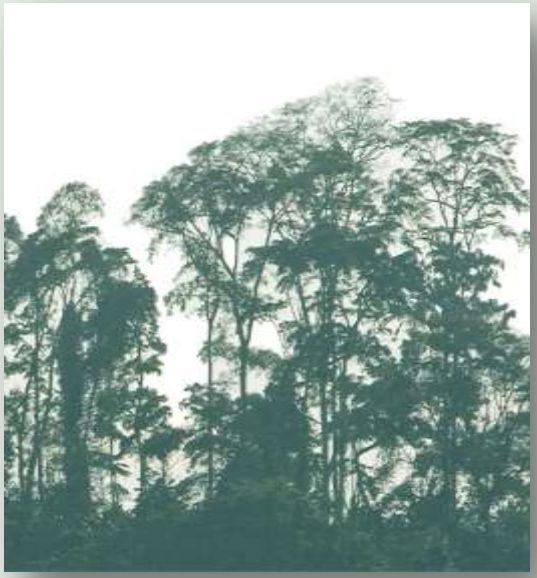
UN-REDD PROGRAMME

National Forest Monitoring System Training Modules

Forest Inventories

Module 4: Observations and Measurements



Observations and Measurements

Module highlights:

- ✓ Methods for collecting observations at different sampling locations selected based on a given sample design
- ✓ General aspects of different observation units, such as points, lines and areal plots
- ✓ The different types of variables typically assessed in forest inventories.

Types of variables

✓ Measurements and observations for National Forest Assessments (NFAs) are drawn from several different sources: **maps, aerial photographs, satellite imagery and the field**, but also: previous inventory reports, documents, research studies and expert knowledge.

✓ **Observations** produce values for variables and are made on defined observation units.

✓ **Variables** (or attributes) may be classified according to different criteria.

Types of variables

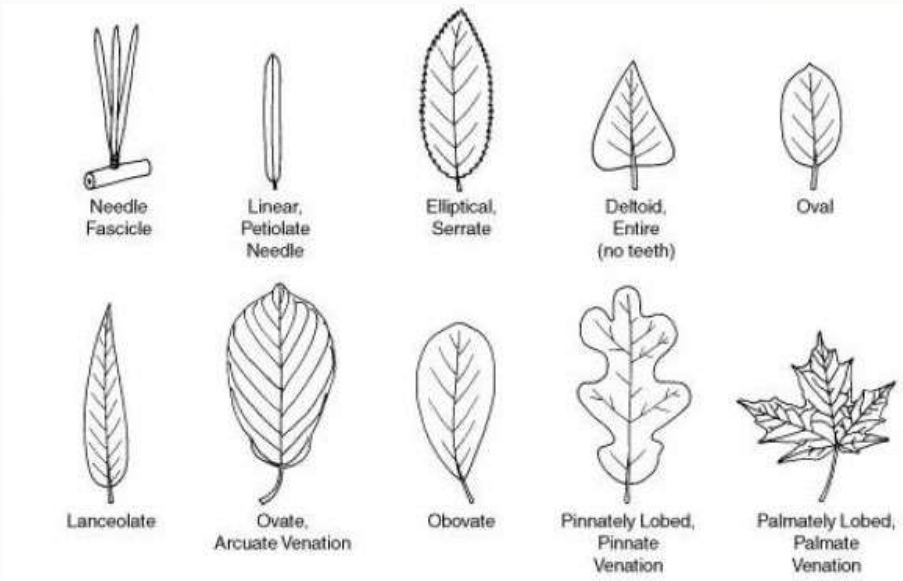
Variables in a statistical sense :

