FOR-247: Methods and Tools in Tropical Forestry
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# Design and implementation of forest inventories.

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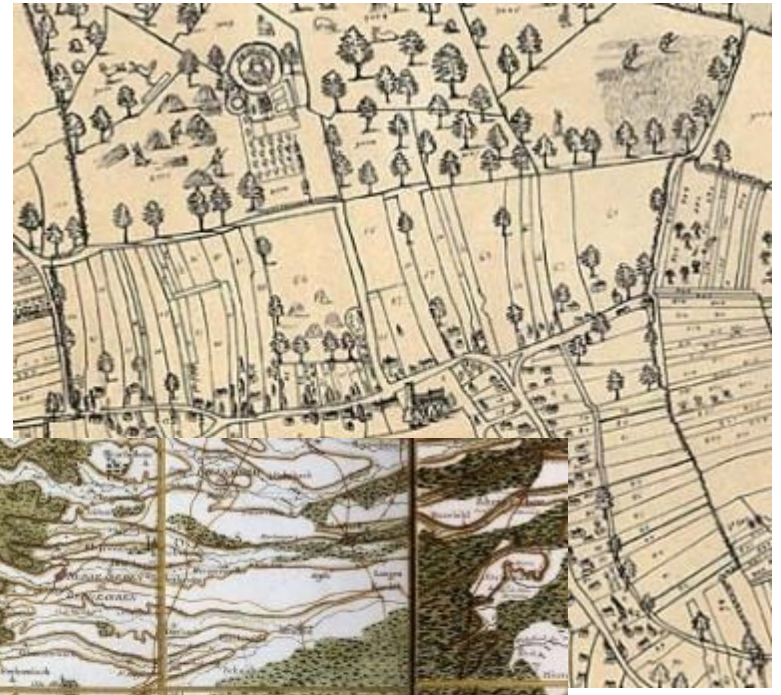
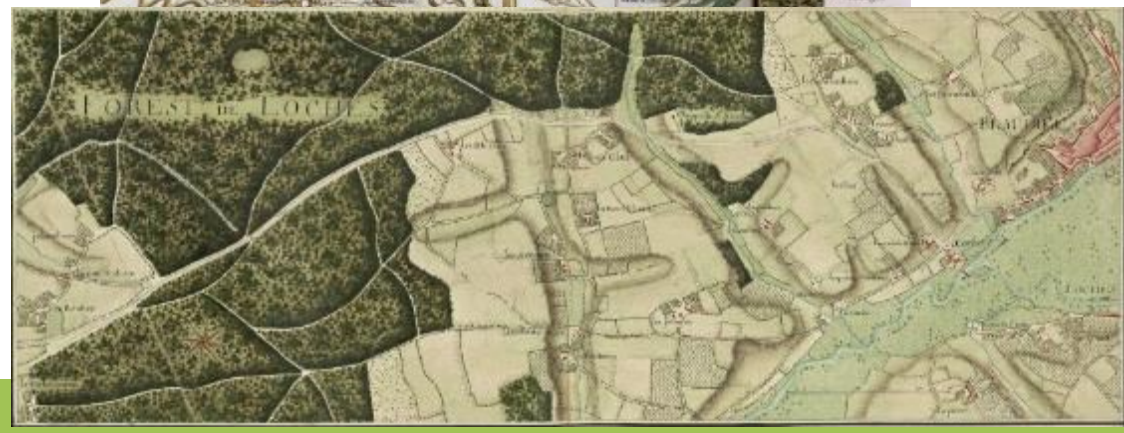
# Content

- Introduction
- Designing an inventory
- Implementation
- Examples
  - ✓ FAO + WWF
  - ✓ VITRI
  - ✓ Field course

# Inventories: Introduction

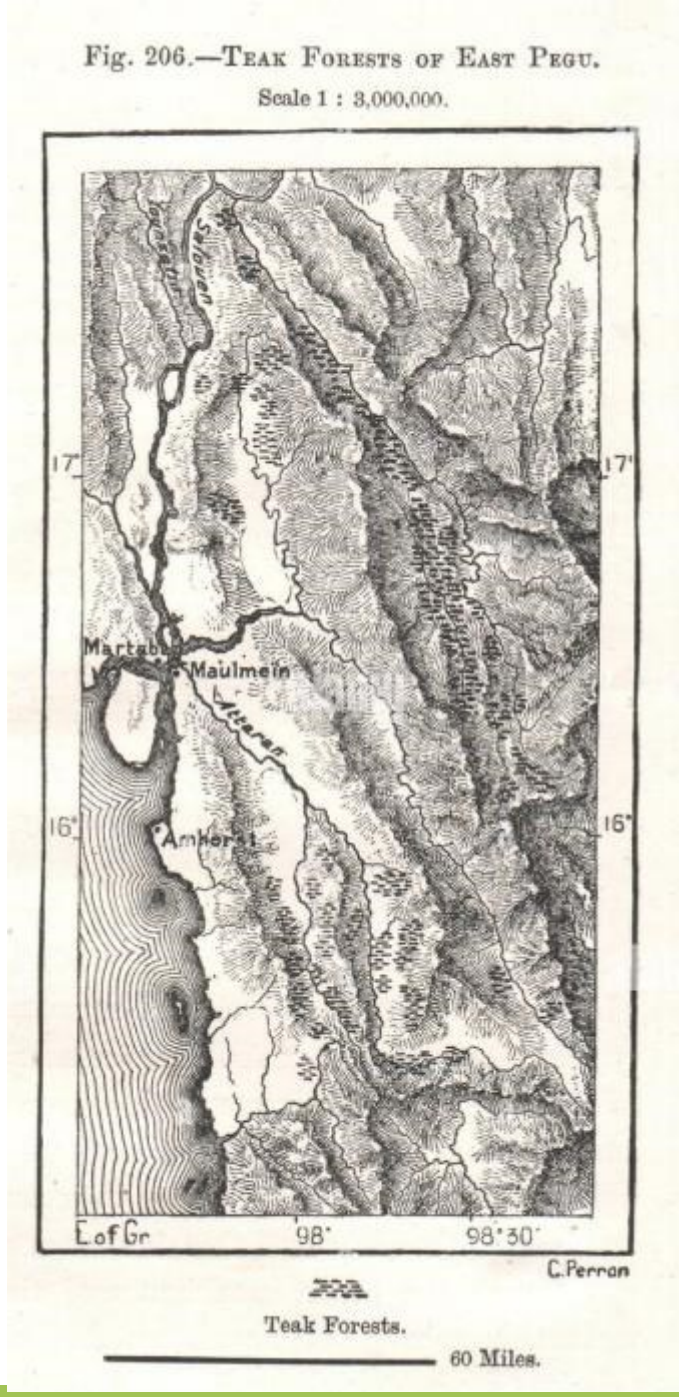
- Earlier references about forest inventories from late middle ages (15th century)
  - Just a complete numeration of specific trees for specific uses (e.g., construction, firewood)
- The late 18th century saw the implementation of maps to plan usage of forests
  - Fears of decreasing resources in some areas
- During the 19th century loggers divided large areas into smaller units with similar species
  - Still mostly based on visual estimations
  - Relationships between diameter, height, and volume were put into practice





