 m from the ground level for a tree usually measured as a reference diameter. If the ground level cannot be defined, it is taken from the tree seeding point. See more explanations and special cases in the section *Tree diameter measurements.*

Cardinal points: Refer to the default location (N, E, S, W) of points immediately outside the plot boundary where litter, woody debris, and soil samples are collected.

Coppice: New tree shoots from a stump (after tree is cut or broken).

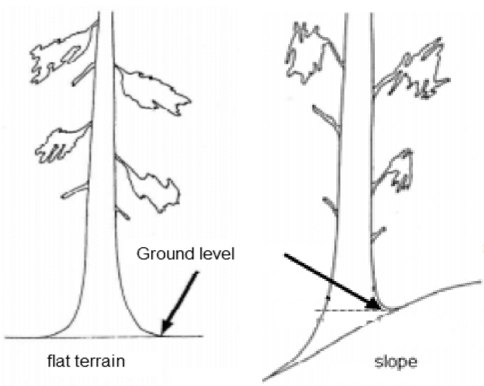
Dead tree: A tree is regarded as dead if it does not have any living branches and the stem is dry. It may be standing or fallen (Trees that are alive but so badly damaged that they cannot grow in the next growing season are regarded as dead trees).

Debris/woody debris: Particles of Dead wood with diameter <10 cm but larger than litter. The boundary between litter and debris is not definite, but their should be no much concerned because both are eventually combined in one sample when calculating carbon.

Farm forestry: Growing of trees on farms in various configurations or in woodlots.

Forked tree: A tree that is branched. If the branching point is below the breast height (1.3 m from the ground), the tree is recorded by giving a unique stem number for each fork, and all stems get the same tree number. If the forking point is above the breast height, the tree is recorded as one tree.

Ground level: Ground level is described as the topmost surface from which a tree roots as illustrated in the picture below.



High-precision GPS: GPS receiver capable to process real-time differential correction (DGPS) in the field.

Litter: Remains of fallen leaves or needles, dead ground vegetation, parts of tree bark and thin branches lying on the ground that have not decomposed.

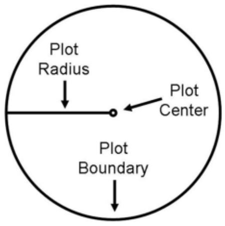
Living tree: A tree that is alive, has living branches and must be able to survive at least to the next growing season.

Mangrove: A tropical tree that grows in mud or at the edge of rivers or sea and may have roots above ground.

Natural forest: A forest that had little or no human assistance in its regeneration/establishment.

Permanent Sample Plot (PSP): Plots whose positions are marked and known for future reassessment and are periodically re-measured to provide data on changes in land use, forest stocking, volume and carbon.

Plot radius, centre and boundary: These are as in the figure below.



Reforestation: Establishing forests in areas that already are classified as forests due to their former land use (which might have been compromised) and does not imply any change of land use from a non-forest use to forest.

Regeneration: Young seedlings or saplings that have germinated naturally.

Sample tree: A tree selected for special measurement of variables beyond what is measured in the other trees. (In this manual every 5th tree within a plot is a sample tree where further variables like height are collected).

Sapling: Usually a young tree larger than seedling but less than 2 cm diameter at breast height.

Seeding point: Seeding point is usually at the ground level. For trees that grow on the top of a stone or old stump, the seeding point is the point where the seeds have started to grow or a stump sprout.

Shrub: Shrubs are woody perennial plants, generally of more than 0.5 m and (usually) less than 5 m in height on maturity and with many stems and branches.

Soil characteristics: In this context parameters describing soil quality including soil depth, soil colour, soil texture and stoniness that can be evaluated in the field.

Soil depth: Depth of soil above the bedrock or a layer impermeable for roots.

Soil pit: A c.a. 40 cm deep pit with a clean vertical wall for observing soil characteristics.

Sub-cardinal points: Refer here to the alternate location (NE, SE, SW, NW) of points immediately outside the plot boundary where litter, woody debris, and soil samples are collected.

Stump height: Stump height is the level of the upper most root collar. If no root collars exist, stump height is expected to be 15 cm from the ground level.

Tally tree: Live or dead standing tree in the concentric circular plot above minimum DBH.

Temporary sample plot: Sample plot that is measured during one inventory and not intended to be re-measured on coming inventories.

Tree: A tree is a perennial woody plant with a height of at least 1.35 m and distinct stem capable of reaching 5 meters height *in situ*. Cactuses and palms are regarded as trees in the data collecting phase, but distinguished in the data analysis phase. Bamboos and shrubs are not recorded as trees. Climbers such as *Ficus* are treated as trees.

Tree height: Tree height is the distance along the stem axis between the seeding (base) point and the tree tip. See more explanations and special cases in the section *Tree height measurements.*

Undergrowth: Includes small trees, bushes, herbs and grasses growing beneath taller trees in a forest or in farms.

1 Introduction

Kenya's forest resources are important for economic, environmental and social welfare of the nation. Forests provide a wide range of products and services such as raw material for wood industry, employment, soil stabilization, non-wood forest products, wildlife habitats, biodiversity, reverence and water catchments. Kenya's growing population, increasing demand for arable land, water and power are causing enormous pressure on the natural resources. Yet, the state and trends of the forestry resources are partly unknown.

The current national estimates of forest areas and mean volumes are mainly based on forest inventories carried out in the beginning of the 1990's during the compilation of Kenya Forestry Master Plan (KFMP) in 1994. Several other forest inventory and resource assessment projects have been accomplished after that, e.g. Kenya Indigenous Forests Conservation project (KIFCON, 1993), Mt Elgon Forest Mapping and Inventory (1997), Forest inventory for indigenous forests in Arabuko Sokoke Forest reserve (2001), Indigenous trees inventory and vegetation survey in Mt Elgon Reserve (2001). Trees Inventory and Vegetation Survey in Mukogodo Landscape (2005), Tree resources inventory of South Nandi forest reserve (2005), Kenya forest plantations inventory (2010 - 2012), Kakamega Forest Mapping by Biota project (2005) and inventory of Mau Forest block (2012). In summary, these inventories have produced relevant information about the forest resources in parts of Kenya, but not the whole country. In addition the sampling designs varied. Thus there is a need to conduct an inventory based on a harmonised and sound sampling design and data analysis, to provide reliable information about Kenya's forest resources.

Proper planning is crucial for the National Forest Resources Assessment to meet its goals. This includes preparation of field manual to enable field crews to collect relevant and accurate data for the project. The purpose of this field manual is to provide the inventory staff with structured information on the inventory techniques that will lead to the achievement of the intended outputs. This manual contains the fieldwork instructions for measurement of biophysical variables on sample plots.

The manual focuses on:

- Sampling design
- Measurement practices
- Biophysical variables
- Inventory field forms

The use of GPS and checklist for tree species codes are not explained in this manual. These will be published as separate documents. In addition, a separate manual will be compiled for the socioeconomic component of the NFI (the household survey).

The forest inventory system and this manual are based on experiences of earlier forest inventories in Kenya, and Integrated Land Use Assessments (ILUA) advised by FAO and successfully implemented in several countries worldwide. In addition, the sampling design and these guidelines have been tailored using experiences and practices adopted from other national forest inventories, e.g. NFI of Finland, Vietnam, Nepal and Tanzania and a pilot forest inventory carried out in five forest types in Kenya.

2 Sampling design

2.1 Sampling

Kenya is stratified into four strata abased on the county boundaries and the agro-ecological zones (Figure 1). The sampling design is a double stratified two-phase systematic cluster sampling. The location of the first sample plot is randomly selected and the other plots are systematically selected based on the position of the first plot. In the 1st phase, 2 km x 2 km cluster grids are generated over all strata and in the 2nd phase, the 1st-phase clusters are stratified into 2nd-phase strata based on the number of forest sample plots in a cluster. The clusters for the 2nd phase (the sample plots to be measured in the field) are selected from the 1st-phase sample. An example of selected clusters in Stratum 2 is presented in Figure 2. The sampling design takes into account the cost estimation (time) and error estimation. The country is divided into four strata: Stratum 1 (Grasslands: 355,000 km^2), Stratum 2 (Forested areas: 210,000 km^2), Stratum 3 (Coast: 27,000 km^2) and Stratum 4 (Mangrove: 1 km^2).

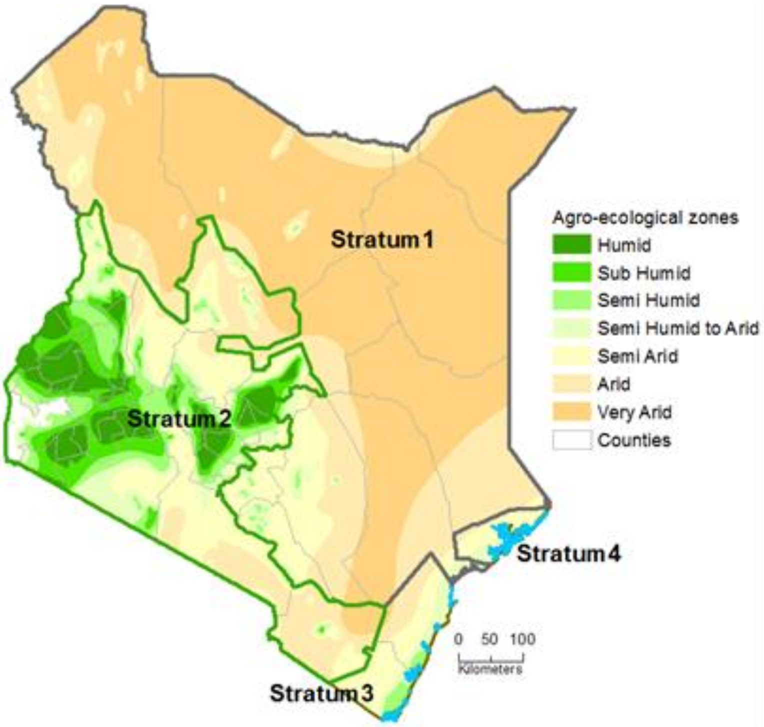


Figure 1. Proposed Strata in the National Forest Resources Assessment and agro-ecological zones and county boundaries in Kenya.

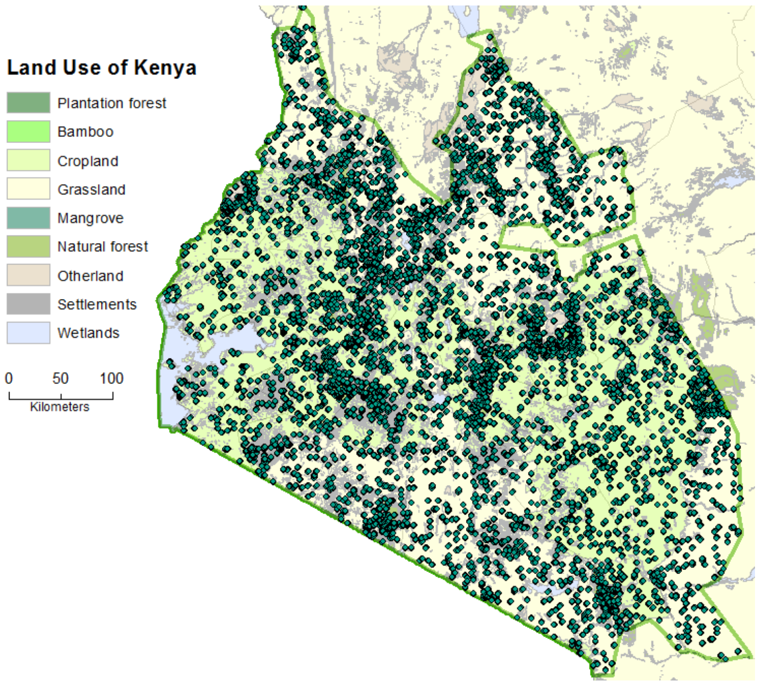


Figure 2. Clusters for field measurement in Stratum 2 (Forested areas).

The exact locations of sample plots are presented on a separate list and on the inventory field maps.

2.2 Cluster and plot design

In each of the above mentioned stratum there can be different cluster designs and the proposed cluster and sample plot design is as follows:

In Stratum 1 (Grasslands), Stratum 2 (Forested areas) and Stratum 3 (Coast) there are six sample plots in a rectangular shape cluster (Figure 3). Distances between sample plots in the cluster are 250 meters (South-North direction) and 250 meters (West-East direction).

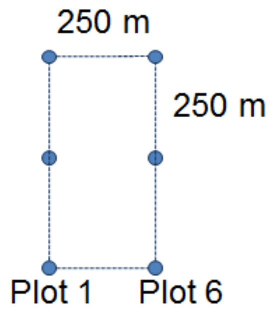
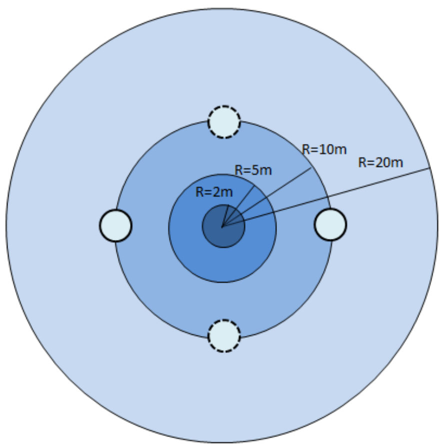


Figure 3. Cluster design for Stratum 1 – Stratum 3.



Radius ≤ 20 m
Trees dbh ≥ 20
Radius ≤ 10 m
Trees dbh ≥ 10 cm
Radius ≤ 5 m
Trees dbh ≥ 5 cm
Radius ≤ 2 m
Trees dbh ≥ 2 cm

Figure 4. Sample plot design for Stratum 1 (arid areas) and Stratum 3 (grassland). Regeneration subplots are marked with light blue colour and the optional regeneration subplots with blue colour and dashed line.

The nested sample plot design is presented in Figure 4. The outer radius of the sample plot in Stratum 2 and Stratum 4 is 15 metres and in Stratum 1 and Stratum 3, it is 20 metres. As the Stratum 1 and Stratum 3 are mostly grassland having scattered natural forest patches, a larger outer radius (20 m) of largest sample plot is recommended. By this way the few scattered trees (e.g. TOF) among grass are better captured. (All distances indicate horizontal distances).

In Stratum 4 (Mangrove, including buffer zone) there are four sample plots in a square shape cluster (Figure 5). Distances between sample plots in the cluster are 150 meters. The sample plot design is as in Figure 4, with the exception that the outermost radius is 15 metres.

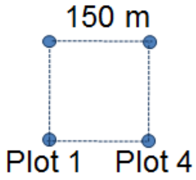


Figure 5. Cluster design for Stratum 4 (Mangrove).

2.3 Sample units

The primary sampling unit is a concentric sample plot (Figure 4). The plots are grouped into clusters for practical reasons in order to take into account the reduced inventory costs. The measurement unit, i.e. a cluster, should as a rule of thumb, be measurable within one working day for a field crew. If some of the plots in a cluster are outside the forest, it may be possible to measure more than one cluster in a day.

Sample plot information is collected in the plot area and observations for stand description are a carried out on the area surrounding the plot. The concept of stand is described in details on page 29 in chapter 4.3.226. The surrounding area is expected to be to some extent homogenous with the plot area with respect to the land use, vegetation type, accomplished measures and proposed future management. The stand parameters are estimated as an average of the forest surrounding the plot. Information for stand description is collected and recorded including use, vegetation type, soil, and forest products and services. Also information about shrubs, regeneration, dead wood, stumps and bamboos is collected. For each tree inside the plot, the species and breast height diameter are recorded. Every 5th tree in a plot is selected as a sample tree and more variables are recorded.

The use of concentric plots in a forest inventory increases accuracy of the measurements and sampling intensity of large trees, and simultaneously saves time. Subtropical and tropical natural forests are characterized by negative exponential diameter distribution (commonly referred to as the reverse or inverse J curve) such that there are more small size trees and the number of trees decreases with increasing tree size. The concentric plot design ensures that small trees are measured in a small plot area and large trees (which constitute most of the biomass per unit area) are measured in large plot area. This arrangement results in measuring approximately the same number of trees for the different size classes.

In addition, the inventory collects data about the regeneration and soil. Measurement activities in the plot centre may cause substantial damage to small seedlings and saplings. The damage is avoided by collecting regeneration data from subplots located in the west and east directions at 10 meters distance from the centre point (Figure 6).The regeneration subplots are circular with a radius of 1.5 m. In case these regeneration subplots are not suitable, regeneration data is collected from similar subplots located in the north or south at 10 meters distance from the centre point.

Collection of samples of soil, litter and woody debris and location of soil pits are described in Chapter 4.

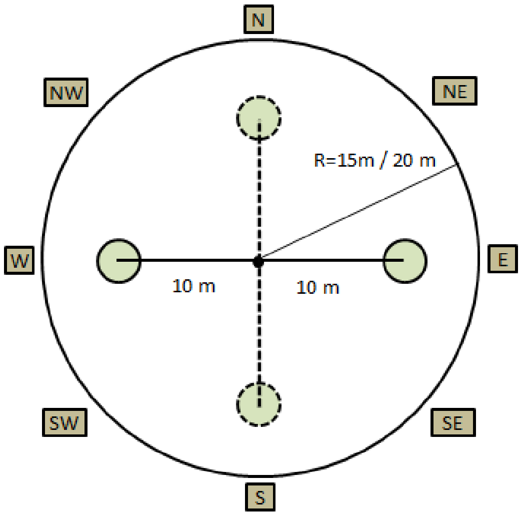


Figure 6. Location of regeneration subplots (circle) and soil pits (rectangular).

Twenty five percent of clusters are established as permanent and their GPS measurements are preferably done using high-precision GPS receiver. Other measurements and markings in the permanent clusters are done in such a way that re-measurement is possible.

There are some additional measurements on permanent plots compared to temporary plots. First, direction and distance from the plot centre to every tally tree are recorded. Secondly, the plot centre point should be marked with a 40 cm long metallic pin and about three fixed points should be marked and data collected, see chapter 4.2.

3 Preparations for the fieldwork

This part includes recommendations to prepare and carry out fieldwork activities. The fieldwork is described step by step for a sample plot, together with recommendations on the data collection techniques.

3.1 Overview of data collection process

Data is collected by the field crews from sample plots. The main information sources for the assessment are:

- Field measurements and observations on the sample plots and the surrounding plot area;
- Interviews with local people, land owners or forest users, key external informants such as foresters/forest rangers responsible for the area where the cluster is located.

These two sources of information will indicate the use of different methods and approaches that complement each other. The process for data collection is summarized in Figure 7.

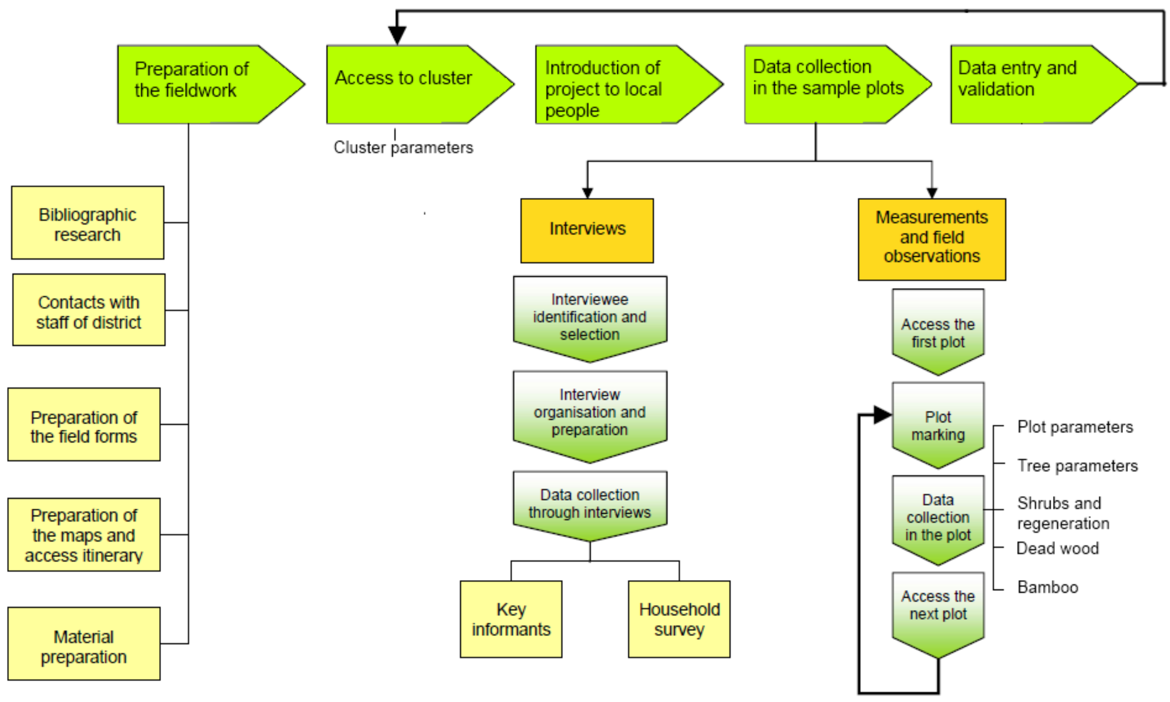


Figure 7. Diagrammatic presentation of data collection procedure.

