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1st National Forest Inventory Papua New Guinea

Field Manual

Papua New Guinea Forest Authority (PNGFA),
Ministry of Forestry

in cooperation with

Food and Agriculture Organization (FAO)

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with technical assistance from the Forestry Department, FAO

1st Edition

The PNG Forest Authority and the supporting partners under the Multi-purpose NFI Project dedicate the first NFI Field Manual to late Roy Banka, for his contribution and support. Roy was known as a passionate plant taxonomist who set the scene in the publishing arena through some of the world's renowned botanical journals and co-authored a few books, including 'Palms of New Guinea'. He served as the NFI Project Coordinator from September 2015 up until his passing in January 2017.

ABBREVIATIONS AND ACRONYMS

cm	Centimeter
CWD	Coarse Woody Debris
dbh	Diameter at the breast height (1.3 m)
DME	Distance Measuring Equipment
EC	European Commission
FAO	Food and Agriculture Organization
FMA	Forest Management Agreement
FRA	Forest Resources Assessment Programme
GHG	Green House Gas
GIS	Geographic Information Systems
GPS	Global Positioning System
ha	Hectare
JICA	Japan International Cooperation Agency
Lat/Lon	Latitude-Longitude Geographic Coordinate System
LLG	Local Level Government
km	Kilometer
m	Meter
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NTFP	Non-Timber Forest Product
OF	Open Foris (software)
OWL	Other Wooded Land
PDF	Portable Document Format
PFO	Provincial Forest Officer
Plot ID	Plot Identification (code)
PMU	Project Management Unit
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PoM	Point of Measurement
PVC	Polyvinyl Chloride
REDD	Reducing Emissions from Deforestation and Forest Degradation
RS	Remote Sensing
UNFCCC	The United Nations Framework Convention on Climate Change
UN	United Nations

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Acknowledgements

“Technical support to the Papua New Guinea Forest Authority to implement a multipurpose National Forest Inventory” project (GCP/PNG/006/EC) and “UN-REDD PNG National Programme” (UNJP/PNG/004/UNJ) collaborate with the Independent State of Papua New Guinea (PNG) to develop the first PNG NFI with technical support provided by the Food and Agriculture Organization of the United Nations (FAO). This field manual and corresponding inventory design is the combined product of the efforts of a large number of people and institutions.

The field manual compilers would initially like to extend their gratitude to all contributors to the development of this assessment and in particular thanks to all Papua New Guinea Forest Authority staff, technical advisors, and national consultants involved in the development of this manual and the field forms and in their efforts in further developing data specifications and definitions.

1 Introduction

The first Papua New Guinea (PNG) National Forest Inventory (NFI) will be an essential part of the establishment of the National Forest Monitoring System (NFMS). The project aims to significantly improve the capacity of the Papua New Guinea Forest Authority (PNGFA) on forest assessment, monitoring and the use of remote sensing technology. The project's financial support is provided by the European Union and Norway, and the technical assistance by FAO.

NFI field assessments are being implemented between 2016 and 2019. This project combines the collection of biophysical forest data about trees and other vegetation, as well as soil carbon and biodiversity data across country. The results of this assessment will be used to support national institutions to address issues of Reducing Emissions from Deforestation and Forest Degradation (REDD+) and Green House Gas (GHG) international reporting obligations.

The purpose of this field manual is to provide field inventory staff with structured information on the inventory techniques that will lead to the achievement of the intended output. This manual includes description of the sampling design and fieldwork instructions used in the data collection of biophysical attributes on sample plots. Particularly, this manual covers the measurement practices, list of equipment, field forms and data collection procedures for standing live trees, standing and fallen dead trees, palms and woody vines. Soil carbon and biodiversity data collecting will be covered in different measurement guidelines.

The forest inventory system and the manuals base on national experiences in PNG, and experiences of FAO projects in other countries. This large-scale forest inventory fills the requirements set for a NFI component as a part of a workable National Forest Monitoring System as demanded for REDD+ results based payment by the United Nations Framework Convention on Climate Change (UNFCCC).

The National Forest Inventory program consists of three phases, as described below.

Phase 1.

During the NFI design phase, a gap analysis was carried out to identify the current forest inventory practices, review the possible NFI design options, methodologies, plot shape/sizes and to come up with new and improved methodology for the PNG NFI. It was recommended after a wide consultation that

I. NFI adopts a Double Sampling Approach where the clusters were systematically selected by over laying a 4km x 4km grid over the entire land area of PNG.
II. The identification and location of plots within different forest types and the number of samples is determined through the Restricted Stratified Random Sampling Approach. Also remote sensing data was used in classifying all land into forest and non-forest land, accessibility and land-use categories.
III. Nested circular plot design is used for in field assessment.

Phase 2.

This phase consists of determining locations of a set of field samples distributed across the country's forest land, and further development of the NFI methodology and field manuals. In addition, a draft operation and coordination plan is produced to coordinate all activities.

Phase 3.

The third phase consists of the field implementation to collect biophysical data including vegetation census, detailed tree data, litter and soil data, biodiversity and non-timber forest product data (NTFP). All collected NFI data will be analyzed, reported and presented for national decision makers, policy analysts, forest planners and resource owners, and finally reported for UNFCCC.

2 Sampling approach

2.1 Sampling design

The main objective of the sampling design was to reach a representative, consistent and realistic design for forest assessment and monitoring in PNG. In collaboration with the recent JICA/PNGFA project "*Capacity Development on Forest Resource Monitoring for Addressing Climate Change in PNG*", PNGFA has developed the forest base map containing 17 confirmed broad vegetation/forest types in the country which form the basis for the stratification of the NFI.

For determination of the number of plots required by strata and location of the plots, natural forest was stratified to the forest types based on vegetative characteristics (Table 1). Among the major forest types, three classes namely 'low altitude forest on plains and fans', 'low altitude forest on uplands' and 'lower montane forest' were further divided to *primary*, *logged-over* and *other disturbance* types. However in the 'lower montane forest', logged-over and disturbed forests were combined due to a small number of logging activities in this forest type. Similarly, some other minor (or less common) categories were combined together in order to have a sufficient number of samples in each stratum.

Table 1. Stratification and number of clusters in strata

			Number of plots *	Required precision	Required number of clusters**		1000 clusters to be visited
				(95% CI)	Brown 1	Brown 2	
Low altitude forest on plains & fans	Primary		2,276	5%	80	60	150
	Degraded	Logged	1,306	10%	20	15	50
		Other disturbance	1,078	10%	20	15	50
Low altitude forest on uplands	Primary		3,732	5%	80	60	150
	Degraded	Logged	1,229	10%	20	15	50
		Other disturbance	1,528	10%	20	15	50
Lower montane forest	Primary (including 21 montane coniferous forest)		3,452	5%	80	60	150
	Degraded (inclding 14 montane coniferous forest)		1,344	10%	20	15	50
Swamp forest			1,141	10%	20	15	50
Woodland			815	10%	20	15	50
Dry seasonal forest			750	10%	20	15	50
Savanna & Scrub			592	10%	20	15	50
Littoral & Seral			274	20%	5	4	25
Montane (including 8 M/coniferous above 3000m)			242	20%	5	4	25
Mangrove			179	20%	5	4	25
					435	**327**	975+25 (M/coniferous forest)

* *Number of plots in Collect Earth survey (i.e., phase I sampling) (Forest and Land Use in Papua New Guinea 2013).*

** *Bases on statistical analysis using FRI Permanent Sample Plot data. Brown 1 & 2 are allometric biomass equations taken from Brown (1997) (in References).*

The NFI method is based on stratified cluster sampling. The first phase samples were set as a 0.04 x 0.04 degree grid (approx. 4.44km x 4.44km) over the whole country. In addition, a denser 0.02 x 0.02

degree grid was created for the three smallest provinces. There were a total of approximately 29,050 tracts (i.e. cluster points) in this systematic grid, but the number of tracks was reduced to 25,279 after remote sensing (RS) analysis. The main focus was to cover only the forested areas in the assessment.

2.2 Cluster and Plot Design

The sampling unit consists of five levels: 1) cluster, 2) plot for trees, stumps, and fallen deadwood, 3) regeneration and other vegetation than trees subplots, 4) quadrates for litter sampling and 5) a soil pit for soil survey (Table 2). The design is as follows (see Figure 1):

- Distance between clusters varies. The cluster and plot coordinates are plotted on the map and entered into Collect Mobile in the tablets;
- A cluster is a group of 4 sample plots. The coordinates of the center of the clusters correspond to those of the points selected in the sampling frame.
- Plots in a cluster are coded as C (Center), N (North), W (West) and E (East).
- Plot N, W and E are located 300 m from the center plot C.
- Plot N is directly to the North from the center plot C. Angles between Plots N, W and E are 120 degrees.
- Plots are nested circular shape. Trees with *dbh* ≥ 40 cm are measured in the plot radius of 25 m, trees with *dbh* ≥ 20 cm in the radius of 15 m, trees with *dbh* ≥ 10 cm in the radius of 10 m, and trees with *dbh* ≥ 1 cm in the radius of 1 m.
- Stump and fallen deadwood measurements in the circle with radius of 15 m.
- Regeneration subplots are four quadrates with sizes of 1m x 1m each. The regeneration subplots provide data about tree regeneration (i.e. about trees *dbh* < 1 cm) and other vegetation than trees. The centers of the regeneration subplots are located 15.5 m off of plot reference point to the cardinal directions.
- Bamboo measurements in the circle with radius of 15 m.
- Understory[1], litter, and coarse woody debris (CWD) biomass samples are taken using 1m x 1m clip plots (i.e., quadrates) outside of the plot. The centers of these subplots are located 25.5 m off of plot center to the cardinal directions. In these subplots, all material will be weighted separately in the field by subplots, but only 200 – 250 g sample will be collected in each subplot of each type of materials and taken for analysis.
- Soils measurements are taken using a soils pit and following a separate guideline (McIntosh *et al.* 2017, see References).

[1] Understory means here other vegetation than trees.

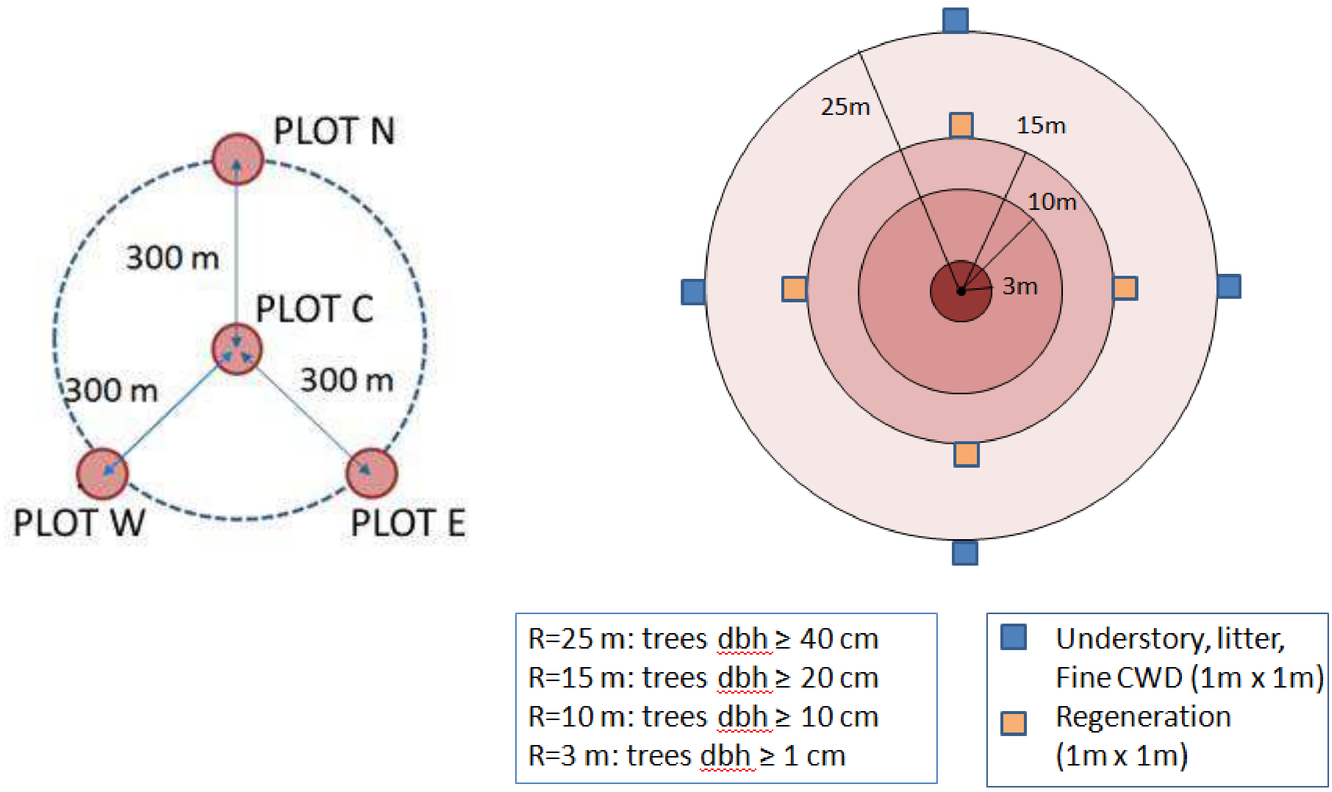

Figure 1. Cluster and plot design

Table 2. Survey unit specification

Unit name	Shape	Size (area)	Number
Cluster		-	One
Plot	Nested circular		Four per cluster
Subplot for regeneration		Four 1 m x 1m squares	Four per plot
Subplot for understory, CWD and litter	Square	Four 1 m x 1m squares	Four sample weights and four samples of 200 – 250 g of each type

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

2.3 Sample units

The primary sampling unit is a sample plot. The plots are grouped into clusters for practical reasons in order to take into account the reduced inventory costs. The measurement of one cluster should preferably be, if possible, measurable within a working day by a field team, but on some sites the work may require a second working day. Hence, in difficult conditions it may take more time to accomplish the measurements.

Sample plot information is collected in the plot area and some observations are also carried out on the plot's surrounding area. Information for each individual plot is collected and recorded, some examples of this data are forest type, natural and human impact, as well as data about regeneration, fallen deadwood, stumps and bamboos. The surrounding area is expected to be in some extent homogenous with the plot area with respect to the land use, forest type, or accomplished measures (0.5 ha minimum).

For each tree inside the plot, the species name, the breast height diameter, and tree status are accurately recorded. For every 5th tree in the plot, angle parameters to calculate the merchantable (bole) height, the total tree height is recorded, or alternatively direct height is recorded by a range finder. These trees are called as the height sample trees.

GPS measurements, other measurements and plot markings are done in such a way that re-measurement will be possible for quality control or future inventories.

3 Land use and vegetation type classification systems

Land use and forest type are recorded in the plot. If a plot is not accessible but the land use, forest type and forest status can be observed visually, this data needs to be recorded.

The classification system used to define each land use/vegetation type section is based on a dichotomous approach and it includes the following two levels:

- The first level is composed of the global classes designed for the assessment of forest and tree resources at the global level;
- The second level is country specific, and includes additional classes integrated to take into account national and sub-national information needs.

The global classes were developed within the framework of the Global Forest Resources Assessment (FRA) of FAO. The terms and definitions used in national assessments are chosen to harmonize national with global level forest assessments. The global FAO-FRA classes include:

- Forests;
- Other wooded land (OWL);
- Other land;
- Inland water.

The global classes ensure harmonisation of the classifications between countries for regional or global assessments. The second level of classification is designed to meet specific country needs of information.

PNG NFI data collection will also inform PNG's efforts to Measure, Report and Verify (MRV) Greenhouse Gas (GHG) emissions from Deforestation and Degradation. Therefore, field data collection needs also to adhere to land use definitions established by the Intergovernmental Panel for Climate Change (IPCC) for GHG reporting. Broad land use definitions established by the IPCC are:

- Forest land;
- Crop land;
- Grass land;
- Wetlands;
- Settlements;
- Other Land.