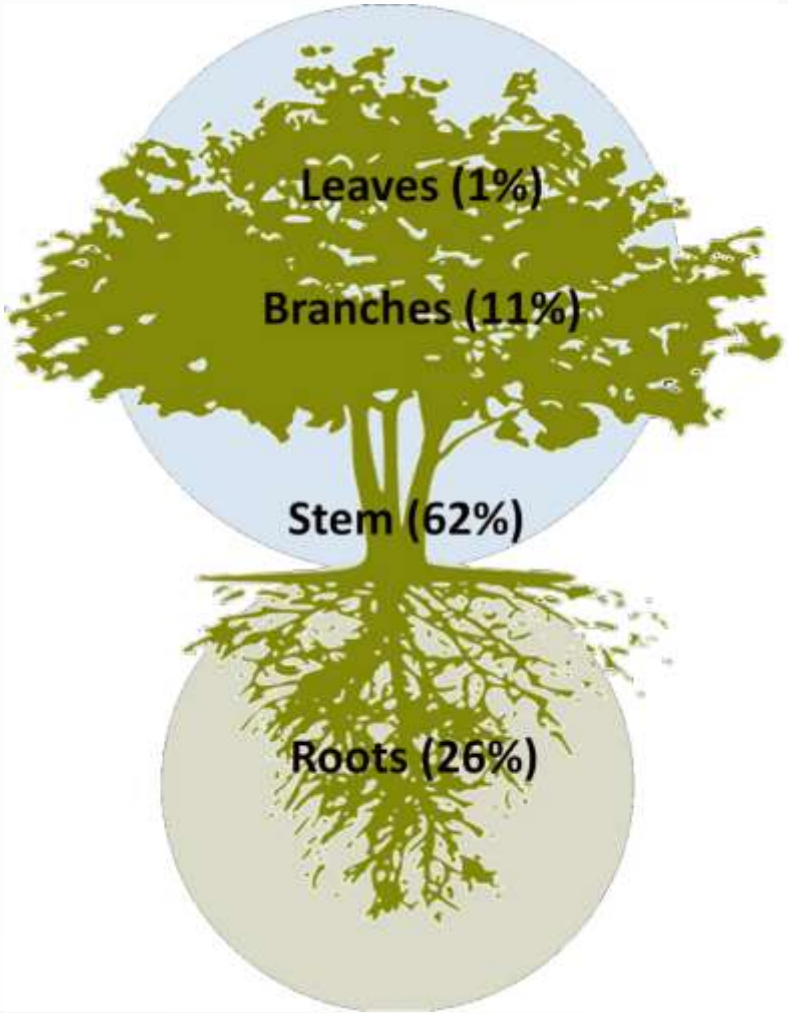
“measurements” may yield a **metric value** (for measured variables such as distance, diameter or height) or a **classification** into one out of a set of two or more categories (for categorical variables such as species, forest type and soil type).

Types of variables

Directly observed vs. Derived variables:

Some variables are directly measured/observed, such as *dbh* or tree species, and some are derived/modelled, such as volume and biomass, and most observations of change





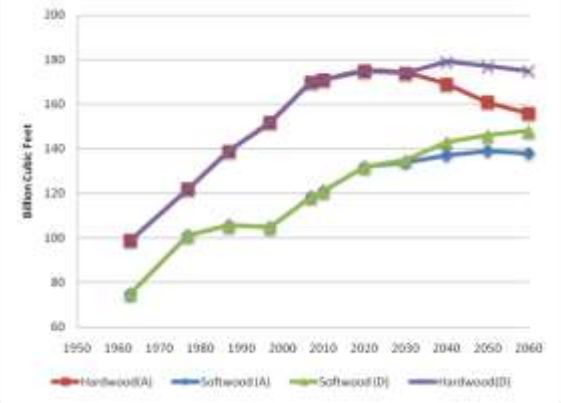
Types of variables

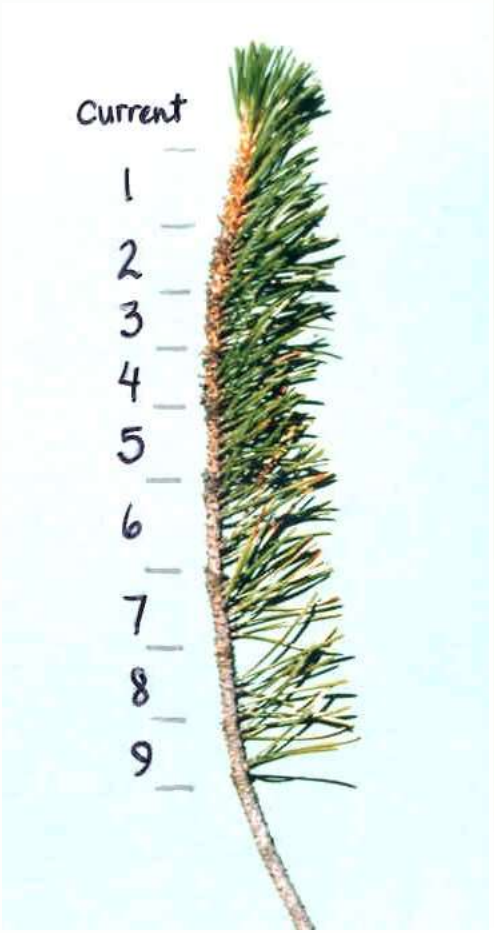
***Status vs. Change variables**:*

The majority of measurements give a *status* value for a given attribute.