3.2 Field crew composition

A Field crew consists of the following members:

- 2 Foresters
- 1–2 Rangers
- 2–3 members to undertake biophysical field measurements (enumerators)
- 1 Taxonomist
- 1 Soil technician
- 2 Socioeconomic interviewers
- 2 Drivers (in case two cars is used)
- 1–3 Casuals

One forester is the crew leader and the other the assistant crew leader. Rangers provide security to the crew in areas known to be unsafe. Two or three casuals from the local communities will be recruited when necessary. The crew leader is responsible for the day to day quantity and quality of the work by the crew. The crew members measure slope percentage, regeneration (i.e. number of tree seedlings), tally and sample trees, dead wood, and stumps. They also take tree measurements.

In order to collect information on the various land uses, the field crew will include at least one person familiar with the area. It is therefore desirable that some members of the field crews are hired locally to act as guides and assist in identifying tree species in the field. Additional persons may be included to improve performance of the field crews when conditions require greater resources, for example to carry camping items and to cook at the camp if camping is done.

The responsibilities of each crew member must be clearly defined and their tasks are proposed as follows’

C**rew leader** is responsible for:

- Organizing all the phases of the fieldwork, including observations, measurements and data collection. He/she has the responsibility of contacting and maintaining good relationships with the community and the informants, has good overview of the progress achieved in the fieldwork, responsible for maintaining harmony and good working spirit within the crew and for the quality of work.

- The specific responsibilities of the crew leader includes: preparing the fieldwork, carry out the bibliographic research, prepare field forms and collect the maps.
- Planning the work schedule for the crew in an efficient way.
- Contacting local forestry officers, authorities and the community, introducing the survey objectives and the work plan to the local forestry staff and authorities, identify informants, guides and workers.
- Administer the location and access itinerary of clusters and plots.
- Taking care of logistics of the crew: organize and obtain information on accommodation facilities; recruit local workers; organize access to the clusters.
- Interviewing external informants and local people.
- Locating of the sample plot centre coordinates, description of the surrounding area, determining of the stand subdivision, recording of time consumed for the time study, determining of slope corrections on sloping areas, and recording of tree measurements.
- Determining the locations of litter/woody debris/soil sampling per each stand.
- Filling in the forms and taking notes.
- Ensuring that field forms are properly filled and that the collected data are reliable.
- Organizing meetings after fieldwork in order to sum up daily activities.
- Organizing the fieldworker's safety.
- Submitting data to the inventory supervisory team for entry into the computer.

Assistant crew leader will:
- Help the crew leader to carry out his/her tasks
- Take necessary field measurements and observations
- Make sure that the equipment of the crew is always complete and operational
- Supervise and orient the workers
- Filling in the forms and taking notes as required
- Take-over when the team leader is absent.

The **soil technician** is responsible for making soil measurements and organizing the collection of litter, woody debris, and soil samples (see the chapter 4.4). The soil technician will also assist in taking other measurements.

The **taxonomist** is responsible for identifying tree species, climbers and other plants. He/she will assist in taking other measurements.

The **rangers** are responsible of providing safety to crew and providing local knowledge of how to access the clusters/sample plots.

The **temporary helpers** (casuals) are assigned for the following tasks, according to their skills and knowledge of local species, language and practices:
- Help to measure distances.
- Open ways to facilitate access and visibility to technicians.
- Provide the common/local name of trees, shrubs and herbs.
- Inform about access to the plots.
- Provide information about the forest uses and management.
- Carry the equipment.
- Help in collecting the litter and woody debris samples, and digging the soil pits as instructed by the soil technician.

The **driver** is responsible of taking crew members to a point near clusters/sample plots and guarding equipment (if left in the car).

Training of the crews on the inventory methodology must be undertaken in theoretical and practical sessions at the beginning of fieldwork where techniques of different forest and tree measurements and tally of data will be explained and practiced. The names and contact details of the crew members and key persons must be written down in field form 8 (Annex 1) for communication in case of emergencies and queries that may arise from the data recorded in the field.

Where possible, team leaders should check data and notify of anomalies or suspect entries within the shortest time possible (preferably a day after the cluster measurement).

The above description is simply the normal way of working, but it is not necessary to follow it to the latter. For example, seedlings, sample trees and dead wood can be measured by any capable crew member.

3.3 Preparations

Field work missions are planned by the Forest Inventory Field Officer who will ensure enough field forms are given to each crew. The forms are described in details in Chapter 4.3.

Preparation of the actual fieldwork consists of the following phases:

A. Bibliographic research
B. Contacts to local KFS office and local communities
C. Preparation of the PDA (with programs and data), securing field forms and maps
D. Field equipment (maintenance, checking)

A. Bibliographic research

Auxiliary information is necessary to prepare the field survey. Existing reports on forest and natural resource inventories, farming systems, national policy and forestry community issues, local people, etc. have to be studied to enable the crew members understand and build better knowledge on the local realities. If a target sample plot is located in plantation forests, the forest's history and management plans need to be examined to prove the planting year and time of previous treatments. In many cases Land use and Forest ownership need to be studied before going to the field.

B. Contacts

Each field crew, through its leader, shall start work by contacting key staff in the target area in order to get information and access to where clusters are located. The local staff may help in contacting the authorities and land owners in order to introduce the field crew and its programme of work in the area. The local staff may also provide information about access conditions to the site and about the people who can be locally recruited as guides or workers. They may also inform the local people about the project.

C. Preparation of field forms and maps

The use of secondary data sources, particularly maps and existing management plans, are necessary to determine information such as names of administrative centres (administrative maps), accessibility and forest ownership. Some sections of administrative data in the form may be filled in during the preparation phase, and be verified in the field.

The crew leader must ensure enough forms are available to cover the planned field data collection. Maps and printed aerial photographs/satellite images covering the study area should be prepared in advance to help the orientation in the field. They may be enlarged and reproduced, if necessary.

Prior to the field visit, each crew must plan the itinerary to access the cluster, e.g. Google Earth, topographic maps, whichever will be the easiest and least time consuming. Sample plot coordinates and topographic maps should be converted to GPS. This should be done the previous day before visiting the cluster. Advice of local informants (local forestry staff, for example) are usually valuable and help save time in searching the best option to access the cluster.

The cluster and sample plot locations will be delineated on topographic maps and eventually on aerial photographs/satellite images, if available. The plot locations in the cluster are to be indicated together with their respective coordinates in the UTM coordinate system (Arc 1960 Universal Transverse Mercator Zone 37S).

An enlarged section of the map corresponding to the area surrounding the cluster will be prepared (photocopy or printed copy) and used to draw the access itinerary to the first plot.
The sample plot order for data collection may vary according to conditions of accessibility and is determined during the preparation phase.

Reference objects (roads, rivers, houses) that contribute to the better orientation of the crew in the field should be identified during the planning phase.

The numbers of the sample plots are entered into the GPS receiver according to the following rule: (five digits cluster ID) +"_" + (**one digit for** *Sample plot* number), e.g. for cluster 1243, sample plot 3: "1243_3".

D. Field equipment per crew

The equipment needed by each field crew is described in Table 1.

Table 1. Equipment and tools for a field crews.

Equipment needed	Number required	Comments
Measurement tools		
Compass (360°)	1	In degrees, Water proof model
GPS receiver (precision ca. 5 m)+ extra batteries + charger + downloading cables	1	
Measuring tape, 30 m	2	Metric, 1 cm units (fibreglass)
Measuring tape, 50 m	2	Metric, 1 cm units (fibreglass)
Calliper for big trees	1	Metric, 1 cm units
Calliper for small trees (<30 cm)	1	Metric, 1 cm units
Diameter tape	1	mm scale
1.3 m stick	1	For measuring tree's breast height level
Tree height and land slope measuring equipment	1	Laser Ace, Haglöf Vertex hypsometer, TruPulse or Suunto hypsometer with 15m, 20m and % scales to measure both tree height, in meters; and slopes, in percent.
Spherical densiometer	1	Canopy coverage measuring equipment. Convex model." ∩ "
Coloured flagging ribbon	Several rolls	For marking
Waterproof bags to protect measurement instruments and forms in case of rain	As necessary	
Digital camera, extra memory card, extra batteries, and charger	1	For photographs of sample plot
Machete / Bush-knife	As necessary	For bush clearing
Pocket knife	1	For general use
Colour spray	1	For marking of fixed points on PSPs
Plastic sticks	As necessary	For marking of fixed points on PSPs
40 cm long metallic pin	As necessary	For marking of plot centre points on PSPs
Spade	1	For digging soil pit
Munsell colour book	1	For soil colour characterization
Soil volumetric corer, 10 cm	1	For taking soil samples
Soil auger	1	For inspecting soil depth and taking indicative soil

		samples below top 30 cm
Plastic bags 3L	As necessary	For storing composite soil samples
Plastic bags 80 L	As necessary	For collecting litter or woody debris
Kitchen electronic scale	1	For weighing composite soil samples
Spring scale	1	For weighing litter or debris composite samples
Clothing		
Boots and waterproof outfits	For permanent team members	
Helmet	For permanent team members	Optional, for area where there is risk for branches to fall
Rain coats	As necessary	Optional
Documents, papers		
Field forms	As necessary	Also plastic ones for rainy days
Code check list with slope correction table	As necessary	Needs to be laminated
Field manual	As necessary	
Flora and species check list	As necessary	
Topographic maps, field maps and printed aerial photo/satellite image	As necessary	
PDA	1	To enter data in the sample plot
Laptop PC	1	To enter/transfer field data into/from PDA
Pencils and markers	As necessary	
Supporting board / writing tablet	1	To take notes
Hand calculator	1	
Clipboard	2	To take notes
A4/A3 size flipchart	1	For photo identification
Newspapers	As necessary	For collection of samples (plants/ leaves)
Other equipment (camping, security, communication…)		
Mobile phone	At least 1	
Radio phones	1+1	One for the field team, one for the driver
Chain saw	1	When necessary
Field car	2	
First aid kit	1	With phone numbers of nearest hospitals / emergency centres
Flashlight and batteries	As necessary	
Camping equipment and cooking utensils	1	
Rucksack	As necessary	
Water and food	As necessary	

The list of equipment specified by measurement type is presented in Table 2. The condition of the inventory equipment needs to be verified prior to field work and missing or damaged items replaced with new or fixed tools.

Table 2. Equipment by type of measurement.

Measurement type	Equipment required
SAMPLE PLOT	
Sample plot locations	GPS, maps, list of sample plot coordinates
Tree location determination	30m measuring tape, slope correction table, 1.3 m stick, callipers and compass
Plot centre marking	Coloured flagging ribbon, metal pins/plastic sticks
Slope	Haglöf Vertex hypsometer, TruPulse or Suunto hypsometer with clinometer
Photo documentation	Digital camera, flipchart
Canopy coverage (Trees)	Spherical densiometer
TREES	
Species code and name	Species check list
Tree diameter	1.3 m stick; callipers and/or diameter tape (mm scale)
Stump diameter	Callipers and/or diameter tape
Tree height	Laser Ace
Bole height	Laser Ace
Stump height	Measuring tape
DEAD WOOD	
Species code and name	Species check list
Dead wood diameters	Diameter tape or callipers
Dead wood length	30m measuring tape
Decay class	Pocket knife
SHRUBS AND REGENERATION	
Shrub coverage	If applicable use spherical densiometer
Mean shrub height	If applicable use Haglöf Vertex hypsometer or Suunto hypsometer
Number of seedlings	1.5 m stick
BAMBOO	
Species code and name	Species check list
Bamboo average diameter	Diameter tape or callipers
Bamboo average height	Laser Ace or Suunto hypsometer

Field forms

There are 9 different forms for biophysical data (Table 3).

Table 3. Field forms and corresponding information for the tree stand inventory.

Form No.	Information
1	Cluster
2	Sample Plot: General plot description data, location, and measuring time
3a	Shrubs: Coverage and mean height of shrubs/bushes.
3b	Regeneration: Number of tree seedlings and saplings
4	Trees: Tree measurements (DBH ≥2 cm)
5a	Dead wood measurements
5b	Stump measurements
6	Bamboo measurements
7	Climber measurements
8	LDS: Litter, debris and soil measurements
9	Field crew

Note when using paper forms for a sample plot containing large number of trees/dead wood/bamboo clumps, the data may not be accommodated in one form set, additional sets may be used.

Clusters are pre-indexed and indicated on the inventory base map. The numbered clusters are identified on the printouts of satellite images, topographic maps and as waypoint data on GPS receivers.

The sample plots within the clusters are also pre-numbered and the numbers are printed on the printouts of topographic maps and maps on GPS receivers.

4 Data collection in the field

4.1 Introduction of the project to local people

If the cluster area is inhabited, the crew must establish contact with local people and on arrival to the site, meet with contacted persons including the village representative, closest government institution and owners and/or people living in the cluster area. Therefore, it will be necessary to contact the local population before visiting the area in order to inform them about the visit and request for permission to access the area. This may be done by holding an introductory meeting.

The crew must briefly introduce and explain the aim of the visit and study. A map or an aerial photograph/satellite image, showing the target inventory area, may be very useful to facilitate the discussion. It is important to ensure that both local people and the field crew understand which area will be studied. The aim of the inventory must also be clearly introduced to avoid misunderstandings or raise false expectations. Cooperation and support from local people are essential to carry out the fieldwork. It is easier to achieve this support if the first impression is good. Nevertheless, it must be stressed that the fieldwork consists only of data collection and not local development or law enforcement project. Some key points about the Forest Resource Assessment (FRA) that this project is aiming at design are mentioned in Box 1.

Box 1. Key points to be stressed during the presentation of the project to the local people

- The broad objective of the National Forest Resources Assessment is to collect data on land uses to support national decision making by interacting with the local users. The collected land use information will be used by the country and the international community. The specific objective is to generate reliable information for improved land use policies that take into account people's reality and needs. Hopefully, this can lead to natural resources being managed in a sound and sustainable way. It could help also in the mitigation of poverty.
- The data are collected from two sources:
  (1) Measurements of the forests and trees outside the forests and other land use practices;
  (2) Interviews with local communities using land including forest users and other people who are knowledgeable of the area. Measurement examples to be mentioned may be: tree diameter and height, as well as forest species composition. *Data on agricultural cropping system, water, pest, energy source and livestock will be collected by interviews.* The field crew should equally be interested in the local people's perception on land use changes, the main products and services derived from the land, land use related problems, and explain the possibility of the data being used for planning the development activities in the area. Thus the crew will therefore interview land users.
- In the full-scale FRA, the clusters, where the survey will be carried out, are distributed throughout the country.
- Some or all of the clusters/sample plots surveyed in the country will be monitored in the future, with the aim of assessing land use changes and development of forest resources and services.

4.2 Access to sample plot, marking of sample plot centre and fixed points

The clusters and sample plots locations will be pre-drawn on the topographic maps. Reference coordinate system with grid and sample plot locations can also be drawn on satellite image maps. In some cases a local guide will be useful to access the sample plots more easily.

Locating a sample plot in the field will be done with the help of a GPS where the location of each sample plot is registered as waypoints. The team should aim to receive and record 3D measurement only - thus receiving at least 4 GPS satellite signals. The procedure to locate sample plots in the field with the help of GPS is following:

1. Plan the route to cluster/sample plots in good time, at least previous evening. If using a car in approaching, mark the car park (where to leave the car) in a GPS as a waypoint. Mark also the other possible waypoints.
2. Use the map to navigate to the car park, check the point with the GPS.
3. Navigate to the sample plot with the help of maps and GPS.
4. When arriving near the sample plot (~10–20 m), select an open point where the GPS works well or gets good position. Collect GPS data for 2–5 minutes to get a fixed position. The GPS will average the collected data and calculate the current location and display the remaining distance and bearing to the sample plot.
5. Use the compass and measuring tape to go exactly to the sample plot centre.
6. Place the GPS at the sample plot centre and collect GPS coordinates while working in the sample plot.
7. Ensure that there is enough GPS coordinates and save collected coordinates before leaving the sample plot.

Slope correction is obligatory when accessing the plot centre from the fixed position near the sample plot with compass and measuring tape, as all distances refer to the horizontal distance (use slope correction table provided in Annex 2 to adjust the distances). Note: If TruPulse, Vertex or similar instruments are used for measuring distances, they automatically correct for the slope.

The sample plots can be measured in any sequence; this is decided during the preparatory phase. However, the crew must follow the original sample numbering when recording the data into the PDA/forms.

IMPORTANT
Sample plot coordinates are ALWAYS recorded using GPS reading; they are NOT taken from the map or from the given list of sample plot coordinates. Due to inaccuracy of any GPS model, recorded coordinates are allowed to differ from the targeted location.

All sample plots
The sample plot centres need to be marked in order to facilitate their re-location during a quality control survey that can be carried out to verify and check the accuracy of the field work. This can be done by using wooden or bamboo pole, which should be marked with colour spray in order to make them easily distinguishable from the mass of other woody material occurring in the forest.

Permanent sample plots
In order to facilitate the relocation of the sample plot, the sample plot centre point (i.e. mid-point) should be marked with a 40 cm long metallic pin. On forest lands and woodlands, leave about 3 cm of the top of the pin to be visible on the ground. On other land use types, the pin can be hit below the ground if it makes any danger for domestic animals or otherwise for the land owner. If the pin cannot be hit into the ground (e.g. due to rocks), this should be indicated in Remarks.

On a permanent sample plot the field crew marks and collects data about **3 fixed points**. A fixed point can be a big stone or a rock, or a recognizable living tree (with DBH>10 cm). A dot is painted or sprayed at the stump height level to the side toward the sample plot centre point. The appropriate diameter of the dot is 10 cm. In addition, a plastic stick is placed in the ground and 5–10 cm of the top of the stick is left visible.

The following information is recorded about the fixed point: type of object, distance from the sample plot centre, bearing (compass reading, degrees) from the sample plot centre to the fixed point, and additional description (text).

4.3 Stand and tree data collection

4.3.1 Cluster information

A Cluster form will be filled in for each cluster. The form contains general information of the cluster, including information about time taken for different activities and location of the cluster. This information is needed for analysing the time used and costs with different inventory designs. There are six different stages in time study, each having starting and ending time:

- Departure from camp to car park
- Departure from car park to sample plot
- Arrival to car park from sample plot
- Departure from car park to next car park
- Arrival to camp from car park

CLUSTER, Form 1a.

Cluster number

Cluster number from inventory field map.

Measurement

Type of measurements in cluster.

Code	Description
P	Planned measurements
QA	Quality assurance measurements
U	Unplanned measurements

Date

Date when measurements on the cluster are done.

Stratum

Information of the stratum, taken from the inventory map/plan.

Code	Description
1	Stratum 1 (Grasslands)
2	Stratum 2 (Forested areas)
3	Stratum 3 (Coast)
4	Stratum 4 (Mangroves)

Stages

Stages in going to field inventory are divided to five main stages at the cluster level. Fill in appropriate stage belonging to cluster. The Stages are:

- Departure from camp to car park
- Departure from car park to sample plot
- Arrival to car park from sample plot
- Departure from car park to next car park
- Arrival to camp from car park

Start time

Starting time of the stage in 24 hours mode. *h*: hours, *min*: minutes.