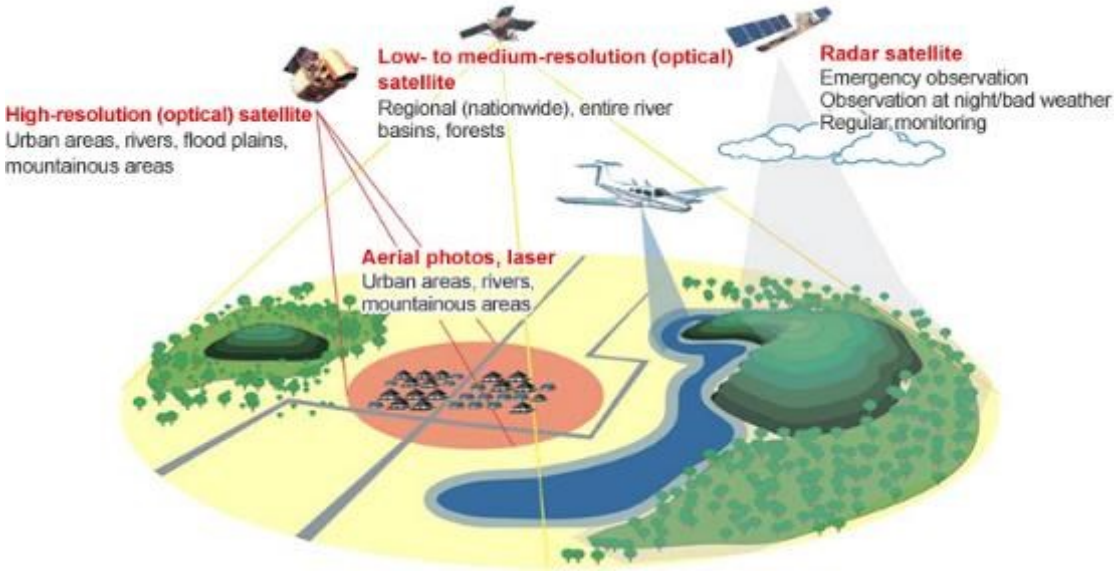
# Inventories: Introduction

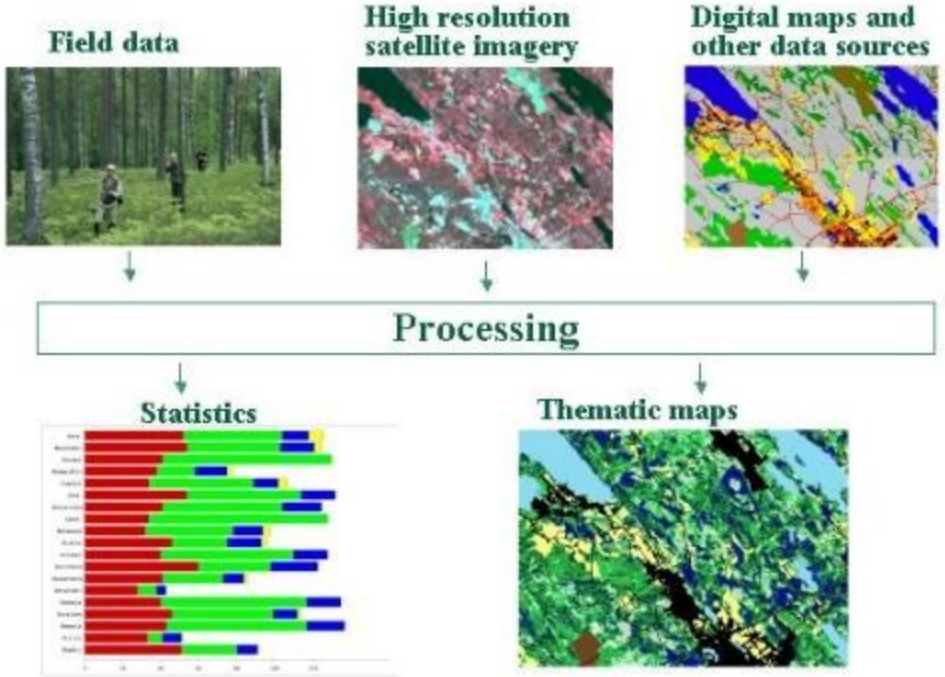
- By the late 19th century, the sampling-based inventory was introduced
  - Sweden 1840
  - Burma 1850, teak forests (Dietrich Brandis -taungya-)
- National forestry inventories were implemented in Scandinavia in the early 20th century
  - Great advances in stratification and statistical analysis
- Aerial forest surveys started in Canada during 1920-30's
- Important advances in terms of equipment and methods during this period



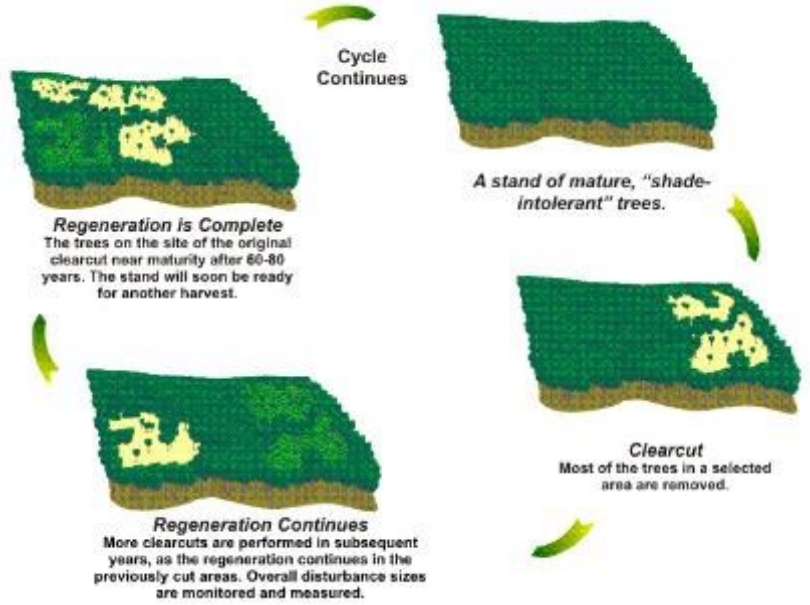
# Inventories: Introduction

- Nowadays there is a pool of technologies to support and complement forest inventories



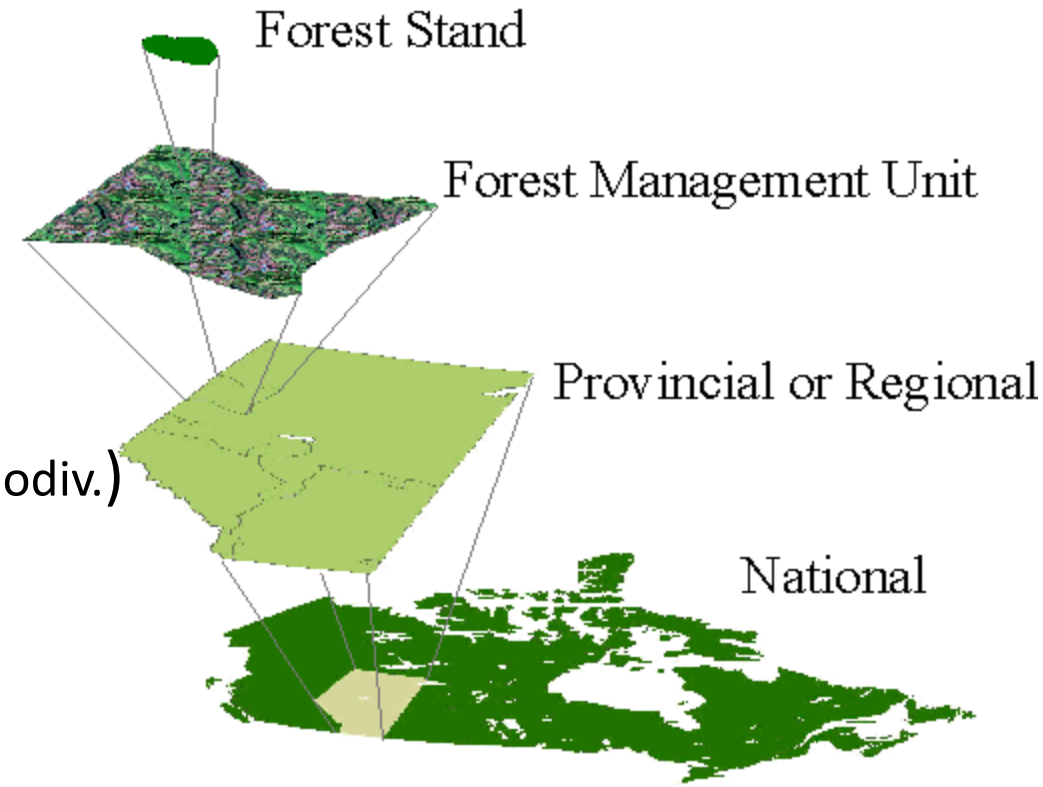
# Inventories: Design




- Purpose:
  - To make informed decisions about forest management
    - Traditionally concentrated on timber volumes
    - Nowadays more components of the ecosystem are often considered – SDGs-
  - It provides information about
    - the effects of previous interventions -if any-,
    - the assessment of current conditions, and
    - potentially, information about the effects of future interventions

# Inventories: Design

- Classification (Scott & Gove 2002):
  - Silvicultural survey
    - pre & post treatments
  - Regeneration survey
    - pre & post treatments
  - Operational inv.
    - pre & post harvest
  - Appraisal survey (biomass-biodiv.)
    - to estimate value of land
  - Strategic inv.
    - allocation of resources
  - National or regional inv.
    - high level policy making

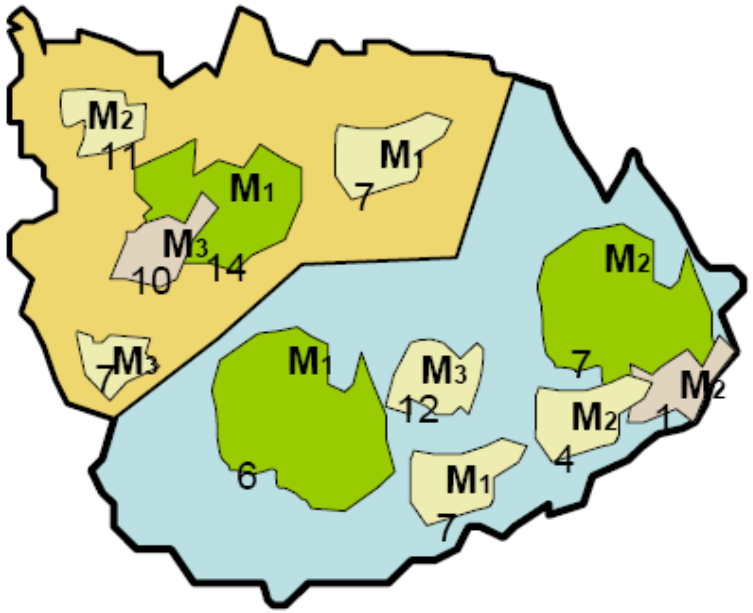


# Inventories: Design

- Based on inventory objectives we should consider that:
  - There should be a reasonable balance between the objectives and the cost (money & time) of the inventory
  - Similar balance with the precision and volume of data collection
  - What information is already available
    - Previous inventories
    - Permanent measurement units
    - Aerial, satellite or lidar material
    - Availability of resources – human & technical-

# Inventories: Design

- Consider whether stratification is needed:



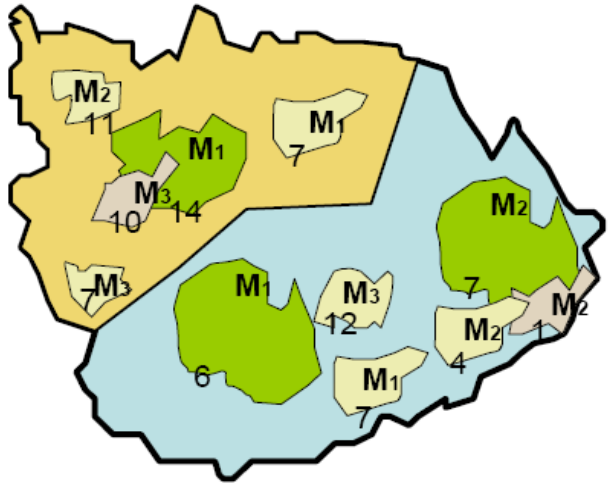

- Allows researchers to obtain precise estimates at a lower cost than without stratification
- Steps:
  - Divide heterogeneous population into homogenous groups
  - Larger samples are taken in the strata with the greatest variability to generate the least possible sampling variance
  - Use standardised methods (sampling and calculations) for each strata and compile results at the end