FAO-FRA and IPCC global classification systems and corresponding NFI forest types are shown in Table 3.

Table 3. Land use/vegetation type classification

FAO-FRA Category	IPCC Category	Definition of FAO-FRA (from FAO 2015)	Forest type in NFI
Forest	Forest land	Area ≥ 0.5 ha Tree crown cover ≥10% Tree height ≥ 5 m	Low altitude forest on plains and fans
			Low altitude forest on uplands
			Lower montane forest
			Montane forest
			Dry seasonal forest
			Littoral forest
			Seral forest
			Swamp forest
			Woodland
			Mangrove
			Mountain coniferous forest
			Plantation
Other wooded land (OWL)	Grassland	Area ≥ 0.5 ha Tree canopy cover 5-10% Shrubs/bushes canopy cover ≥10%	Savanna
			Scrub
Other land		Tree canopy cover <5% or shrubs/bushes <10%	
	Other land		
	Cropland		
	Settlement		
Water	Wetlands		
Other areas	Other land		

4 Preparations for the fieldwork

This section of the manual includes recommendations on preparing and carrying out fieldwork activities. The fieldwork is described step by step for a sample plot, together with recommendations on the data collection techniques.

> Notice: The entire data collection process will be under the control of the Field Coordinator. This will be a member of the PMU stationed in the province where field work is underway. All communication and data collection forms will be transmitted through the Field Coordinator.

4.1 Overview of data collection process

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

- Field measurements and observations in sample plots;
- Remote sensing, GIS and map data.

Those two sources of information imply the use of different methods and approaches that complement each other. The process for data collection is summarized in Figure 2.

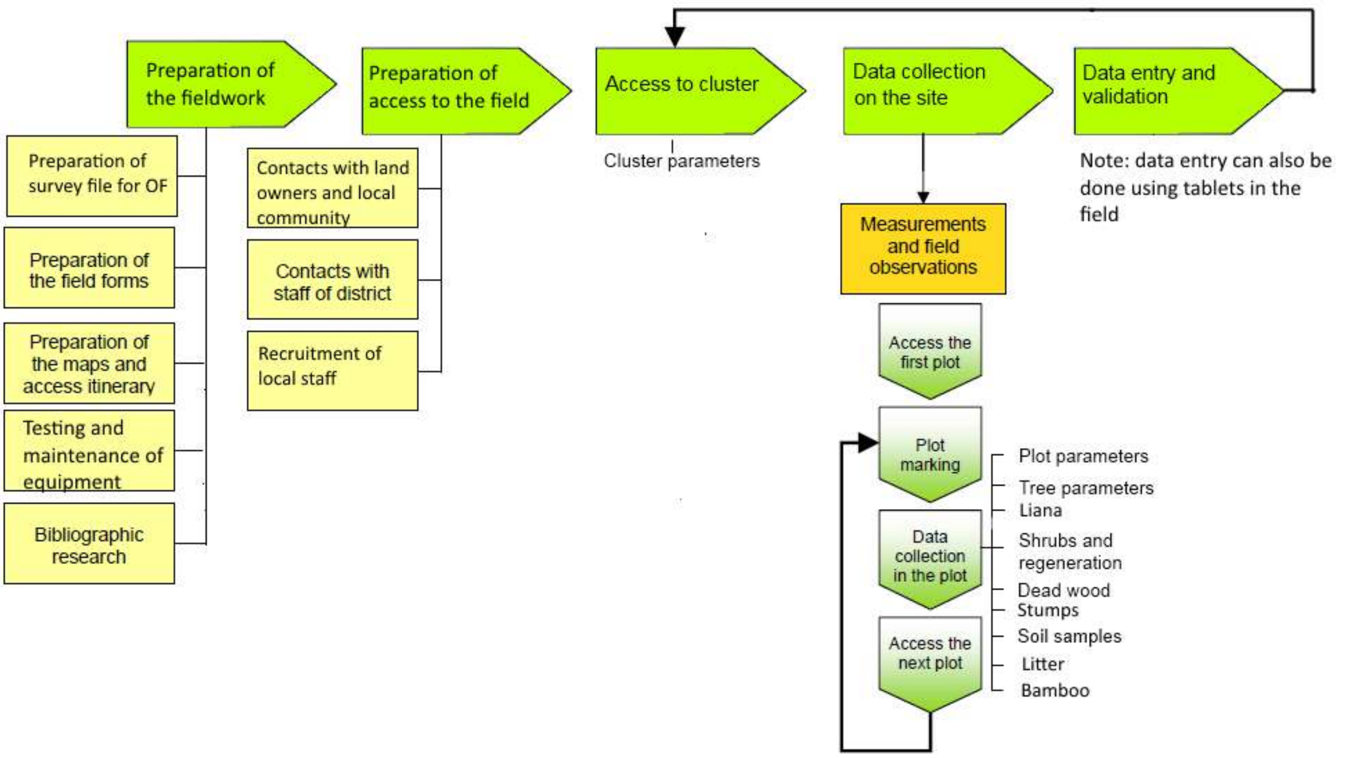

Figure 2. Data collection procedure

4.2 Field team composition and responsibilities

The field teams will be responsible for collection of data in the field and transmission of the field forms to the Project Management Unit (PMU) for the data entry and validation. The PMU is responsible of the nomination of the team members and the allocation of clusters for each team. The composition of the team is as follows:

- Team Leader; a qualified forester who will act as data recorder.
- There will be 7 members to undertake the field measurements (enumerators), as follows:
    - Assistant team leader: qualified technical assistant who shall be responsible for setting up of plots and measurement of tree diameter and height;
    - Botanist: qualified and experienced person who is able to carry out identification of all plant species and specimen collection;
    - Para-botanist: experienced technical staff to assist the chief botanist;
    - Biodiversity officer(s): qualified person(s) able to identify animals (fauna) and birds in the field;
    - Soils expert: qualified soil scientist with capability to collect soil samples;
    - Non Timber Forest Products specialist;
    - GPS expert.
- 2–3 local community members if possible. (One can act also as assistant tree identifier);
- Driver.

In general, a minimum of eight (8) personnel is considered appropriate number of members per team; however additional manpower can be hired on site bringing the total number to ten persons. The field team will all be answerable to the Field Supervisor. The field supervisor is responsible in ensuring that the standard of work by the team is of high standard, accurate and accomplished within the scheduled time frame. The field supervisor will be responsible to the Project Coordinator.

Responsibilities of the team members

For effective and smooth execution of the project, a structure and duty statement for the field personnel has been drawn up to give clear definitions of commands and responsibilities by each officer in charge. These responsibilities of each team member must be clearly defined. Their tasks are proposed as follows below.

The **team leader** is responsible of the following tasks:

- Organizing all the phases of the fieldwork, from the preparation to the data collection, and planning the work schedule in an efficient way. He/she has the responsibility of contacting and maintaining good relationships with the community and has a good overview of the progress achieved in the fieldwork; he/she has the responsibility of maintaining harmony and good working spirit within the team;
- Contacting local forestry officers, authorities and the community. Introduce the survey objectives and the work plan to the local forestry staff and authorities, and request their assistance to contact the local people, guides and workers;
- Specifically preparing for the fieldwork: carry out the bibliographic research, collect photocopies of the field forms, recharge tablets and collect the maps;
- Take necessary measurements and observations. The team leader is responsible for the quality of the work of team members.

- Taking care of logistics of the team: organize and obtain information on accommodation facilities; recruit local workers; organize access to the clusters;
- Filling in the forms and take notes;
- Ensuring that field forms are properly filled in and that collected data are reliable;
- Take data backup from tablets;
- Organizing meetings after fieldwork in order to sum up daily activities;
- Organizing the fieldwork safety;
- Submitting data to the PMU, soil and biomass samples to the laboratory;
- Submitting tree samples for identification;
- Weekly updates on progress to the PMU.

The **assistant of the team leader** will:

- Help the team leader to carry out his/her tasks;
- Take necessary measurements and observations;
- Make sure that the equipment of the team is always complete and operational;
- Supervise and orient the workers;
- Filling in the forms and take notes as required;
- Take-over in the team leader's absence.

The team members (enumerators) will carry out the field measurements. They measure/assess forest and tree attributes (tally and sample height trees, fallen deadwood, stumps), regeneration data (i.e. number of tree seedlings), land use, vegetative cover and status. Together with the soil expert, they also collect soil and biomass samples.

The **botanist(s)** will focus on species identification, specimen collection, storage, and identification, and helping enumerators as time permits. He will be ably supported by the **para-botanist** who shall also act as botanist in his absence.

The **biodiversity officers**[2]:

- Ornithologist – a qualified person who is able to identify and collect information on bird species in the field.
- Entomologist –a qualified person who is able to identify animals/insects (fauna) in the field.

The **soil specialist/expert** is a qualified soil scientist with capability to collect and prepare soil samples for laboratory analysis.

NTFP specialist is a specialized person with sound knowledge on non-timber forest products, and who is able to identify various plants and their uses.

GPS expert is a specialized person with good practical knowledge on the use of GPS to locate plots in the field.

[2] Responsibilities of biodiversity officer(s), soils expert, and NTFP specialist are defined in the separate NFI guidelines.

The **community members** are assigned the following tasks, according to their skills and knowledge on local tree species, language and practices:

- Help to measure distances;
- Clear vegetation to facilitate access and visibility for technicians;
- Provide the common/local name of tree species;
- Inform about access to the plots;
- Provide information about the forest uses and management;
- Carry the equipment and soil and biomass samples;
- Carry camping equipment and set up camp;
- Cooking.

The above description is simply the normal way of working, but it is not necessary to follow it exactly. Teams should choose their organization according to the specific skills and efficiencies of the team composition, optimizing for quality and time. Seedlings, sample height trees and deadwood etc. can be measured by any capable team member.

The **driver** is responsible for the vehicle and passengers, and he will guarantee the following:

- Take care of the vehicle maintenance and security;
- Assure there is adequate fuel and extra fuel supplies when needed (using Jerry cans);
- Help in loading and packing the equipment;
- Ensure equipment is secure;
- Transport the team members safety from and to the field;
- Be ready in case of emergency.

4.3 Preparation phases

The preparation of fieldwork consists of the following phases:

A. Bibliographic research;
B. Preparation of the field forms and maps;
C. Field Coordination responsibilities assigned;
D. Quality Assurance Team established and activated;
E. Soil survey and analysis coordinator activated;
F. Field equipment (maintenance, checking);
G. Contacts to provinces and local communities.

4.3.1 Bibliographic research

Auxiliary information is necessary to collect at the preparation phase. Existing reports on forest and natural resource inventories at the target area, farming systems, national policy and forestry community issues, local people, etc. have to be studied to enable the team members to understand and to build better knowledge on the local situation. If a target cluster is located in a forest plantation, the forests' history and management plans need to be examined, especially planting year and time of previous treatments are important details to be found.

4.3.2 Preparation of the field forms and maps

The PMU will ensure that the necessary field forms to cover the clusters are prepared and assigned to each team. The Team Leader must ensure that enough forms are available to carry out the planned field data collection. The forms are described in detail in chapter 6.

The use of secondary data sources, particularly maps and existing management plans, is necessary to determine information such as names of administrative centre (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.

Maps and printed aerial photographs/satellite images covering the study area should be prepared in advance to help the orientation in the field. These may be enlarged and reproduced, if necessary, but a scale bar needs to be printed on maps. The plots' locations in the cluster are to be indicated together with their respective coordinates in latitude/longitude system[3].

Prior to the field visit, each team must plan the itinerary to access the cluster (e.g. using printed *RapidEye* (from year 2012) or *Google Earth* images, road and topographic maps) which should be the easiest and least time consuming. Sample plot coordinates and topographic maps should be converted to GPS on 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.

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.

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

4.3.3 Coordination of field work

A **Field Coordinator** from the Forestry Department will always be stationed close to the provinces where field work is active. The designated Field Coordinator will coordinate all field activities, and will be the first point of contact for field teams. The nominated Field Coordinator (to be nominated by the Forestry Department) will be the first point of contact for field teams.

The Field Coordinator will be responsible for coordinating and executing all field activities, and finally to collate, validate, and transfer all field data to the PMU. He/ she will provide the logistical support and supervision to the field personnel and to monitor, supervise, and provide backstopping support to the fieldwork including field report checks, in order to ensure timely completion for field work, data quality and homogeneity among field teams, The Field Coordinator should also facilitate the procurement and maintenance of field tools and equipment for the field teams, and provide immediate response and support to field teams if an emergency occurs. The Field Coordinator will also control and coordinate the data collection process, the transfer of field forms to the PMU, and the validation of field forms in preparation for data entry. The designated Field Coordinator will provide bi-weekly field work progress reports to the PMU.

4.3.4 Quality Assurance

A designated Quality Assurance (QA) team will ensure that the technical quality of field measurements adhere to this manual. The QA team visits completed NFI clusters and undertakes a complete control measurements for comparison with measurements from the field team. The QA team then examines the data collected by the field teams relative to the control measurement and completes a checklist. A specific booklet for the QA team should be followed; this consists of the field

[3] Lat/Long coordinates are given and recorded in decimal degrees, with 6 digits.

forms and a QA checklist. The control measurement and comparison should be done in the cluster within 1–2 weeks after the measurements of the ordinary team. The purpose of the control is to ensure that the team has done measurements according to the instructions. Furthermore, results of control measurements can be used for training purposes, that is, to find out issues which were unclear for the teams after training. Control measurement and checklist is for feedback and for making a conclusion report of all QA measurements in the reporting period.

The QA field team will consist of experts in the various disciplines (botany, soil science, forest inventory) required for the field work, and will consist of the following members:

- Team leader (inventory expert);
- Soil science expert
- Botanical expert
- 1-2 local community members, if possible. (One can act also as assistant tree identifier);
- Driver.

4.3.5 Quality Assurance work flow

The Field Coordinator works in conjunction with the QA team to determine a timetable for control clusters. Field coordinator also hands over a copy of the original field forms filled by the ordinary field crews to the QA team.

The QA team hands over the completed QA booklet to the field coordinator. Feedback is given both to the field team and field coordinator who is in charge of the field work. The feedback is given to the original field measurement team on the same day as the QA team visits the cluster when possible. The QA team leader decides which way the feedback is given, in a meeting or by phone. The differences, shortcomings and errors are gone through in the feedback session. Also reasons behind errors are discussed. Field coordinator decides if more control is needed for the crew.

The implementation of control measurements is important for the Quality Assurance. The QA is especially important for field crews having new members and the feedback is a part of training. The field crews are able to correct the possible errors in their work when they get immediate feedback from the QA crew.

4.3.6 Field equipment per team

The equipment needed by each field team are described in Table 4.