End time

Ending time of the stage in 24 hours mode. *h*: hours, *min*: minutes

GPS Receiver model

Model name of the GPS device.

GPS unit ID

Identification number of the GPS

Starting position, (coordinates)

Position where team leaves the car (or camp).

Variable	Description
GPS Easting (X)	UTM system coordinate (in metres)
GPS Northing (Y)	UTM system coordinate (in metres)

Remarks

Additional remarks about the cluster and its surroundings.

4.3.2 Sample plot information and stand description

A separate copy of Sample Plot Form will be filled for each sample plot belonging in the cluster. The forms contain the general data describing the sample plot, including the information on its location and how the plot is accessed.

A sample plot maybe divided into several stands (= plot sections). Separate stands are distinguished if there are different land use classes or vegetation types within the outermost radius (R = 15 m / 20 m) of the plot (Figure 8).

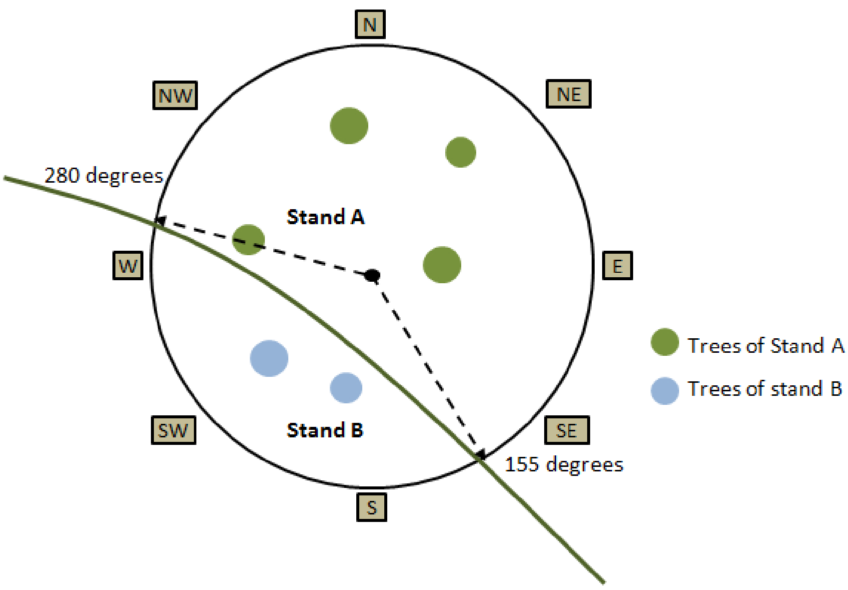


Figure 8. Example of a sample plot divided into two separate stands.

Soil sampling points can be easily determined for both stands with the help of compass using bearings measured from the plot centre.

On a shared sample plot (i.e. at the border of two land use classes/ vegetation types) the crew needs to fill in two or more forms for the same sample plot, so that the sample plot is divided into parts A and B (and C, etc., as required). The part of the sample plot where the sample plot centre point locates is recorded as Stand **A**[1]. *A small sketch representing the shared sample plot with land use class/vegetation type borders will be drawn on the circle on the field form.* The share is presented as percentages of the total sample plot area within all sample plot radiuses; see Figure 9for quick help.

If the plot is divided into two or more stands, there will be extra work in particular in soil sampling, because separate samples are needed for each stand. However, soil sampling is done only in those stands where at least three soil pits can be established. No litter debris or soil samples are taken in stands that include only one or two potential soil pit locations. Therefore it is paramount that when the Team Leader divides the sample plot into two or more stands, Soil Technician is immediately informed of which soil pit locations are used for each stand.

The cardinal points and sub-cardinal points are used for litter and soil sampling. The Soil Technician needs precise information of which points are used, in order to start the sampling routines. The soil pit locations in each stand are best determined with help of a compass or bussole. Figure 8 shows an example of how the soil pit locations are found for each stand. Stand 1 (with the centre point) has potential soil pits at locations NW, N, NE, E, and SE. Any four of those can be chosen. It may be advisable to choose only three in order to decrease the workload for this sample plot. The second stand, Stand 2 in Figure 7, has three potential soil pit locations, S, SW, and W. All these have to be used.

Height of the Arc	Share(%), with different circle radius: 20 m	15 m	10 m	5 m	2 m
1	1	1	2	5	20
2	2	3	5	14	50
3	3	5	9	25	
4	5	8	14	37	
5	7	11	20	50	
6	9	14	25		
7	12	18	31		
8	14	21	37		
9	17	25	44		
10	20	29	50		
11	22	33			
12	25	37			
13	28	42			
14	31	46			
15	34	50			
16	37				
17	40				
18	44				
19	47				
20	50				

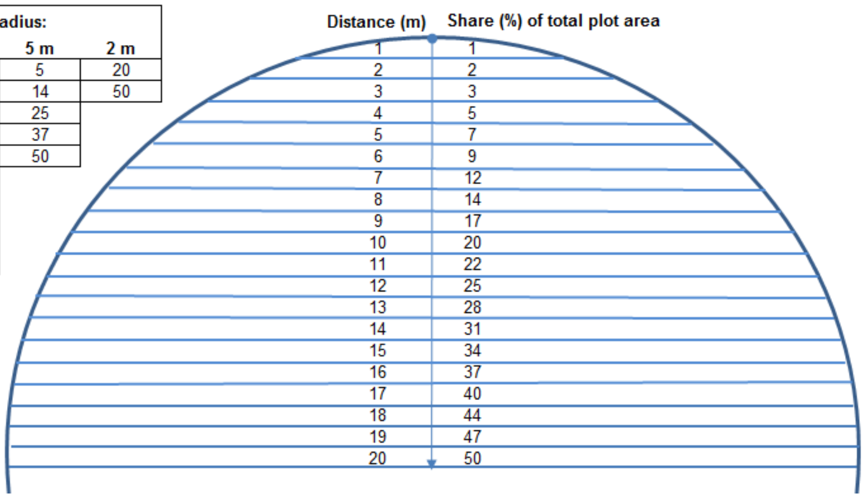


Figure 9. A schematic of proportional shares in a circle.

Slope corrections

All reference distances, such as a tree distance from sample plot centre point, are expressed as horizontal distances. Thus, sample plot areas are also computed upon horizontal plane. When the terrain is flat, distances can be measured directly. But on sloping terrain the horizontal distances differ from direct distances (see Figure 10). A corrected distance is taken from a slope correction table (Annex 2) and these distances are applied at all slopes above or equal to 5 percentage.

[1]Adopted from Kangas & Maltamo (2006), p. 193.

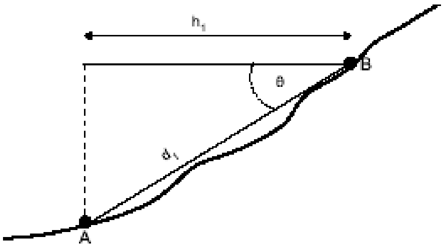


Figure 10. Distances on slope.
Note: The distance between two points, measured along slope (d_1) is always longer than an equivalent horizontal distance (h_1) (Figure 10). On slope terrain, the horizontal distance must be multiplied by a factor that corresponds to the inclination, in order to obtain a corrected distance.

Slope is measured using a Haglöf Vertex hypsometer, TruPulse, clinometer or Suunto hypsometer. The unit in this inventory is percentage. Where distances are measured using a measuring tape on sloping ground, slope distance will need to be corrected back to horizontal using the following equation:

$$\text{Horizontal distance} = \text{Slope distance} \times Cos(\sigma)$$

Where σ = slope angle in degrees.

The equation can be written in the following form when slope angle is in percentages:

$$\text{Horizontal distance} = \text{Slope distance} \times Cos(Atan(\alpha/100))$$

Where α = slope angle in percentages (%).

The slope correction table for distances is presented in Annex 2.

Note: The points recorded by the GPS will reflect horizontal distance. No corrections for distances on slope are required.

Canopy coverage measurements
A spherical densiometer (Figure 11) is a simple instrument for measuring forest over story density or **canopy cover** from unobstructed sighting positions. The instrument has reflective spherical surface divided into equi-spaced square grids. When the instrument is taken under forest canopy, the images of overhead crown can be seen in the mirror and the amount of canopy coverage is estimated based on proportion of the mirror surface reflecting the overstory crown. The measurement procedure can be efficiently handled by one person using the following procedure.

1. Hold the densiometer far enough away from your body so that your head is just outside the grid (30–45 cm away). Maintain the densiometer approximately at elbow height. Keep the densiometer instrument levelled, as indicated by the round level in the lower right hand corner.

2. There are a total of 24, 3 x 3 mm squares in the grid. Each square represents an area of canopy opening (sky image or unfilled squares) or canopy cover (vegetation image or filled squares). **Count the filled square areas** that are covered by the canopy (only by trees; bananas, bamboos etc. are not counted). If the squares are only partially filled, less than 50 % filled it is regarded as Empty Square and more than or equal to 50 % it is regarded as a complete square. For deciduous trees in the dry season, which do not have leaves, the crown area needs to be visualized for a proper reading. Only squares that are completely free of branches should be counted as sky.

3. Canopy cover measurements are implemented at five points on the sample plot, i.e. first at the sample plot centre and then at the cardinal points (N, E, S and W) 15 meters apart from the sample plot centre. Canopy cover is measured by stands. In case the sample plot is divided to two or more stands, Canopy cover is measured at as many cardinal points as possible but not at a point crossing the stand border. All readings are recorded into the *Stand Form*. If it is not possible to record *filled square areas* using the densiometer in some measurement point (for example due to river or steep slope), then that reading is left blank (not zero) and explanation is written into the *Remarks* column.

The actual canopy coverage percentage is computed later by the computer program. The procedure is as follows: first the average of all 5 readings is computed. The result is then multiplied by 4.17 to obtain the estimated canopy coverage (over storey density) in percentage, i.e.
[*Canopy coverage* %] = [*Average number of filled squares*] x 4.17

Photo of the plot
Each inventory group uses the digital camera to record the view on the sample plot. Photos will be used to document the plot characteristics as vegetation type, and to possibly ease the relocation of the sample plot in future reassessments. Collected photos will also be utilized as training materials in the future.

The camera setting should be set to *Auto* position, and by using wide focus a field member captures a photo of the representative forest. *The crew should add a flipchart hanging on a tree with the following information: Cluster ID and Sample Plot ID before taking the photo to avail plot identification in the photo.*

On each sample plot 4 pictures will be taken from the centre of the plot in all the cardinal directions starting from the north and then continuing clockwise (east, south and west).The photo should include both some soil and vegetation, if available. On private lands close to human settlements the crew should ask for permission to take a photo. The crew should try to avoid taking photos against the sun light.

Data about the first photo are recorded on the *Sample Plot Form*. The crew indicates the image ID Number of the first photo (northward) in the camera's memory stick. In the office the photos are transferred from the camera into a separate '*Kenya Pilot Inventory Photos*' folder, and each photo is renamed as follows:

C*xx*_S*s*_*D*.jpg

where *xx* refers to cluster ID, *s* refers to sample plot ID and D refers to cardinal direction; e.g. C283_S3_E.jpg.

SAMPLE PLOT FORM

Cluster number

Cluster number from the inventory field map.

Sample plot number

Sample plot number within the cluster from the inventory field map.

Permanent sample plot

Information whether sample plot is permanent or not.

Code	Description
Y	Permanent sample plot
N	Temporary sample plot

Group leader

Name of the group leader.

Date

Date when the measurements on the sample plot are done.

Time

Start and end time of the work in the sample plot.

County

Name of the county.

District name

Name of the district.

Division

Name of the division.

Accessibility code

Condition of accessibility is recorded for each sample plot. If a sample plot is not accessible but the land use (based on Kenya's definition of forests), FRA land use class, vegetation type or ownership types can be observed in the field or detected from other sources (as from maps or aerial photos/satellite images), these data are filled into the field form.

Code	Description
0	Accessible
1	Inaccessible due to slope
2	Inaccessible due to owner refusal; owner does not allow one to enter the site
3	Inaccessible due to restricted area; e.g. military or border areas
4	Inaccessible due to water body
99	Inaccessible due to other reason; specify in Remarks

Assessment method

Assessment method is recorded for each sample plot. A sample plot can be accessible and measured normally, or inaccessible but data can be recorded remotely in the field, or with the help of maps and/or images
.

Code	Description
0	Measured
1	Remote assessment, sample plot is visible
2	From map and/or images

GPS Coordinates (or reference point location)

Location of the sample plot centre or in case of poor GPS reception the location of a reference point close to the plot centre is recorded in UTM coordinates with no decimals. Coordinates are taken from the GPS receiver.

Variable	Description
GPS Easting (X)	UTM system coordinate (in metres)
GPS Northing (Y)	UTM system coordinate (in metres)

Direction to plot centre (m) (in case sample plot coordinates in the centre not recorded)

Direction from GPS measurement point (reference point location) to the sample plot centre in degrees (0-360). Needed in case that GPS coordinates can't be taken in the sample plot centre due to big trees/dense crown cover, etc. (week satellite connections).

Distance to plot centre (m) (in case sample plot coordinates in the centre not recorded)

Distance from GPS measurement point (reference point location) to the sample plot centre in metres. Needed in case that GPS coordinates can't be taken in the sample plot centre due to big trees/dense crown cover, etc. (week satellite connections).

Slope (%)

Slope is recorded as average of two measurements; 20 meter downhill and 20 m uphill. The Unit is percentage.

Slope orientation (^{o})

Main slope orientation downward is estimated in degrees (0–360). E.g. slope to west (downward) should be near 270 (degrees).

Count of soil pits

Count of soil pits in sample plot. In case soil samples are not taken, mark "0".

Photo

Shooting direction and photo identification number in camera:

Shooting direction: E, W, N, S

Photo ID: image ID number in camera memory card

Descriptions surrounding the sample plot

Erosion

Erosion is recorded on all vegetation types. Erosion refers to the condition in which the earth's surface is worn away by the action of water and wind.

Code	Description	Explanation
0	No erosion	No evidence of soil erosion
1	Light erosion	Slight erosion where only surface erosion has taken place.
2	Moderate erosion	Where mild gullies and rills are formed on the top surface of the soil
3	Heavy erosion	Areas which have deep gullies, ravines, land slips etc.

Grazing

Grazing is recorded on Forest, Woodland and Cropland vegetation types. Grazing refers to the intensity of grazing in the forest land or bush land. It refers to the impact animals have on forage growth and reproduction and on soil and water quality (see e.g. Holechek & Galt 2000).

Code	Description	Explanation
0	No grazing	There is no evidence of grazing
1	Occasional	Only choice plants and areas show use. There is no evidence of use of poor forage plants
2	Frequent	Most range shows use. 1/3 – 2/3 of primary forage plants showing use
3	Extensive	Lands can be severely hedged. There is evidence of life-stock trailing to forage. More than 2/3 of primary forage plants showing use

Water catchment

Water catchment is recorded on all land use classes. Water catchment refers to the importance of an area in collecting and feeding water into rivers, lakes and underground water reserves.

Code	Description	Explanation
0	Bare land	No water catchment value
1	Low	The area has vegetation but is not a particular source of water
2	Medium	Seasonal rivers providing water to lower land areas
3	High	Area contains lakes, ponds, rivers etc. or it is a forest land which collects/feeds water to lower land areas

Non-wood forest products and services

Data about non-wood forest products (NWFP) and services is recorded on Forest, Woodland, Cropland and Grassland vegetation types. These data refer to non-wood products and services provided by the trees, forest and other wooded land. There are three data input fields in the field form for tree most important NWFP to record this variable.

Code	Description	Explanation
0	No data	
1	Fruits, nuts, seeds, roots, berries, etc.	Vegetable foodstuffs and beverages provided by fruits, nuts, seeds, roots, etc.
2	Mushrooms	Foods provided by mushrooms
3	Fodder	Animal and bee fodder provided by leaves, fruits, etc.
4	Rattan	
5	Plant medicines	Medicinal plants (e.g. leaves, bark, roots) used in traditional medicine and/or for pharmaceutical companies
6	Herbs and spices	
7	Dying / tanning	Plant material (bark and leaves) providing tannins and other plant parts (especially leaves and fruits) used as colorants
8	Other plant products	Specify in Remarks
9	Wildlife	Provides habitat for wildlife
10	Beekeeping	Beekeeping activities
11	Windbreak	Acts as a windbreaker
12	Shade	Provides shade
13	Aesthetic	Provides landscape beauty
14	Recreation and tourism potential	Including ecotourism, hunting or fishing as leisure activity. Unique feature
15	Cultural heritage potential, sacred place	Including religious / spiritual potential
99	Other	Specify in Remarks

Biodiversity

Biodiversity is recorded on Forest, Woodland and Cropland vegetation types. Specify recorded species or other special characteristics. Digital photos of rare forest objects can be captured; make notice in Remarks.

Code	Description
0	No data
1	Big mammals
2	Other mammals
3	Reptiles
4	Birds
5	Insects, Butterflies
6	Climbers
7	Plants. Excluded trees and bamboos
8	Epiphytes
9	Fungus
10	Rare biotope. E.g. spring, oasis
99	Other. Specify in Remarks

Stand description in the sample plot

Stand

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use/vegetation types. Note, minimum width for roads, power lines etc. in stand delineation is 5 metres.

Code	Description
1	Stand where the sample plot's centre point is located
2	The second stand etc.

Share (%)

Stand's estimated share of the total sample plot area in percentage. Shares for circles with different radius are given separately.

Ownership

Ownership is recorded on all land use classes. Ownership refers here to the legal right to exclusively use, control, transfer, or otherwise benefit from a forest. Ownership can be acquired through transfers such as sales, donations, and inheritance. Forest ownership refers here to the ownership of the trees growing on land classified as forest, regardless of whether or not the ownership of these trees coincides with the ownership of the land itself.

If a sample plot is not accessible but the ownership type can be observed, this information needs to be filled into the field form.

Code	Description	Explanation
1	Central government land	Land is owned by central government, or by government-owned institutions or corporations
2	Community	Land is owned by local community
3	Private	Land is owned by private individuals or families, private co-operatives, religious and educational institutions or other private institutions
4	General land	Public land that does not belong to any of the above categories
99	No information	No information available on the land ownership

Land use class

Land use class refers to the dominant land use purpose at the time of observation. If a plot is not accessible but the land use can be observed, this information needs to be filled into the field form. Note, minimum width for roads, power lines etc. is 5 metres in classification.

Code	Description	Explanation
1	Production forest	Land designated for production and extraction of products. E.g. wood, fibre, bioenergy, and/or non-wood forest products
2	Protection forest	Protected forest lands. Including also nature reserves, soil conservation, water and watershed protection, protection against erosion and landslides
3	Wildlife reserve	National parks, game reserves etc.
4	Shifting cultivation	Land where there is evidence of slash and burn or recent farming activities but area is abandoned
5	Agriculture, including agro forestry	Land with crops and trees or livestock in the same management unit
6	Grazing land	Land with livestock on it or pasture land
7	Built-up areas	Urban or rural or mixed. Including roads, buildings, power lines etc.
8	Water body or swamp	Permanent, seasonal or swamp
99	Other land	To be specified in Remarks

Past land use class

Specify the previous land use class in case the land use class has changed in the past, after year 2000.

Code	Description
0	No land use change
1–99	Other codes as in land use class

Time of change

Estimated time of land use change. Year is recorded as number in 4 digits.

Code	Description
0	No land use change after 2000
Year	Estimated year of change; e.g. 2004

FRA land use/cover class

*FRA land use/cover class*is recorded on all land use classes. According to the FRA guidelines, the land is divided into *forest* and *other wooded land* according to the tree height and crown coverage. Land falling neither into the *forest* nor the *other wooded land* classes is classified as *other land*. If a sample plot is not accessible but the land use/cover class can be observed in the field, this information needs to be filled into the field form.