# Inventories: Design

- Stratification can be based on
  - Changes in species composition – forest types-
  - Soil types
  - Climatic conditions
  - Other relevant factors related to the objectives of the inventory
- Also check whether preliminary inventories or previous inventories indicate
  - High standard errors → high variability across samples
  - Changes in the species/area curve

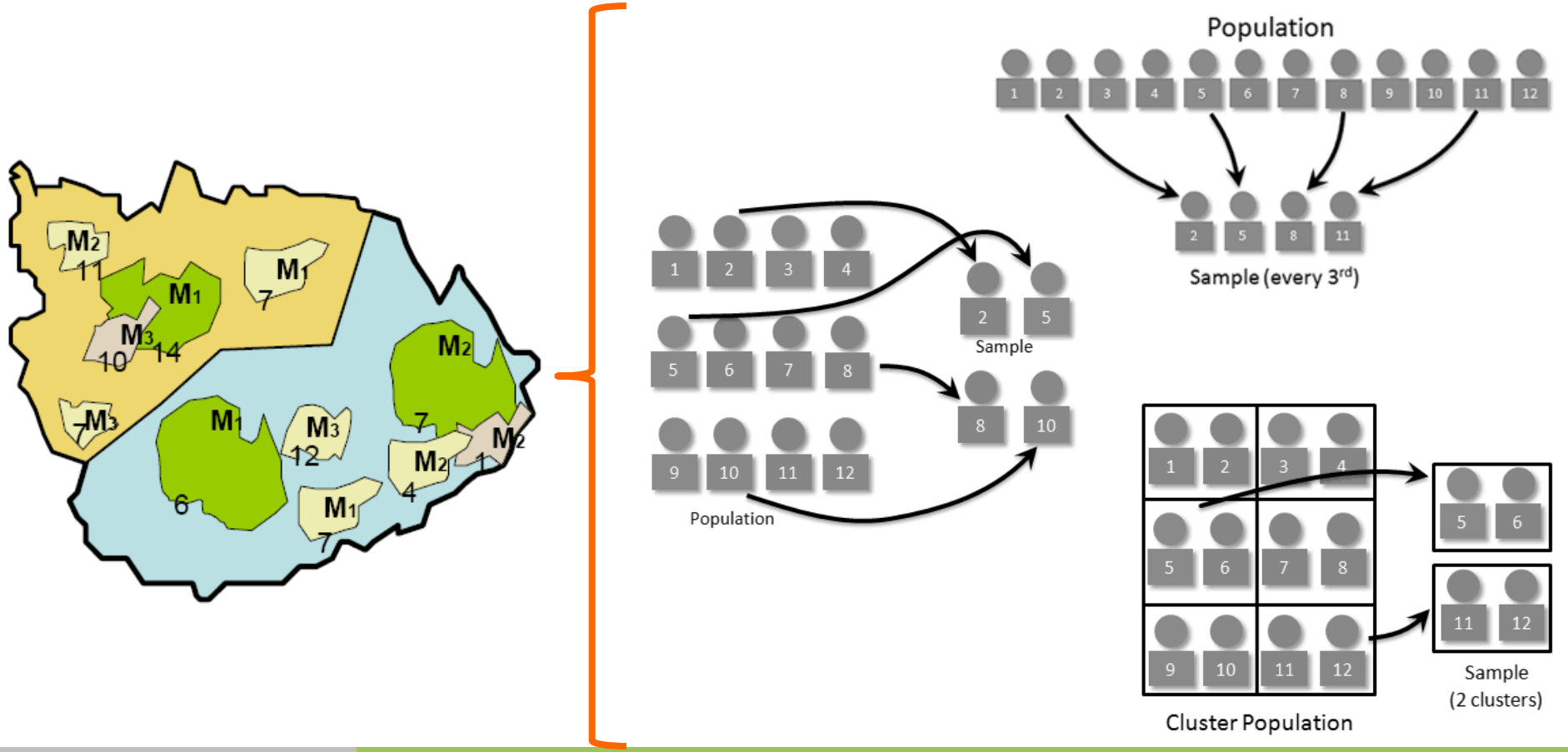
# Inventories: Design

- Sampling intensity
  - Based on inventory objectives and targeted precision
  - Stratification will allow for lower standard errors within each strata thus reducing sampling intensity
  - Winrock Sample Plot Calculator can help you to get an idea of sample intensity needed
    - http://www.winrock.org/resources/winrock-sample-plot-calculator
    - The calculator allows stratification



# Inventories: Design

- For all strata choose sampling method (usually without replacement)

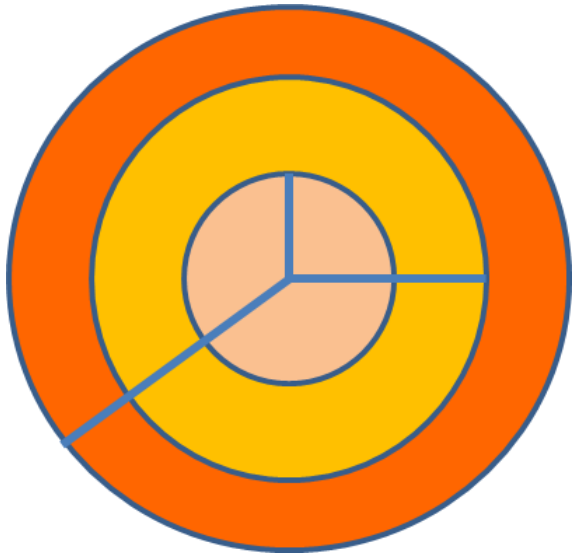


# Inventories: Design

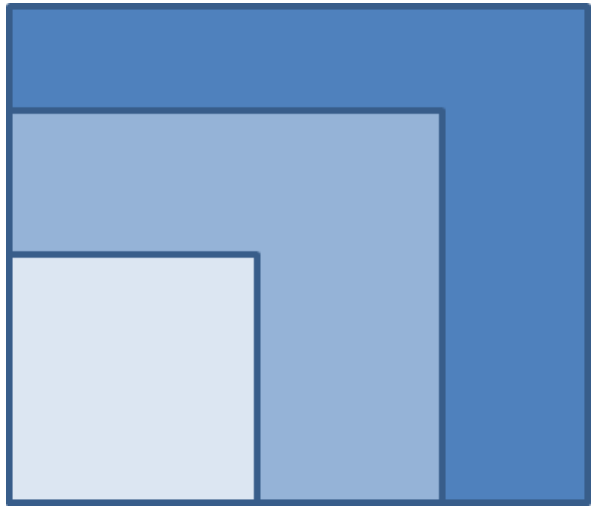
- Inventory plots
  - Develop clear rules about when to ignore or shift a sample plot if necessary
    - Plot fall into the wrong land-use or forest type
    - Plot too close to the edge of land-use or forest type
    - Plot is inaccessible
    - Other reasons…
  - Depending on the objective of the inventory
    - The plot is recorded as unmeasured, still use for data analysis
    - The plot is moved or an extra plot is added to the sample
    - Other….

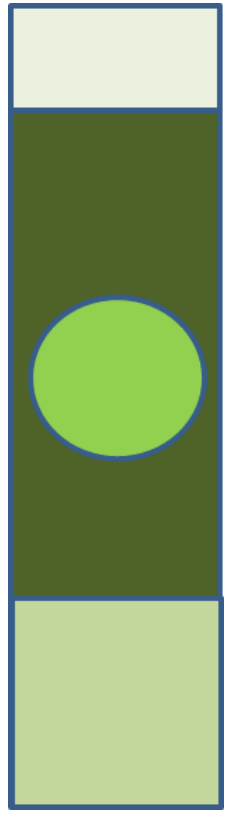
# Inventories: Design

- Inventory plots
  - Shape and dimensions based on objectives, experience and constrains



$r$ = 0,8 → 2m$^2$
$r$ = 5,64 → 100m$^2$
$r$ = 12.62 → 500m$^2$





# Inventories: Design

- What information to collect?
  - Basic info: forest type, slope, DBH, tree height, species
  - Additional info: tree form/quality, crown cover, ecological position, location, etc

**Formulario 1.**
**Boleta de campo para árboles ≥ 25 cm dap, pimienta (≥10 cm dap) y chicozapote (≥20 cm dap); subparcela 10x50 m**

INVENTARIO FORESTAL INTEGRADO DE _____

No. parcela: _____ No. subparcela: _____ No. de Cuadrilla: _____ Fecha: _____ Tipo de Bosque (1 – 4): _____
Topografía (1 – 4): _____ Drenaje (1 – 4): _____ Estado del bosque (1 – 6): _____ Sitios arqueológicos (1 – 6): _____

| No. | Nombre común | Dap (cm) | Calidad fuste (1- 6) | Altura com. (m) | Observaciones |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

Evaluación Pimienta y Chicozapote

| Especie | Dap (cm) | Cosecha-bilidad |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

# Inventories: Design

- What information to collect?
  - Only trees: seedling, sapling, tree (DBH > 5cm or 10cm)
  - Other than trees: Palms, bamboo, other vegetation

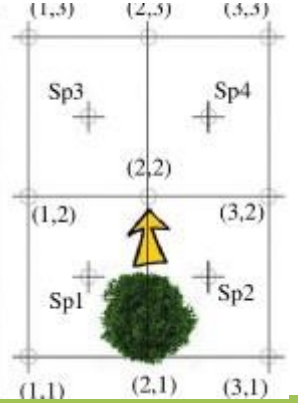
**Formulario 3. Boleta de campo para muestreo diagnóstico lineal.**