Only a few *change* attributes can be measured directly at one point in time. [i.e. increment borings; length of terminal shoots of coniferous trees].

The <u>estimation of change</u> for other variables is therefore based on measurements taken at <u>two points in time</u>.





Types of variables

How many variables?

A wide number of attributes are typically covered in an NFI.

Traditionally, **biophysical variables**; more recently, **multipurpose inventories**: data on forest use, socio-economic variables, etc. to analyze drivers of change.

The number of attributes observed on each plot can be as high as over **250** and, in most cases, is **not less than about 100**.

Some examples: *land use, forest area, forest type, growing stock, non-wood forest products, biodiversity, soil erosion*, etc.

Which variables to include?

✓ The decision concerning which variables to observe is **strategic**

✓ Commonly a core set of variables but **customization** is possible

✓ Focus on those variables that will yield the target information or are required as input for models (i.e. height)

✓ Decision depends also on **staff capacity** and **resource availability**

Variables definition and Measurement protocol

All variables need to be <u>clearly defined</u>

<u>Measurement procedure</u> must also be defined in detail.

Field manual

Example: for the variable ***dbh*** a complete definition comprises the following:

- The height in which the dbh is to be measured (1.3 m)
- How to proceed in cases where 1.3 m is an impossible height to measure
- The measurement unit to be taken and the scale (e.g. centimetre, to the first decimal)
- The measurement device to be used and what to observe while using it.

Measuring Point

Dbh measurement position on steep terrain

Dbh measurement position on Forked Trees

Measurements

Measurements that are carried out in forest inventories are usually of the following types:

- ✓ Measurement of **distance/lengths**
- ✓ Measurement of **angles**
- ✓ Measurement of **areas** (using maps or remote sensing)
- ✓ Measurement of **position** (satellite navigation)
- ✓ “Measurement” of a **condition** class (i.e. classification - assigning an object to a defined set of condition classes)

Measurements

Measurement of **distance/lengths**

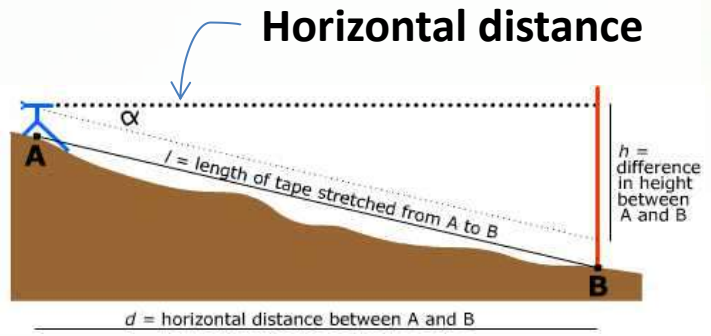
- for individual tree characteristics (diameter and height)
- plot establishment (e.g. the radius of a circular plot)
- when navigating to the chosen plot location

Direct vs. Indirect measurements

How?

Pacing, tape, mechanical-optical devices (Suunto), laser technology (Vertex)

Always follow clear definitions!