Code	Description	Explanation
11	Forest (FRA)	Land spanning more than 0.5 hectares with **trees higher than 5 meters and canopy cover of more than 10 %, or trees able to reach these thresholds in situ**. It does not include land that is predominantly under agricultural or urban land use
12	Forest (Kenya)	Land spanning more than 0.5 hectares with **trees higher than 2 meters and a canopy cover of more than 15 %, or trees able to reach these thresholds in situ**. It does not include land that is predominantly under agricultural or urban land use
2	Other wooded land	At maturity stage the height of trees are at least 5 meters and a canopy cover of 5–10 %; **or** with a combined cover of shrubs, bushes and trees above 10 %. Other wooded land must exceed 0.5 hectares in size. It does not include land that is predominantly under agricultural or urban land use
3	Other land	All land that is not classified as “Forest”, “Other wooded land” or “Other land with tree cover”
4	Other land with tree cover (sub-category of “Other land”)	Land classified as “Other land”, spanning more than 0.5 hectares with a canopy cover of more than 10 % of trees able to reach a height of 5 meters at maturity. E.g. parks, wooded yards, groves
5	Inland water bodies	Inland water bodies generally include major rivers, lakes and water reservoirs

Past FRA land use/cover class

Specify the previous FRA land use/cover class in case the land use class has changed in the past, after year 2000.

Code	Description
0	No land use change
1–99	Other codes as in FRA land use class

Time of change

Estimated time of FRA land use/cover class change. Year is recorded as number in 4 digits.

Code	Description
0	No land use change after 2000
Year	Estimated year of change; e.g. 2004

Vegetation type

Vegetation type is recorded on all land use/cover classes. If a plot is not accessible, but the vegetation type can be observed in the field, this information is recorded.

Code (numeric)	Code (text)	Land use	Land cover	Crown cover	Description
101	FnD	Forestland	Natural forest	Dense	Crown cover ≥65%
102	FnM			Medium	Crown cover 40–64%
103	FnL			Low	Crown cover 10–39%
111	FbD		Bamboo forest	Dense	Crown cover ≥65%
112	FbM			Medium	Crown cover 40–64%
113	FbL			Low	Crown cover 10–39%
121	FmD		Mangrove forest	Dense	Crown cover ≥65%
122	FmM			Medium	Crown cover 40–64%
123	FmL			Low	Crown cover 10–39%
131	FpD		Plantation forest	Dense	Crown cover ≥65%
132	FpM			Medium	Crown cover 40–64%
133	FpL			Low	Crown cover 10–39%
134	FpP				Pelis
201	WcD	Woodland	Closed	Dense	Crown cover ≥65%
202	WcM			Medium	Crown cover 40–64%
211	WoM		Open	Medium	Crown cover 15–39%
212	WoL			Low	Crown cover <15%
301	Ca	Cropland	Agro-forestry		Home gardens with multi-storey tree covers shading e.g. bananas, coffee etc.
302	Cpc		Perennial crops		Monocultures and mixed crops of, e.g., tea, oranges, nuts etc.
303	Cac		Annual crops		Various herbaceous crops, e.g. cotton, flower plantation, maize, millet etc.
401	Gw	Grassland	Wooded		Grazing, hunting, recreation
402	Gb		Bushed		
403	Go		Open		
501	Bh	Build-up land	Human settlement		
502	Bi		Infrastructure		All other developed land, air fields, power lines, roads, etc.
601	Wao	Waterbodies	Ocean		
602	Wai		Inland water		Lake, river
603	Waw		Wetland		Swamps, seasonally inundated, other
700	Ol	Other land			Bare soil, rock

Undergrowth

Undergrowth is recorded on Forest, Woodland and Cropland vegetation types. Undergrowth refers here to the **dominating** type of brush (small trees, bushes, or grasses) growing beneath taller trees in the forest.

Code	Description
0	No undergrowth
1	Bushes
2	Grass
3	Elephant grass
4	Herbs
5	New tree generation
6	Mixed of bushes, grasses, herbs or new tree regeneration. Neither is clearly dominating alone
99	Other vegetation. To be specified in Remarks

Canopy coverage

Canopy coverage is recorded on Forest, Woodland and Cropland vegetation types. Canopy coverage **caused by trees** is measured using the spherical densiometer at the sample plot centre and then at the cardinal points (N, E, S and W) 15 meters apart from the sample plot centre. In case the sample plot is divided to two or more stands, canopy cover is measured at as many cardinal points as possible but not at a plot crossing the stand border. If coverage is caused for instance by bamboos or banana leaves, these are not recorded as canopy cover. The measured value will be recorded in the form. (Note: *Shrub coverage* is estimated separately and recorded on the *Shrub form*). **Counts of the filled square areas at five points on the sample plot are each recorded on form**.

Damage

Damage is recorded on Forest, Woodland and Cropland vegetation types. Damage refers to the causative agents that have been identified to cause damages to several **live trees** in the sample plot (diseases, insects, animals, etc.). Individual tree damage is recorded in the Tree Form as *Health status*, as well as dead trees and stems.

Code	Description	Explanation
0	No damage	Naturally open area, or normal tree vegetation where there might be some individual trees damaged by insects, fungus or other reason but otherwise forest is in good condition
1	Fire	Disturbance caused by fire
2	Insects, fungus or diseases	Disturbance caused by insect pests or by fungi. Disturbance caused by diseases attributable to pathogens, such as bacteria, fungi, phytoplasma or virus
3	Other biotic agents	Disturbance caused by biotic agents other than insects or diseases, such as wildlife browsing, grazing, physical damage by animals, etc. Specify in Remarks
4	Wind or other abiotic factor	Disturbances caused by abiotic factors, such as storm, drought, air pollution, etc. Specify in Remarks
5	Human activities	Cuttings, firewood collecting, debarking, other human-made damages

Damage severity

Damage severity parameter is recorded adjoining with *Damage* code. Damage severity is an estimate of the prevalence of damages **to the living trees**, and it is needed to predict future mortality. If substantial numbers of living trees are classed as very severely damaged (class 3), mortality is likely to remain high for a long time.

Code	Description	Explanation
0	No damage	No damage
1	Slight	Evidences of damage are visible, but not causing long-term damages. Only few trees are affected
2	Serious	Damages are clearly visible, probably causing long-term damages or loss of growth. Several trees are affected
3	Very serious	Damage is finally causing wide mortality of trees, or hinders them from healthy growing. Mortality is likely to remain high for a long time

Human impact

Human impact is recorded on Forest, Woodland and Cropland vegetation types. Human impact or influence refers to a disturbance or change in ecosystem composition, structure, or function caused by humans. There are three data input fields in the field form to record this variable.

Code	Description	Explanation
0	No impact	No cutting or other impact; or the cutting has happened more than 5 years ago
1	Selective cutting	Commercial
2	Selective cutting	Domestic use
3	Clear felling	Removal of all trees has been carried out. The generation of forest is done by planting, seeding or coppicing
4	Shifting cultivation	
5	Silvicultural treatment	E.g. pruning, planting, climber cutting, weeding, boundary clearing, fire line construction
6	Burning	
7	Charcoal production	
8	Medical activities	Collecting of medicinal plants used in traditional medicine and/or for pharmaceutical companies
9	Mining, sand collection	Mining and land extraction activities
10	Agriculture	E.g. cattle grazing
11	PELIS	Plantation Establishment and Livelihood Improvement Scheme
12	Afforestation	
99	Other	Specify in Remarks

History of human impact

Estimated timing of occurrence caused by a human, indicated as years (**1–5**). If the occurrence is estimated to be older than 5 years, mark **5+**.

Management proposal

Management proposal is recorded on Forest and Woodland vegetation types. The proposed action is suggested to be done during the next 3 years. This information is used to estimate the potential amount of silvicultural and sustainable harvesting activities to be done on forest lands. There are two data input fields in the field form to record this variable.

Code	Description
0	No treatment
1	Selective cutting
2	Thinning. In the case of plantation
3	Clear felling
4	Silvicultural treatment. E.g. pruning, planting, climber cutting, weeding, boundary clearing

Planting year

Planting year is recorded in plantation forests only, if this information is available. Information sources e.g. forestry documents and plans. Year is recorded as number in 4 digits, e.g. 2007.

FIXED POINTS **Only on permanent sample plots**

Locations and descriptions of fixed points are recorded on permanent sample plots. Fixed points are needed to relocate permanent sample plots for re-measurements.

Description

Description of fixed point; e.g. stone about 1 m^3.

Distance from sample plot centre

Distance from sample plot centre point to fixed point in decimetres.

Direction from sample plot centre

Direction from sample plot centre point to fixed point in degrees (360^o).

4.3.3 Shrubs and Regeneration

SHRUBS, Form 3A

Shrubs data are recorded on Forest, Woodland and Cropland vegetation types. The crew records the information inside the sample plot, radius 15 m.

Cluster number

Cluster number from the inventory field map

Sample plot number

Sample plot number within the cluster from the inventory field map

Stand

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use type.

Code	Description
1	Stand where the sample plot’s centre point is located
2	The second stand etc.

Shrub coverage (%)

Shrub coverage refers to the vertical projection of the shrub canopies as percentage of the total ground area. This parameter is usually visually estimated, but if the use of spherical densiometer is possible, this device can also be used.

Code	Description	Explanation
0	No data	
1	< 10%	very open shrub canopy cover
2	10–39%	open shrub canopy cover
3	40–69%	sparse shrub canopy cover
4	≥ 70%	closed shrub canopy cover

Mean shrub height

Mean shrub height is estimated and recorded in decimetres (dm).

TREE REGENERATION, Form 3B

Tree regeneration is recorded on Forest, Woodland and Cropland vegetation types, and it is collected on two circular, 1.5 m radius subplots locating 10 meters from the sample plot centre. The data is collected on all seedlings and saplings with height at least 10 cm and DBH less than 2 cm.

Notice:

- On a single form, write each species name only once, always including the count. Don't repeat tree species names.
- Count saplings and seedlings separately by origin.

Cluster number

Cluster number from the inventory field map

Sample plot number

Sample plot number within the cluster from the inventory field map

Stand

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use type.

Code	Description
1	Stand where the sample plot's centre point is located
2	The second stand etc.

Regeneration subplot

Plot number referring to location of the regeneration subplot where data is collected. Target is to collect regeneration information from two subplots in every stand. In case "west" or "east" plot (or both) are not usable, use "north-plot" and then "south-plot" instead. **Note, circle the measured regeneration subplots (number) in the field form.** This indicates the measured/checked regeneration subplots even if no data is recorded (=no saplings/seedlings in the regeneration subplot).

Code	Description	Explanation
1	West	Regeneration subplot is in the west of the sample plot centre
2	East	Regeneration subplot is in the east of the sample plot centre
3	North	Regeneration subplot is in the north of the sample plot centre
4	South	Regeneration subplot is in the south of the sample plot centre

Species code

Tree species check list.

Species name

Scientific genus and species names are recorded. If genus name is unknown, common name may be written.

Health

Health of seedlings and saplings.

Code	Description	Explanation
H	Healthy	No symptoms of diseases or other damages
M	Moderate	Minor symptoms of diseases or other damages that affect the growth
P	Poor	Symptoms of diseases or other damages that affect the growth so that seedling/sampling might die

Number of saplings and seedlings **h $\geq$ 10 cm and DBH <2 cm**

Count of saplings and seedlings.

Origin

Saplings and seedlings are counted separately by origin.

Code	Description
S	Sapling/seedling from seed
C	Coppice, saplings by shoots from stumps

4.3.4 Tree measurements

Tree data is recorded on all vegetation types. *Tree number*, *species name*, *DBH*, *Health* status and *Tree origin* are recorded for **all trees**. Trees are selected and measured in each sample plot in the following manner:

i) Within 2 m radius; all trees with DBH ≥2cm will be recorded
ii) Within 5 m radius; all trees with DBH ≥ 5cm will be recorded
iii) Within 10 m radius; all trees with DBH ≥ 10 cm will be recorded
iv) Stratum 2 and Stratum 4: Within 15 m radius; all trees with DBH ≥ 20 cm will be recorded
Stratum 1 and Stratum 3: Within 20 m radius; all trees with DBH ≥ 20 cm will be recorded

A tree is in the plot if the estimated centre point of its base is inside the plot boundary. **Plot radii are corrected for each tally tree** unless the crew uses an instrument that can automatically calculate the right distance (e.g. TruPulse). (Note: read more in the section *Slope correction*).

All trees within the sample plot's borders are recorded, both live and dead trees. Every 5th tree in the cluster is selected as a sample tree. 3rd tally tree in each cluster is the first sample tree, then 8th, etc. Note, in case 5th tree is dead, the next living tree is selected as a sample tree but the counting of next sample tree continues from the original (dead) 5th tree. The data collection starts at the sample plot starting point (= plot centre) and continues from the North in clockwise direction. First, all tally trees are measured and possible sample trees are marked with coloured ribbon. Secondly, all marked sample trees are measured. Additional measurements for sample trees are bole height, total height, stump diameter and stump height.

Cactuses and palms are recorded as trees. Information about bamboos is filled into the Bamboo Field Form.

Species names are recorded in the field for every tally tree. If a tree species is unknown to the crew, the team leader can take a photo of the particular tree and ask advice later from a botanist. The crew can also collect leaf, flower and/or fruit samples.

The recording of species names on all field forms should follow these rules:

- Scientific genus and species name should be recorded whenever possible;
- If exact species is not known, teams must write at least the scientific genus name;
- When exact species is not known, genus names must always be followed by "sp." (e.g. *Shorea* sp.) to indicate it is a scientific name;
- If genus name is also not known, common name may be written;
- If species is completely unknown, enter '**?**' as code; local name and indicate which Kenyan language (later the common and scientific names can be found out from this information)
- When taking samples of unknown species, always write cluster, sample plot, form name, and *regeneration subplot/tree number* so that data can be reconciled later. Use waterproof ink on samples to avoid data loss due to rain or humidity.
- New species which are not in the tree species checklist, but correctly identified by the botanist should be added on the appropriate page by the botanist.

Tree height measurement may be carried out by means of several instruments (as Laser Ace, Blume-Leiss, Suunto, Haga, electronic range finders). *Laser Ace* and Suunto hypsometer are in use for the field teams.

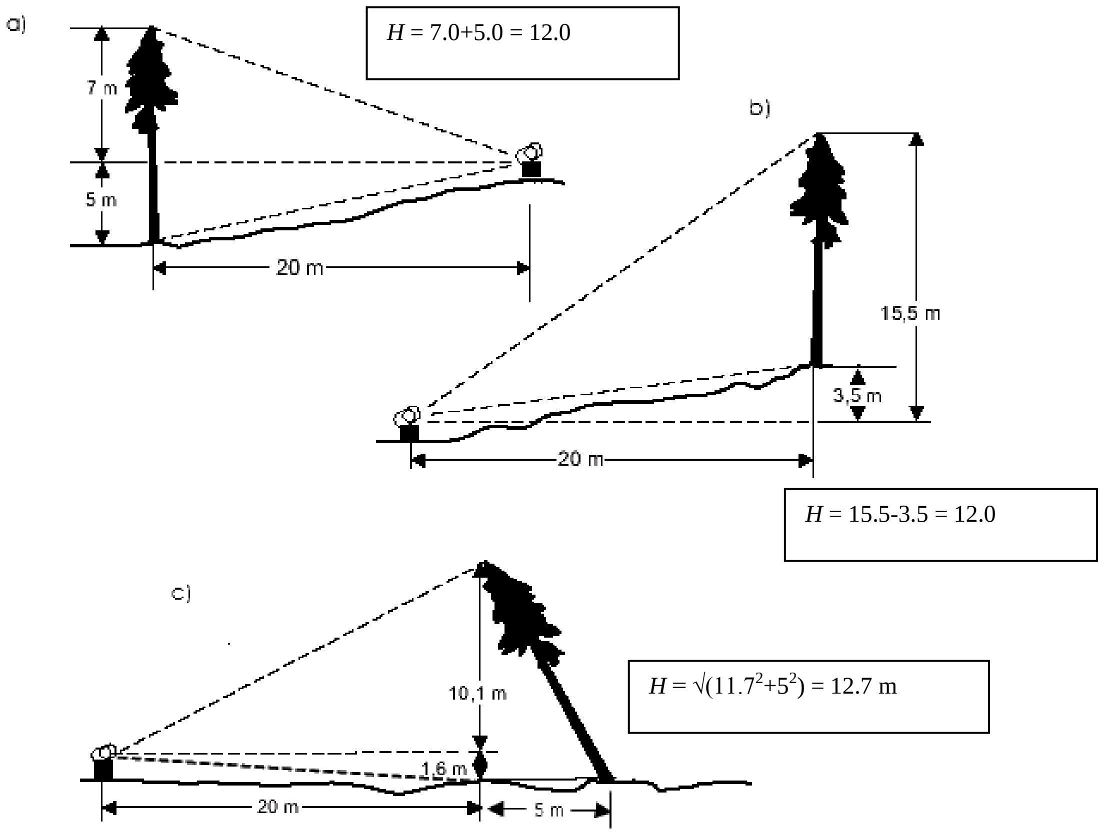


Figure 11. Tree height measurements.

Note: You can get the height of a tree

a) By adding the results above and below the horizontal measurement (7.0+5.0)*;*

b) By subtracting from the total the difference between the base of the tree and the horizontal line (15.5-3.5);

c) By applying the Pythagorean theorem. Measure first the height of the tree top, then measure the horizontal distance from the stump point to the top point projected on the horizontal level. Apply equation: $H = \sqrt{(Height^2 + Distance^2)}$

Every 5th tree in the plot is selected as a sample tree (if the 3rd tree is the first sample tree, the 8th the second etc.). The crew measures the following variables from the sample trees: stump diameter, stump height (default=15 cm above ground), total tree height and bole height (for trees DBH≥20 cm). In order to facilitate the finding of sample trees, these are temporarily flagged with coloured ribbon, and the tree number is marked on the stem as the field crew advances. A healthy stem in a forked tree can also be a sample tree if it is the 5th in the count.

Note: Bole height is **measured** for each sample tree DBH≥20 cm, but **estimated for every** tree where DBH≥20 cm. So these data are recorded for every living tree where DBH≥20 cm. Bole height refers to merchantable height that is defined as the distance from the base of the tree to the first occurrence of the lowest point on the main stem, above the stump, where utilization of the stem is limited by branching or other defect.

TREE FORM

Tree data is recorded on all land use classes. Each tree is recorded as a tally tree, and every 5th tree within the cluster as a sample tree.

Cluster number

Cluster number from the inventory field map.

Sample plot number

Sample plot number within the cluster from the inventory field map.

Stand

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use or vegetation type.

Code	Description
1	Stand where the sample plot’s centre point is located
2	The second stand etc.

Tree number

Tree number, starting from number 1

Stem number

Stem number. In case tree forks below 1.3 m, each fork is measured as individually stems (if diameter limit is reached) and forks are numbered starting from number 1. Note; measured forks in the same tree has the same tree number.

Sample tree

Code indicating whether tally tree is sample tree or not.

Code	Description
Y	Tally tree is a sample tree (additional measurement is needed)
N	Tally tree is not a sample tree

Tree diameter, DBH (mm)

Tree diameter is measured over bark, at 1.3 m height above the ground with the exception of particular cases mentioned below. The diameters are measured over bark. If bark does not exist estimate the bark thickness and add it to the diameter. Measurement may be carried out using preferably the diameter tape or with the use of the caliper. Both devices should have metric scale and the smallest unit in millimetres. Diameter is recorded in millimetres. If a caliper is used, the measurement is always carried out at right angles to sample plot’s centre point (Figure 12), also for non-circular shape trees, but care should be taken to avoid conscious bias in measuring irregular shaped trees. Diameter tapes are best for irregular diameter trees to ensure consistency of measurements. If a tree is leaning in flat terrain, the measurement point is at that side where the tree leans (Figure 13). Make sure the caliper tightly holds the stem, in order to prevent the caliper clasps from grasping without compressing the bark.

If the diameter tape is used, make sure it is not twisted and is well stretched around the tree in a perpendicular position to the stem. Remove climbers and loose bark before taking measurements. Nothing must prevent a direct contact between the tape and the bark of the tree to be measured.