Nombre sitio: _____ No. de cuadrilla: _____ Fecha: _____ CUADRADO 10x10 m
Identificador: _____ Anotador: _____
No. de línea o brecha: _____Desde: _____ m A: _____ m

| Distancia sobre largo de línea | | Tipo de bosque 1, 2, 3, 4 | Inventario de árboles aprovechables | | | | Deseable Sobresaliente <60 cm caoba y cedro; <50 cm otras especies | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Desde ___m | Hasta ___m | | ≥60 cm dap caoba y cedro ≥50 cm dap otras especies nombre común ó 9 si no hay | Dap (cm) | Calidad fuste (1 – 6) | Alt. com. (m) | Tipo 1, 2,3 4, 9 | Nombre del DS | Dap (cm) | Clase llum. copa | Clase lianas (1-4) |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

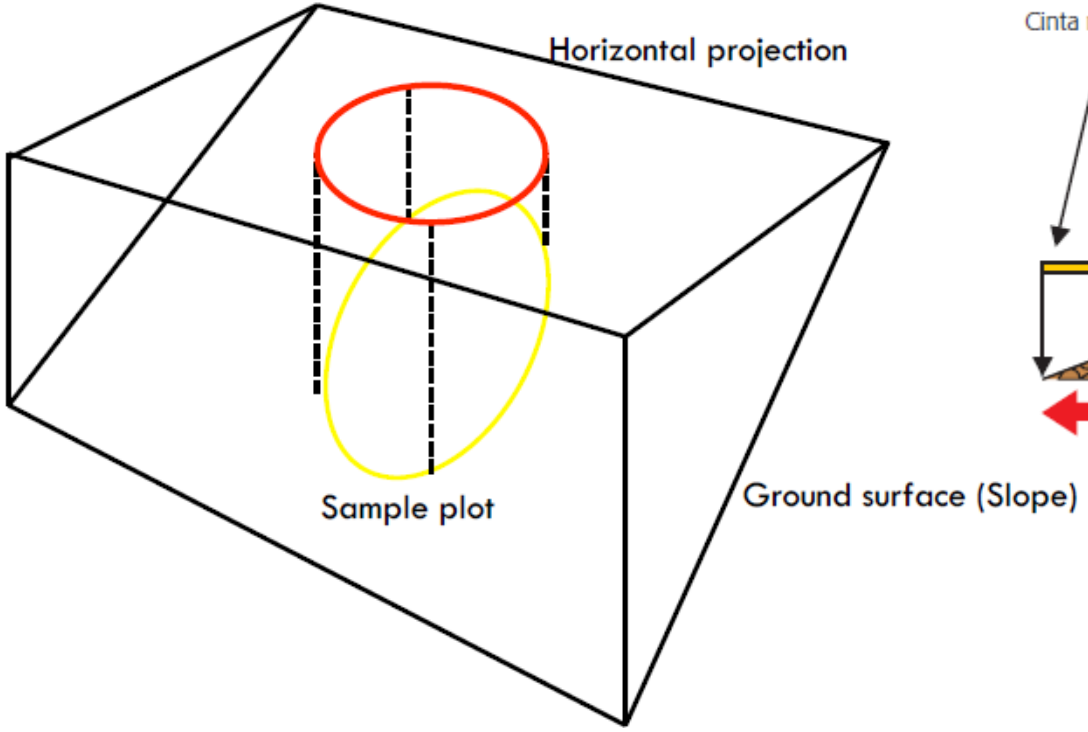
# Inventories: Implementation

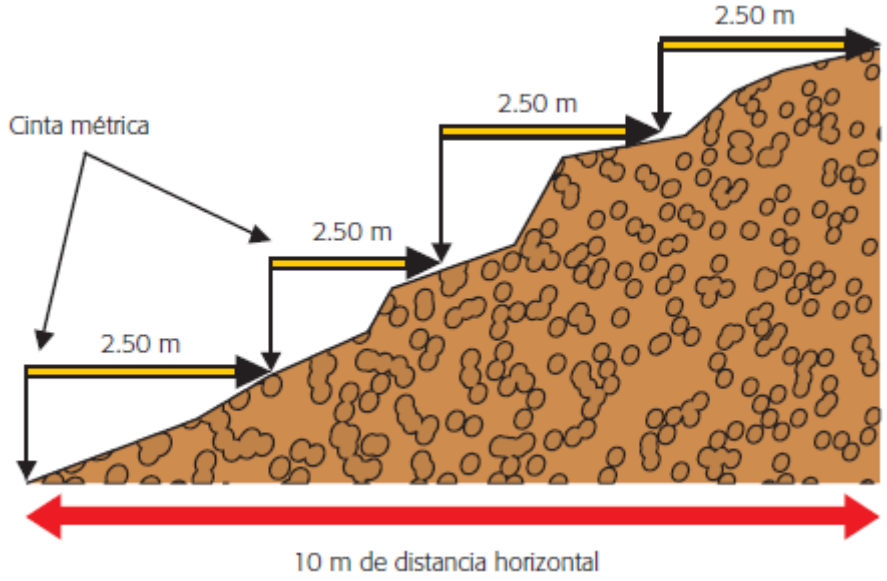
- Basic equipment
  - DBH: Diameter tape, caliper, relascope (basal area)
  - Height: clinometer, Blume Leiss (Haga),
  - Distance: GPS, long tape, ropes
- More specialised equipment depending of the objectives
  - Laser instruments: vertex, postex, criterion/trupulse



# Inventories: Implementation

- To consider while stablishing plots
  - Slope



# Inventories: Implementation

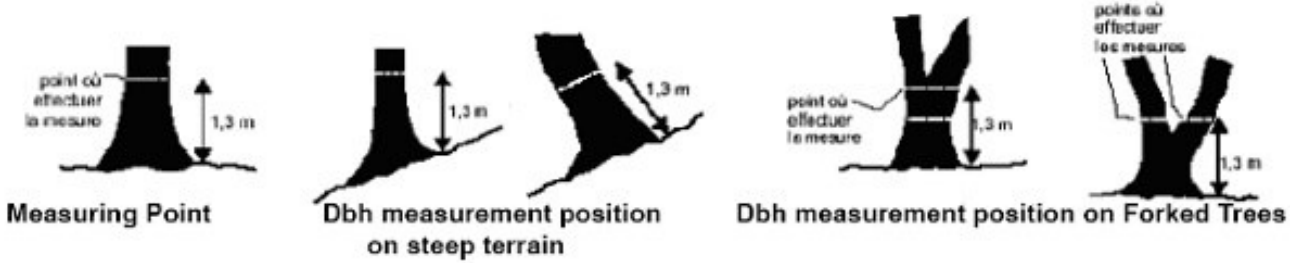
- To consider while stablishing plots

| Slope | Degree | Factor | Horizontal distances | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | ° | $f_s$ | 5 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 125 | 245 |
| **15** | 9 | 1.0112 | 5.1 | 10.1 | 15.2 | 20.2 | 25.3 | 30.3 | 40.4 | 50.6 | 126.4 | 247.7 |
| **20** | 11 | 1.0198 | 5.1 | 10.2 | 15.3 | 20.4 | 25.5 | 30.6 | 40.8 | 51.0 | 127.5 | 249.9 |
| **25** | 14 | 1.0308 | 5.2 | 10.3 | 15.5 | 20.6 | 25.8 | 30.9 | 41.2 | 51.5 | 128.8 | 252.5 |
| **30** | 17 | 1.0440 | 5.2 | 10.4 | 15.7 | 20.9 | 26.1 | 31.3 | 41.8 | 52.2 | 130.5 | 255.8 |
| **35** | 19 | 1.0595 | 5.3 | 10.6 | 15.9 | 21.2 | 26.5 | 31.8 | 42.4 | 53.0 | 132.4 | 259.6 |
| **40** | 22 | 1.0770 | 5.4 | 10.8 | 16.2 | 21.5 | 26.9 | 32.3 | 43.1 | 53.9 | 134.6 | 263.9 |
| **45** | 24 | 1.0966 | 5.5 | 11.0 | 16.4 | 21.9 | 27.4 | 32.9 | 43.9 | 54.8 | 137.1 | 268.7 |
| **50** | 27 | 1.1180 | 5.6 | 11.2 | 16.8 | 22.4 | 28.0 | 33.5 | 44.7 | 55.9 | 139.8 | 273.9 |
| **60** | 31 | 1.1662 | 5.8 | 11.7 | 17.5 | 23.3 | 29.2 | 35.0 | 46.6 | 58.3 | 145.8 | 285.7 |
| **70** | 35 | 1.2207 | 6.1 | 12.2 | 18.3 | 24.4 | 30.5 | 36.6 | 48.8 | 61.0 | 152.6 | 299.1 |
| **80** | 39 | 1.2806 | 6.4 | 12.8 | 19.2 | 25.6 | 32.0 | 38.4 | 51.2 | 64.0 | 160.1 | 313.8 |
| **90** | 42 | 1.3454 | 6.7 | 13.5 | 20.2 | 26.9 | 33.6 | 40.4 | 53.8 | 67.3 | 168.2 | 329.6 |
| **100** | 45 | 1.4142 | 7.1 | 14.1 | 21.2 | 28.3 | 35.4 | 42.4 | 56.6 | 70.7 | 176.8 | 346.5 |
| **110** | 48 | 1.4866 | 7.4 | 14.9 | 22.3 | 29.7 | 37.2 | 44.6 | 59.5 | 74.3 | 185.8 | 364.2 |
| **120** | 50 | 1.5620 | 7.8 | 15.6 | 23.4 | 31.2 | 39.1 | 46.9 | 62.5 | 78.1 | 195.3 | 382.7 |
| **130** | 52 | 1.6401 | 8.2 | 16.4 | 24.6 | 32.8 | 41.0 | 49.2 | 65.6 | 82.0 | 205.0 | 401.8 |
| **140** | 54 | 1.7205 | 8.6 | 17.2 | 25.8 | 34.4 | 43.0 | 51.6 | 68.8 | 86.0 | 215.1 | 421.5 |
| **150** | 56 | 1.8028 | 9.0 | 18.0 | 27.0 | 36.1 | 45.1 | 54.1 | 72.1 | 90.1 | 225.3 | 441.7 |