Table 4. Equipment for the field teams

Equipment	Number required	Comments
Measurement tools		
GPS receiver	1	+ extra batteries + charger
Measuring tapes (fiber glass), 20m, 30m, 50m, 100m	2	Metric, 1 cm units
Measuring tape, 2 m	1	For measuring soil depths of the soil pit, mm scale
Diameter tape	1	mm scale
Caliper	1	mm scale
Suunto compass	1	Degree scale (0-360)
Suunto clinometer	1	with 20m and % scales to measure both tree height, in meters; and slopes in degrees.
Spherical densitometer	1	Canopy closure measuring equipment. Concave model.
10 m height pole	1	For tree height measurements
Aluminium ladder	1	For tree diameter measurements
Range finder, Distance Measuring Equipment (DME) or Vertex	1	For distance measurements. Range finder also for height measurement.
Tablet + charger	1	Electronic field data recording equipment
Waterproof bags	As necessary	To protect measurement instruments and forms
Shovel	1	Used for excavating the soil pit
Spades	3	
Crowbar	1	
Soil profile scale	1	Soil sampling. Marked at 10 cm intervals
Builders' trowels	3	Soil sampling
Square-ended paint scrapers	2	Soil sampling
Munsell Soil Color book	1	For soil color assessment
"Rowfit" soil sampler	1	Soil assessment
Utility Pail	1	For collecting and mixing biomass samples
Weight measuring scale	1	For measuring the weight of biomass samples
Zip seal plastic bags	several	For storing composite soil samples (see separate manual)
Digital camera + extra batteries, and charger	1	For photographs of plots, reference points, soil pit wall and unknown species;
Bush-knife	As necessary	
Pocket knife	1	Deadwood decay assessment
Kitchen knife	1	Soil sampling
Small branch cutter	1	For collecting understory samples

Equipment	Number required	Comments
30-50 cm long metallic pin	As necessary	Galvanized steel bars for plot marking
50-100 cm long PVC pipes	As necessary (17 per a plot)	For temporary plot radius marking
Clothing		
Boots and field outfit	For permanent team members	
Helmet	For permanent team members	Should always be worn in forested areas where there is overhead vegetation
Rain coats	As necessary	
Gloves	As necessary	
Documents, papers		
Field forms	As necessary	Use water-proof paper. Keep in plastic covers for rainy days.
Code check list with slope correction table	As necessary	Needs to be laminated
Field manual	As necessary	See separate guidelines for soil sampling
Topographic maps, field maps and printed aerial photo/satellite image maps	As necessary	
Pencils and markers	As necessary	
Supporting board / writing tablet	1	To take notes
A4/A3 size flipchart	1	For photo identification
File Folder	1	
Materials for botanical collections	As necessary	For collection of samples (plants/ leaves)
Other equipment (camping, security, communication)		
Mobile phone	At least 1	Not procured – use personal mobile phone (credit will be provided to the team leaders for communications)
Satellite phone	1	One for the team leader
First Aid Kit	1	With phone numbers of hospitals / emergency. Extra First Aid Kits should be kept in the camp.
Flashlight and batteries	As necessary	
Camping equipment	1	
Jerry can	As necessary	
Rucksack	As necessary	30 or 45 litters back packs; for carrying and keeping filed forms
Water and food	As necessary	

The list of equipment is specified by measurement type in the next table (Table 5).

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Table 5. Equipment by measurement type

Measurement type / Activity	Equipment required
PLOT	
Plot location determination	GPS, maps, list of plot coordinates
Tree location determination	50m measuring tape, slope correction table, compass, range finder / DME / Vertex
Plot establishment	GPS, Metal pin, compass, measuring tape, PVC pipes
Slope	Suunto clinometers, Vertex
Photo documentation	Digital camera, flipchart
Canopy closure	Densitometer
TREES	
Species name	
Tree diameter	1.3 m stick; Diameter tape (mm scale)
Tree height	Clinometer & 10 m height pole / Range finder
Bole height	Clinometer & 10 m height pole / Range finder
STUMPS	
Stump diameter	Diameter tape / Caliper
Stump height	Measuring tape
FALLEN DEADWOOD	
Deadwood diameters	Caliper
Deadwood length	20m measuring tape
Decay class	Pocket knife
REGENERATION	
Number of seedlings	Measuring tape
BAMBOO	
Species name	
Bamboo average diameter	Diameter tape or caliper
Bamboo average height	Clinometer & 10 m height pole / Range finder
UNDERSTORY, COARSE WOODY DEBRIS, LITTER	
Understory, Litter, CWD sample	Utility pail, measuring tape or sticks
Understory, Litter, CWD weight	Weight measurement scale
SOIL	
Follow separate soil sampling manual	

The condition of the inventory equipment needs to be verified prior to field work and missing or damaged items should be replaced with new or fixed tools.

4.3.7 Contacts

Each field crew, through its leader, should start its work by contacting PNGFA regional and provincial staff in the area where the clusters are located. These local staff may help contacting the authorities, community leaders 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.

A recommendation letter written by Provincial Forest Officers (PFOs), asking for support and assistance to the field crew members should be issued to facilitate the work.

4.4 Data collection in the field

4.4.1 Introduction of the project to local people

If the cluster area is inhabited, the team must establish contact with local people and on arrival to the site, meet with contacted persons and others, village representative(s), closest government institution, land owners and/or people living in the cluster area. It is recommended to contact the local leaders well before visiting the area in order to inform or sensitize them of the visit and request permission to access the area.

The team 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 useful to facilitate the discussion. It is important to ensure that both local people and the field team 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 project introduction are mentioned in the next text box.

Key points to be stressed during the presentation of the project to the local people are as follows:

- An objective of this 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 objective is to generate reliable information for improved land use policies that takes 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 measurements of the forest site, trees and soil. Measurement examples to be mentioned may be: tree diameter and height, as well as forest species composition, fallen deadwood, and soil carbon.
- Some of the clusters surveyed in the country will be monitored in the future, with the aim of assessing land use changes and development of forest resources.

Besides the presentation of the project, this initial meeting aims at resolving logistic matters. After the general introduction, access to the forest and other lands, as well as food and accommodation issues will be discussed.

4.4.2 Access to plot

The locations of plots will be pre-drawn on topographic maps. Clusters and plots are pre-numbered/coded and provided on the inventory base map and in Collect Mobile in tablets. Reference numbers of the plots are indicated on the printouts of topographic maps and as waypoints in the GPS receivers.

At the place of leaving the vehicle, the team records the accessibility of the cluster, the GPS coordinates of the vehicle, the date, the departure/start time, bearing and distance to the 1st plot of the day, the plot to which they are headed and the time of return to the vehicle on the *Form F1*.

4.4.3 When the sample plot is inaccessible

In some instances, the complete sample or some part of it will not be accessible because of factors such as dangerous slopes, denied access, or physical safety concerns. In some cases small unmapped local features such as water bodies may be encountered. The field crew is not expected to sample beyond what is considered reasonable and safe. **The safety of the field crew is the first priority.**

A cluster is accessible if any plot in it is accessible. When a sample plot is dropped, complete the *Form F2* and mark that sample plot as inaccessible. Specify the reason why the sample cannot be established, for example:

- access to plot is too dangerous;
- plot would be located in an unsafe area;
- plot would be located in a river or lake;
- permission denied to access private land.

If a plot is not accessible but visible, then its land use, forest type (if applicable) and forest status (if applicable) need to be recorded on the field form or into Collect Mobile.

4.4.4 Arrival at the plot

The position of all four sample plots in the cluster needs to be precisely located and marked. On all plots, a permanent marker (i.e. galvanized metal pin) is placed into the ground exactly at the center point of the plot**.** If for any reason (presence of rock etc.) the marker pin cannot be placed at the center, the permanent marker should be placed as close as possible to the center of the plot and this should be noted in the field form accordingly (field '*Remarks*).

If the GPS signal in a forest is poor due to dense canopy cover at the plot's center and GPS reading cannot be accessed, the team must record the GPS coordinates at the **closest available position as the reference point** and then measure the bearing and distance **from the plot's center to this reference point**. Distance can be measured with a measuring tape or using a range finder if there are no obstacles between the plot center and the reference point. Notice the following rules:

- The coordinates of plot marker position are determined with the help of GPS receiver (as averaging positions of several measurements during 10-15 minutes). Then, an identification code will be assigned to identify each points measured by the GPS as follows:
  [Cluster number] + [Plot code], e.g. for cluster 11355, plot C => **11355C**
- A marker pin should be positioned in the ground.

4.4.5 Data collection in the plots

Rods or PVC pipes with coloured ribbon can be placed to show the nested plot dimensions in order to help the identification of the trees within the plot's four sectors. Different attributes are collected according to the data collection rules described in the next chapters. In addition, the use of Vertex Laser model is briefly described in Annex 3 and Nikon Forestry range finder in Annex 4.

Trees located at the border of the plot will be considered as inside the plot if the estimated centre point of its base is inside the plot boundary. If the stem centre is exactly on the plot boundary then it will be considered alternately in and out. Similarly, if a living tree is leaning, it is considered inside the plot if the estimated centre point of its base is inside the plot boundary.

Once the work on the plot is completed, any flagging tapes are removed and the ending time is recorded in *Form F2*. The team walks to the next plot with the help of the GPS navigation.

4.4.6 Photos of the plot

Each inventory team uses the digital camera or tablet's camera to record four views from the plot. The photos are taken to the cardinal directions from the plot center. Photos will be used to document the plot characteristics and its surroundings as vegetation type. The camera setting should be set to *Auto* position, and with using wide focus. In any case, avoid taking photos directly against the sun light. The photo should include both some soil and vegetation, if possible.

The photos captured with tablet and Collect Mobile are automatically stored into the database. If using field forms, data about each photo are recorded on the *Plot Form*. The recorder writes down the image ID Number in the camera's memory stick. In the office the photos are transferred from the camera into a separate '*<Province Name> NFI Photos*' folder, and where each photo is renamed as follows:

C*xxx_p_*z.jpg

Where *xxx* refers to cluster number, *p* refers to plot code, and *z* refers to the compass direction (N/E/S/W) of image captured on the plot.

4.4.7 Handling of data before data entry to the database

Team Leader or Regional Coordinator is responsible to take photocopies or scanned copies of field forms right before these are given to the data entry staff. The original forms are sent to PMU for filing. Scanned copies should be in PDF format, one cluster in one file, and file name should contain the cluster number.

If data is taken from tablets, then copy of exported back-up file should be sent to PMU. If file size is too big to be attached to email, then DropBox or Google Drive should be used for data transfer.

All previous works should take place within 1–2 days after data is collected from the field teams.

5 Measurement techniques

5.1 About entities

A tree is inside the plot, if the estimated centre point of its base is inside the plot boundary. All trees within the plot's borders are recorded, both live and dead trees. Palms are recorded as trees, and data about lianas and other climbers are also recorded on the tree form if they fill the criteria set for the diameter in nested plots. Bamboo data are recorded separately.

In case of a dead tree, the stem is recorded as (dead standing) tree if it has some branches in its canopy (Figure 3). However the maximum stump height is set to 250 cm in the data entry software, so stumps higher than 250 cm are recorded as "broken top dead trees" in the Tree Form.

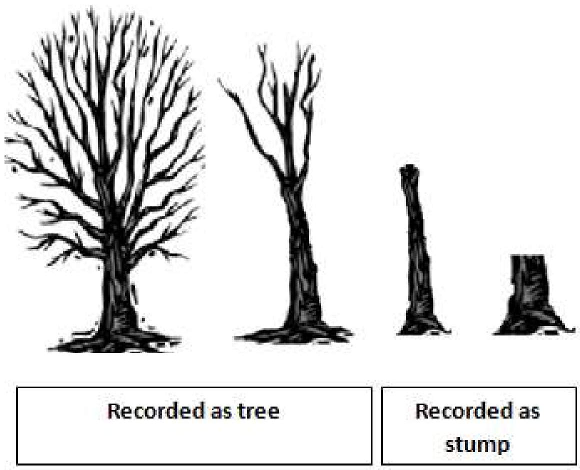


Figure 3. Detecting whether a dead stem is a tree or a stump

5.2 Species

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

The recording 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 species is completely unknown, enter '***Unknown***';
- When taking samples of unknown species, always write cluster, plot, form number, and *regeneration/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.

For database management each species in NFI has been given a code. The codes will be filled in automatically when you type in the first 4-5 letters of the species name or select it from a dropdown list using a Collect Mobile.

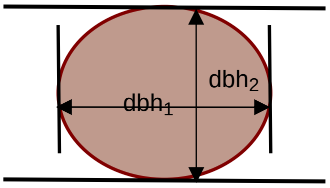
5.3 Diameter

Tree diameter at the breast height (*dbh*) is the most common and important measurement made on trees in forest inventory. A 1.3 m long stick should be used when determining the breast height up from the ground level. Measurement may be carried out **using the diameter tape** and the device should have metric scale and the smallest unit in millimeters.

To measure ***dbh***:

- Determine where the ‘breast height’ or 1.30 m is on the stem using the 1.30 m long stick and make a mark. Take the diameter reading at that point (see illustrations in the following page).
- Remove any loose or flaking bark from the tree bole to allow for more accurate reading to be taken. This also includes vines, lianas and other debris from around the tree stem.
- Make sure that the measuring tape is not twisted and it is well stretched around the tree in a perpendicular position to the stem.
- Tree diameters are to be measured over bark to the nearest 1/10 centimeter (0.1cm).

If a caliper is used, see the measurement rule for a non-circular shape trees in Figure 3.



$$dbh = (dbh_1 + dbh_2)/2$$

Figure 4. Non-circular tree measurement with caliper

Whilst you are out in the field undertaking the inventory, you are most likely to encounter a number of measurement scenarios that you will have to deal with. The illustrations presented in the next page are common and highlighted to guide you on how to measure a tree breast height diameter under each circumstance.

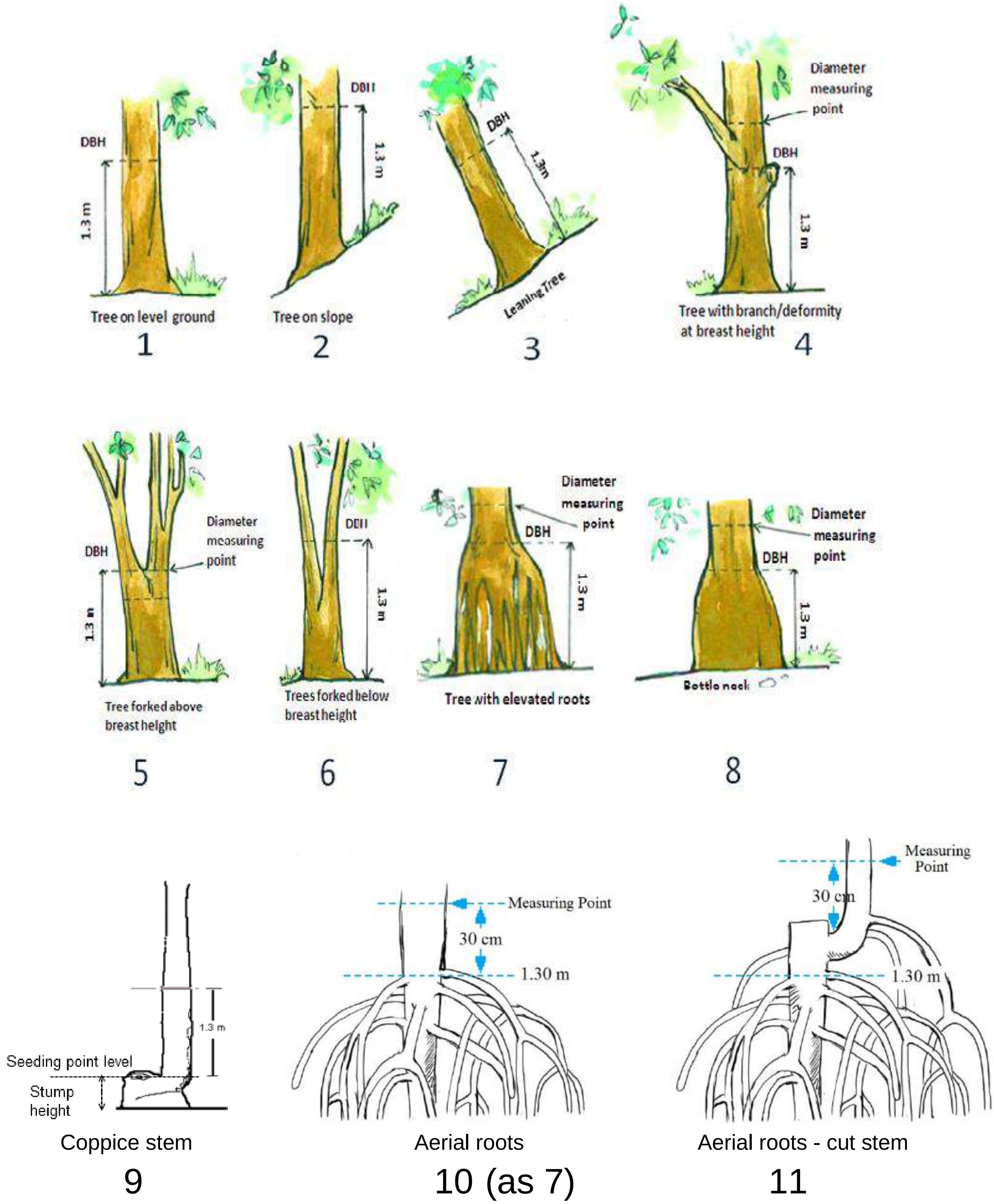


Figure 5. Measuring of breast height diameter (*dbh*)

Illustration 1. *Tree on level ground (flat terrain*)

Determine where the ‘breast height’ or 1.30 m is on your 1.30 m stick and make a mark. Take the diameter reading at the 1.30 m point as illustrated. If a tree is leaning in flat terrain, the measurement point is at that side where tree leans (as in Illustration 3).