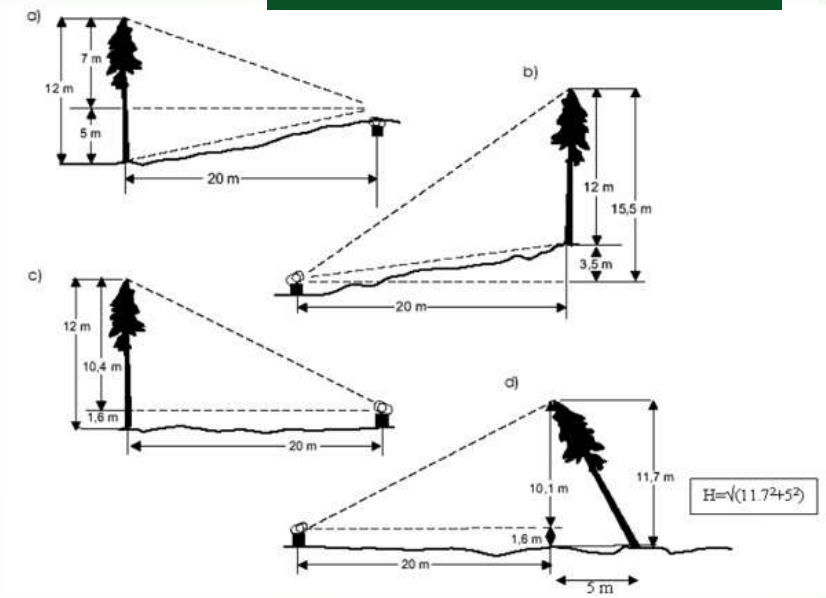
Measurements

Measurement of **angles**

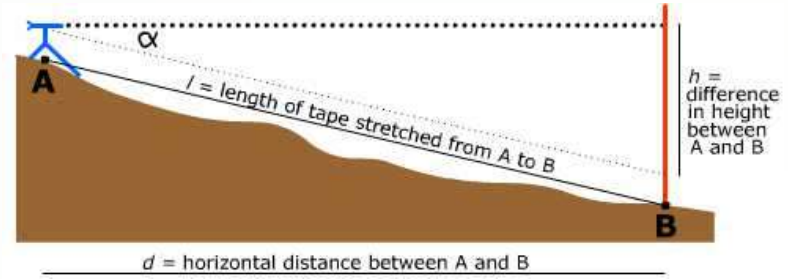
- Slope angle and bearing

Navigating to the plot

Tree height



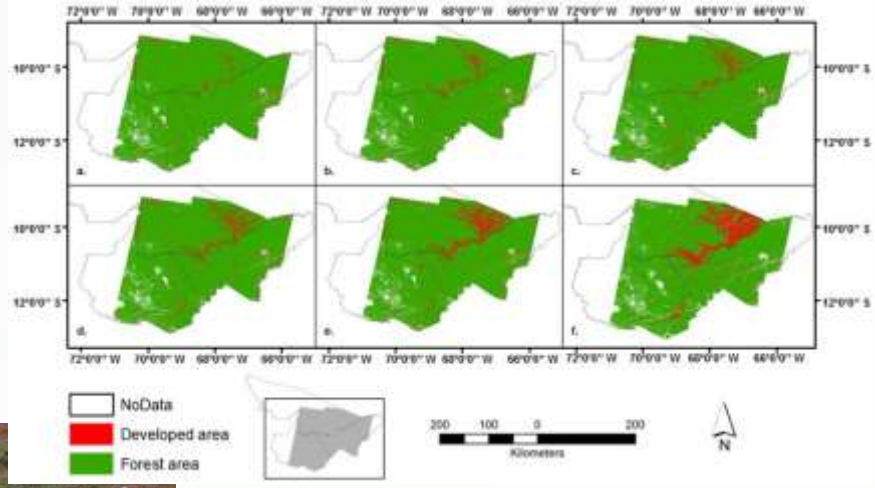
Horizontal distance



Measurements

Measurement of **areas**

- Usually carried out with **maps, GIS** or **remote sensing** data



Area (for examples of plots) is measured in the field using a compass and measuring tape

Measurements

Measurement of **position**

Satellite navigation uses distance measurements via a set of satellites to determine three-dimensional positions

Three basic functions for NFIs:

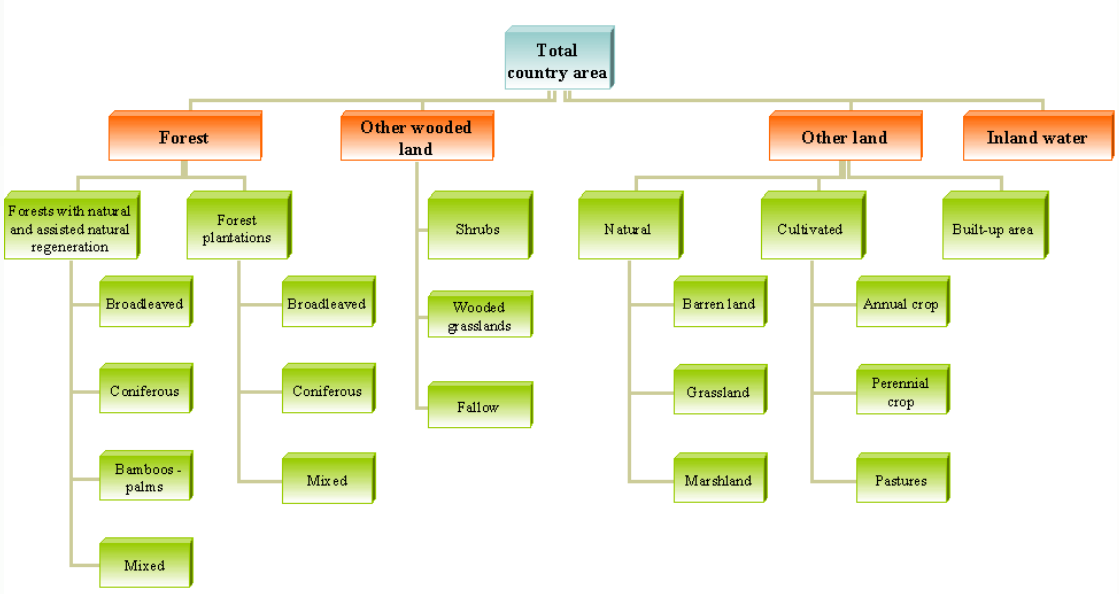
- **navigation** or “finding the way to the sample plot in the field”
- **position** or “determining the position of sample points or other reference points in the field”
- **tracking** or “monitoring the movement of people”. (can be used to document the access path to a plot, thereby helping to ensure that field crews reached the correct target sample plot location).

the highest-grade GPS receivers affordable should be considered !!

Measurements

Measurement of a **condition** (Classification)

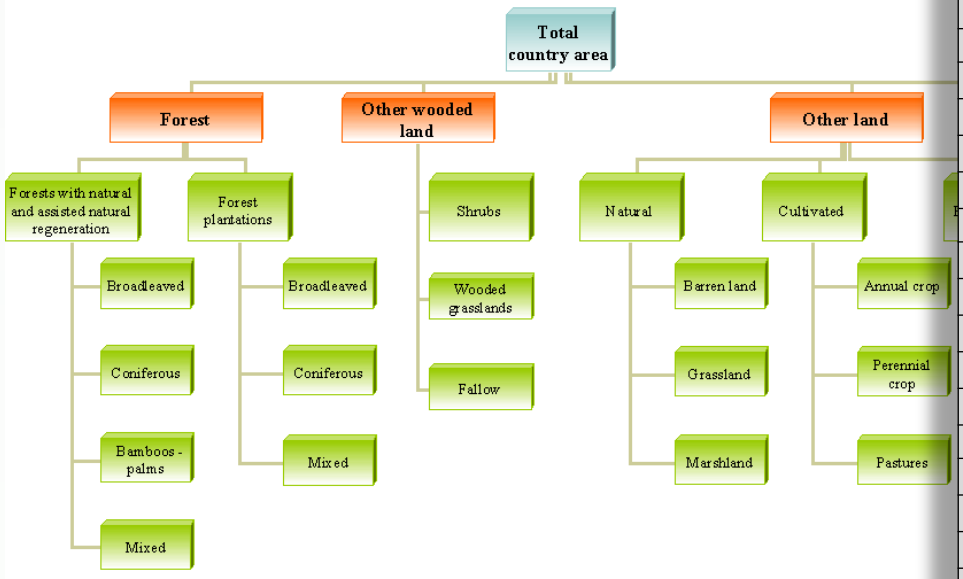
For categorical variables, measurement concerns the assignment of a response to one of a set of defined classes. Here, the complete set of possible “values” (classes) needs to be defined. Typical examples include the variables “forest type” or “tree species”.



Measurements

Measurement of a **condition (**

For categorical variables, measurem
response to one of a set of defined c
possible “values” (classes) needs to
include the variables “forest type” or



Classes	Code
Forest	
Forest with natural or natural assisted regeneration	
Broadleaved forest	FB
Coniferous forest	FC
Bamboo or palm forest	FB
Mixed forest	FM
Forest plantations	
Broadleaved forest plantation	PB
Coniferous forest plantations	PC
Mixed forest plantations	PM
Other wooded lands	
Shrubs	Sh
Fallow	Fa
Wooded grassland	WGL
Other land	
Natural and semi natural land	
Barren land	Bl
Grassland	Gl
Marshland	Ml
Cultivated and managed land	
Annual crop	AC
Perennial crop	PC
Pastures	Pa
Built up area (urban or rural)	BUA

Measurements

Lastly, the **set of variables** to be covered by a specific NFA depends on the specific **set of objectives**. The variables can be grouped into major subject areas.