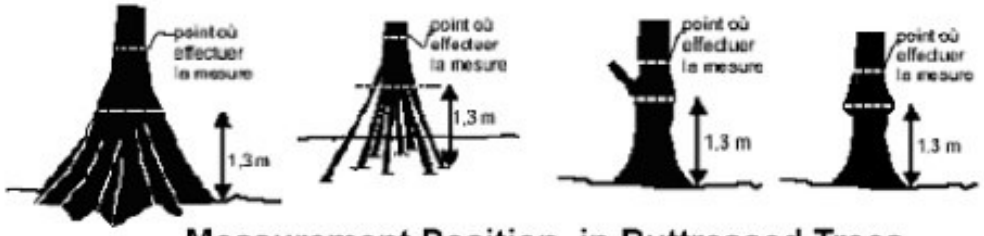
Source: FAO 2004. National Forestry Inventory Manual

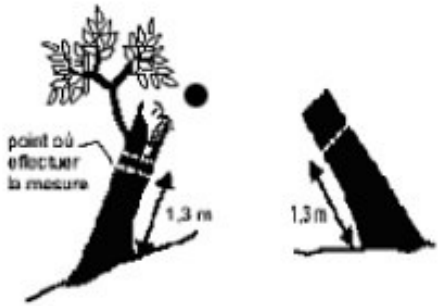
# Inventories: Implementation

- To consider while stablishing plots
  - Tree shapes



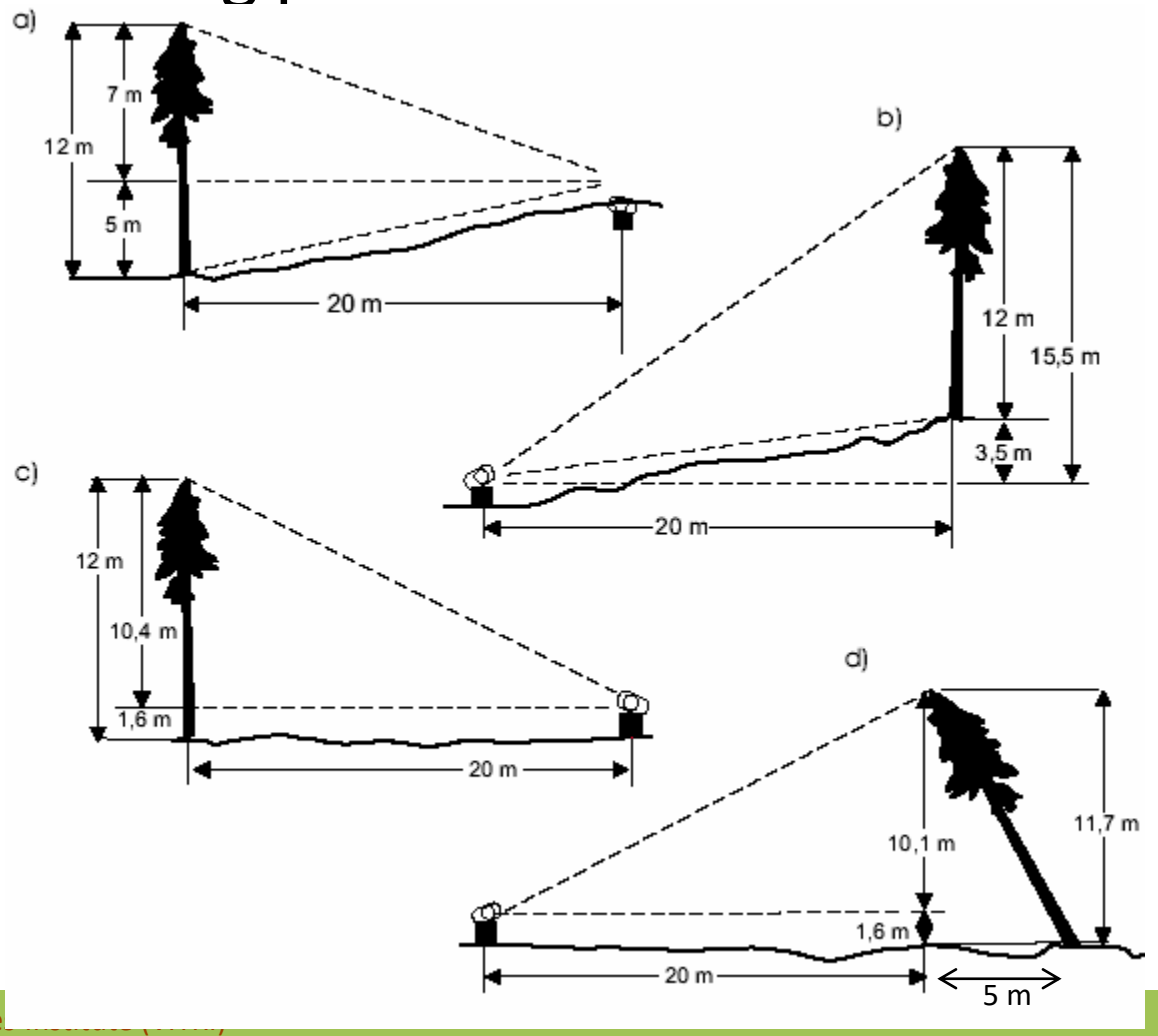

$$\overline{DBH} = \sqrt{x_1^2 + x_1^2}....$$



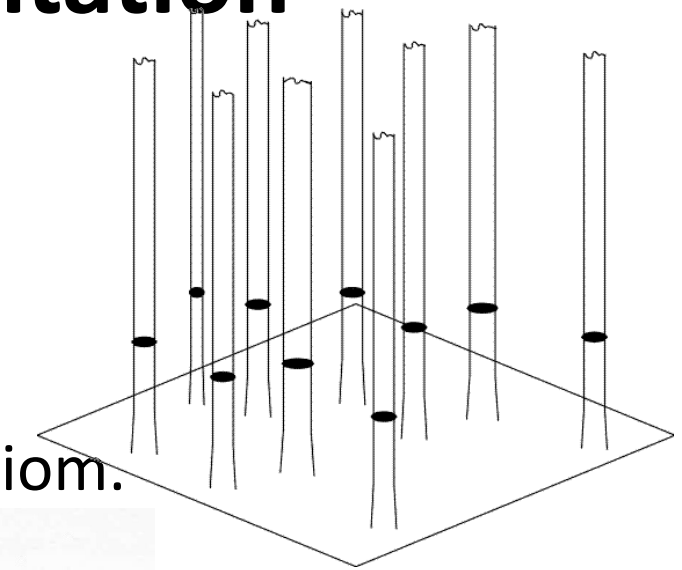



# Inventories: Implementation

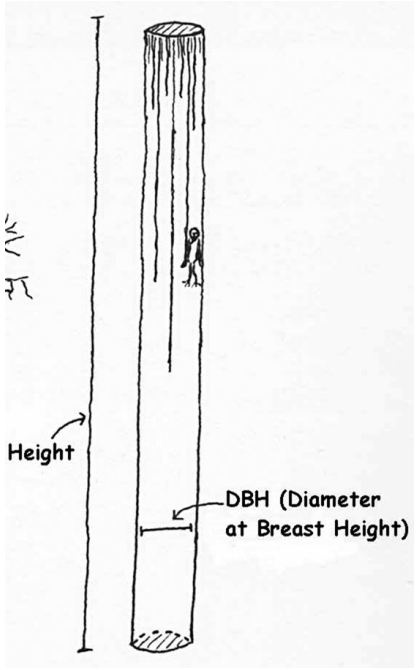
- To consider while stablishing plots
  - Height of the trees
    - a) 7 + 5 = 12
    - b) 15,5 – 3,5 = 12
    - c) 10,4 + 1,6 = 12
    - d) $\sqrt{11{,}7^2 + 5^2}$



# Inventories: Implementation

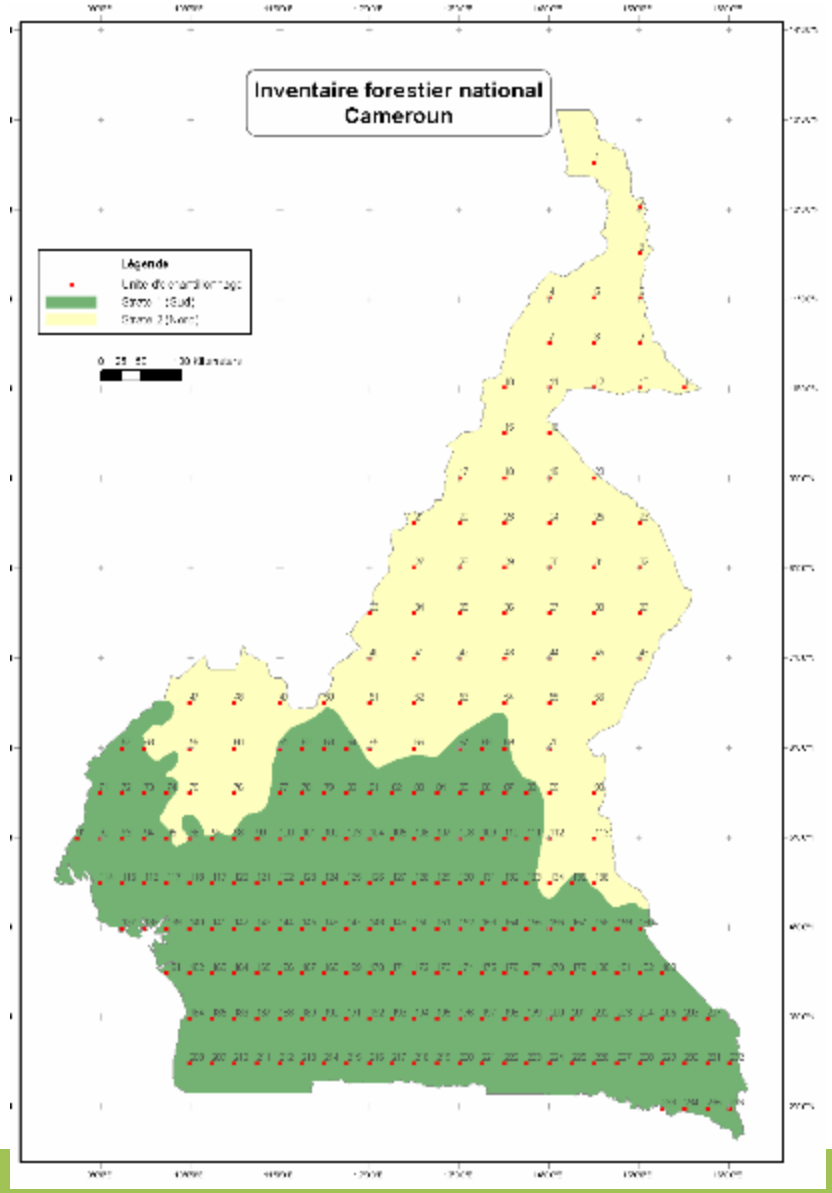


- Basic metrics to estimate
  - Basal area per hectare
  - Volume/biomass per hectare
  - Diametric distribution of trees/vol./biom.
- Additionally
  - Canopy cover
  - Site index
  - Carbon stocks
  - Biodiversity indexes
  - Leaf area index…..