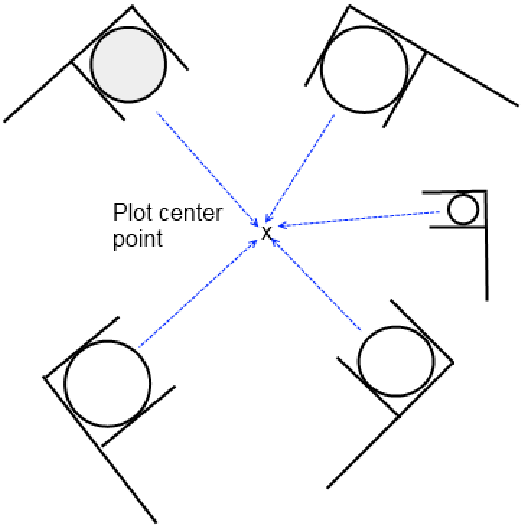


Figure 12. Measurement of DBH with caliper.

Note about Permanent Sample Plot measurements:

1) All tree diameters on the permanent sample plots should be recorded only using the diameter tape;
2) A 1.3 m stick must be used when determining the breast height up from the ground level.
3) If there is a mound at the tree base then general ground level in the tree neighbourhood should be used.

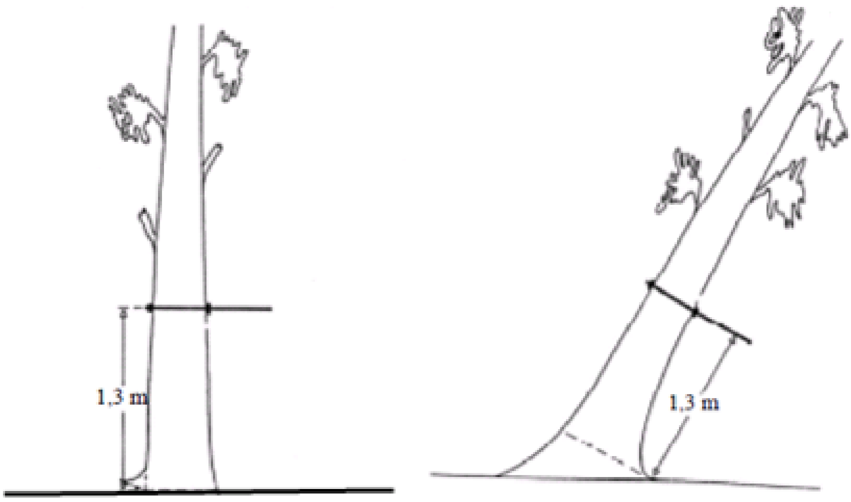


Figure 13. Diameter measurement on flat terrain.

When a tree is growing on slope, the measurement point is located at the upper side of slope (Figure 14).

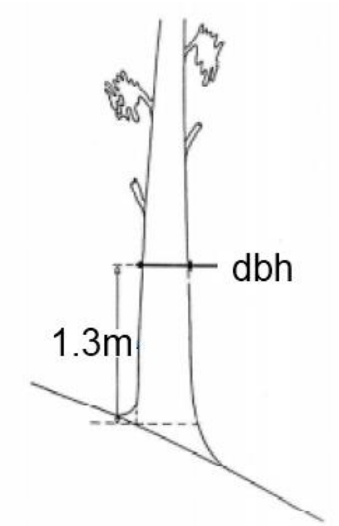


Figure 14. Diameter measurement of tree on slope.

There are several cases where a **forked tree** exists. The first thing is to determine the point where the tree forks.

1) If the fork originates (the point where the core is divided) below 1.3 m height, each stem reaching the required diameter limit will be considered as a separate stem to be measured, and the diameter is measured at 1.3 m height.

   The first measured fork is recorded with a new tree number. The other forks get the same tree number and running stem number

4. TREE FORM

Stand	Tree No.	Stem No.	Sample	Species code	Species name
A	1		N	154	*Juniperus procera*
A	2	1	N	10	*Acacia mellifera*
A	2	2	N	10	*Acacia mellifera*
B	3		N	154	*Juniperus procera*
B	4	1	Y	10	*Acacia mellifera*
B	4	2	N	10	*Acacia mellifera*
B	4	3	N	10	*Acacia mellifera*

Figure 15. Diameter measurement points for forked tree.

A living stem can be a sample tree. For a forked sample tree record the stump diameter at the default stump height level (15 cm above ground). This stump diameter usually refers to the stump diameter of the whole tree. If a forked sample tree originates below 15 cm, then write a remark to that stem as '***fork below 15 cm***'.

A fork can be dead or alive. Record this information into *Health* status.

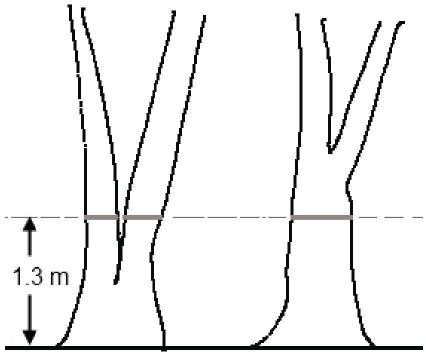


Figure 16. Diameter measurement points for forked tree.

2) If a fork originates at 1.3 m or a higher, the tree will be counted as a single tree. The diameter measurement is thus carried out **below** the forks' intersection point, just below the bulge that could influence the DBH.

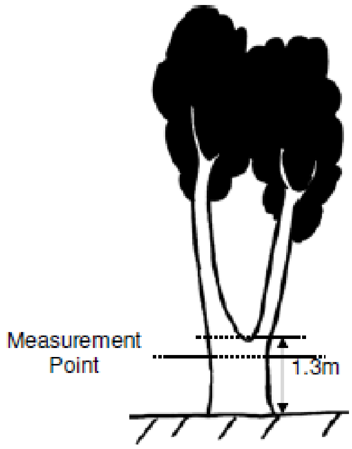


Figure 17. Examples of forks' intersection at the 1.3 m height.

Coppice tree: Coppice shoots considered similarly as forked trees. The measuring height is 1.3 m above the seedling point (Figure17).

Record also the stump height (cm) for each coppice shoot. This is the height of the estimated level where the shoot originates.

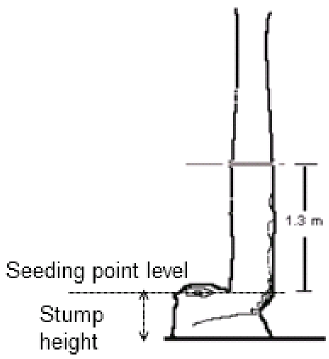


Figure 18. Diameter and stump height measurements of coppice tree.

Trees with an enlarged stem base or buttressed tree: diameter measurement is made at 30 cm above the enlargement or main width of buttress, if the buttress/enlargement reaches more than 90 cm height above the ground (see Figure 18).

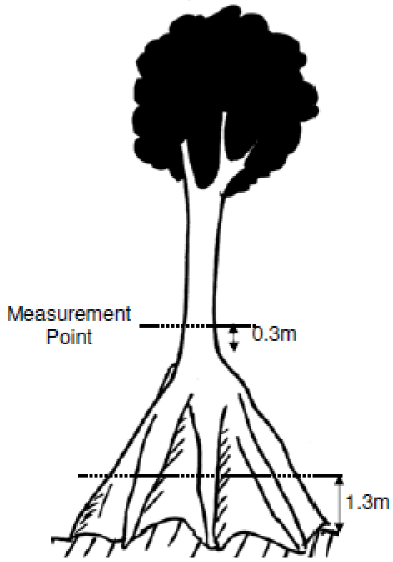
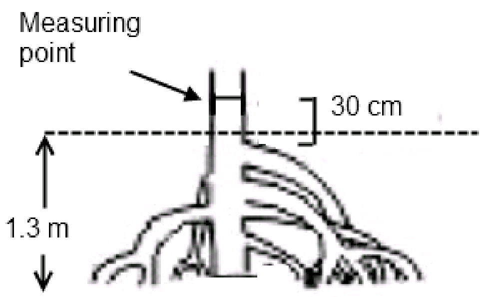
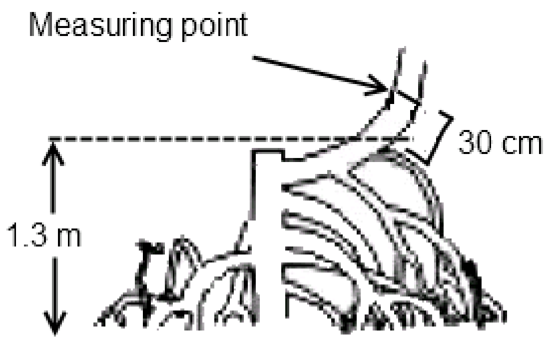


Figure 19. Diameter measurement of a tree with large buttress.

Trees with aerial roots exceeding 130 cm from the ground: diameter is measured 30 cm above the upper root (see Figure 19). Among *Rhizophora* genus (mangrove) there are some species which usually contain prop roots above 130 cm from the ground. Some upper roots are well established in the mangrove mud, while others have just started forming, or are formed from within the canopy. Therefore only roots originating from the central stem and touching the mangrove soil or permanent water body are considered, when pointing out the 'upper root'.





a) Growing mangrove stem

b) Cut mangrove stem

Figure 20. Diameter measurement of a tree with aerial roots.

Trees with irregular shape at 1.3 m level

Trees with bulges, wounds, hollows and branches, or other reasons causing irregular shape at the breast height, are to be measured above and beneath the deformation, and the average of both is the calculated as DBH of the tree (Figure 21).

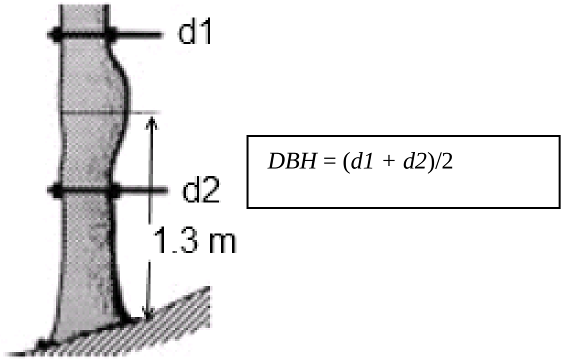


Figure 21. Diameter measurement of deformed trees.

Other special cases

The diameter of a tree with a horizontally protruding stem should be measured 1.3 m along the stem, even if this is less than 1.3 m above the floor.

A case of damaged and broken stem where the DBH measurement is done below 1.3 m is presented in Figure 21.

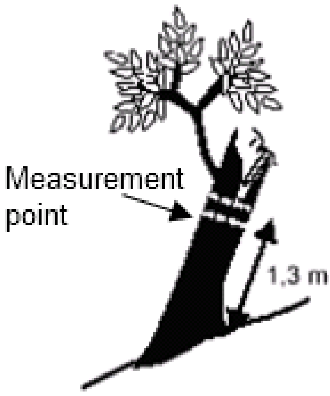


Figure 22. Diameter measurement of damaged and broken stem.

Distance (cm) **Only on permanent sample plots**

On permanent sample plots, the horizontal distance from the sample plot's centre to the tree side at the BH (1.3 m) is measured. Distance is recorded in centimetres.

Direction (degrees) **Only on permanent sample plots**

On permanent sample plots, the direction from the sample plot's centre to the centre of the tree at the BH (1.3 m) is recorded with the compass (360 degrees).

Bole height (0.1m) **Sample/tally tree, dbh $\geq$ 20 cm**

Bole height refers to merchantable height that is defined as the distance from the base of the tree to the first occurrence of the lowest point on the main stem, above the stump, where utilization of the stem is limited by branching or other defect. **Note!** Bole height is measured for each sample tree (dbh $\geq$ 20 cm) and estimated for every tree (dbh $\geq$ 20 cm). Bole height is recorded in meters with one decimal digit.

Additional measurements for sample trees only

Stump diameter (mm) **Sample tree**

Stump diameter is measured at the top of the stump (i.e. at the stump height).Diameter is recorded in millimetres.

Stump height (cm) **Sample tree**

Stump height is the level of the upper most root collar. If no root collars exist, stump height is expected to be 15 cm from the ground level. Stump height is recorded in centimetres

Total height (0.1 m) **Sample tree**

Total height is measured from the seeding (base) point to the top of the tree. If the seeding point is higher than the ground level (e.g. in case where a tree growing on the top of a stone), the tree height is measured from the seeding point. Total height is recorded in meters with one decimal digit.

Species code

Tree species check list. If species is completely unknown, enter ‘**?**’ as code

Species name

Scientific genus and species name are recorded. If genus name is unknown, common name may be written. If not known give local name and the dialect then refer later (e.g. Kenya Trees Shrubs and Lianas by Beentje 1994 or Kikuyu dictionary of trees and shrubs by Norman Gachathi KEFRI)

Quality

Timber quality is an essential variable for the estimation of the share of trees by quality classes. Quality status is recorded of every tally tree.

Code	Description
1	Living tree, good quality long branch-free stem
2	Living tree, 50–70% of stem volume with economic potential
3	Living tree, less than 50% of stem volume with economic potential
4	Dead tree (standing)

Health

Health status refers to the current observed condition of a tally tree and to the main causative agent. Health status is recorded for every tally tree. For dead trees record the most obvious original reason for mortality.

Code	Description	Explanation
1	Healthy	A tree is healthy when it does not show symptoms of disease or others that have any substantial effect on the tree’s growth and vitality
2	Diseased	A tree is affected when it shows symptoms of disease or attack by insects or fungi that affect the tree’s growth and vitality
3	Burnt	Will probably recover
4	Burnt	Will probably die
5	*Ficus sp.*	Affected by *Ficus sp.*: which may eventually destroy its host
6	Other	Other damage agent: Specify in Remarks

Origin

This variable describes the origin of a tree. ‘*C’* should be used for coppicing trees, regardless of whether they are originally naturally occurring or planted. On afforested sites, please remember to add the code for ‘*Afforestation’* on the Sample plot Form (*Human impact*).

Code	Description	Explanation
1	Natural	Natural regeneration by seed
2	Planted	Artificial regeneration by seeding or planting
3	Coppice	Regeneration by a shoots from a stump or roots
4	Unknown	

4.3.5 Lying Dead Wood and Stumps

Dead wood data is recorded on all vegetation types. Dead wood are tree parts that are lying on the ground. Minimum length of dead wood to be measured is 1 metre. Note, combined broken parts (separately shorter than 1 m) from the same tree are counted and measured as one if total length of parts exceed 1 metre. The field crew determines dead wood parts which are inside the sample plot area (within the radius of 15 m). The length and diameter at **both ends of all pieces** of fallen wood with diameter equal to or larger than 10 cm within the sample plot area are measured. Standing dead trees are measured as tally trees (see section 4.3.4, Quality). Minimum length of dead wood is 1 metre. Dead wood, when its diameter is less than 10 cm is treated as woody debris when it is found within the spots reserved for litter/woody debris/soil sampling. For details, see Chapter 4.4.

Tree species of dead wood is identified, if possible. Dead lianas, bamboos, cactuses and palms are included to the dead wood if they exceed the given diameter and length limits.

Measurements of length are made to the sample plot border with radius of 15 m (Figure 23). Hence when a stem crosses the sample plot border, the length is measured to/from that limit where the stem's centre line crosses the border. Note, dead wood is measured even if the length of the particle lying inside the sample plot is less than 1 meter and if this particle otherwise fulfils the diameter and length criteria.

Two diameter measurements are carried out: the first measurement in the base part of the stem (or branch), the second in the other end (Figure 24). The diameters are measured over bark. If bark does not exist then estimate the bark thickness and add it to the diameter. For measurements at the bases of fallen, buttressed trunks, diameters are measured above the buttress. The total length of the stem part equal to or larger than 10 cm in diameter is also recorded.

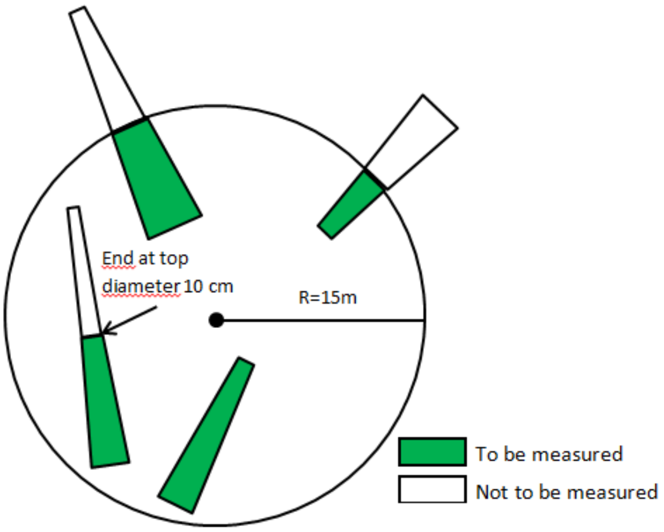
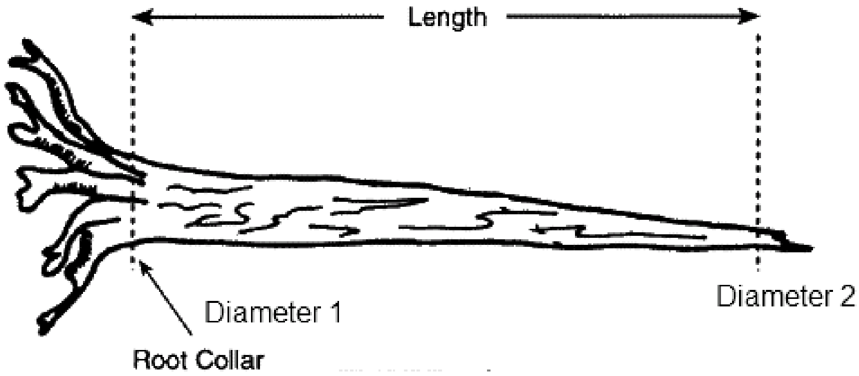


Figure 23. Selection of dead wood parts in the sample plot.

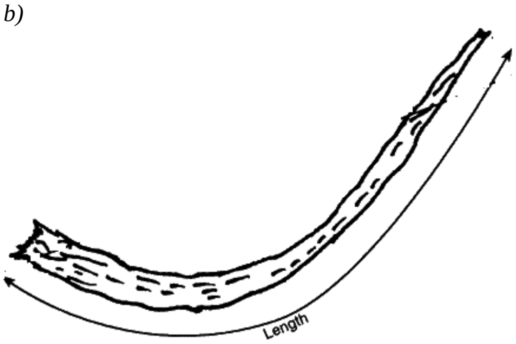
If a part of laying stem has been removed from the sample plot (e.g. for making charcoal), the remaining main wood particles are recorded if they are equal to or exceed diameter of 10 cm. If there are several dead trees or dead wood parts on the sample plot (as branches), then the recorder can tally the estimated mean dimensions of dead wood and give the total number of stems/parts.

a)



Note: Record this type of dead tree into two forms: *Dead Wood* data (Form *5a)* and *Stump* data (Form *5b*). Stump diameter is equal to *Diameter 1* in the figure above. *Diameter 2* denotes the diameter of 10 cm.

b)



c)

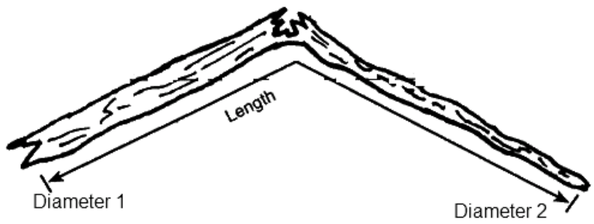


Figure 24. Dead wood measurements.

Decay class is detected applying two classes: solid wood or (partially) rotten wood. This can be detected by as pushing a knife into the wood. Decay class is used when we compute dead wood biomass and carbon: rotten coarse woody debris has lower density value than a solid wood.

A dead laying stem can contain a stump part with some roots. In case of a broken dead tree the stump can be located in the sample plot. In both cases the stump data is recorded into the Stumps section on the field form **5b**.

Cluster number

Cluster number from the inventory field map

Sample plot number

Sample plot number within the cluster from the inventory field map

Stand

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use or vegetation type.

Code	Description
1	Stand where the sample plot's centre point is located
2	The second stand etc.

Species code

Tree species check list.

Species name

Scientific genus and species name are recorded. If genus name is unknown, common name may be written.

Diameter 1 (mm)

Diameter at the stump part of the stem in millimetres.