Illustration 2. *Tree occurring on slope*

Stand on the uphill side of the slope/tree, wrap the tape around the tree at 1.30 m with the diameter measurements showing, being careful not to twist the tape.

Illustration 3. *Leaning tree - measure at right angles to the lean of stem*

Read the diameter measurement from where the diameter scale starts, as the graduations on the tape do not commence from the very end.

Illustration 4. *Tree with branch at 1.3 m*

When there are swellings, bumps or branches occurring at 1.30 m, the diameter should be measured at an equal distance above and below 1.30 m and the two measurements averaged.

Illustration 5. *Forked tree (≥ 1.3 m)*

For trees forking at or just above 1.30 m, measure diameter below the fork at the point of minimum bole. The tree is considered as a single stem.

Illustration 6. *Forked tree (< 1.3 m)*

For trees forking below 1.30 m, measure each stem at 1.30 m and treat them as two separate trees. A forked tree can be dead or alive; record this information to *Status* field.

Illustration 7. *Tree with tall stilt roots*

For trees with stilt roots taller than 1.30 m, diameter is measured 30 cm above the upper root. Record also the measurement point ((PoM) for *dbh*.

Illustration 8. *Tree with high buttresses or swollen base*

Trees with high buttresses or swollen base like a bottle neck type formation; the diameter is measured at 30 cm above where the swelling ends. Record also the measurement point for *dbh*.

Illustration 9. *Coppice tree*

Coppice shoots are considered as forked trees. The diameter measuring point is 1.30 m above the seedling point.

Illustration 10. *Tree with aerial roots exceeding 1.30 m from the ground*

Diameter is measured 30 cm above the upper root. Among *Ficus* genus there are some species of which often contain prop roots above 1.30 m from the ground. Some upper roots are well established in the soil, while others have just started forming, or are formed from within the canopy. Therefore only roots originating from the central stem and touching the soil are considered, when pointing out the ‘upper root’.

Illustration 11. *Cut tree with aerial roots exceeding 1.30 m from the ground.*

Other special cases

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

One special case is a **living tree lying on the ground with branches growing from the main stem** (Figure 6). It is recommended to determine first if the main stem whether it is above the litter or not. If the main stem is above the litter, use the same rules as for a forked tree; if the major part of the main stem is under the litter, do not measure it as a tree, but treat each branch as a separate tree and measure height 1.3 m above the seedling point of each branch (i.e. new stem).

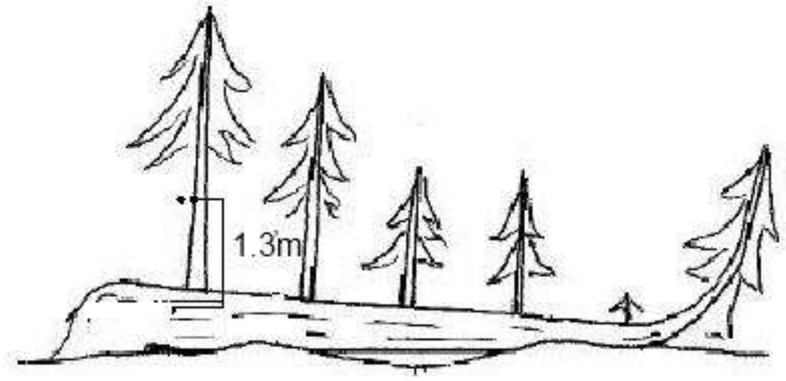


Figure 6. Diameter measurement of living tree lying on the ground with branches growing from the main stem

5.4 Height

Tree height measurement may be carried out by means of several instruments (as Suunto, Vertex, range finder). *Suunto* clinometers and a 10 height measuring pole are used by the NFI field teams.

Tree heights are recorded for every 5th tree in the plot. In case of a palm, standing dead or broken top tree its top height is always recorded. Heights can be recorded using three methods:

1) **Trees higher than 10 m**. Record as angles from three points of the tree: base, bole and top height points. In addition, the angle is recorded to the top of the 10 m long height pole that is kept standing next to the tree, and its lower end is at the same level as tree base (Figure 7).
2) **Trees height $\leq$ 10 m, or liana**. Direct height measurement (in 0.1 meters) using the 10 m long measuring pole.
3) **Range finder** direct measurement.

Base 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.

Bole height refers to merchantable or utilizable 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.

The first height measurement method is adopted from a JICA project ("Central Suau Inventory"). This method is fast and convenient under tropical forest conditions as it does not require taking distance measurements. Thus, this method eliminates the need to measure horizontal and slope distance from the base of the tree to the height reader. The measuring devices are a Suunto clinometer and a 10 m height pole.

Suunto clinometer will be read on the left side of the instrument in degrees (°). As a general rule, clinometer readings must not exceed 50°, implying that the person taking the readings has to move further away from the tree as much as possible. This will enable him/her to have a clear line of site to the top of the tree as this also helps in reducing instrumental error. This height measurement technique caters for all different situations in the field regardless of whether you are measuring tree heights on flat ground, downhill or uphill.

The following procedures apply with Method 1:

1. An observation position is located from where the observer's eye can clearly observe the base of the tree, the point of merchantable height and the top of the tree.
2. For each height sample tree you need have to take four readings (in degrees);
   1) Take the reading to the very top of the tree.
   2) Take the reading to the tip of the 10 meter height pole.
   3) Take the reading to the merchantable height of the tree.
   4) Take the reading to the base of the tree.

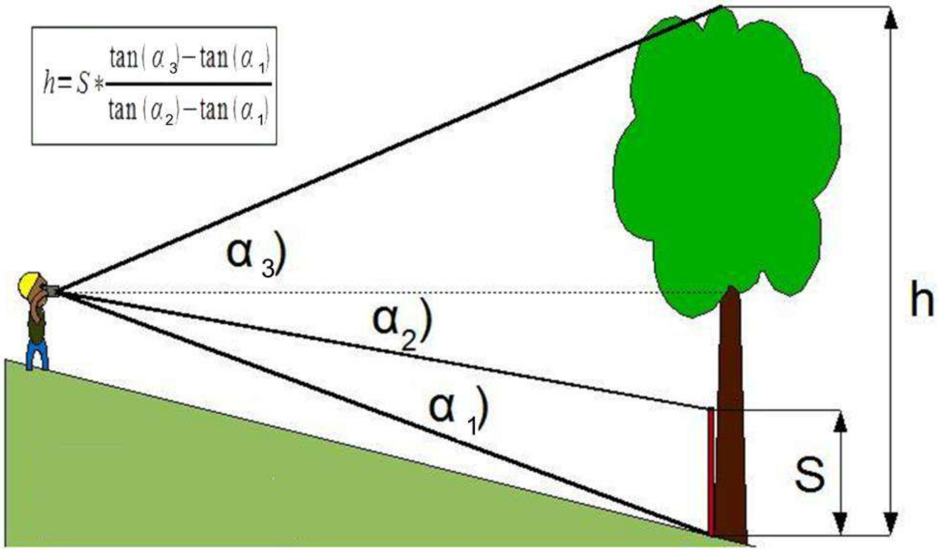


Figure 7. Tree height measurements

The formula shown in Figure 8 will be used to calculate the tree height (*h*), when *S*=10 m.

Point	Reading (degrees)	Reading (radians)	tan()
base	-7	-0.12217	-0.12278
10m	12	0.20944	0.212557
top	30	0.523599	0.57735
S	10	m	
height	**20.9**	m	

Figure 8. Example on tree height calculation in MS Excel

When using the **Vertex Laser** or **Nikon Forestry range finder** (Figure 9) then follow the next rules: In tree height measurement make sure of your target, sometimes when the canopy of the tree is round shape, the laser ray might reach the twigs or leaves and not really the top of the tree. So, the figure will be less than the real height of the tree.

- When measuring distance, wrong figures might be captured where there are a lot of shrubs and tall grasses. Move the obstacles in front of the target.

For more instructions about using Vertex Laser in the field see Annex 3, and for Nikon Forestry see Annex 4.

Figure 9. Vertex Laser (left) and Nikon Forestry (Right) range finders

5.5 Regeneration

Data on tree regeneration is collected in the four subplots (referred also as clip-plots) each of size 1 m x 1 m on *Form F4*. The clip-plots' center points are located 15.5 m from the plot's center to the cardinal directions. The data is recorded in two classes:

a) Vegetation other than trees.
   Record: species, count, and coverage (%).
b) Tree seedlings. These are tree seedlings more than 10 cm tall and *dbh* less than 1 cm.
   Record: species and count.

5.6 Stumps

Stump data is recorded on tree stumps, not on bamboo. Stumps with stump diameter $\geq$30 cm at the cutting level are recorded within the plot with radius of 15 m.

The stump diameter is measured at *dbh* (1.3m above ground) or at the point of the cut if below 1.3m. **Note that when a stump is taller than 1.3 m the diameter is measured at the 1.3 m height.** Non-circular shape stump's diameter can be measured as an average of two diameter readings (Figure 10)

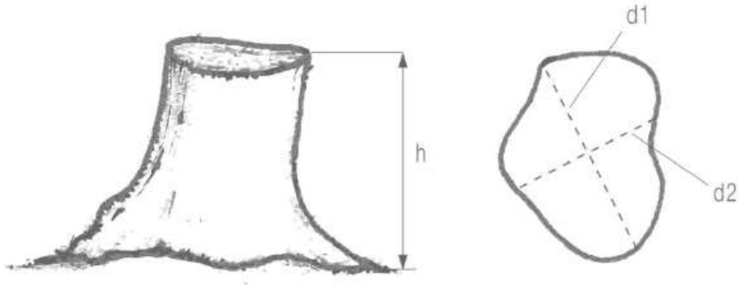


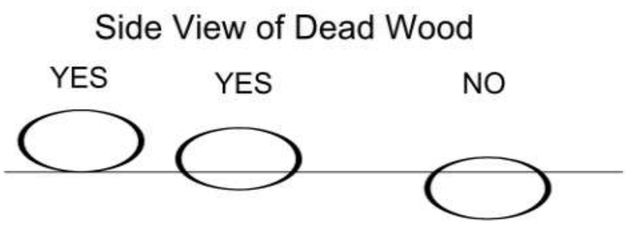
Figure 10. Measuring of stump diameter

Stump data includes the following variables: diameter, and height of stump.

5.7 Fallen deadwood

Fallen deadwood data is recorded within the plot within 15 m radius. Deadwood is considered to be tree parts that are lying on the ground. Minimum length of deadwood to be measured is 1 meter. Note that combined broken parts (separately shorter than 1m) from the same tree are counted and measured as one if total length of parts exceed 1 meter. The field team determines deadwood parts which are inside the plot area. The length and diameter at **both ends of all pieces** of fallen wood with diameter larger or equal to 10 cm within the plot area are measured. Standing dead trees are measured as normal tally trees.

Data on fallen trees are registered in *Form F5a*, and they consist of two diameter measurements, length, number of similar parts and decomposition status. Dead wood lying more than 50 % in the soil or mud is not recorded (Figure 11).



(Source: Walker *et al.*, 2012)

Figure 11. Selection criteria for recording of dead wood

Measurements of length are made to the plot border (Figure 12). Hence when a stem crosses the plot border, length and diameter are measured to/from that limit where the stem's centre line crosses the border.

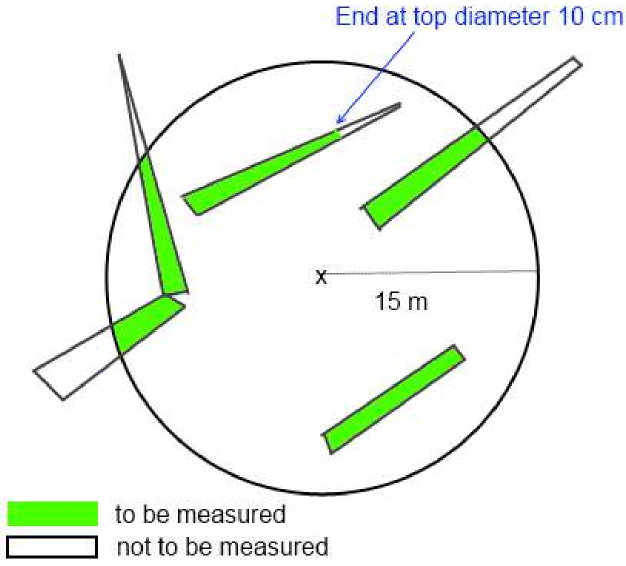
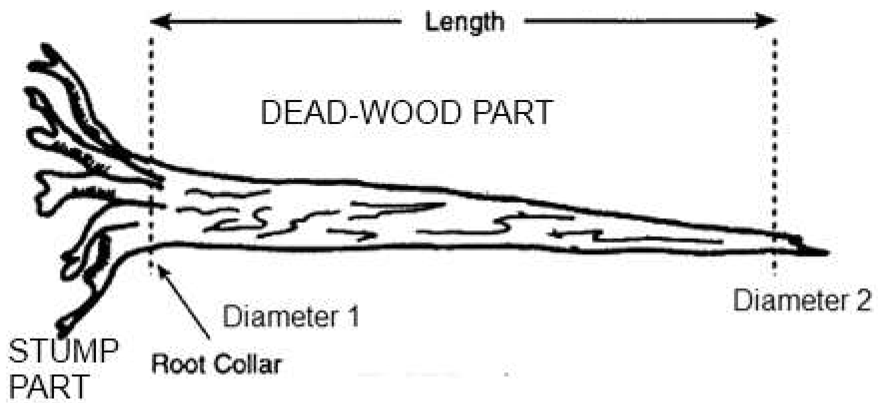


Figure 12. Selection of deadwood parts in the plot

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 13). **Use caliper to measure fallen deadwood diameters, not diameter tape.** The diameters are measured over bark if bark exists. Record also if the measurement is done over or under bark. For measurements at the bases of fallen, buttressed trunks, diameters are measured above the buttress. The total length of the stem part larger than or equal to 10 cm in diameter is also recorded.

If a part of laying stem has been removed from the plot (e.g. for making charcoal), the remaining main wood particles are recorded if they are larger than or equal to 10 cm in diameter. If there are a plenty of similar size deadwood parts on the plot (as branches), then the recorder can tally the estimated mean dimensions of that deadwood and give the total number of similar parts.

a)



Note: Record this type of dead tree into two data entry tables: *Lying Dead Wood* data (Form F5a) and *Stump* data (Form F5b). Stump diameter is equal to *Diameter 1* in the figure above. *Diameter 2* cannot be less than 10 cm.

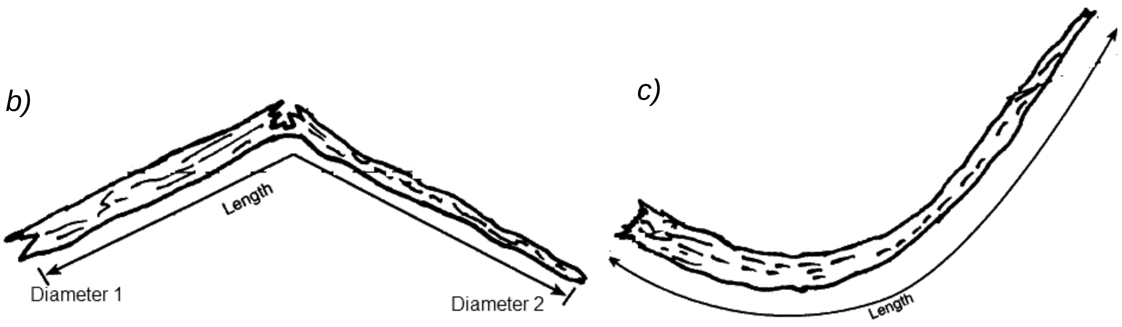


Figure 13. Deadwood measurements

Decay class is detected applying three classes: solid wood, intermediate and rotten wood. Decay class is used when we compute deadwood biomass and carbon contents: rotten coarse woody debris has a lower density value than solid wood.