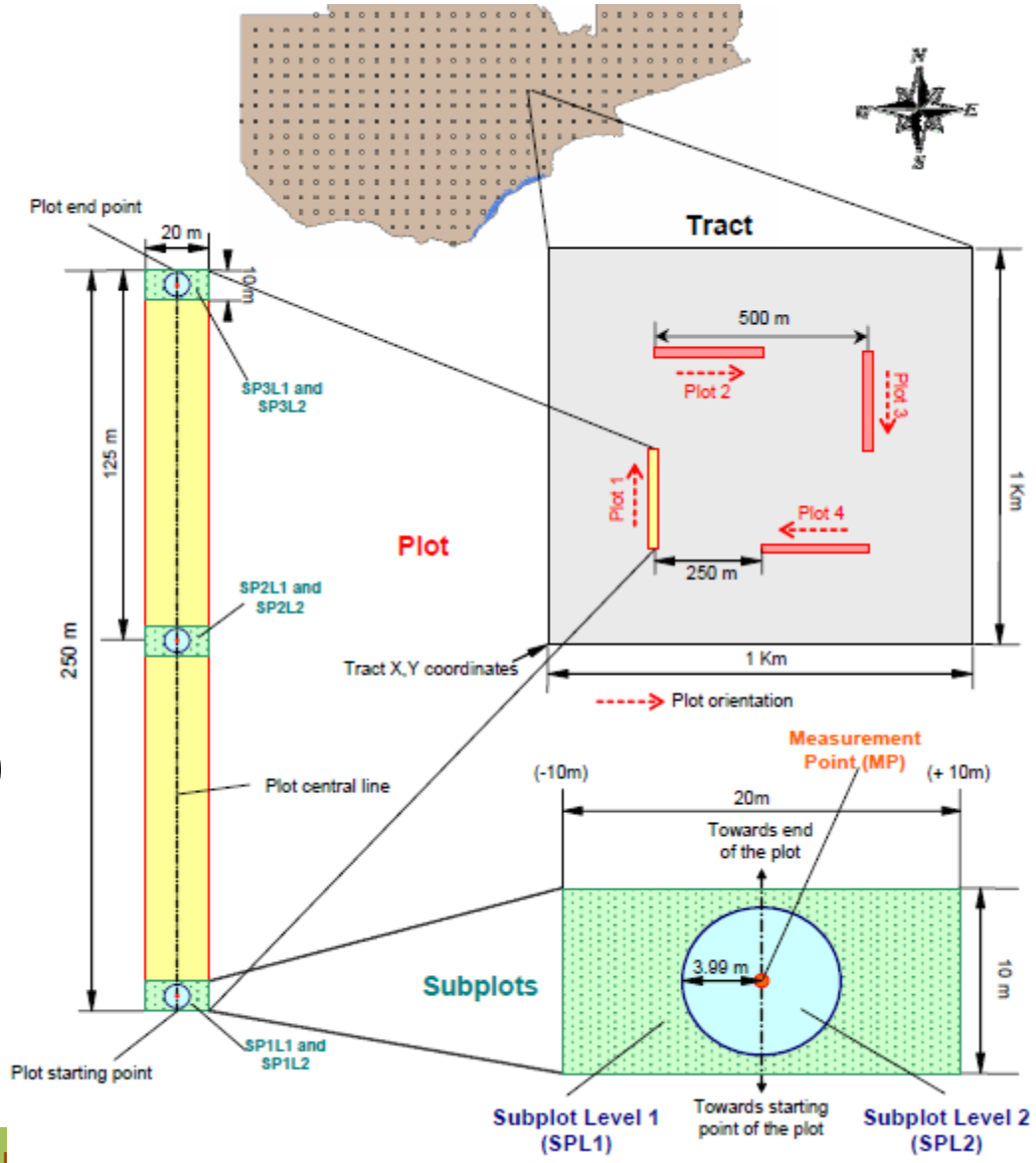
# Inventories: Examples

- Suggested by FAO (2004)
  - To assess forest resources and tree resources outside forest
  - Countries can add objectives
  - “Tracks” are created using the latitude/longitude grid
  - Density will depend on national characteristics, at least 1x1 degree latitude



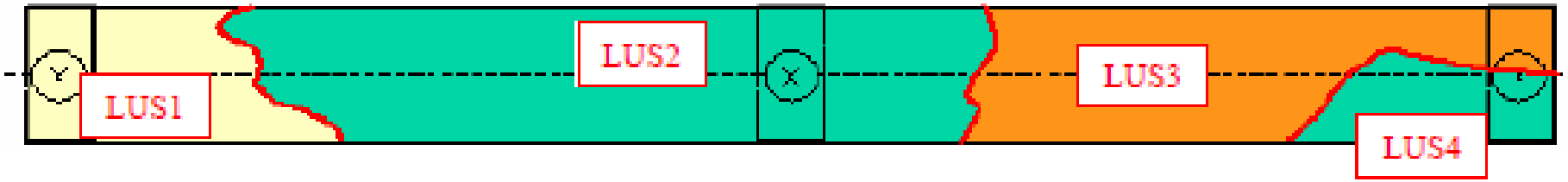
# Inventories: Examples

- Suggested by FAO (2004)
  - Each “Track” contains 4 plots
  - Each plot contains 6 subplots
  - In the plot measure all trees DBH>20cm
  - Rectangular subplots for small trees 10 < DBH < 20
  - Circular subplots for regeneration DBH < 10cm



# Inventories: Examples

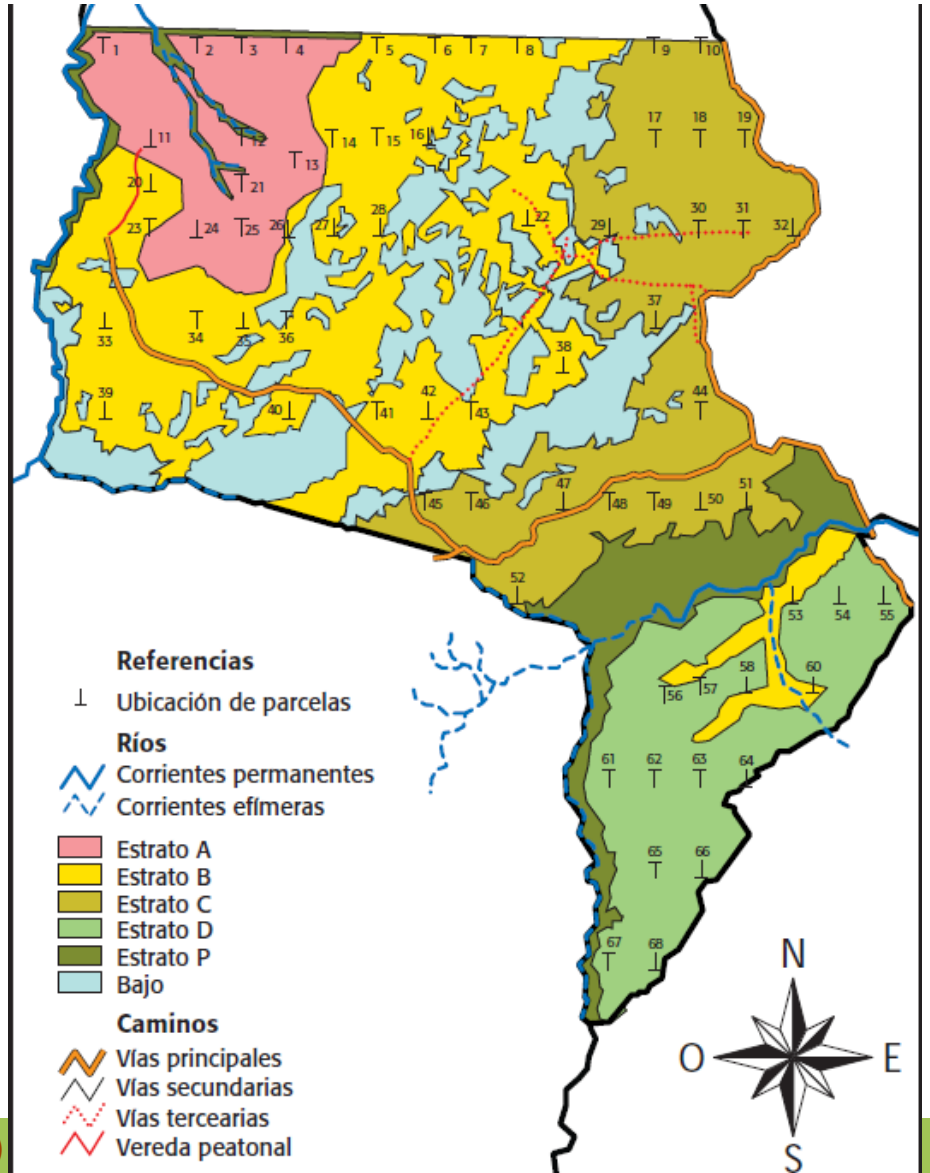
- Suggested by FAO (2004)
  - For each plot the different land-uses (international classification) will be identified and recorded
  - If subplots fall in land uses other than forest (defined by FAO or national law), they won't be mark