Diameter 2 (mm)

Diameter at the top part of the stem in millimetres.

Length (0.1 m)

Length of wood part in metres with one decimal digit.

Number of stems

Number of similar size of dead wood parts.

Decay

Decay refers to the decomposition of wood substance caused by the action of wood-destroying fungi, resulting in softening, loss of strength and loss of biomass.

Code	Description
S	Solid wood material
R	Fully or partially rotten wood material

STUMPS, Form 5B

Stump data are recorded on all vegetation types. Stumps with stump diameter equal to or larger than 10 cm are recorded within sample plot radius of 15 m. The stump diameter is measured outside bark immediately under the cutting point (felling cut). If the bark is damaged or missing, a judged addition for bark is done. When a stump is taller than 1.3m the diameter is measured at the 1.3 m height.

Because in the FRA one aim is to get estimates for the annual removal, it is essential to collect data about the estimated year of cutting, especially for stumps that are less than three years old. In some cases this data will be challenging to estimate, but the team should also ask from local people if they have some knowledge about the right timing.

Stand

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use or vegetation type.

Code	Description
1	Stand where the sample plot's centre point is located
2	The second stand etc.

Species code

Tree species check list. If species is completely unknown, enter '**?**' as code

Species name

Scientific genus and species name are recorded. If genus name is unknown, common name may be written.

Diameter (mm)

Diameter is measured immediately (in maximum 5 cm) under the cutting point in millimetres. Note, stump diameter is measured as tree diameter: if caliper is used the measurement is always carried out at right angles to sample plot's centre point (Figure 13).

Height (cm)

Stump height is measured from the ground level to the cutting point in centimetres.

Number of stumps

Number of stumps with the similar size. In case stumps are similar (difference in diameter 0–5 cm and in height 0–20 cm) record only average diameter and height and the number of similar stumps. This concerns especially bamboo stumps.

Years ago

Estimated time in years from cutting or when the stem was otherwise broken. Local knowledge and interviews can be employed.

Possible Reason

Possible reason of tree mortality is recorded if possible. Local knowledge and interviews can be employed.

Code	Description
1	Cutting
2	Natural dying, mortality
3	Unknown

4.3.6 Bamboo

Bamboo data are recorded on Forest, Woodland and Cropland vegetation types, whenever applicable. This form contains information related to bamboo groups (all bamboo shoots taller than 1.3 m) within sample plot radius of 10 m. The average diameter is at the breast height (1.3 m above ground). Bamboo measurements are done for a single clump/group i.e. one source or base. Count, average diameter and height by species and maturity classes in a clump is first marked on notepaper. After measuring all the clumps inside the plot, the total amounts and average diameters and heights are recorded to the field computer. In case bamboos are evenly situated (no groups/clumps) in the sample plot area, two subplots, with radius of 2 metres situated in west and east in 5 meters distance from the sample plot centre, can be used to calculate all bamboos. Count of bamboos in these two subplots is multiplied with 25 to get number of bamboos in the sample plot. Note, bamboos with differences in species and maturity, diameter and height classes are recorded separately. Examples of bamboos of different maturity classes are presented in Figure 25.

Figure 25. On the left picture is “Mature bamboo” and on the right is “young bamboo”.

Cluster number

Cluster number from the inventory field map

Sample plot number

Sample plot number within the cluster from the inventory field map

Stand number

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use or vegetation type.

Code	Description
1	Stand where the sample plot’s centre point is located
2	The second stand etc.

Species code

Tree species check list.

Species name

Scientific genus and species name are recorded. If genus name is unknown, common name may be written.

Maturity

Observation of Bamboo status(or Bamboo group/clump).

Code	Description	Explanation
Y	Young	Green in colour and not yet developed leaves
M	Mature	Brown in colour and with leaves and branches
O	Old	Greyish in colour and has moulds on the stems. Leaves are still green
D	Dead	Greyish in colour with mould in stem. Leaves are dry or completely dropped

Average diameter (mm)

Mean diameter of the bamboos at 1.3 m above ground (DBH) in a group in centimetres.

Average height (0.1 m)

Mean height of the bamboos in a (similar) group in metres with one decimal digit (0.5metre accuracy).

Number of stems

Number of bamboo stems in a (similar) group/clump.

4.3.7 Climbers (lianas)

Climber data is recorded on all vegetation types. Climbers can have a remarkable share of the biomass in certain areas, especially in natural forests. Climbers are selected and measured in each sample plot based as follows:

i) Within 2 m radius; all climbers with DBH ≥ 2 cm are recorded
ii) Within 5 m radius and more; all climbers with DBH ≥ 5 cm are recorded

In case climbers cross over the sample plot border, only the length inside the sample plot is measured.

Cluster number

Cluster number from the inventory field map

Sample plot number

Sample plot number within the cluster from the inventory field map

Stand number

Code indicating the stand in the sample plot. The sample plot is shared into several stands in case it is situated on the border of more than one land use or vegetation type.

Code	Description
1	Stand where the sample plot's centre point is located
2	The second stand etc.

Species code

Tree species check list.

Species name

Scientific genus and species name are recorded. If genus name is unknown, common name may be written.

Diameter (mm)

Diameter of the climber at 1.3 m above ground (DBH)or 1.3 m distance from the seeding point in millimetres.

Length/height (m)

Length/height of the climber in metres.

4.4 Soil, litter and woody debris sampling

4.4.1 Goals and locations

Soil information is increasingly required as part of the forest ecosystem and carbon reporting. A systematic mapping of soil in a country scale is a tedious and expensive task. FRA Kenya includes a protocol of collecting forest soil samples for analysis of Soil Organic Carbon (SOC) from the top 30 cm soil layer. In addition, soil physical properties that are relatively easy to describe in the field, e.g. **soil type, soil structure** and other **surface soil features** (FAO, 2006) are determined. To observe and characterize the relative carbon input to soil from the above-ground forest ecosystem, litter and woody debris stores at the moment of sampling are also estimated. In addition, information about erosion can be recorded. This chapter describes how the sampling spots are determined, how the litter, woody debris, and soil samples are collected and weighed *in situ* conditions, and how the samples for further analyses in laboratory are collected and stored. A crucial task is to label the samples so that the data derived in laboratory can be later connected to the forest and environment data observed in the field using the tools of Forest Information System. Such a database provides a very interesting source of information and may support many aspects of ecological research and forest management.

Soil, litter and woody debris samples are taken from as many plots as possible within the cluster, determined by time since the soil data collection team works parallel with the biophysical survey team**.** The first samples are taken from the plot first entered in each cluster. In case the first entered sample plot is inaccessible, the soil team moves to the next sample plot. Sampling of Litter, woody Debris and Soil may take more time than the tree measurements at the plot. In that case the soil team may stay behind and join the rest of the inventory group after they have marked the boundaries of the next plot if possible. The goal of the upland soil sampling is to get samples covering at least two plots in each cluster.

Sampling of Litter, woody Debris, and Soil (LDS) is performed for each stand determined in the inventory plot (see section 4.3.2). Each item of the LDS is collected separately as a composite sample of preferably *four* sub-samples in order to degrease the large spatial variability typically encountered in these parameters. In particular cases described below, a minimum of *three* subsamples can constitute the composite sample. It is the responsibility of the Crew Leader to determine the actual sampling locations with the Soil Technician.

When the cardinal or sub-cardinal points for the LDS sampling are determined, the practical placement of the actual soil pit can be done anywhere within a 2 x 2 m area close to the “theoretical” sampling point. This is because there can be a tree or other common obstacle that could be easily avoided by such flexible placement of the pit and common sense needs to be applied for reaching the goals for the LDS sampling. The goals are as follows: A representative area for litter and debris on soil surface, and a representative, undisturbed sample of soil, particularly containing the fine fraction (soil particles passing a 2 mm sieve). As there are often stones that do not fit into the corer, those samples can be avoided in favour of finer soil texture. The stoniness will be estimated from the soil pit wall, and taken into account later when the organic soil carbon stock is calculated. Availability of a stoniness estimate is crucial for correcting the carbon stock estimates for the site. Therefore stoniness should be recorded from each soil pit and averaged over the stand.

The exact locations where the sampling is performed for the plot, or subplots according to forest stands, are determined by the crew leader when the plot has been reached. Depending on if the plot has to be divided into separate stands, there can be a maximum of two stands where the LDS samples are taken.

If there is only one stand in the plot, then the default sampling is performed at cardinal points 1 m outside the plot boundary (Figure 26).

If some of these (and their 2 x 2 m surroundings) cannot be reached for e.g. topographical reasons, or the point falls outside the stand (e.g. belongs in another stand or a different landscape element such as cropland or brook), then sub-cardinal points within the same stand can be used as a supplement.

When the plot is divided in more than one stands, it may happen that a stand contains less than *three* cardinal and sub-cardinal points as shown in Figure 27. In those stands no sampling for litter, woody debris, or soil is to be performed, but the situation is noted on the field form. It is important that all locations accepted for sampling are marked on the respective field form of the stand.

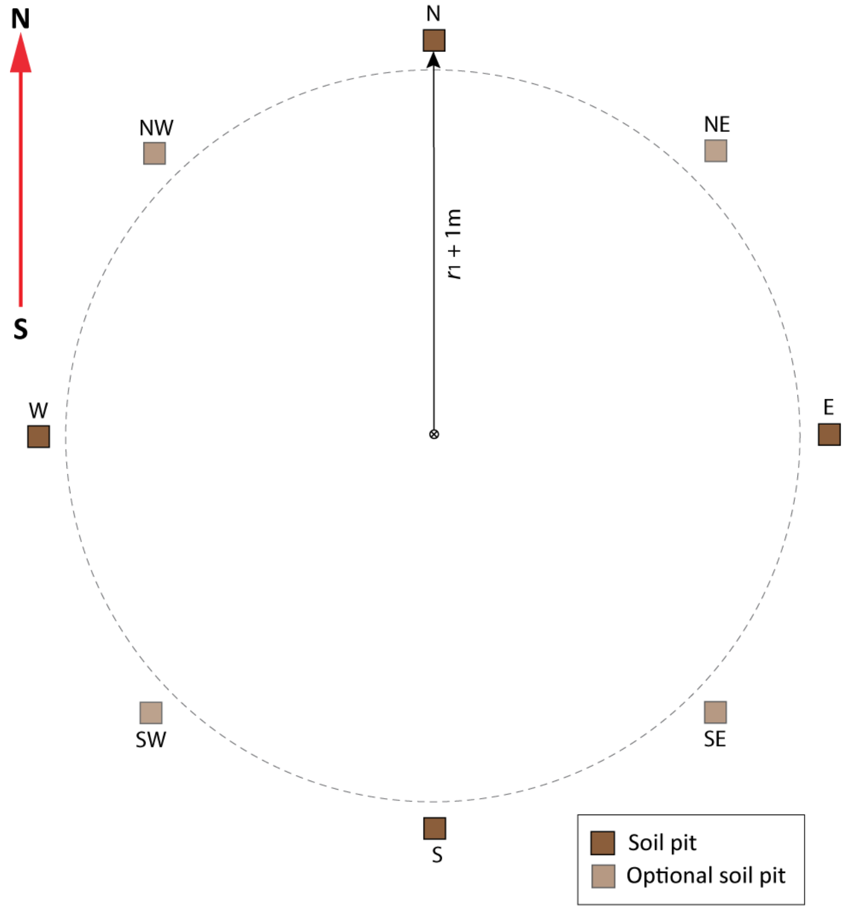


Figure 26. Locations of LDS pits.
Locations where LDS sampling is performed are marked as squares. The default locations (dark colour) are the cardinal points (N, E, S, W), while complementary locations (light colour) for sampling are the sub-cardinal points (NE, SE, SW, NW).

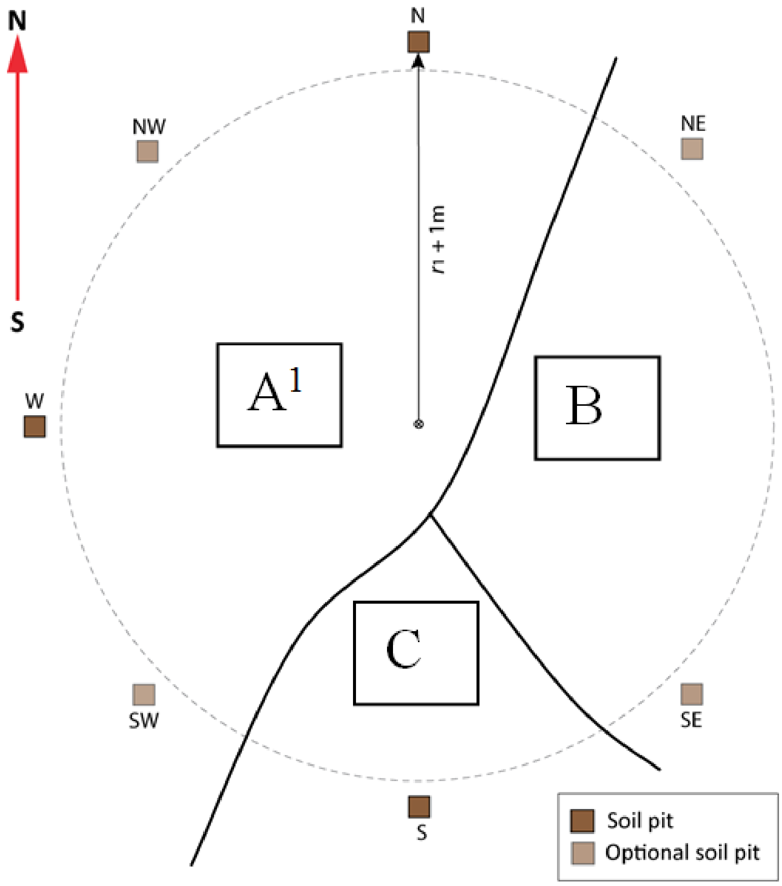


Figure 27. Example of soil pit locating when the plot is divided into three stands.
For stand A1 the locations SW, W, NW, and N are selected for LDS sampling. The locations used for stand B are NE, E, and SE. Stand C only contains the cardinal point S, and will be omitted from LDS sampling.

4.4.2 Composite samples of litter, woody debris and soil

Composite samples are taken following the schematic procedure shown in Figure 28. After the sampling locations have been determined and marked using a marker stick, a ring of $1m^2$ area is set on the soil surface. Within that ring litter and woody debris are first collected into separate large (ca. 80 L) plastic bags. All locations within the stand are visited and litter or debris is incremented in the bags to form the respective composite samples. The mass of litter and woody debris in field moisture conditions is weighed using a spring scale. The results are recorded after subtracting out the mass of the empty bag.

In some cases the amount of litter and debris may be so large that it is not practical to use the 1 m^2 ring for collecting the materials from four soil pit locations to the composite bag. In those cases a smaller ring of ¼ m^2 can be employed. Note that the small ring has to be **used for all pits** of the stand in order to get **the results corrected using the following procedure**. If the¼ m^2 ring was employed, the fresh masses obtained by weighing the composite litter and debris bags have to be corrected to full square meters multiplying the composite mass (excluding the mass of the plastic bag) by the factor of four.

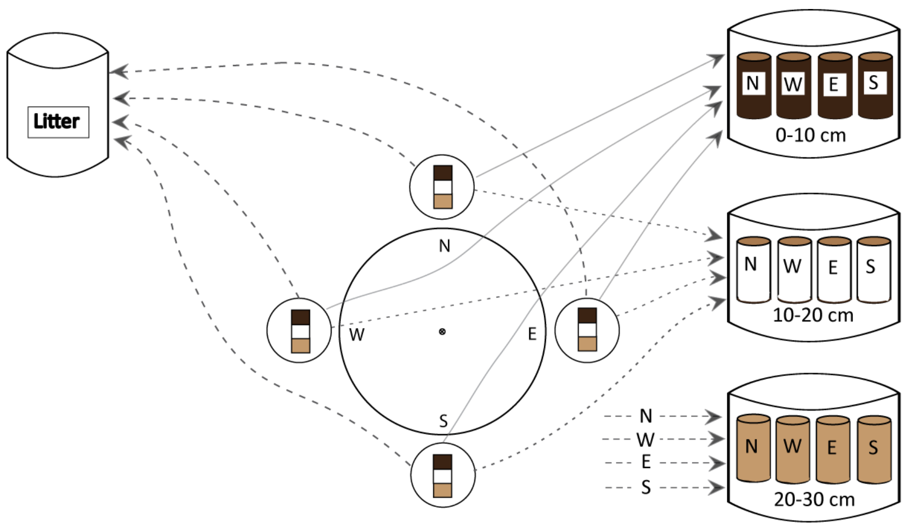


Figure 28. A schematic presentation of collection of LDS composite samples.
Optimally four sub-samples are collected for each composite sample, representing the fractions Litter, woody Debris, and Soil layers 0-10 cm, 10-20 cm, and 20-30 cm. These soil samples are carefully taken using the volumetric corer. From one plot of each cluster, an extra soil sample is taken, representing the depths of 30-60 cm (not shown in the picture). Volumetric sampling of this extra 30-60 cm layer may not be possible, and a qualitative sample with a volume of ca. 0.3-0.6 L is acceptable.

4.4.3 Litter and debris sub-samples for the laboratory

For determining of dry mass of the samples, the litter and debris must be oven-dried in laboratory. Because the composite samples can be very big in size and difficult to transport and process, a small, representative sample of both fractions is taken and stored safely in a maximum 10 L plastic bag with a paper label containing the following, obligatory codes that completely identify the sampling site: *Row*, *Column*, *Plot*, and *Stand*. The samples are transported to the laboratory at the earliest convenience together with soil samples.

4.4.4 Soil pits and soil characteristics

After the litter and woody debris samples are collected, the soil pit (Figure 29) is prepared. The pit depth can be 30 - 40 cm for normal soil sampling. The soil pit is first used for soil profile characterization. The following measures are taken to characterize the soil at each forest stand. The sample point where the characterization is made is marked on the field form.

Sample point

Code of the soil pit (N, NE, E, ..., NW) used to collect (volumetric) samples of soil layers (see Figure 27).

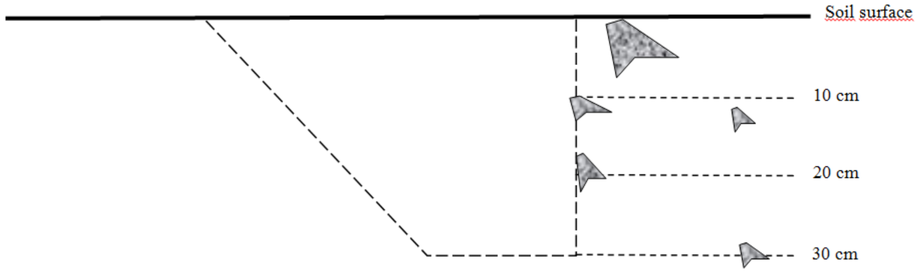


Figure 29. Soil pit with a vertical wall. (The depth zones for soil sampling are indicated).

On one plot per cluster, additional deeper soil representing the layer of 30-60 cm is collected using a soil auger. That sample does not need to be a volumetric one, it will be used to test if marked concentrations of soil organic carbon are found deeper than in the 0-30 cm intensively sampled layer.

Type of the organic layer

The type of the organic layer is recorded as follows:

0 **Missing.** Organic layer missing or very thin (< 1 cm).

1 **Raw humus.** Formed from the dead vegetation growing on mineral soils, a "felt" layer clearly distinctive from the mineral soil.

2 **Humus**. Typically thin, lower part mixed with mineral soil, but in the upper part there is a clear decomposed dead vegetation layer under the litter fall.

3 **Mull**. Organic layer fully mixed with mineral soil, between the litter and mineral soil. Occurs on the richest sites and abandoned agricultural land.

4 **Peat**. Formed of litter from peatland vegetation, mostly sedges or mosses but also remains of woody plants such as shrubs or trees. Decomposition stage of peat can vary in different layers resulting in different consistencies. If there is a layer of raw humus above the peat layer, the organic layer is regarded as peat if the peat layer is more than 50 % of the total thickness of the organic layer, otherwise raw humus

Thickness of the organic layer

The thickness of the organic layer is defined at the soil sampling pits (Figure 29).). It is measured with the reading accuracy of 1 cm. With more than one forest stand the type and thickness of organic layer is to be measured from the pits established in each forest stand separately.