Decay class can be detected by pushing a knife into the wood. If the knife does not sink into the piece of deadwood but it bounces off, classify it as sound. If the knife sinks partly into the piece, and there has been some wood loss, classify it as intermediate. If the machete sticks into the piece, if there is more extensive wood loss, and the piece is crumbly, classify it as rotten.

A dead laying stem can contain the stump part with some roots. In case of a broken dead tree the stump can be located in the plot. In both cases the stump data is recorded into the Stumps section on the *Form F5b*.

Dead lying lianas and palms are included to the dead wood if they exceed the given diameter limit. Dead lying bamboos are not recorded as deadwood.

5.8 Bamboo

Bamboo data is recorded within plot within radius of 15 m. All bamboos that form clumps (i.e. groups) will be serially numbered and measured. Live and dead bamboos are recorded separately, when possible. Bamboo shoots to be measured should have *dbh* $\geq$ 2 cm.

Bamboo groups located right at the plot boundary are measured as follows: if half of the clump is located inside the plot boundary, such clump is considered to belong into the plot. If less than half of the clump is located outside the plot boundary, such group is considered to be outside of the plot.

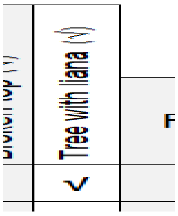
For each bamboo clump in the plot, the following variables are recorded: species, status (*live/dead*), average *dbh*, average height, and number of stems in the clump.

5.9 Lianas and other climbers

Data about lianas and other climbers are recorded in *Form F3* together with trees, if the liana's size exceeds the given diameter limit. Diameter of the liana is recorded at 1.3 m above the ground. There is a special column in the form *F3* for marking that the plant is liana.

Length (or height) of the liana is recorded up the canopy of the tree. If a liana is rotating along the tree stem, then its length can be estimated and recorded.

Trees with liana(s) with diameter $\geq$ 1cm at 1.3m height grows are marked as a tick (√) into the field form 3.



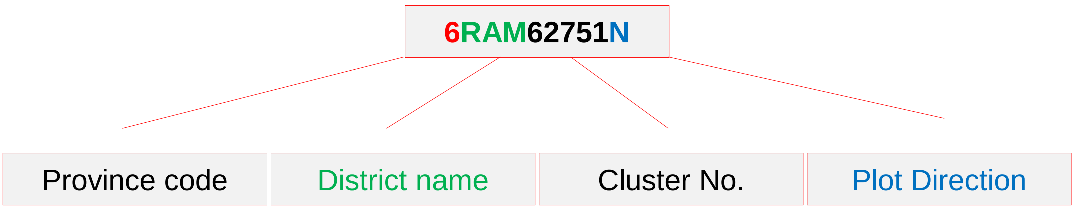
5.10 Surface plant litter sampling

Surface plant understory, coarse woody debris and litter samples will be collected at 4 locations outside of the plot (see Figure 2). Use a 1m x 1m quadrates (i.e. clip plots), and collect all the plant, debris and litter material within the square, weigh samples using an electronic balance and record the reading.

Understory consists of plants *dbh* less than 1 cm. CWD consists of small deadwood which diameter is from 2.0 to 9.9 cm. Fine litter consists of all debris above the soil with diameter less than 2 cm.

If there is no biomass of certain type within the clip plot area, the biomass shall be recorded on the data sheet as 'zero'.

After each weight is taken, the materials from all the four positions are thoroughly mixed on a ground sheet, from which a 'grab' sample weighing 0.2 kg is obtained, bagged, and labelled according to cluster and plot IDs for transportation to the laboratory to determine the dry matter weight. Figure 14 illustrates the labelling method.



How this would look on a sample bag:

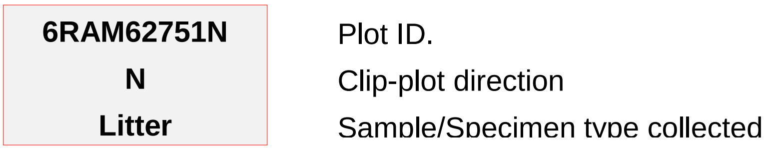


Figure 14. Labelling of biomass samples

All samples should remain in staple-sealed paper bags, stored in large plastic containers for storage with lids to prevent ripping and water damage during transportation. Ensure the sample bags can 'breath' to prevent mould and water damage. This is done by perforating sample bags with a paper perforator.

Sample bags should have labels that are printed prior to field work, with the required information details to be completed in the field. Each sample must have a set of two labels: one will be placed inside the sample bag, while the other will be placed, or tied on the outside of the bag for easy identification and sorting of the samples.

6 Description of field forms and variables

There are 7 different field forms for collected data, as indicated in Table 6.

Table 6. Field forms description and corresponding information

Form No.	Information
F1	Cluster data
F2	Plot data
F3	Tree measurements (also incl. palms, lianas)
F4	Regeneration data
F5	Deadwood and stumps
F6	Bamboo, Understory, CWD, Litter
F7	Crew information

6.1 Form F1: Cluster

The *Cluster **Form F1*** will be filled for each cluster. It contains general information about the cluster location and identification, specification of GPS equipment, and date of data collection. Description of the cluster form is given below.

F1- 1. **Cluster number**

Cluster number from the inventory plan.

F1- 2. **Accessibility**

Condition of accessibility is recorded for each cluster.

Code	Description
0	Accessible
1	Inaccessible due to slope
2	Inaccessible due to owner refusal; owner does not allow one 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

F1- 3. **Date**

Date when work in the cluster started (day/month/year)

F1- 4. **Day number**

Circle by day when work in the cluster started/continued

F1- 5-8. **Cluster location**

General information on cluster location.

a) Province name

b) District name
c) Local Level Government (LLG) name
d) Village name

F1- 9. **Crew number**

Crew number in the region. Coded in OF Mobile.

F1- 10-11. **Number of crew members**

a) Number of officers.
b) Number of local assistants.

F1- 12. **Team leader**

Team leader name.

F1- 13-16. **Land tenure**

Information about land tenure (i.e. ownership) in the sample plots.

- Name
- Plot list: ALL, or list of the plot codes (comma separated)
- Clan, Village
- Contact details of the person

F1- 17. **GPS Model**

GPS Model: brand name and type.

F1- 18-19. **Starting position: GPS reading (decimal degrees)**

GPS Y (Latitude)	Latitude coordinate (6 digits)
GPS X (Longitude)	Longitude coordinate (6 digits)

F1- 20. **Starting position: Start time**

Time when leaving the vehicle, boat or camp to access the cluster by foot (hour : minutes).

F1- 21. **End time**

Time of returning to vehicle, boat or camp by foot. This information can also be recorded on the plot form. (hour : minutes)

F1 -22. **Remarks**

Additional remarks and notices about the cluster or access to it. Reason for inaccessibility must be filled in.

6.2 Form F2: Plot

Plot Forms 2 will be filled in for each plot in the cluster. The forms will include the general data about the plot properties and information on its location and access. **Each plot is expected to have the Form F2 filled in if the cluster is accessible**.

F2- 1. **Cluster number**

Cluster number from inventory plan.

F2- 2. **Plot ID**

Plot ID code within the cluster from the inventory plan.

F2- 3. **Plot accessibility**

Condition of accessibility is recorded for each plot.

Code	Description
0	Accessible
1	Inaccessible due to slope
2	Inaccessible due to owner refusal; owner does not allow one 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 the reason
100	Inaccessible but visible; Specify the reason

F2- 4. **Name of recorder**

Name of the person to record the data.

Time record within the plot

F2- 5. **Date**

Date when measurements on the plot are conducted (day/month/year).

F2- 6. **Start time**

Time when team arrives at the plot (hour : minute).

F2- 7. **End time**

End time of measurement in the plot (hours : minutes).

F2- 8. **End time II**

End of field work heading back to camp. This is recorded if this is the last plot assessed for the day, otherwise do not fill.

Plot location

F2- 9-10. **Plot centre coordinates, pre-determined (decimal degrees)**

GPS Y (Latitude)	Latitude coordinate (6 digits)
GPS X (Longitude)	Longitude coordinate (6 digits)

F2- 11-13. **Plot centre coordinates, recorded in the field (decimal degrees)**

Collect GPS readings at least 15 minutes. Taken as an average of several readings, in Garmin use the ***Waypoint Averaging*** function.

- GPS Y (Latitude)	Latitude coordinate (6 digits)
- GPS X (Longitude)	Longitude coordinate (6 digits)
- Number of GPS readings (if the GPS receiver can show this, otherwise leave this blank)

F2- 14. **Elevation (m)**

Elevation is taken as GPS reading.

F2- 15. **Slope angle (degrees)**

Determine whether the slope direction (collected in the following attribute) is recorded

1	from High to Low, or
2	from Low to High

F2- 16. **Slope direction (degrees)**

Compass direction of the slope as degrees (0-360).

F2- 17. **Description of plot centre**

Description how to relocate the plot centre point. This is important especially if the marker pin cannot be put into the plot’s center. Here you can bind plot center location into visible, stable objects as to a big stone, remarkable big tree, etc. Compass and measuring tape can be used, and compass readings are recorded **from the plot center towards the reference object**.

F2- 18-19. **Photo**

- Photo number in the plot, or photo index number.
- Photo file name.

Read more at chapter 4.4.6.

Plot variables collected in the plot

F2- 20. **Collect Earth information: Land use**

Predetermined as Collect Earth information on land use applying the IPCC land use classification system.

Code	Description	Explanation
1	Forest Land	Area ≥ 0.5 ha, Tree crown cover ≥10%, Tree height ≥ 5 m
2	Crop Land	Land used for cultivation of crop plants (as annual or perennial crop, fruit trees, oil palms), includes also pasture land and fallow
3	Grass Land	Wooded or plain grassland
4	Wetlands	Lakes, rivers, dams, mangrove forests
5	Settlements	Built-up areas (urban, rural)
6	Other Land	

F2- 21. **Collect Earth information: Forest type**

Predetermined Collect Earth information on forest type. The following codes are applied:

Code	Forest type	Description
P	Low Altitude Forest on Plains and Fans	below 1000 m
H	Low Altitude Forest on Uplands	below 1000 m
L	Lower Montane Forest	1000 – 3000 m
Mo	Montane Forest	Montane: above 3000 m
Mc	Mountain coniferous forest	High altitude forests dominated by coniferous species (*Podocarpaceae*)
B	Littoral Forest	Dry or inundated beach
D	Dry Seasonal Forest	Restricted to southwest PNG in a low-rainfall area (1800-2500 mm)
Fri	Seral Forest	River line, upper stream, river plains and volcano blast area
Fsw	Swamp Forest	Swamp area
M	Mangrove	Along coastline and in the deltas of large rivers
W	Woodland	Low and open tree layer
Sa	Savanna	Low (< 6m) and open tree layer in low rainfall area with a marked dry season.
Sc	Scrub	Community of dense shrubs up to 6 m

F2- 22. **Land use**

Actual field observation on land use. The codes as in F2-20 are applied.

F2- 23. **Forest type**

Actual field observation on forest type. The codes as in F2-21 are applied.

F2- 24. **Status**

Actual field observation on forest status.

Code	Description	Explanation
1	Primary	
2	Commercially logged	
3	Disturbed other than commercial logging	

.

F2- 25. **Canopy closure**

Canopy closure is recorded on forest land using the spherical densitometer at five plot locations (center, and 15m from the plot center to the cardinal directions). If canopy coverage is caused for instance by banana leaves, these are not recorded as a part of the forest canopy. The measured value (0 – 24) will be recorded in the form.

F2- 26. **Disturbance (Yes / No)**

Tick ‘yes’ if there has been a land use change or any disturbance of the forest in the plot.

1) Observed overall disturbance,
2) Observed disturbance caused by natural factors,
3) Observed disturbance caused by humans,

F2- 27. **Type of disturbance**

If disturbance is ‘Yes’, fill in the type of disturbance as code. If there are several disturbance factors, record the primary (abiotic) or most important (human) damage causing factor.

Code	Description	Explanation
Abiotic factors		
0 / blank	No data	
1	Fire	Disturbance caused by fire
2	Flooding	A flood is an overflow of water that submerges land which is usually dry.
3	Erosion	Erosion refers to the condition in which the earth's surface is worn away by the action of water and wind.
4	Drought	A drought is a period of below-average precipitation in a given region, resulting in prolonged shortages its waters supply.
5	Wind damage	Disturbance caused by storm
6	Insects, fungus or diseases	Disturbance caused by insect pests or by fungus. Disturbance caused by diseases attributable to pathogens, such as bacteria, fungi, phytoplasma or virus.
7	Salinization	Salinization is the process by which salts accumulate in the soil. Excess salts hinder the growth of crops by limiting their ability to take up water.

Human factors		
10	Selective cutting (commercial)	
11	Selective cutting (domestic use)	
12	Shifting cultivation	
13	Timber sawing	
14	Exploration activities	Mining and land extraction activities
15	Grazing	
99	Other	Specify in *Remarks*

F2- 28. **Impact (of disturbance)**

If disturbance is 'Yes', the impact (or intensity) of disturbance is filled.

Code	Description	Explanation
1	Low	Evidences of damages are visible, but not causing long-term damages. Only few trees are affected.
2	Medium	Damages are clearly visible, probably causing long-term damages or loss of growth. Several trees are affected.
3	High	Damage is finally causing wide mortality of trees, or hinders them growing. Mortality is likely to remain high for a long time.

F2- 29. **Time of disturbance (years ago)**

If disturbance is 'Yes', fill in the estimated number of years from the disturbance.

F2- 30. **Non-timber forest products and services (Yes / No)**

Tick 'yes' if there are any non-timber forest products or/and services in the plot area.

F2- 31. **Non-timber forest products and services**

These data refer non-timber forest products (NTFP) and services provided by the trees, forest and other wooded land. Discussions with the community members may be necessary to get this data. **This data is recorded even if local people do not currently use that NTFP.**

Multiple responses allowed, however record only the most important forest products / services if the space is limited (in the paper form).

Code		Description	Explanation
0/blank		No data	
1	NTFP	Fruits, nuts, seeds, roots, berries, etc.	Vegetable foodstuffs and beverages provided by fruits, nuts, seeds, roots, etc.
2		Mushrooms	Foodstuffs provided by mushrooms.
3		Fodder	Animal and bee fodder provided by leaves, fruits, etc.

Code		Description	Explanation
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		Seeds	Seeds collected for regeneration purposes
9		Other plant products	Specify in *Remarks*
10		Wildlife	Provides habitat for wildlife
11		Beekeeping activities (e.g. honey)	Products provided by bees
12		Caterpillar	Important collection areas
21	Forest services and benefit	Windbreak	Acts as a windbreak
22		Shade	Provides shade
23		Aesthetic	Provides landscape beauty
24		Recreation and tourism potential	Including ecotourism, hunting or fishing as leisure activity. Unique feature.
25		Cultural heritage potential	Including religious / spiritual potential
99		Other	*Specify*

F2- 32. **NTFP description**

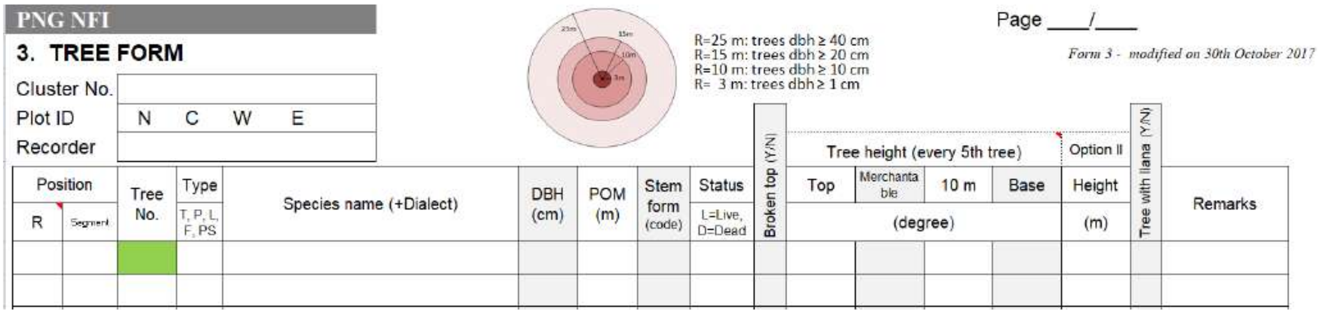
Short description of use/value NTFP. If more information, fill under 'Remarks'.