Examples of NFI variables:

- Geographic and **topographic** variables.
- **Ownership** classes
- **wood production**
- site and **soil**
- **forest structure**
- **regeneration**
- **forest condition**
- **accessibility and harvesting**
- **forest ecosystems**
- **non-wood forest products**

Observation units and their characteristics

The “objects” selected for observation in NFAs usually comprise one of the following types:

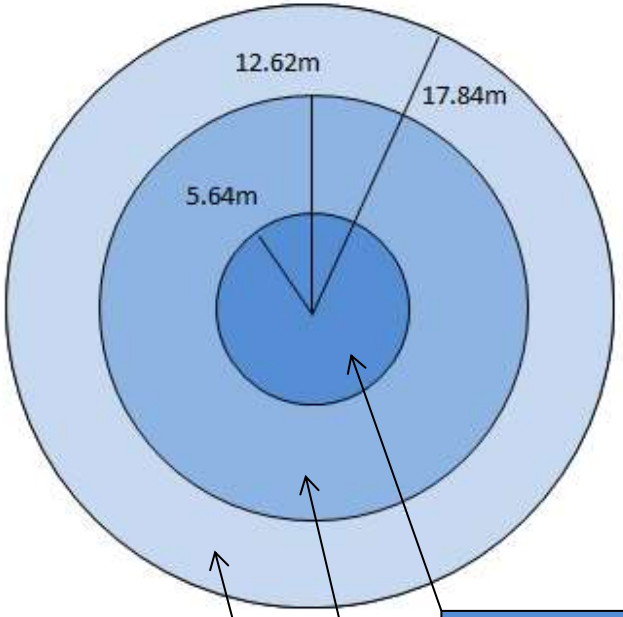
- ***Individual elements*** *(e.g. tree)*
- ***Points*** *(dimensionless observation units)* – often center of the plot - one point determines the characteristic of the plot (forest/non forest; forest type, soil type, ownership etc.)
- ***Lines –*** “line intersect sampling” *i.e. for measuring deadwood*
- ***Areas (fixed/variable) -*** *entire plot* is the observation unit and each plot delivers *one* independent observation for estimation (i.e. the plot mean or the plot total).
    - ***Fixed area plot –*** *most frequent*
    - ***Nested plot*** *(e.g a regeneration plot inside a bigger plot)*

Observation units and their characteristics

- **Nested plots** contain smaller subunits of various shapes and sizes depending on the variables to be measured
- For example, saplings could be measured on a small subunit, trees between 5-50 cm on a medium subunit and trees above 50 cm could be measured on the entire plot
- Nested plots can be cost-efficient for forests with a wide range of tree diameters or stands with changing diameters and stem densities