*There are 4 land use sections in this plot. The red lines indicate the limits between them. LUS2 and LUS4 belong to the same Land Use class.*

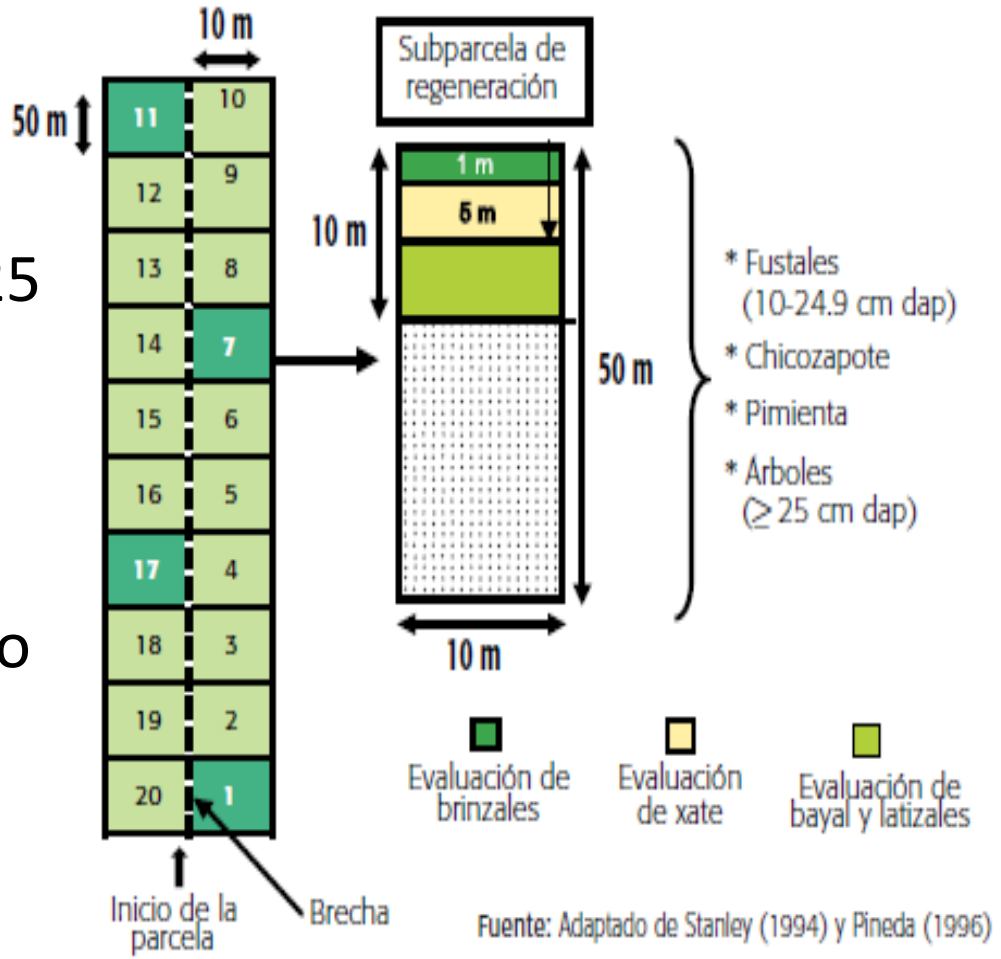
# Inventories: Examples

- Suggested by WWF (2004)
  - Combines forest inventory with NTFP and diagnostic sampling (for planning silvicultural activities)
  - Stratification was done considering forest cover maps, satellite images and altitude
  - Plots systematically arrange for each land use and based of sampling intensity



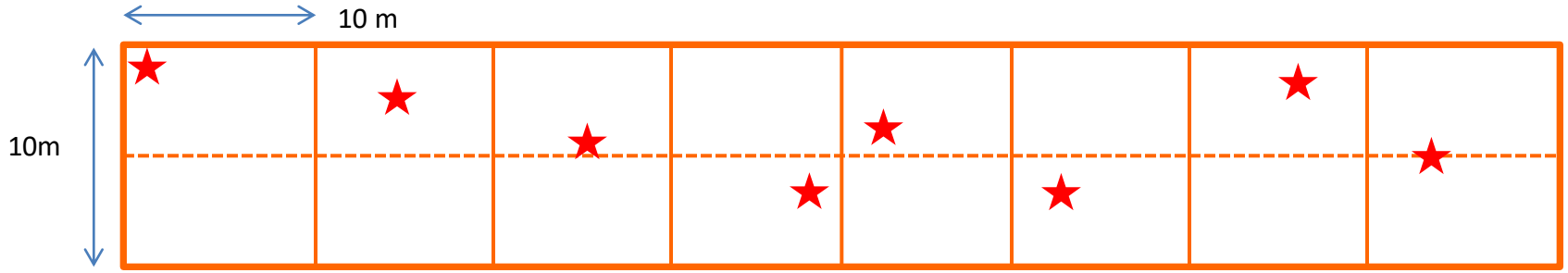
# Inventories: Examples

- Suggested by WWF (2004)
  - In the plot all trees DBH > 25
  - In subplots 1-7-11-17 also small trees 10 < DBH < 25 and some NTFP
  - In the selected subplots also small plots for seedling, saplings and NTFP



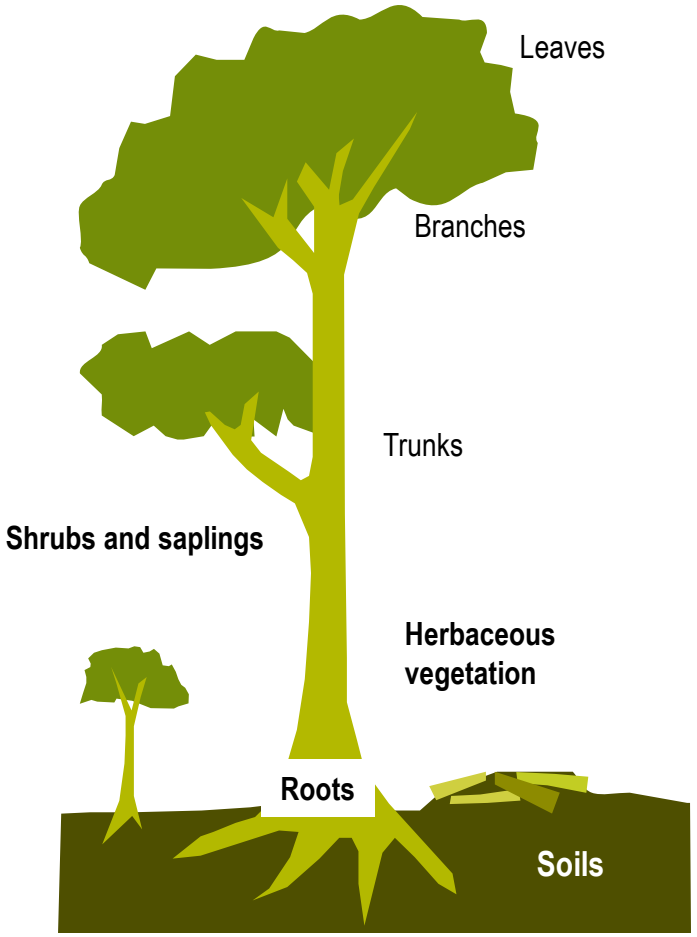
# Inventories: Examples

- Diagnostic sampling survey
  - Aim at recognising and selecting one Leading Desirable (LD) within a sample area, usually a plot of 10 × 10 m. The LD is the "best" tree or sapling present. It is the tallest and with the largest DBH of a desirable species present in the sample plot in terms of its potential value as a future crop tree. The LD must have a 5/10cm < DBH < "minimum cutting diameter"; straight bole > 4 m long, without defects, malformation, decay and large knots, vigorous, and well formed crown.



# Inventories: Examples

- By VITRI in Mozambique
  - Compare carbon stocks (Mg ha-1) between native vegetation and forest plantations in the study area
  - Aboveground carbon stocks:
    - Trees
    - Shrubs and saplings
    - Herbaceous vegetation
  - Belowground carbon stocks:
    - Roots
  - Soil organic carbon



# Inventories: Examples

- By VITRI in Mozambique
  - Four types of native vegetation + 2 types of plantations (eucalyptus, pine)
  - Measuring of trees, saplings and herbaceous vegetation
  - Also soil samples