F2- 33. **Remarks**

Additional information about the plot.

6.3 Form F3: Trees

Tree data are recorded in ***Form F3*** (Figure 15). Both live and dead standing trees are recorded. Lying dead trees are recorded in *Form F5A*.


PNG NFI

3. TREE FORM

Page ___/___

Form 3 - modified on 30th October 2017

R=25 m: trees dbh ≥ 40 cm
R=15 m: trees dbh ≥ 20 cm
R=10 m: trees dbh ≥ 10 cm
R= 3 m: trees dbh ≥ 1 cm

Cluster No.	
Plot ID	N C W E
Recorder	

Position		Tree No.	Type	Species name (+Dialect)	DBH (cm)	POM (m)	Stem form (code)	Status	Broken top (Y/N)	Tree height (every 5th tree)				Option II	Tree with liana (Y/N)	Remarks
R	Segment		T, P, L, F, PS					L=Live, D=Dead		Top	Merchantable	10 m	Base	Height		
										(degree)				(m)		

Figure 15. Form F3 – Tree data

F3- 1. **Cluster number**

Cluster number from the inventory plan.

F3- 2. **Plot ID**

Plot ID within cluster from the inventory plan.

F3- 3. **Recorder**

Name of the recorder.

F3- 4. **Tree position**

Record the radius of the nested plot (3,10,15 or 25).

F3- 5. **Segment**

Sector where a tree is standing: NE, SE, SW, NW. See Figure 16.

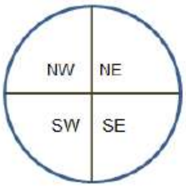


Figure 16. Sectors with corresponding codes

F3- 6. **Type**

Type (i.e. life form) of the observation unit is recorded here.

Code	Explanation
T	Tree
F	Fern
L	Liana, climber
P	Palm
PS	*Pandanus* spp.

F3- 7. **Species name**

Scientific genus and species name are recorded. As a last resort, when the scientific name cannot be derived, local name may be written, but the language/dialect must be clearly stated. If species is completely unknown, a sample for the herbarium must be collected. Enter 'Unknown' followed by the specimen number noted on the collected sample.

F3- 8. **Tree diameter, *dbh* (0.1cm)**

Tree diameter is measured above bark in centimetres, with 1 decimal digit, at 1.3m breast height above the ground with the exception of particular cases mentioned in Chapter 5.3. The diameters are measured above bark.

F3- 9. **Point of Measurement (PoM) (0.1 m)**

When tree has a large buttress, then *dbh* is measured above the standard 1.3 m. The height from the ground at which *dbh* was measured must be recorded. If the measuring height of *dbh* is standard 1.3 m, this field is left blank.

F3- 10. **Stem form**

Stem form is a measure of the quality of a tree stem normally used to indicate the commercial value of the tree for log export purposes. In NFI, the same criteria for grading of tree stems will be used. The shape of the stem's log part is observed for each big living tree (*dbh* ≥40 cm) and it recorded as a letter code.

Code	Explanation
A	The bole of the stem is round and straight over its entire length from buttress (if any) to crown break, without visible defects or injury.
B	The bole of the stem is round and straight over its entire length but should be able to yield at least one straight, round log. There are no visible defects or injury.
C	The stem is straight but not round due to spiralling, fluting or twisting. No visible damage or injury.
D	The stem is neither straight nor round, but there is no or little visible damage or injury.
E	Stem with severe sweeps, bends, kinks, damage or injury, but there is at least one section which could produce a marginal log.
F	The stem will not produce any utilizable log, now or in the future, because it is very crooked, twisted, deformed, hollowed or decayed.

F3- 11. **Status**

Tree status has two classes.

Code	Explanation
L	Live (*default*)
D	Dead

F3- 12. **Broken top**

A tree with a broken top is ticked if 'YES'. A broken top tree can be alive or dead.

F3- 13-18. **Height measurements**

Tree heights are recorded for every 5th tree in the plot. In case of a palm or a standing dead tree, tree heights are always recorded. Heights can be recorded using three alternative methods:

1) **Trees higher than 10 m**. Record as angles from three points of the tree using the Suunto clinometer: **base, bole** and **top height points**. In addition, the angle is recorded to the top of fixed 10 m long height pole that is kept standing next to the tree.
2) **Trees height ≤ 10 m**. Direct height measurement (in 0.1 meters) using the 10 m long height pole.
3) **Using range finder**.

Base 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.

Bole height refers to merchantable or utilizable 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.

F3- 19. **Tree with liana**

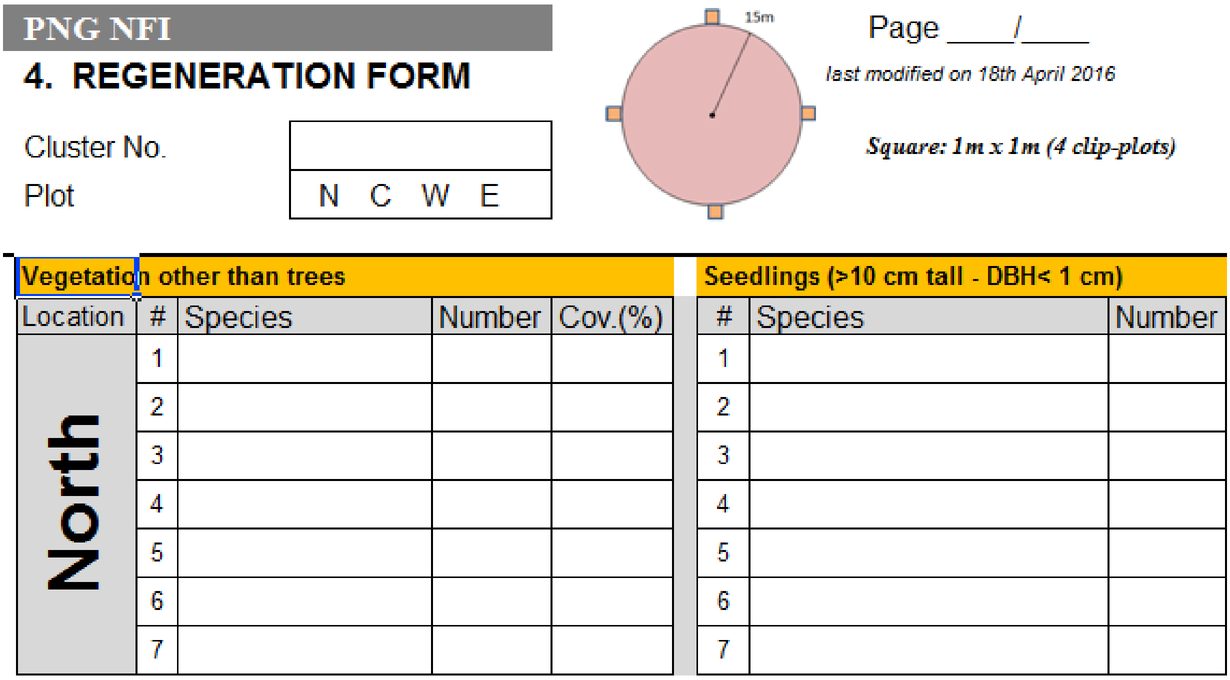
A tree with liana(s) is ticked as 'YES', if any liana with diameter ≥ 1cm at 1.3m height grows with the tree.

F3- 20. **Remarks**

Remarks about the tree, this field can be used especially by the team's botanist collecting specimen.

6.4 Form F4: Regeneration data

Regeneration data contains information about undergrowth and these are recorded in *Form F4*, and are collected on four quadrates (i.e. clip-plots) of 1 m x 1m. This data are recorded for two classes (Figure 17): all plants other than tree species and the small trees under the dominant canopy layer in the observation point. The seedling data is collected on all seedlings with *dbh* less than 1 cm and height greater than 10 cm. Note that shrubs can be recorded together with seedlings.


PNG NFI
4. REGENERATION FORM
Page ____/____
last modified on 18th April 2016
Square: 1m x 1m (4 clip-plots)
15m

Cluster No.	
Plot	N C W E

Vegetation other than trees					Seedlings (>10 cm tall - DBH< 1 cm)		
Location	#	Species	Number	Cov.(%)	#	Species	Number
North	1				1		
	2				2		
	3				3		
	4				4		
	5				5		
	6				6		
	7				7		

Figure 17. Form F4 - Regeneration data

F4- 1. **Cluster number**

Cluster number from the inventory plan.

F4- 2. **Plot ID**

Plot ID within cluster from the inventory plan.

Code	Explanation
N	North
C	Center
W	West
E	East

Other vegetation than trees (i.e. understory)

F4- 3. **Species name**

Scientific genus and species name are recorded.

F4- 4. **Coverage (%)**

Estimated coverage of understory plants.

Seedlings (>10 cm tall and *dbh*< 1 cm)

F4- 5. **Species name**

Scientific genus and species name are recorded.

F4- 6. **Number of seedlings**

Count of seedlings by species.

6.5 Form F5: Deadwood and Stumps

Note: that this data will be collected in the radius of 15 m of the plot.

F5- 1. **Cluster number**

Cluster number from the inventory plan.

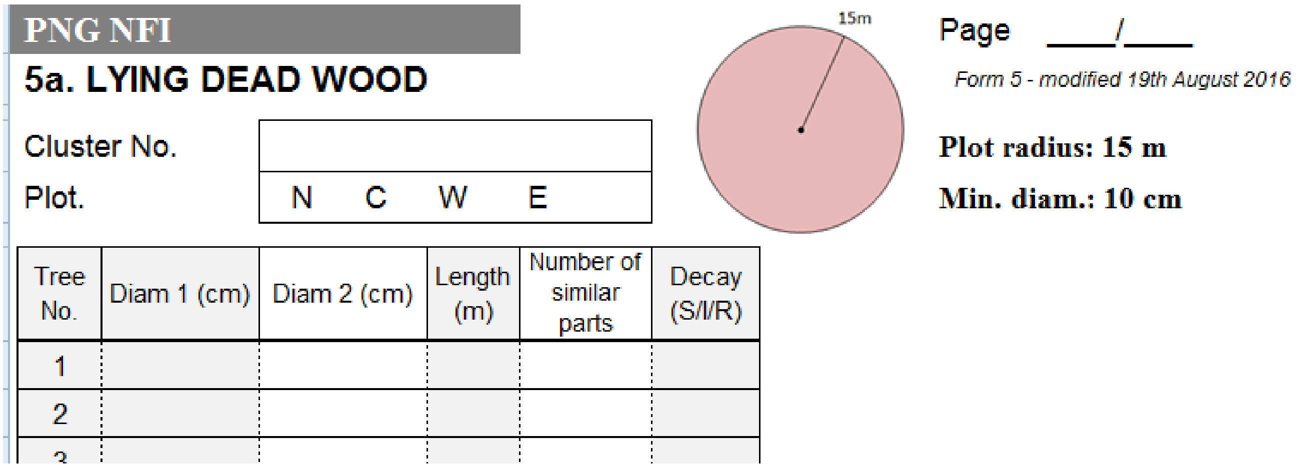
F5- 2. **Plot ID**

Plot ID within cluster from the inventory plan.

6.5.1 Form F5a: Lying deadwood

Deadwood data are recorded in *Form F5a* (Figure 18). In this section, data are recorded on fallen dead logs and branches with a diameter equal to or above 10 cm and which are found within 15 m circle in the plot (regardless of where they originated). Minimum length of a deadwood piece to be measured is 1 meter.

Note that combined broken parts (separately shorter than 1 m) from a same tree are counted and measured as one if the total length of parts exceed 1 meter. The length and diameter at **both ends of all pieces** of fallen wood with diameter larger or equal to 10 cm are measured. Measurements of length are made up to the plot border. Standing dead trees are measured as normal tally trees and recorded in *Form F4*.


PNG NFI
5a. LYING DEAD WOOD
Page ___/___
Form 5 - modified 19th August 2016
Cluster No.
Plot. N C W E
Plot radius: 15 m
Min. diam.: 10 cm

Tree No.	Diam 1 (cm)	Diam 2 (cm)	Length (m)	Number of similar parts	Decay (S/I/R)
1					
2					
3					

Figure 18. Form F5a – Lying deadwood data

F5- 3. **Diameter 1 (cm)**

Diameter at the stump part of stem in centimeters (*dbh* $\geq$10cm)

F5- 4. **Diameter 2 (cm)**

Diameter at the top part of stem in centimeters (*dbh* $\geq$10cm)

F5- 5. **Length (0.1 m)**

Length of wood part in meters with one decimal digit (length ≥1m).

F5- 6. **Number of similar stems/parts**

Number of similar size deadwood parts (species, diameter 1, diameter 2, length and decay).

F5- 7. **Decay**

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

Code	Explanation
S	Solid wood material
I	Intermediate (partially rotten) wood material
R	Rotten wood material

6.5.2 Form F5b: Stumps

Stump diameter is then measured at breast height or at the top of the stump if the stump height is less than 130 cm, and stump minimum recorded diameter is 30 cm. The maximum stump height is set to 250 cm, so stumps higher than that are recorded as "broken top dead trees" in the Tree Form.

Stump data are recorded on *Form F5b* (Figure 19).

5b. STUMPS

Plot radius: 15 m

Harvested stump min. diam.: 30 cm

No.	Diam. (cm)	Height (cm)		No.	Diam. (cm)	Height (cm)
1				15		
2				16		
3				17		
4				18		

Figure 19. Form F5b – Stump data

F5- 8. **Stump diameter (0.1 cm)**

Measured at the top of the stump or at breast height if more than 130 cm tall.

F5- 9. **Height (cm)**

Height of stump.

6.6 Form F6: Bamboo and Understory, Coarse Woody Debris, Litter

Form F6 contains two sections: section A for bamboo data, and section B for understory, litter, and CWD data.

F6- 1. **Cluster number**

Cluster number from inventory plan

F6- 2. **Plot ID**

Plot ID within cluster from inventory plan

6.6.1 Form F6a: Bamboo

This form contains information related to bamboo clumps (all bamboo shoots taller than 1.3 m) within radius of 15 m. Record all bamboos if clump's center is located in plot. If clump's center is located outside of the plot, that bamboo clump is not recorded. The average diameter means *dbh* (at 1.3 m above ground). Dead and alive bamboos are recorded separately, when possible. Bamboo data are recorded in *Form F6a* (Figure 20).

No.	Species name	L=Live D=Dead	Average diameter (cm)	Average height (m)	Number of stems
1					
2					
3					
4					

Figure 20. Form F6a – Bamboo data

F6- 3. **Species name**

Scientific genus and species name are recorded. If genus name is unknown, local name (with dialect) may be written. If species is completely unknown, enter '*Unknown*'**.**

F6- 4. **Status**

Bamboo status has two classes.

Code	Explanation
L	Live (default)
D	Dead

F6- 5. **Average diameter (cm)**

Diameter at the breast height (1.3m above ground) of mean size bamboo stem.

F6- 6. **Average height (0.5 m)**

Mean height of bamboo culms.

F6- 7. **Number of stems**

Number of bamboo stems in the clump.

6.6.2 Form F6b: Understory, Coarse Woody Debris and Litter

Understory, Coarse Woody Debris (CWD) and litter **data are recorded using** ***Form F6b*** **(**

Figure 21), and these are collected on 4 subplots outside of the plot area (on 1 m x 1 m quadrates).