Effective soil depth

The effective soil depth is the depth to which micro-organisms are active in the soil, where roots can develop and where soil moisture can be stored. As such it is an essential indicator of soil health. The vertical soil pit wall, soil auger, and other visible soil profiles or bare bedrock outcrops found at the plot can be used to classify the effective soil depth.

A steel rod or soil sampling auger with a 1 m shaft can be used to measure the soil depth. Soil depth is determined for each forest stand or land use class demarcated within the sample plot. Classes according to the World Reference Base (WRB) are recorded as follows:

0 bare bedrock
1 soil depth 1–10 cm
2 soil depth 11–25 cm
3 soil depth 26–50 cm
4 soil depth 50–100 cm
5 soil depth over 100 cm.

Soil stoniness

Stoniness of soil is estimated visually from the vertical soil pit wall using a percentage (%) scale and values of 1%, 3%, 5%, 10%, …, 90% as depicted below.

Charts (Figure 30) for estimating the proportions of coarse mineral fragments (> 2 mm) and mottles in mineral soil (FAO 2006, p. 30).

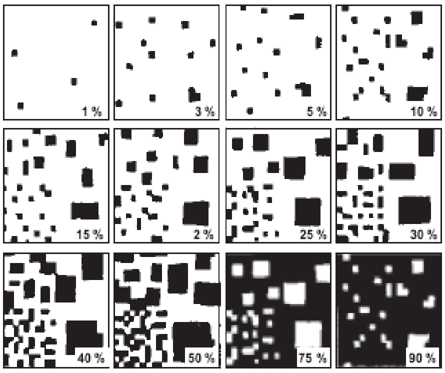


Figure 30. Munsell's soil colour.

Munsell's soil colour

Maximum/minimum moist colours are defined in terms of hue, value and chroma according to Munsell's (2009) 'soil colour charts' to characterize the soil profile.

Soil texture

Estimate for the soil texture is obtained from the surface soil, i.e. 10 to 30 centimetres below the ground level, using soil pits excavated for soil depth measurements. Estimates are determined by forest stands using the classification as follows:

1 Boulders. Grain size > 200 mm
2 Rocky sand. Sand mixed with stones (60 – 200 mm)
3 Sand (S, US, CS, MS, FS, VFS)
4 Loamy sand (LS)
5 Sandy loam (SL)
6 Loam (L)
7 Silt loam (SiL, Si)
8 Clay loam (CL)
9 Sandy clay loam (SCL)
10 Silty clay loam (SiCL)
11 Sandy clay (SC)
12 Silty clay (SiC, SiCL)
13 Clay (C, HC)

For the definitions of soil texture classes 3 to 13 and for their estimation in the field conditions see the instructions given below. Note that the soil sample used for feeling the constituents of soil must be in a moist to weakly wet state. Gravel and other constituents > 2 mm must be removed.

Table 4. Key to the soil textural classes according to the Guidelines for Soil Description by FAO (2006).

Definition		Soil texture class	Code	Clay content, %
1 Not possible to roll a wire of about 7 mm in diameter (about the diameter of a pencil)				
1.1 not dirty, not floury, no fine material in the finger rills:		Sand	S	< 5
	• if grain sizes are mixed:	unsorted sand	US	< 5
	• if most grains are very coarse (> 0.6 mm):	very coarse and coarse sand	CS	< 5
	• if most grains are of medium size (0.2–0.6 mm):	medium sand	MS	< 5
	• if most grains are of fine size (< 0.2 mm) but still grainy:	fine sand	FS	< 5
	• if most grains are of very fine size (< 0.12 mm), tending to be floury:	very fine sand	VFS	< 5
1.2 not floury, grainy, scarcely fine material in the finger rills, weakly malleable, adheres slightly to the fingers:		loamy sand	LS	< 12
1.3 similar to 1.2 but moderately floury:		sandy loam (clay-poor)	SL	< 10
2 Possible to roll a wire of about 3–7 mm in diameter (about half the diameter of a pencil) but breaks when trying to form the wire to a ring of about 2–3 cm in diameter, moderately cohesive, adheres to the fingers				
2.1 very floury and not cohesive				
	• some grains to feel:	silt loam (clay-poor)	SiL	< 10
	• no grains to feel:	silt	Si	< 12
2.2 moderately cohesive, adheres to the fingers, has a rough and ripped surface after squeezing between fingers and				
	• very grainy and not sticky:	sandy loam (clay-rich)	SL	10–25
	• moderate sand grains:	loam	L	8–27
	• not grainy but distinctly floury and somewhat sticky:	silt loam (clay-rich)	SiL	10–27
2.3 rough and moderate shiny surface after squeezing between fingers and is sticky and grainy to very grainy:		sandy clay loam	SCL	20–35
3 Possible to roll a wire of about 3 mm in diameter (less than half the diameter of a pencil) and to form the wire to a ring of about 2–3 cm in diameter, cohesive, sticky, gnashes between teeth, has a moderately shiny to shiny surface after squeezing between fingers				
3.1 very grainy:		sandy clay	SC	35–55
3.2 some grains to see and to feel, gnashes between teeth				
	• moderate plasticity, moderately shiny surfaces:	clay loam	CL	25–40
	• high plasticity, shiny surfaces:	clay	C	40–60
3.3 no grains to see and to feel, does not gnash between teeth				
	• low plasticity:	silty clay loam	SiCL	25–40
	• high plasticity, moderately shiny surfaces:	silty clay	SiC	40–60
	• high plasticity, shiny surfaces:	heavy clay	HC	> 60

Volumetric soil coring

Soil is cored from all pits using the volumetric corer, and collecting the sub-samples (0-10 cm, 10-20 cm, and 20-30 cm) in separate plastic bags marked for the respective soil layer. When all pits are cored, the composite samples are weighed for fresh mass, and the mass of the empty bag is subtracted from the total mass. An electric kitchen balance with 1 g accuracy is used. The marking is made with both permanent marker on the lower side of the bag and with a pencil on a paper that is enclosed in the bag before closing the bag. The volumetric corer is shown in .

Figure 31. A volumetric corer.

An example of the practical work flow:
The aim of volumetric soil sampling is to get composite samples collected from each soil pit and stored to separate plastic bags, keeping separate the fractions of litter and woody debris, and keeping the soil samples separate according to the depth zone of the sample (0-10 cm, 10-20 cm and 20-30 cm).

First locate the litter, debris and soil sampling pit area. Place the litter and debris ring on the correct location on the ground. Collect all litter and debris from within the ring to their respective composite bags. When done, move the bags to the next sampling pit area of the stand, where the litter and debris collection can continue into the same bags.

When all litter and debris subsamples are collected, weigh the composite fresh mass of the both fractions. If the collection was done using the small ¼ m^2 ring, multiply the litter and debris total fresh masses by four to obtain respective mass estimates for the number of full square meters. If the total amounts of litter and debris are much larger, take representative ca. 500 g amounts of litter and debris from the composite bags, and close the small amounts in smaller bags for sending to laboratory for dry mass analysis. Weigh and record those masses accurately, excluding the bag masses.

Dig the soil pit. Record the soil characteristics according to the field form. Remember to record the estimate of stoniness as seen on the pit wall. Proceed to volumetric soil sampling. The first layer, 0-10 cm, is taken by penetrating the corer from the soil surface down to its depth (10 cm). Pour the entire sample in a plastic bag marked using the following codes: *Cluster number, Plot, Stand, Depth layer* 0-10. Avoid live and dead vegetation by selecting a proper microsite for coring. Litter of ground vegetation is part of the litter.

For coring the second (marked as 10-20 cm) and third layer (marked as 20-30 cm), cut the soil vertically from the pit wall at the respective upper depth of the layer (Figure 32). Remove the already cored soil layer above the cut.

It is important that the cutting is done carefully and accurately so that the soil below the cutting line is not compressed or otherwise disturbed. As coring may compress the soil below the coring point, remove enough soil from above the next vertical cutting line so that the corer can be placed on an uncompressed area of the exposed soil layer.

Collect volumetric soil samples from the deeper layers into separate plastic bags, marked using the location codes *Cluster number, Plot, and Stand,* and the respective *Layer codes,* 10-20 or 20-30 cm.

When all soil depths of the stand have been collected into the respective plastic bags, weigh each bag, and subtract the mass of an empty bag prior to the input of the figure input on the form.

Mark the plastic bag with the *location codes* using a permanent marker and a paper slip using a pencil.

If the plot is chosen to represent the cluster for deep soil sampling, use auger to collect soil starting from the deepest sampled soil layer downwards, and take a non-volumetric soil sample that integrates the soil layer 30-60 cm. Store that ca. 0.3 L deep soil sample into a plastic bag. Weigh the bag and subtract the mass of an empty bag from the total mass. Mark *the location codes* described below on the bag with a permanent marker and inside the bag on a paper clip using a pencil. For *Depth layer* code, use 30-60 cm.

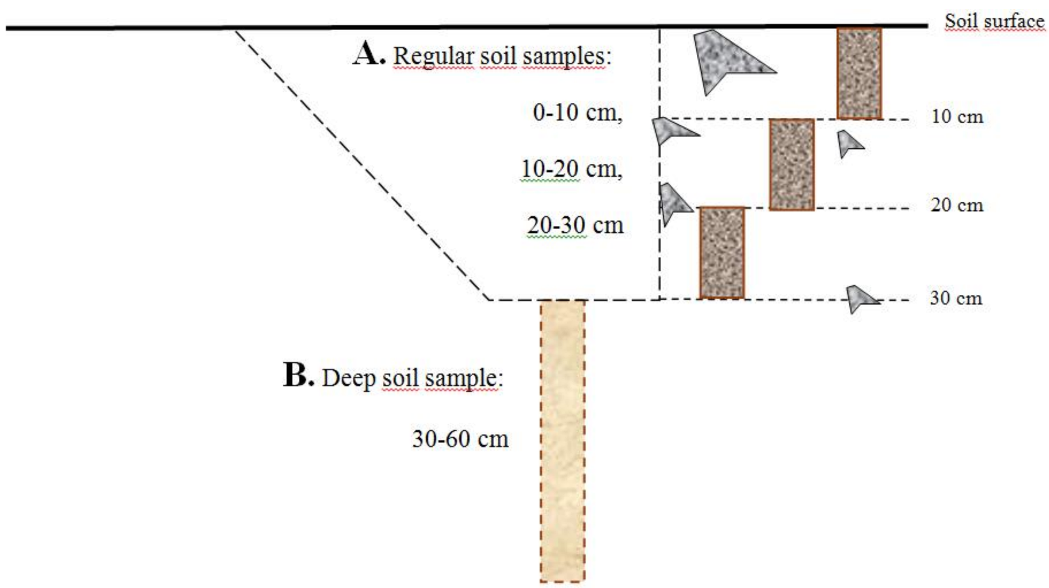


Figure 32. A schematic presentation of soil pit.

A denotes the regular soil pit for characterizing of the soil (stoniness, soil colour, soil texture), and for taking the composite soil samples 0-10 cm, 10-20 cm, and 20-30 cm using the volumetric corer. The first 0-10 cm sample is taken by driving the corer vertically below the soil surface until the corer is just filled with soil. A steel spatula or space can be used to close the lower end of the corer before the sample is lifted up. For taking e.g. the 10-20 cm core, the 10 cm soil plane is first exposed using a space or large knife. Then the sample is taken as described above. B denotes the non-volumetric deep soil sample that is taken only from one plot of the cluster. See text for details.

4.5 Sediment sampling in mangroves

4.5.1 Special features of mangrove woodlands

Mangroves are among the most productive woodland ecosystems. Originally they occupied up to 75% of tropical coastlines, protecting coral reefs from sedimentation by terrestrial suspended solids and inhabited coastlines from tsunamis. They provide habitats for fish, crabs and a wealth of other marine animals. Less than half of the historical domains of mangroves remain due to degradation resulting from collection of firewood, poles and timber.

Mangroves are characterized by a strong assemblage (or zonation) of species according to tidal water current, geomorphological and salinity gradients that result in contrasting site productivity levels. There are nine species of mangrove trees in Kenya. The species follows a typical zonation pattern with the seaward side occupied by *Sonneratia alba*, followed mainly by *Rhizophora mucranata*, then *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Avicennia marina*, *Lumnitzera racemosa* and *Heritiera litoralis*, respectively (Kokwaro, 1985; Kairo et al., 2001). Other mangrove species include *Xylocarpus granatum* and *Xylocarpus mollucensis*. Mangroves tidal wetlands are confined to narrow strips along the coastline or in river outlets with saline water occupying larger areas in sheltered bays. The species structure is either pure or in mixed stands in systematic small scale with spatial variability measurable in field only by a spatially dense network of inventory plots.

The good productivity of mangroves (Figures 33 to 35) results in significant turnover of biomass and creation of litter and fine root biomass. Leaf litter is consumed by a multitude of mangrove and hermit crab species that bury large amounts of leaf litter underground. The decomposed organic matters are mixed with water, mineral particles and accumulate as water-saturated, salty and muddy sediments. Perhaps, the largest part of carbon stock in mangrove woodlands is found belowground (Figures 36 and 37) making sediment sampling very important. It should be noted that wading in deep muddy mangrove sites require proper shoes (Figure 38).

The inventory method used to estimate above and below ground biomass of terrestrial trees in the Pilot inventory was found unsuitable for mangroves and sediment carbon stocks. In particular, sediment sampling was different from upland soil sampling. While in uplands the soil sampling focused in the layer from soil surface down to 30 cm depth, mangrove sediment was sampled to a depth of 100 cm by means of four 5 cm high subsamples from centres of sections 0–15 cm, 15-30 cm, 30-50 cm, and 50-100 cm.

Figure 33. Zones of different mangrove assemblages near Gazi, Kenya. The landward margin is mostly occupied by dwarf stands *of Ceriops tagal* either alone or mixed with *Avicennia marina*.

Figure 34. Mangrove restoration site.

Figure 35. Mangrove nursery.

Figure 36. Moving around in the mangrove can be physically difficult and time consuming.

Figure 37. Remains of coral reefs and past volcanic activity add complexity in the mangrove sampling because sharp coral.

Figure 38. Wading in the deep mangrove mud requires proper shoes.

4.5.2 Sampling in mangroves

This section describes how the sampling spots are determined, how the woody debris and soil samples are collected and weighed *in situ* conditions, and how samples for further analyses in the laboratory are collected and stored. A crucial task is to label the samples so that the data collected in field and those derived from laboratory analyses can be later correlated to the forest and environment data observed in the field using the tools of Forest Information System. Such a database provides a very interesting source of information and may support many aspects of ecological research and forest management.

In the mangrove inventory, soil and woody debris samples are taken from all sample plots and the undisturbed sediment surface is the starting point (Figure 39). This is possible to the contrary of upland soil sampling, because only one soil core is taken at each stand, and because tree measurements in mangrove**s** probably takes more time than those in upland forests. Another reason is that a major part of ecosystem carbon in mangroves is found in the sediment.

Figure 39. Undisturbed sediment surface is the starting point.

Figure 40. Mangrove crabs bury and eat leaf litter.

Litter is practically absent in mangroves due to regular tidal flooding and very efficient crab activity (Figures 40 and 41). If some debris are found, they should be collected and combined with the woody debris fraction. Sampling of woody debris and soil is performed for each stand determined in the inventory plot and it is the responsibility of the Crew Leader and the Soil Technician to determine the actual sampling locations. .

The cardinal or sub-cardinal point(s) for the sediment sampling are determined following the inventory plot stand division and the practical placement of the actual soil pit is anywhere within a ca. 2 x 2 m area close to the "theoretical" sampling point so as to avoid a tree or other common obstacle that would hinder flexible placement of the pit. Anyhow, common sense needs to be applied for reaching the goals for the sediment sampling.

Figure 41. Small and larger pellets are found everywhere on the sediment surface. They are formed by crabs as they dig escape holes in the sediment.

The goals of sediment sampling are as follows:

- A sample of debris on both soil surface and those hanging on the above ground parts of trees at maximum height of 1.5 m above the sampling location is obtained
- An undisturbed sediment core is obtained so that all subsamples representing the different depth layers of the sediment can be taken from the same core.

As there are often roots that prevent the corer penetration, such samples should be avoided in favour of a complete, undisturbed sediment core. The locations where the sampling is performed for the CCSP or subplots according to forest stands are determined by the crew leader when the plot has been reached. Debris and sediment samples are taken using a 0.1 m^2 ring within one 2x2 m area (cardinal point) from each stand.

If there is only one stand in the plot, then the default sampling is performed at cardinal point N, 1 m outside the plot boundary. If some of these (and their 2 x 2 m surroundings) cannot be reached because of e.g. trees with supporting roots covering the area, any other cardinal or sub-cardinal point within the same stand can be used.

4.5.3 Planning of field work according to tides

Field work in mangroves should be planned according to tide tables. Access of the area is hard or impossible during high tide. In particular, sediment sampling may successfully take place only when the sediment surface is above the sea level. Official tide tables are available for harbours. Both official and unofficial tide tables and tide forecasts can be found from internet. A prediction for October and November, 2013 for Kilindini Harbour is appended at the end of this document.

As tides are caused by the gravity of the moon, low tides occur approximately during the rise and setting of moon, while high tides occur at times of high moon. Figure 10 shows a large variability in the difference in water level at both low tides and high tides. The variability, or *tidal range*, is largest, i.e. the low tides are lowest during periods of new moon to first quarter, and from full moon to third quarter, and smallest during the *neap* tide periods.

Best periods of accessing the lowest elevation mangrove areas would therefore be during low tides. The higher elevation areas, close to the shore line, could perhaps be accessed also during the neap low tides. The field work should be carefully planned using the latest tidal predictions. It can be very dangerous if the team is captured by the rising tide. The spring tidal range in Kenyan coast can be almost as high as 4 m, and is well over 1 m at minimum during neap tides, see Figure 44. In some cases the best means is even to approach the site by boat during the high tide, wait until the water withdraws, and work until the next high tide, and leave the site again by boat. Alternatively, the team must reach solid ground in good time before the tide rises.

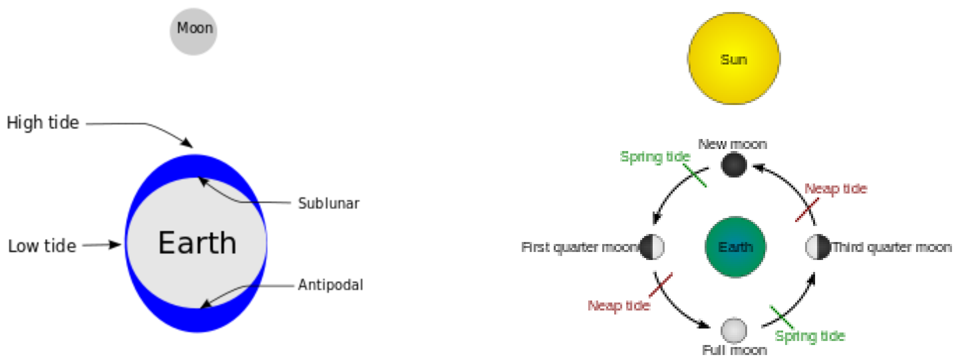


Figure 42. Status of sea tide in relation to the position of the moon.