Observation units and their characteristics

Nested plots

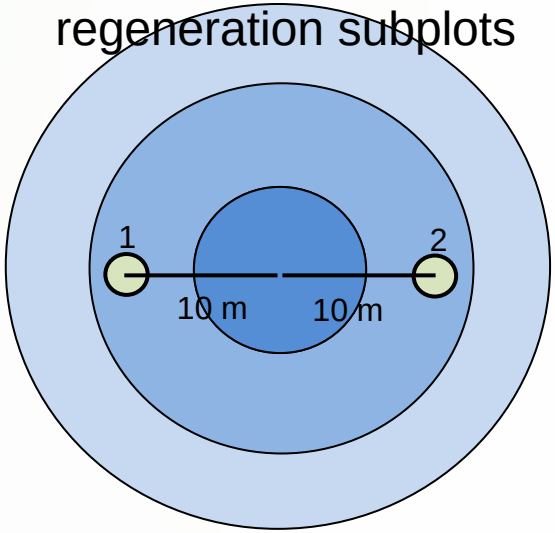


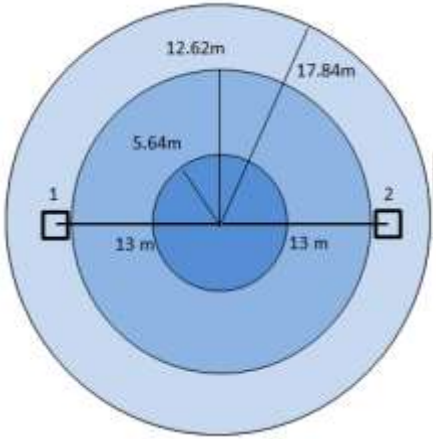
100 m^2 dbh >= 6cm

500 m2 dbh >= 20cm

1,000 m^2 dbh >= 40cm

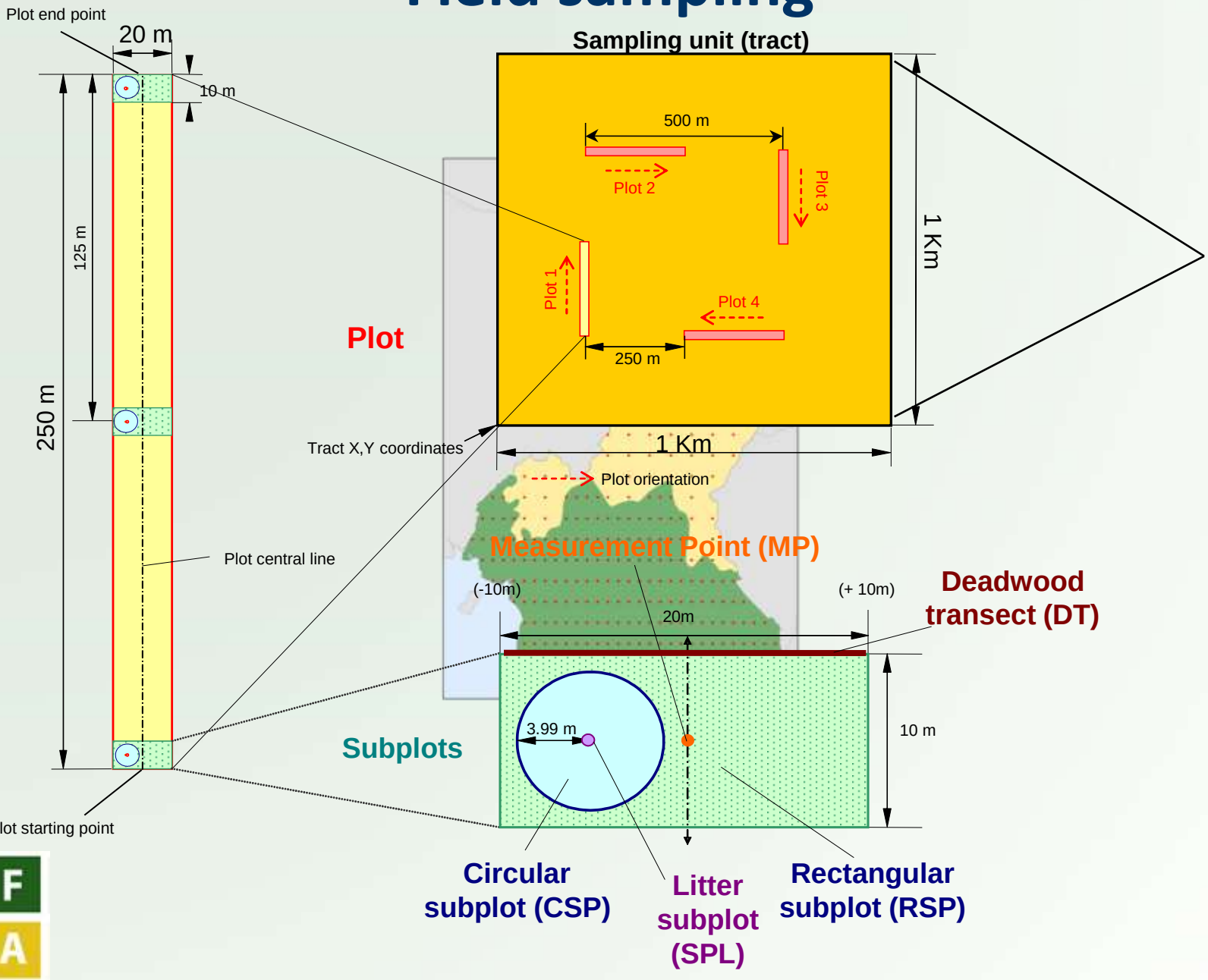
regeneration subplots





Litter plot (1x 1m)

Field sampling



Sample Plots / Plot Size

Objective:

• to achieve the **highest possible precision** for a **given cost** (or the lowest cost for a defined level of precision).