Litter and small coarse woody debris (less than 2 cm diameter) is included in the litter collection. CWD is all woody material with diameters between 2 cm and 10 cm.

If total weight is more than 250g, 200-250 g sample will be collected in each subplot of each type of materials and taken for analysis.

F6- 8. **Subplot location**

Subplot ID code (i.e. location code) is given here.

Code	Explanation
N	North
E	East
S	South
W	West

Litter weights are measured accurately in the field using a weight measurement scale (in grams).

	Location	Total weight (g)	Sub-sample weight (g)
Understory	**N**		
Fine CWD	**N**		
Litter	**N**		

Figure 21. Form F6b - Understory, CWD and Litter data

F6 -9. **Understory: Total weight (g)**

Total litter weigh in the subplot.

F6 -10. **Understory: Sub-sample weight (g)**

Collected understory sub-sample weight.

F6 -11. **Coarse Woody debris: Total weight (g)**

Total Coarse Woody debris (CWD) material weight in the subplot.

F6 -12. **Coarse Woody debris: Sub-sample weight (g)**

Collected CWD material weight in the subplot.

F6 -13. **Litter: Total weight (g)**

Total litter weight in the subplot.

F6 -14. **Litter: Sub-sample weight (g)**

Collected litter sub-sample weight.

Annex 1. Definitions

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

Afforestation: The establishment of a forest or stand in areas where the preceding vegetation or land use was not forest.

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 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 the stem form is changing or utilization of the stem is limited by branching or other defect.

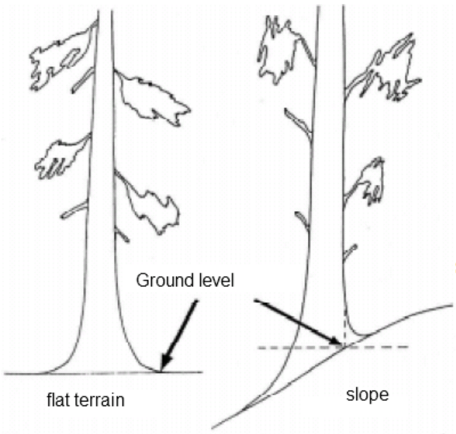
Breast height: Breast height is the height of 1.3 m from the ground level, or if the ground level cannot be defined, from the seeding point. See more explanations and special cases in the chapter 5.3.

Dead tree: A tree is regarded as dead tree if it does not have any living branches. Trees that are alive but so badly damaged that cannot grow in the next growing season (e.g. trees felled by storm) are regarded as dead trees.

Deadwood: Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Deadwood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter.

Forked tree: If the forking point is below the breast height (1.3 m), each fork is recorded as a unique tree. If the forking point is above the breast height, a tree is recorded as one stem.

Ground level: Ground level is described as in the following figure.



Living tree: A live tree must have living branches. The tree must be able to survive at least to the next growing season/next year.

Sample tree: A tree selected for measurements of additional parameters. Note: Every 5^{th} tree in the plot is selected as a height sample tree.

Seeding point: Seeding point is usually at the ground level. 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.

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.

Tally tree: Live or dead standing tree in the sample plot above minimum *dbh*.

Tree: A tree is at least 1.35 m tall perennial woody plant with distinct stem capable of reaching 5 m height *in situ*. Palms are regarded as trees in the data collecting phase, but distinguished in the data analysis phase. Bamboos are not recorded as trees. *Ficus sp.* are considered trees.

Tree height: Tree height is the distance along the stem axis between the seeding (base) point and the tree tip. 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. See more explanations and special cases in the chapter 5.4.

Undergrowth: Undergrowth includes small trees, bushes, herbs and grasses growing beneath taller trees in the forest or other wooded land.

Annex 2. Slope Correction Table

Slope Correction

All reference distances, such as plot distances in the cluster, are expressed as horizontal distances (Table 7). Moreover, plot areas are also computed upon horizontal plane (Table 8). When the terrain is flat, distances can be measured directly. But on sloping terrain the horizontal distances differ from direct (slope) distances. A corrected distance is taken from a slope correction table and these distances are applied at all slopes greater than or equal to 3 degrees. **Note that there two tables: one for horizontal distances, one for plot radius**.

Slope is measured using a Suunto clinometer. The slope unit in NFI is degree.

Table 7. Slope correction table for horizontal distances

SLOPE CORRECTION TABLE
Horizontal Distance to Slope Distance

The table shows slope distance for given horizontal distance in meters and slope in degrees

SLOPE in	HORIZONTAL DISTANCE in meters														
degrees	1	2	3	4	5	6	7	8	9	10	20	30	40	50	100
1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.0	30.0	40.0	50.0	100.0
2	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.0	30.0	40.0	50.0	100.1
3	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.0	30.0	40.1	50.1	100.1
4	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.0	30.1	40.1	50.1	100.2
5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	20.1	30.1	40.2	50.2	100.4
6	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.1	20.1	30.2	40.2	50.3	100.6
7	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	20.2	30.2	40.3	50.4	100.8
8	1.0	2.0	3.0	4.0	5.0	6.1	7.1	8.1	9.1	10.1	20.2	30.3	40.4	50.5	101.0
9	1.0	2.0	3.0	4.0	5.1	6.1	7.1	8.1	9.1	10.1	20.2	30.4	40.5	50.6	101.2
10	1.0	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.1	10.2	20.3	30.5	40.6	50.8	101.5
11	1.0	2.0	3.1	4.1	5.1	6.1	7.1	8.1	9.2	10.2	20.4	30.6	40.7	50.9	101.9
12	1.0	2.0	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.2	20.4	30.7	40.9	51.1	102.2
13	1.0	2.1	3.1	4.1	5.1	6.2	7.2	8.2	9.2	10.3	20.5	30.8	41.1	51.3	102.6
14	1.0	2.1	3.1	4.1	5.2	6.2	7.2	8.2	9.3	10.3	20.6	30.9	41.2	51.5	103.1
15	1.0	2.1	3.1	4.1	5.2	6.2	7.2	8.3	9.3	10.4	20.7	31.1	41.4	51.8	103.5
16	1.0	2.1	3.1	4.2	5.2	6.2	7.3	8.3	9.4	10.4	20.8	31.2	41.6	52.0	104.0
17	1.0	2.1	3.1	4.2	5.2	6.3	7.3	8.4	9.4	10.5	20.9	31.4	41.8	52.3	104.6
18	1.1	2.1	3.2	4.2	5.3	6.3	7.4	8.4	9.5	10.5	21.0	31.5	42.1	52.6	105.1
19	1.1	2.1	3.2	4.2	5.3	6.3	7.4	8.5	9.5	10.6	21.2	31.7	42.3	52.9	105.8
20	1.1	2.1	3.2	4.3	5.3	6.4	7.4	8.5	9.6	10.6	21.3	31.9	42.6	53.2	106.4
21	1.1	2.1	3.2	4.3	5.4	6.4	7.5	8.6	9.6	10.7	21.4	32.1	42.8	53.6	107.1
22	1.1	2.2	3.2	4.3	5.4	6.5	7.5	8.6	9.7	10.8	21.6	32.4	43.1	53.9	107.9
23	1.1	2.2	3.3	4.3	5.4	6.5	7.6	8.7	9.8	10.9	21.7	32.6	43.5	54.3	108.8
24	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	10.9	21.9	32.8	43.8	54.7	109.5
25	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0	22.1	33.1	44.1	55.2	110.3
26	1.1	2.2	3.3	4.5	5.6	6.7	7.8	8.9	10.0	11.1	22.3	33.4	44.5	55.6	111.3
27	1.1	2.2	3.4	4.5	5.6	6.7	7.9	9.0	10.1	11.2	22.4	33.7	44.9	56.1	112.2
28	1.1	2.3	3.4	4.5	5.7	6.8	7.9	9.1	10.2	11.3	22.7	34.0	45.3	56.6	113.3
29	1.1	2.3	3.4	4.6	5.7	6.9	8.0	9.1	10.3	11.4	22.9	34.3	45.7	57.2	114.3
30	1.2	2.3	3.5	4.6	5.8	6.9	8.1	9.2	10.4	11.5	23.1	34.6	46.2	57.7	115.5
31	1.2	2.3	3.5	4.7	5.8	7.0	8.2	9.3	10.5	11.7	23.3	35.0	46.7	58.3	116.7
32	1.2	2.4	3.5	4.7	5.9	7.1	8.3	9.4	10.6	11.8	23.6	35.4	47.2	59.0	117.9
33	1.2	2.4	3.6	4.8	6.0	7.2	8.3	9.5	10.7	11.9	23.8	35.8	47.7	59.6	119.2
34	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.9	12.1	24.1	36.2	48.2	60.3	120.6
35	1.2	2.4	3.7	4.9	6.1	7.3	8.5	9.8	11.0	12.2	24.4	36.6	48.8	61.0	122.1
36	1.2	2.5	3.7	4.9	6.2	7.4	8.7	9.9	11.1	12.4	24.7	37.1	49.4	61.8	123.6
37	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.5	25.0	37.6	50.1	62.6	125.2
38	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.2	11.4	12.7	25.4	38.1	50.8	63.5	126.9
39	1.3	2.6	3.9	5.1	6.4	7.7	9.0	10.3	11.6	12.9	25.7	38.6	51.5	64.3	128.7
40	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.1	26.1	39.2	52.2	65.3	130.5
41	1.3	2.7	4.0	5.3	6.6	8.0	9.3	10.6	11.9	13.3	26.5	39.8	53.0	66.3	132.5
42	1.3	2.7	4.0	5.4	6.7	8.1	9.4	10.8	12.1	13.5	26.9	40.4	53.8	67.3	134.6
43	1.4	2.7	4.1	5.5	6.8	8.2	9.6	10.9	12.3	13.7	27.3	41.0	54.7	68.4	136.7
44	1.4	2.8	4.2	5.6	7.0	8.3	9.7	11.1	12.5	13.9	27.8	41.7	55.6	69.5	139.0
45	1.4	2.8	4.2	5.7	7.1	8.5	9.9	11.3	12.7	14.1	28.3	42.4	56.6	70.7	141.4
46	1.4	2.9	4.3	5.8	7.2	8.6	10.1	11.5	13.0	14.4	28.8	43.2	57.6	72.0	144.0
47	1.5	2.9	4.4	5.9	7.3	8.8	10.3	11.7	13.2	14.7	29.3	44.0	58.7	73.3	146.6
48	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	14.9	29.9	44.8	59.8	74.7	149.4
49	1.5	3.0	4.6	6.1	7.6	9.1	10.7	12.2	13.7	15.2	30.5	45.7	61.0	76.2	152.4
50	1.6	3.1	4.7	6.2	7.8	9.3	10.9	12.4	14.0	15.6	31.1	46.7	62.2	77.8	155.6

Table 8. Slope correction table for plot radius

	Radius (m)			
	3	10	15	25
slope (°)				
2	3.00	10.00	15.00	25.01
4	3.00	10.01	15.02	25.03
6	3.01	10.03	15.04	25.07
8	3.01	10.05	15.07	25.12
10	3.02	10.08	15.12	25.19
12	3.03	10.11	15.17	25.28
14	3.05	10.15	15.23	25.38
16	3.06	10.20	15.30	25.50
18	3.08	10.25	15.38	25.64
20	3.09	10.32	15.47	25.79
22	3.12	10.39	15.58	25.96
24	3.14	10.46	15.69	26.16
26	3.16	10.55	15.82	26.37
28	3.19	10.64	15.96	26.61
30	3.22	10.75	16.12	26.86
32	3.26	10.86	16.29	27.15
34	3.29	10.98	16.47	27.46
36	3.34	11.12	16.68	27.79
38	3.38	11.27	16.90	28.16
40	3.43	11.43	17.14	28.56
42	3.48	11.60	17.40	29.00
44	3.54	11.79	17.69	29.48
46	3.60	12.00	18.00	30.00

Annex 3. Vertex Laser 5 - Field Guide

The Vertex Laser instrument uses laser or ultrasound technology to calculate distance and a tilt sensor to measure angles. The different measuring methods can be used individually or combined with each other. The choice of measuring method and technology is up to the operator. In general terms, the ultrasound method offers more precise results for shorter distances, whereas the laser method will allow longer distance measuring and a quick presentation of measuring results without having to use a transponder.

Vertex Laser 5 (VL5) package set includes VL5 instrument, transponder *T3*, plot centre staff, adapter, and charging cable.

VL5

Plot Centre Staff

Transponder T3

SETUP – Settings

All settings to measure heights, distances and angles are made in the SETUP menu. Settings for data transfer format and saving in the internal memory of the instrument are also made in the SETUP menu. There are three buttons on the VL5: ***SEND***, ***DME*** and ***ON***.

1. Press ***ON*** to activate the instrument.
2. Select SETUP and press ***ON*** to confirm your selection. To find SETUP, once the instrument is activated (***ON***), press ***SEND*** to go through the different Modes until you find SETUP.
3. Use the ***DME*** and ***SEND*** to change values and settings. Press ***ON*** to go to the next field. Settings are saved when you have stepped through all fields. To quit, press ***DME*** and ***SEND*** simultaneously.

METRIC/FEET

Select if to use metric or feet for heights and distances.

DEG/GRAD/%

Select unit for inclination/angles as DEG (degrees 0…360), GRAD (grades 0…400) or % (percentage)

- To switch the **VL5 Off**, press and hold ***SEND*** and ***DME*** at the same time.
- To view different modes, press ***SEND*** to move forward and ***DME*** to go back.
- Once Height/Distance is taken, to return to the Mode Settings (e.g.: ***HEIGHT 1PL↑***), press ***DME*** and ***SEND*** like double clicking a mouse when using the computer.

How to operate the VL5 Laser Range Finder to take the heights and to verify the radius class

1. Press the ***ON*** button and the external LCD display will show this (see image on the right). When in this mode (***HEIGHT 1PL↑***), it is suitable to measure heights of trees and other plants on a generally flat surface

2. Press the ***ON*** button again, this will show on the External LCD Display; "***AIM AND PRESS ON TO FIRE LASER"***
3. The in internal LCD display will show a ***RED CROSS*** This is the Laser in view.
4. Looking through the Internal LCD display, aim at the point of measure; Note: when measuring height, it must keep in mind that the laser must point something that can reflect back, therefore aim the crown leaves clustered together or the end of the last branch at the top of the tree; this will give a good approximate.
5. Once on point and when steady press and hold the ***ON*** button, the **Laser will blink** and you should hear a sound, that's when you let the finger go and view the External LDC display and record the reading;

   SD - Slope Distance
   HD - Horizontal Distance
   H - Height
   DEG - Angle

How to measure height when object is Up-slope or Down-slope

- There are several ways to measure directly using the instrument, however, this seems more appropriate and easy to understand, using still; ***HEIGHT 1PL↑*)**,
- Follow steps 1-4 above

1. In this case, the first measurement must be to the base of the object, this reading will give your height in relation to the object.
2. If you are standing up slope, when taking the base of the object; there will most likely be a negative figure; here is an example: H: -1.6m
   In this case, once the object height is taken, add (+) the base height to the height and this will give the actual height of the object.
   When standing down slope you subtract (-).

   NOTE: there is no mention of the transponder and the plot centre stuff in this field guide, mainly because these are mostly used in an open forest (plantations). In NFI case the teams will mainly us Laser measurements.