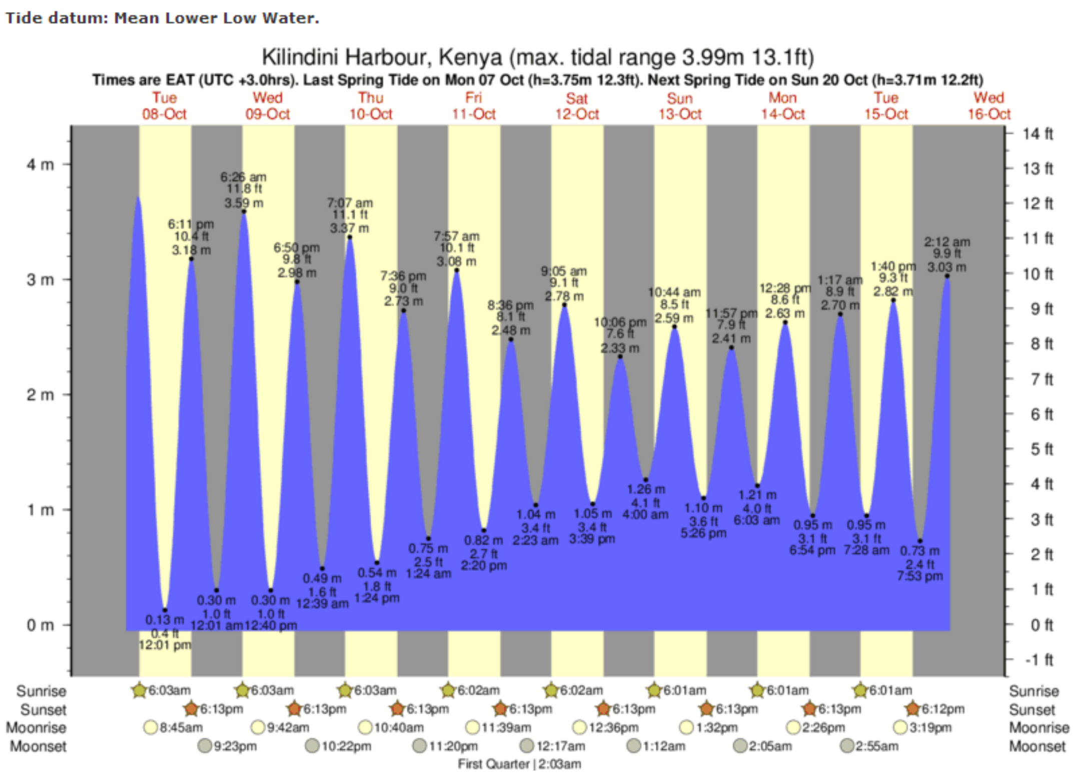


Figure 43. Tide prediction for Kilindini Harbour from Oct 8 to Oct 16, 2013.
Note the differences in occurrence of low tide with respect to the time of the rising and setting of the Moon. Low tides can therefore occur at different times of the day. Source: Wikipedia.

4.5.4 Litter and debris sub-samples for the laboratory

For determining of dry mass of the samples, debris (and litter) must be oven-dried in laboratory. Because the samples can be very big in size and difficult to transport and process, a small, representative sample of both fractions is taken, weighed, and stored safely in a 3-10 L plastic bag with a paper label containing the following obligatory codes that completely identify the sampling site: *Plot ID (*containing both *Cluster number* and *Plot number),* and *Stand*. The samples are transported to the laboratory at the earliest convenience together with the sediment samples.

The best means to preserve the samples would be keeping them refrigerated until drying in the laboratory. If this is not possible, the samples should be kept as cool as possible in darkness. Note that evaporation from a water-saturated ceramic pot or from a thick wet cloth covering the sample container keeps the samples cooler than dry storage only. Innovations are welcome.

4.5.5 Sediment sampling and characteristics

After the litter and woody debris samples are collected, the sediment core is taken. The following measures are taken to characterize the soil at each forest stand. The sample point where the characterization is made is marked on the field form.

Volumetric sediment coring

A 1.2 m long sediment sampler with a half-arc sampling tube is used. The diameter of the sampler is 7 cm. The sampler can take a cylindrical, ca. 1 m deep sediment sample, or core, when correctly operated. Four subsamples of the complete core are taken so that they represent sediment depth layers 0-15 cm, 15-30 cm, 30-50 cm, and 50-100 cm, respectively. Exactly 5 cm long subsamples with a volume of 192.4 cm^3 are taken from the centres of the listed depth layers. The cutting should be straight so that a perfect cylinder is formed from the subsample. Only then the subsample has the aimed volume. Any error in the shape (Figure 45) results in error in the bulk density of the subsample and consequently, the carbon stock estimate.

A good undisturbed location is selected for coring. The sediment surface has to be untouched. It is also important that tree roots and other obstacles will not prevent turning the handle when the sampler is driven into the sediment as follows.

1. The sampler is positioned on the selected spot and held as vertically as possible when pushed into the sediment (Figure 44 and 45). While force of two persons may be needed in driving the sampler down in the sediment, the corer may not be rotated or tilted during the push. The aim is to push the sampler's upper end down to the sediment surface, but not further in the sediment. If the sampler is pushed too deep, the core must be discarded. When the sampler is down in the sediment, turn around the sampler by the handle until the sampler begins to turn easily.

2. When the sample has been loosened by turning around the sampler, draw the sampler up carefully, in vertical position, avoiding any contact with the core (Figure 45). Do not turn the sampler any more while lifting it. That may contaminate the sample profile with materials from upper layers.

Figure 44. The sampler has been driven down in a tilted position, not in the proper vertical position. Tilting will probably result in a disturbed core that has to be discarded. Furthermore, the sampler is not taking the optimal sediment core because it is still too high.

Figure 45. The sampler is now properly driven into the sediment and can be turned around by the handle until it moves easily

3. Lay the corer on a horizontal position (Figure 46 and 47) and inspect the core. Look for loss of sediment especially from the parts of the core where the subsamples will be taken. It is good practice to take the subsamples from a single, complete core rather than using separate cores for different subsample depths. If the sample is not complete, or is disturbed, it should be discarded. At least an 80 cm long undisturbed core is needed, see point 5 below. If new coring has to be made, the sampler is washed clean in order to avoid contamination by materials from the earlier sample.

4. If no material is missing from the core, note if part of the sample has moved down on the sampler. In such case the width of the fracture has to be taken into account when positioning the subsamples. A complete, undisturbed core is always the best for further sectioning.

5. When the core is accepted, the location of the subsamples is determined and marked using a ruler and a knife. The KMFRI standard sample sections are used in NFRA mangrove sediment sampling to facilitate comparisons with earlier studies in Kenya and elsewhere. Mark the centre-points of the subsamples by measuring from the sediment surface downwards (Figure 48).

Figure 46. .Material is missing from the upper end of the core. It may still be possible to extract the 0-15 cm slice. The crack in the core may not mean lost sediment and discarding of the core. Inspect the crack walls for corresponding features on both sides.

Figure 47. The core is broken and the lower part of the core has moved downwards on the sampler. The positions of the lower subsamples need to be corrected taking into account the movement (=crack width).

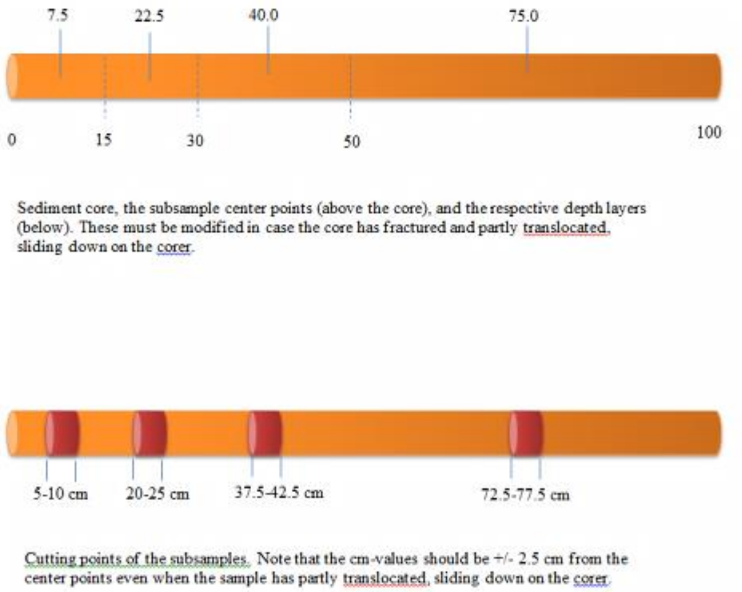


Figure 48. Mark the centre-points of the subsamples

6. When the centre-points have been marked, taking into account any translocations within the core, mark the upper and lower ends of the subsamples as shown above (Figure 48).

7. Record the Munsell colour codes for each subsample. Moist colours are defined in terms of hue, value and chroma according to Munsell's (2009) 'soil colour charts' to characterize the sediment profile.

8. Start extracting the subsamples. First remove excess sediment (> 80 cm) below the marked 50-100 cm subsample (72.5-77.5 cm).

   Removal of excess sediment gives space to operate the subsample. When only a thin slice of extra sediment remains below the lower marker of the subsample, carefully cut the lower end of the subsample, and remove the rest of excess materials below it.

   Cut the upper end of the subsample clean, and take the sample carefully from the corer (Figure 49). Now clean roots can be removed. Avoid loss of any sediment materials and unnecessary touching of the subsample. Take any remains belonging to the subsample corer. Place the complete subsample into a plastic bag and place a water-proof tape tag with location codes *Plot ID*, *Stand No.*, *Cardinal point*, and *Depth layer* written with a pencil on the lower end of the bag. Close the bag air-tightly. Weigh it using a kitchen scale and fill the field form. Repeat for the rest of the subsamples.

Figure 49. The excess bottom part of the sample has been removed and the subsample is cut to perfection using a sharp knife.

Depth of sediment

Penetration depth study is made at mangrove sites. The idea of the penetration study is to probe the sediment depth systematically using a 1.2 m steel probe rod. Average penetration depth is supposed to indicate the average (true) depth of the sediment layer if it is thinner than 100 cm. If the layer is deeper or equals to 100 cm, that is indicated by average penetration depth of 100 cm.

The rod is to be pushed into sediment down to 1 m depth. If the rod does not go to the full depth in sediment, but stops due to stone contact, the depth it could go is registered on the form each time. If the rod goes all the way to 1 m (100 cm), then 100 is recorded for that point.

It is important that a hard stone contact, not root contact is detected in case the steel rod stops. If in doubt, push the rod again just close to the point where it stopped, to make sure the contact was due to coral or rock basin, not due to tree root or dead wood buried in the sediment.

The 20 points where the rod is used are distributed per each Cardinal Point of the CCSP; the first point is 1 m inside of the CCSP perimeter, and the rest 4 points follow a line 1 m apart of each other towards to plot centre.

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Annex 1. Field Forms

Note: Printed forms from PDF files are used in the field. These are examples for this manual.

IC-FRA Kenya Page ____/____

Cluster No. [ ] Date dd / mm / yyyy

1a. TIME STUDY

Measurement [ ]

Stages:	Start time h	Start time min	End time h	End time min
Departure from camp to car park				
Departure from car park to sample plot				
Arrival to car park from sample plot				
Departure from car park to next car park				
Arrival to camp from car park				

Remarks

In the permanent sample plot

1b. FIXED POINTS

Fixed point 1

Type of object

Distance from plot center [ ] dm

Direction from plot center [ ] deg.

Description

Fixed point 2

Type of object

Distance from plot center [ ] dm

Direction from plot center [ ] deg.

Description

Fixed point 3

Type of object

Distance from plot center [ ] dm

Direction from plot center [ ] deg.

Description

Remarks

Form No. 1, Dated 11.07.2013

IC-FRA Kenya	Page ____/____

2. SAMPLE PLOT FORM

Date: dd | mm | yyyy

Cluster No.		Plot No.	

Walk between sample plots (from | to)

	from	to
Start time (h:min)		
End time (h:min)		

	Y	N
Permanent plot		

Group Leader

Start time (h:min)		County code	
End time (h:min)		County Name	
Accessibility code		District code	
Assessment method		District name	
Reference point location		Division name	

GPS X (Easting)		Direction to plot center		deg.
GPS Y (Northing)		Distance to plot center		m

Slope ____ % Slope orient. ____ deg Count of soil pits ____

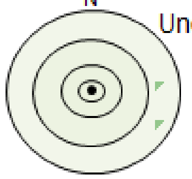
	number	file name in computer/database (Cxxx_Ss.jpg)
Photo		

Photo taken, from sample plot centre: Direction ____ Distance ____ m

Remarks

Stand description

Stand *					(A,B,C...)
Share	15	10	5	2	%
Owner					
Land use class					
Past land use class					
Time of change					
FRA land use/cover					
Past FRA land use					
Time of change					



Vegetation	
Undergrowth	

	Damage	Severity
(1)		
(2)		

	Human impact	years ago (1-5, 5+)
(1)		
(2)		
(3)		

Management proposal (1) ____ (2) ____ (3) ____

	C	N	E	S	W
Canopy coverage					

Plantation forests, planting year: [yyyy]

Remarks

Surrounding the sample plot

Erosion	
Grazing	
Water catch.	

Non-wood forest products and services

NWFP (1)	
NWFP (2)	
NWFP (3)	

Biodiversities observed		Specify
Biod. (1)		
Biod. (2)		
Biod. (3)		

** Fill own form for every stand*

Form No. 2, Dated 7.10.2013

IC-FRA Kenya	Page ____/____

Cluster No. ______ Plot No. ______ Date dd | mm | yyyy

Stand ______

3a. SHRUBS

Plot radius: 15 m

Shrub coverage ______

Mean shrub height ______ dm

3b. REGENERATION

Radius: 1.5 m (on two sub-plots)

Time study

Start time (h:min) ______

End time (h:min) ______

Reg plot: *1 = west, 2 = east, 3 = north, 4 = south*

No.	Reg plot	Sp. Code	Species name	Health	Count origin: seed	Count origin: coppice
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Remarks

______

______

Form No. 3, Dated 11.07.2013

IC-FRA Kenya

Cluster No. ____ Plot No. ____ **Time study** Start time (h:min) ____ Date dd mm yyyy

Stand ____ End time (h:min) ____

4. TREE FORM

					On permanent sample plot						Sample tree data *Every 5th tree in the cluster*				
Tree No.	Stand	Sample	Species code	Species name	Direction (deg)	Distance (cm)	DBH (mm)	Quality	Health	Origin (N/P/C)	**Bole height (dm)**	**Total height (dm)**	**Stump diam. (mm)**	**Stump height (cm)**	Remarks

Number of trees to be carried to the next subplot for sampling: ________

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Page ____/____

Cluster No. | | Plot No. | | Date | dd | mm | yyyy

Stand | |

5a. DEAD WOOD

Time study

Start time (h:min) ____

End time (h:min) ____

Plot radius: 15 m
Min. diam.: 10 cm
Min. length: 1 m

Tree No.	Stand	Species code	Species name	Diam 1 (cm)	Diam 2 (cm)	Length (dm)	Number of stems	Decay (S / R)	Remarks
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

S=solid, R=rotten

5b. STUMPS

Stand | |

Time study

Start time (h:min) ____

End time (h:min) ____

Plot radius: 15 m
Min. stump diameter: 10 cm

No.	Stand	Species code	Species name	Diam. (mm)	Height (cm)	Number of stumps	Years ago	Rea-son	Remarks
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

at stump top *(1-5, 5+)*

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Cluster No. ____ Plot No. ____ Date dd ____ mm ____ yyyy ____

Stand ____

Time study

Start time (h:min) ____

End time (h:min) ____

Plot radius: 10 m

6. BAMBOO

No.	Stand	Species code	Species name	Number of stems				Average diameter (cm)				Average height (5 dm)			
				Y	M	O	D	Y	M	O	D	Y	M	O	D
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															

Remarks

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Cluster No. ______ Plot No. ______ Date dd ____ mm ____ yyyy ____

Stand ______

Time study

Start time (h:min) ______

End time (h:min) ______

7. CLIMBER

Plot radius: 15 m

No.	Stand	Species code	Species name	Diameter (mm)	Height (m)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Remarks

Form No. 7, Dated 11.07.2013

Cluster No.		Plot No.		Date	dd	mm	yyyy
Stand						

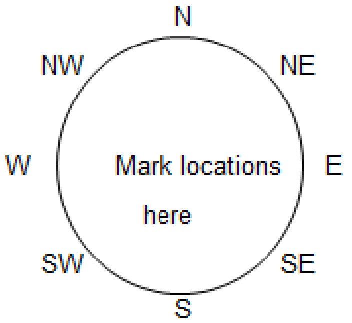
8. LITTER, DEBRIS AND SOIL

Time study

Start time (h:min)	
End time (h:min)	

Group leader ____________________

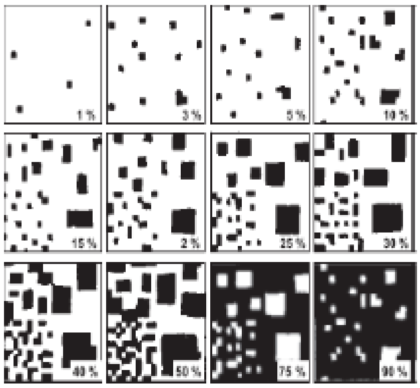
	1	2	3	4
Sampling locations				



Subtract bag mass!

Litter total		g
Litter subsample		g
Debris total		g
Debris subsample		g

Soil pit	1	2	3	4	
Type of organic layer					
Thickness of org. layer					cm
Effective soil depth					cm
Soil stoniness					%
Munsell color, hue					
value					
chroma					
Soil texture					



Soil composites

Layer	Subtract bag mass!		Number of volumetric subsamples obtained	Total volume of alternative corer	
0 - 10		g			ml (cm3)
10 - 20		g			ml (cm3)
20 - 30		g			ml (cm3)
30 - 60		g	non-volumetric		

Form No. 8, Dated 11.07.2013

9. CREW CONTACT DETAILS

No	Name	Title	Mobile phone	E-mail
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Form No. 9, Dated 11.07.2013

Annex 2. Slope Correction Table

Table A2. Slope corrections for distance measurements.
The table provides correct distances for horizontal distances in function of slope. E.g. the distance correction for a horizontal distance of 15 m with a slope of 20% is 15.3 m. For other horizontal distances, other than in the table, please use Factor f: multiply the horizontal distance by the slope correction factor f. E.g. aim is to find horizontal distance of 7 m on a terrain with slope of 50% → 7 * 1.118 = 7.83 m.

Slope		**Factor**	**Horizontal distance (m)**					
%	**degrees**	**f**	**2**	**5**	**10**	**15**	**20**	**50**
5	**2.9**	1.001	2.00	5.01	10.01	15.02	20.02	50.06
10	**5.7**	1.005	2.01	5.02	10.05	15.07	20.10	50.25
15	**8.5**	1.011	2.02	5.06	10.11	15.17	20.22	50.56
20	**11.3**	1.020	2.04	5.10	10.20	15.30	20.40	50.99
25	**14.0**	1.031	2.06	5.15	10.31	15.46	20.62	51.54
30	**16.7**	1.044	2.09	5.22	10.44	15.66	20.88	52.20
35	**19.3**	1.059	2.12	5.30	10.59	15.89	21.19	52.97
40	**21.8**	1.077	2.15	5.39	10.77	16.16	21.54	53.85
45	**24.2**	1.097	2.19	5.48	10.97	16.45	21.93	54.83
50	**26.6**	1.118	2.24	5.59	11.18	16.77	22.36	55.90
55	**28.8**	1.141	2.28	5.71	11.41	17.12	22.83	57.06
60	**31.0**	1.166	2.33	5.83	11.66	17.49	23.32	58.31
65	**33.0**	1.193	2.39	5.96	11.93	17.89	23.85	59.63
70	**35.0**	1.221	2.44	6.10	12.21	18.31	24.41	61.03
75	**36.9**	1.250	2.50	6.25	12.50	18.75	25.00	62.50
80	**38.7**	1.281	2.56	6.40	12.81	19.21	25.61	64.03
85	**40.4**	1.312	2.62	6.56	13.12	19.69	26.25	65.62
90	**42.0**	1.345	2.69	6.73	13.45	20.18	26.91	67.27
95	**43.5**	1.379	2.76	6.90	13.79	20.69	27.59	68.97
100	**45.0**	1.414	2.83	7.07	14.14	21.21	28.28	70.71
105	**46.4**	1.450	2.90	7.25	14.50	21.75	29.00	72.50
110	**47.7**	1.487	2.97	7.43	14.87	22.30	29.73	74.33
115	**49.0**	1.524	3.05	7.62	15.24	22.86	30.48	76.20
120	**50.2**	1.562	3.12	7.81	15.62	23.43	31.24	78.10
125	**51.3**	1.601	3.20	8.00	16.01	24.01	32.02	80.04
130	**52.4**	1.640	3.28	8.20	16.40	24.60	32.80	82.01