• to **maximize variability** by encompassing as many different conditions as possible.

• **High variability within a plot** minimizes the differences between plot values of a sample, which in turn leads to **smaller standard error**.

Key principles:

• **Optimization** is usually done on **one key variable**, often growing stock.

• In the case of NFIs, many important variables are observed → advisable to make a formal optimization along a key variable (usually volume) and make a **pragmatic decision** taking into account general experiences from other NFAs.

Sample Plots / Plot Size

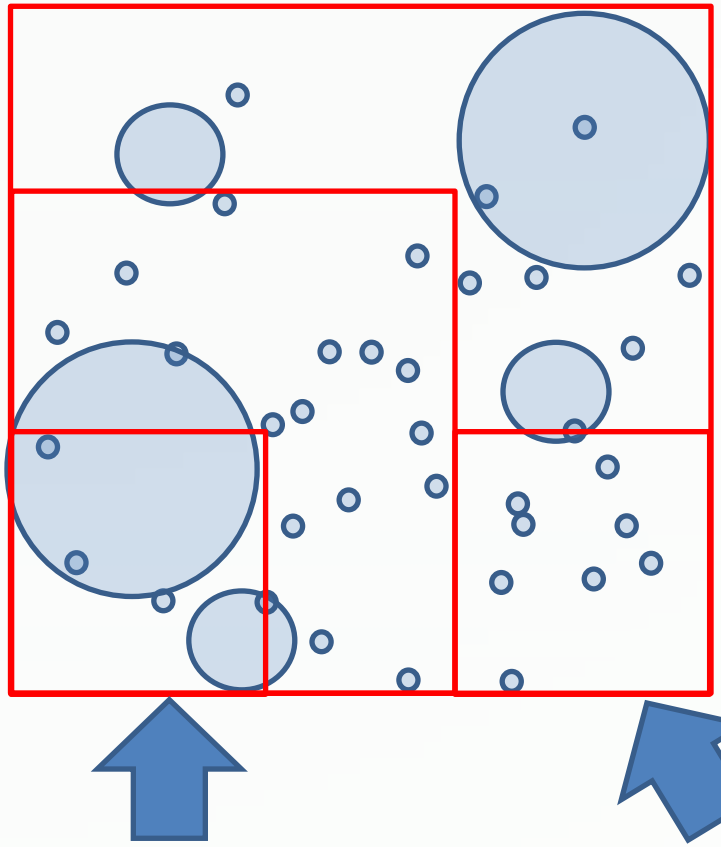
Key principles (2):

- **Practical consideration** (time and budget) often determines the decision
- In **Cluster plots** the field crews spend much time walking
- In **Strip plots** the number of boundary trees is much higher than in circular plots of the same area (because of the minimized perimeter).
- In **Circular plots** field implementation is more straightforward, as these are defined by locating a single centre point.

Also consider:

- **Visibility**: strip plots are preferred for poor in-forest visibility while Circle plots are preferred for good visibility.
- A valid (though uncommon) approach is to combine in the same survey, plots of the **same area** but **different shapes.**
- Integration with **Remote Sensing**
- Empirical evidence has found that about **15-20 trees per plot** is a good value for plot size.

Sample Plots / Plot Size



Over estimate

Under estimate

example: projection of crowns in an evergreen seasonal forest in Cambodia.

Sample Plots / Plot Size

Basically, the more similar the observations are, the more efficient is the small plot, and vice versa.

As a rule of thumb, a plot should be large enough to contain enough trees per plot to be representative of the population

Small plots should be employed for **dense stands** with small trees, and **large plots** for **open stands** and large trees

When travel time is significant, as in a tropical forest, the size of inventory plots tends to be large, often in the 0.4–0.5-ha range.

Conclusions

Data quality

- Each single measurement is made with care and accuracy.
- All measurements of a particular attribute follow the same specifications (in terms of definition and measurement procedure).

→ Avoid (minimize) measurement errors!

Assessment and measurement protocols: ensure complete and clear documentation and descriptions.

Staff: undertake careful selection and training of field crews.

Supervision: ensure oversight and control of fieldwork, measurement devices (calibration) and data delivered.

Verification: undertake careful checks and calibration of measurement devices.

Plausibility: undertake final checks when data are entered into the database.

Observation units and their characteristics