(These instructions were adopted from Haglöf Sweden AB, Vertex Laser Manual v.1.6, http://www.haglof.jp/download/vertexlaser_vl400_me.pdf)

Annex 4. Nikon Forestry Pro Range Finder – Field Guide

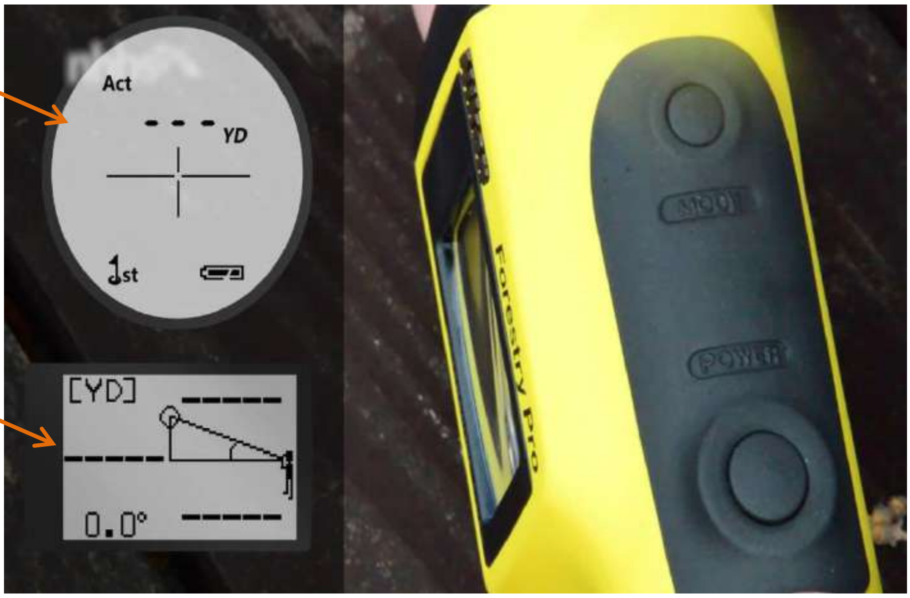
These basic steps will guide the user on the usage of the Nikon Forestry Pro. The Forestry Pro consists of a combined clinometer and range finder; this means that higher, lower and horizontal points can be taken to find distances and angles of objects.

HOW TO OPERATE

Linear distance

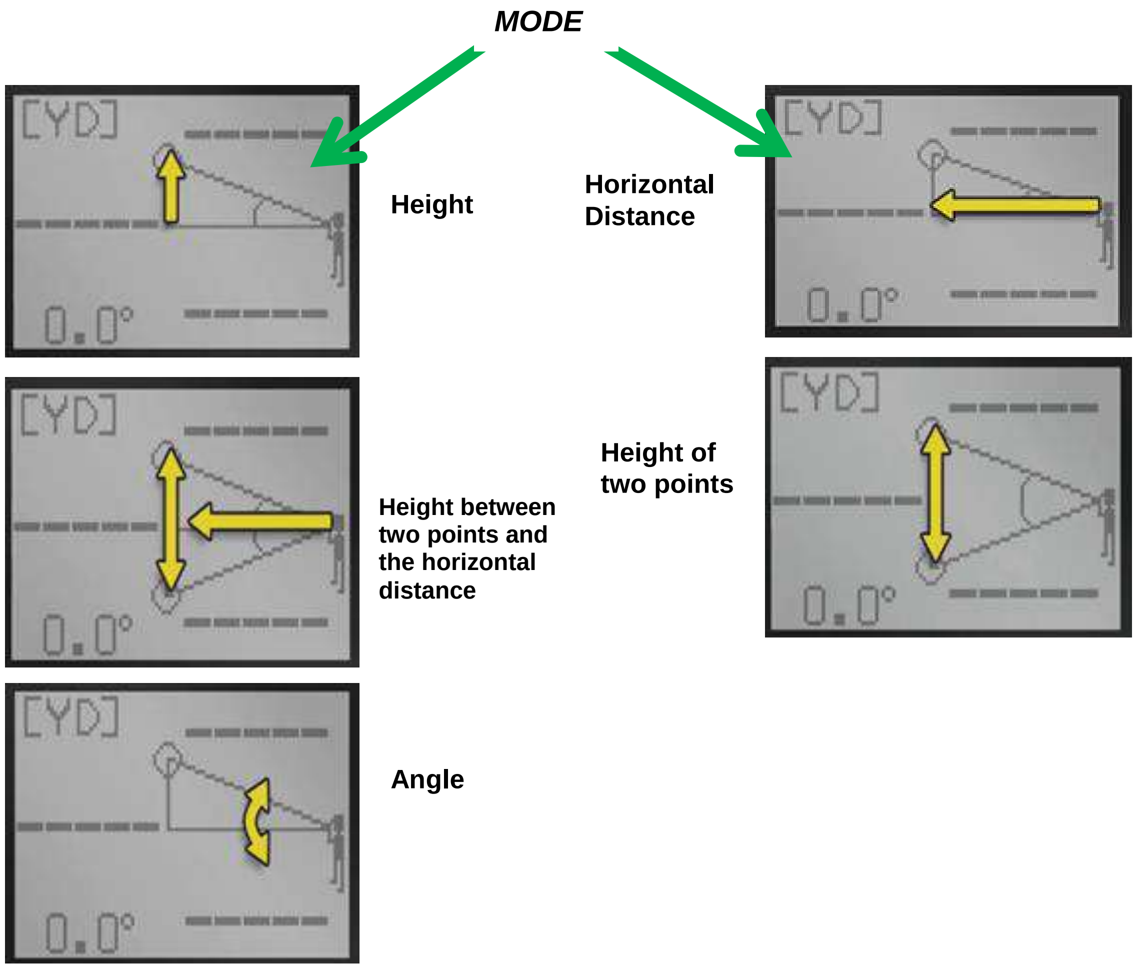
Internal LCD Display

External LCD Display



Press ON for a second and the LCD becomes visible. Then press the **MODE** button and the LCD display will open (see below). The external LCD display is used to show results and the internal one (viewed through the eye piece) is used to check the settings. By default, the device is set to measure the Linear Distances, however you can change that setting.

1. To change the Mode (*linear, angle*, etc.), press down the **MODE** button for half a second while viewing the Internal LCD and you will see the changes. Stop at the preferred mode.

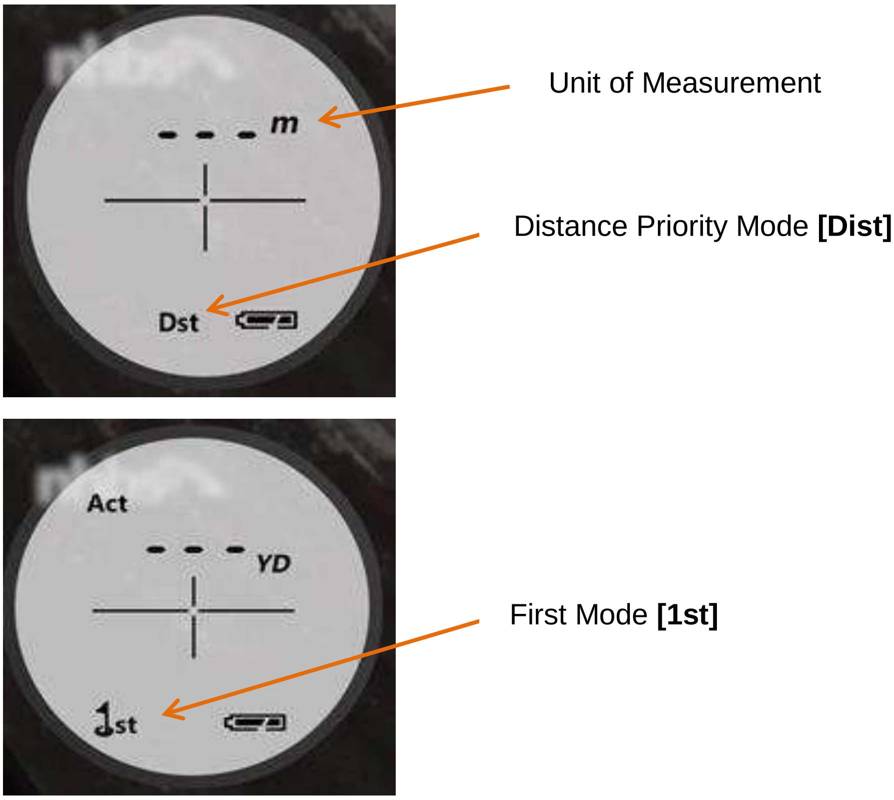


2. To change the **Units of Measurement** (metres [M], feet [FT]) from the default ***[YD]*** or from other unit that you are not going to use, press and hold the **MODE** button for a couple of seconds and internal display will change to the new priority mode. Press and hold again and again until you have reached the unit you are going to use.

3. ***Priority Mode*** - set this when the object you are trying to measure is behind another object. In our case a tree is blocked by a patch of other vegetation
   a) You can use **distance mode -** this will take the furthest measurement; or

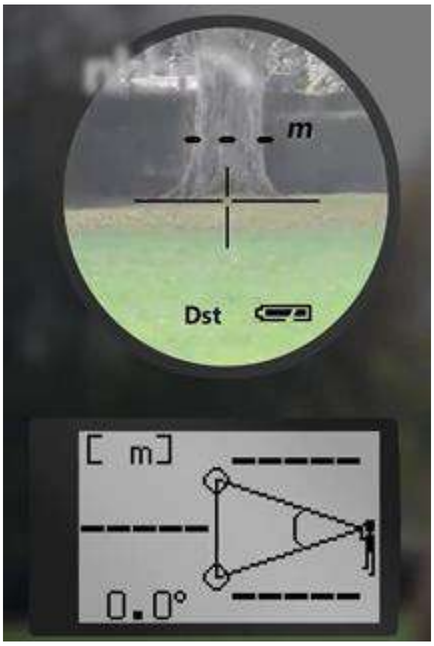
b) You can use the **first mode**, which will take the first object it comes to

4. When using the instrument to change ***Priority Mode***, press down the **POWER** button and quickly press down the **MODE** button**.** Afterwards and without letting go of the **POWER** button**,** press and hold for a few seconds until the internal display is switched to the new priority mode.



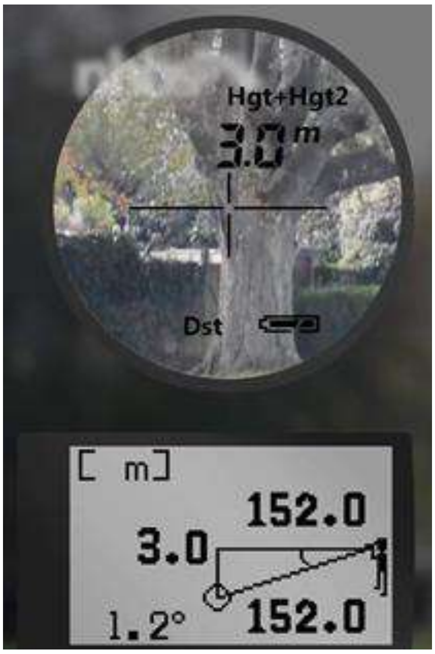
WARNING
As mentioned above, there are two LCD displays, the circular picture represents the internal LCD display and the square represent the external display.
PLEASE CHECK BOTH DISPLAYS WHEN TRYING TO SET THE EQUIPMENT

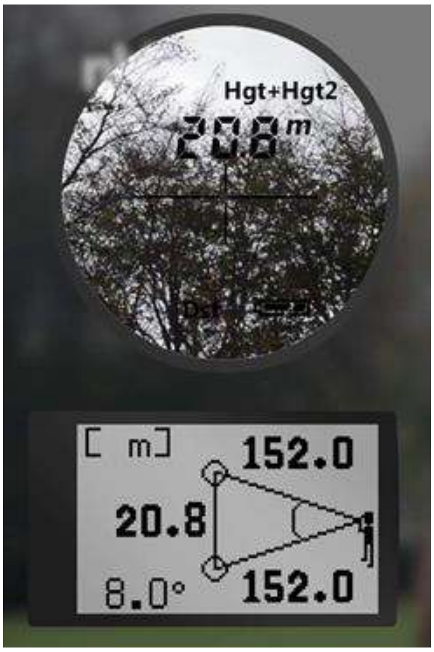
5. Taking of Measurement; simply point and click; for a standing tree, target the lowest point and press **POWER**, then target the tree to the highest point and do the same again. View the result.



Target at the lowest point and press **POWE**R button

Scan the tree to the top





Press **POWER** again at the top, the reading should look similar to this

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Annex 5. Spherical densitometer – Field Guide

A spherical densitometer is a simple instrument for measuring forest overstory density or canopy closure from unobstructed sighting positions. Canopy closure is used as close estimate for canopy cover in this assessment.

The instrument has reflective spherical surface divided into equispaced square grids. When the instrument is used under the forest canopy, the images of overhead crown can be seen in a mirror and the amount of canopy cover is estimated based on proportion of the mirror surface reflecting the over storey crown. The measurement procedure can be efficiently handled by one person using the following procedure.

1. Hold the densitometer far enough away from your body so that your head is just outside the grid (30–45 cm away), **at 0.8 m above the ground** (i.e. at waist height). Use a measuring stick to get the correct height. Keep the densitometer instrument level, as indicated by the round level in the lower right hand corner.
2. There are a total of **24 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 or palms; bananas etc. are not counted). If there are squares that are only partially filled, these can be added to make a complete square.
   For those deciduous tree species 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. Crown cover measurements are implemented with 5 measurements: plot center, and 15m from the center towards North, East, South, and West. All readings are recorded into the *Plot Form F2*.
4. If it is not possible to use the densitometer at some measurement points (for example due to river or steep slope), then that reading is left <u>blank</u> (not zero).

The actual canopy closure percent is computed later in the data analysis phase. The procedure is as follows: first the average of all readings is computed. The result is then multiplied by 4.17 (=100/24) to obtain the estimated canopy closure (overstory density) in percent, i.e.

[Canopy %] = [Average number of filled squares] x 4.17

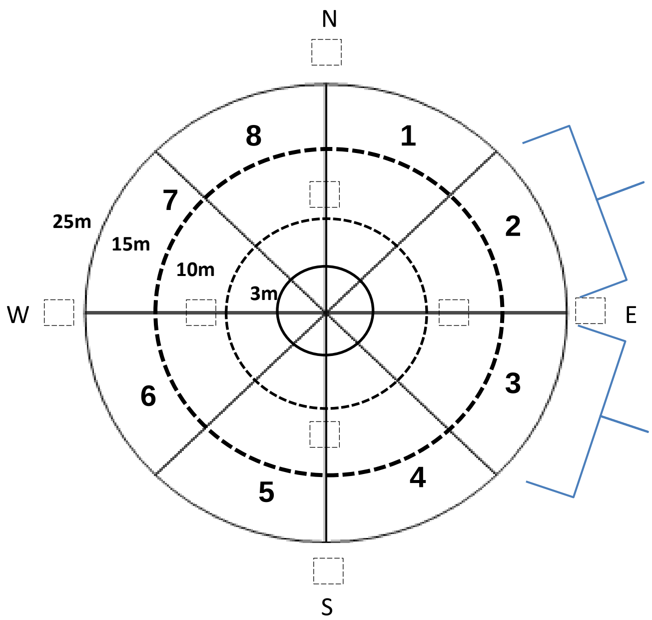
Annex 6. Plot Establishment / Measurement Procedure

The procedure is to ensure minimal damage is done to the sampling variables when establishing a plot and following a structure of measurement respective of each protocol that allows consistency, efficient and quality data collection and saves time.

1. The first task is to divide the plot into 8 segments as shown below;
2. Secondly, the assessment within the plot will follow an order with reverence to each protocol; ❶ Vegetation Cover, ❷ Regeneration, ❸ 3m radius assessment (Upper Plants), ❹ Super Plot and ❺ other Upper Plants.

   The aim is to avoid destruction to the lower vegetation. This process in this guideline is valid only for the centre-plot (C), where the super-plot assessment is to be conducted. However it can be followed in the other three plots to ensure a consistent assessment pattern.

   Please notice that when conducting measurements within the 3m radius, it can be done in two ways: 1) follow through, take measurements and record data or 2) tag trees only and conduct assessments of the upper plants protocol once super-plot assessment is complete.



The plot is divided into 8 segments. This will help the upper plant assessment when trying to know the radius or quadrate where a tree falls in if it stands somewhere in-between. Segment data also provides the advantage of tracing back to missing records, and where to continue in the next day if the work is interrupted by any natural forces.

Segments make the Super Plot and vegetation coverage assessment easier as well.

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