Dense miombo

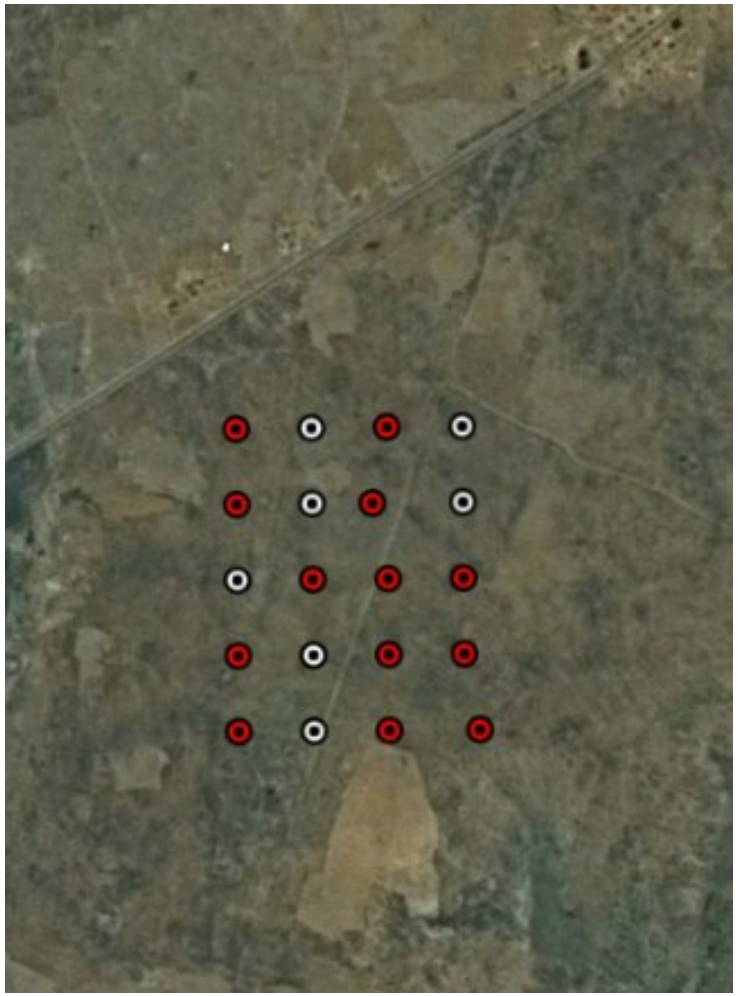
Open miombo

Other woody vegetation

Fallow land

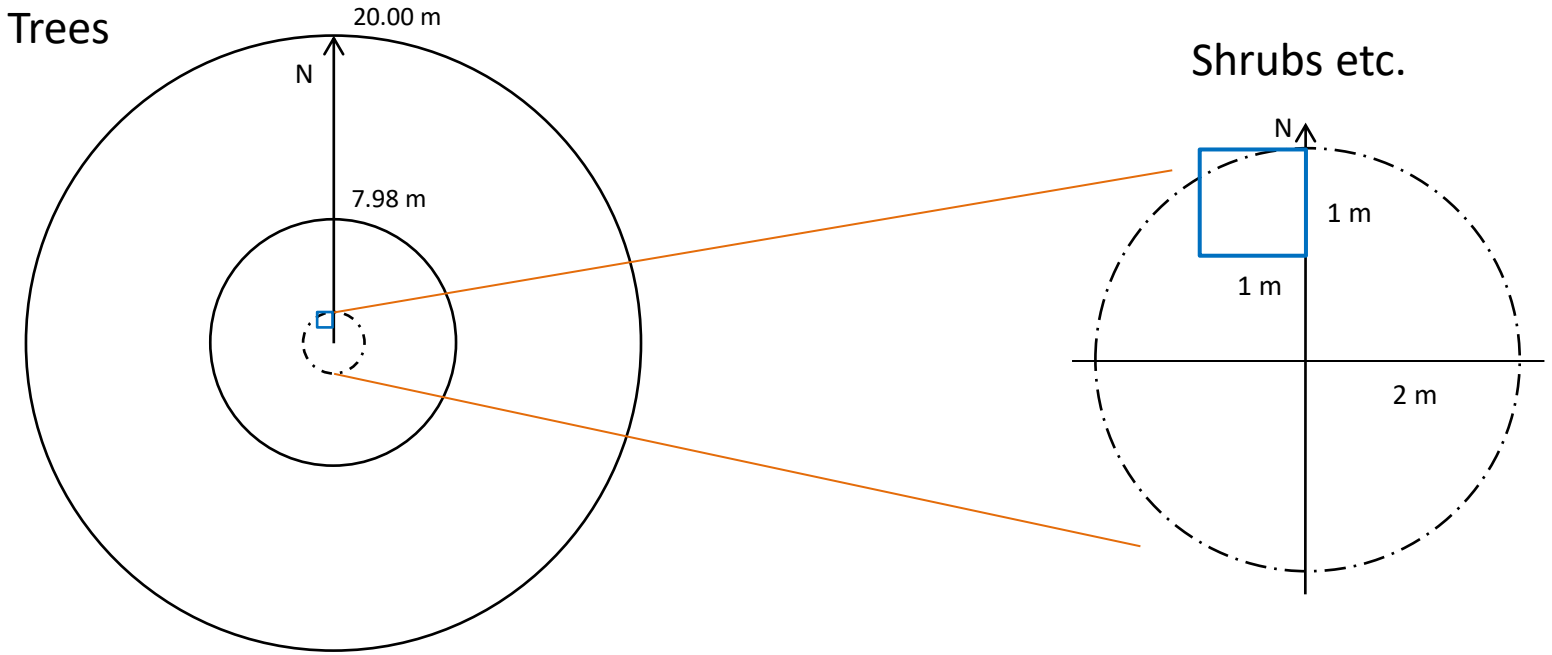
# Inventories: Examples

- By VITRI in Mozambique
  - Subjective selection of areas
    - Four main areas for native land use
    - Plantation areas based on age
  - Systematic sampling method:
    - Random starting point
    - 100x100 or 50x50 grid for native and plantations respectively
  - Starting point randomly selected to create a grid.
  - Plots with wrong classification (white) are excluded.
  - If plot falls into rivers or roads, the center is moved



# Inventories: Examples

- By VITRI in Mozambique




Trees from 5-19.9 cm of DBH measured in the smaller circle (all trees in forest plantations). Trees larder than 20 cm DBH measured in the larger circle. The dashed circle represents the subplot on which shrubs and saplings were sampled

The dashed circle represents the subplot on which shrubs and saplings were sampled (r = 2.0 m). The clip plot (1.0 $m^2$) for sampling herbaceous vegetation

# Inventories: Field course

- Mosaic landscape -working on transects-

# Inventories: Field course

- Subjective starting point

# Inventories: Field course

- Circular plots every 100m in different land-uses

# Inventories: Field course

- Circular plots areas 2 $m^2$, 50 $m^2$ and 200 $m^2$

# Inventories: Field course

- Keep going all the way until we meet forest!

# Inventories: Field course

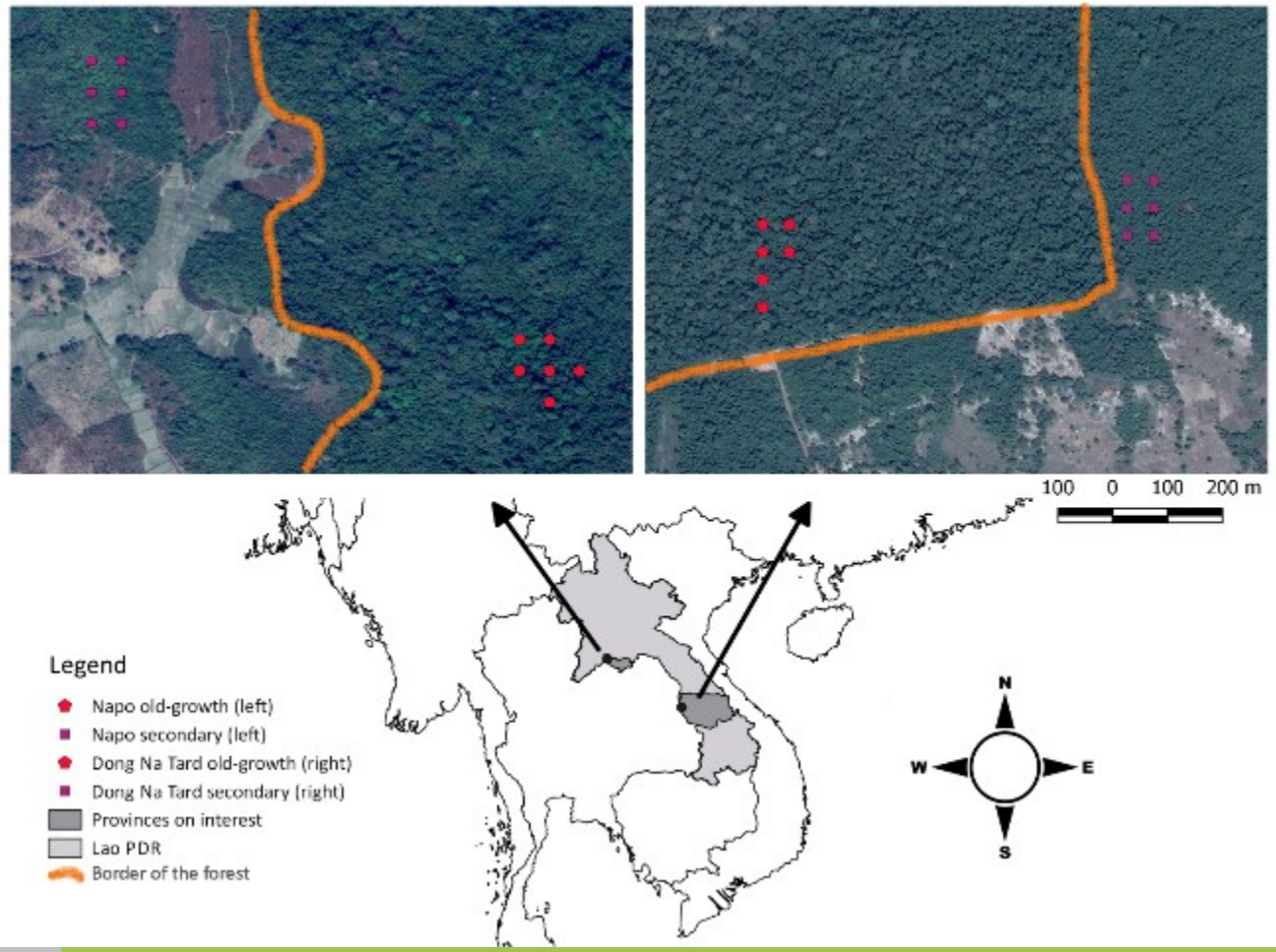
- Hopefully several plots for each land-use

# Inventories: Field course

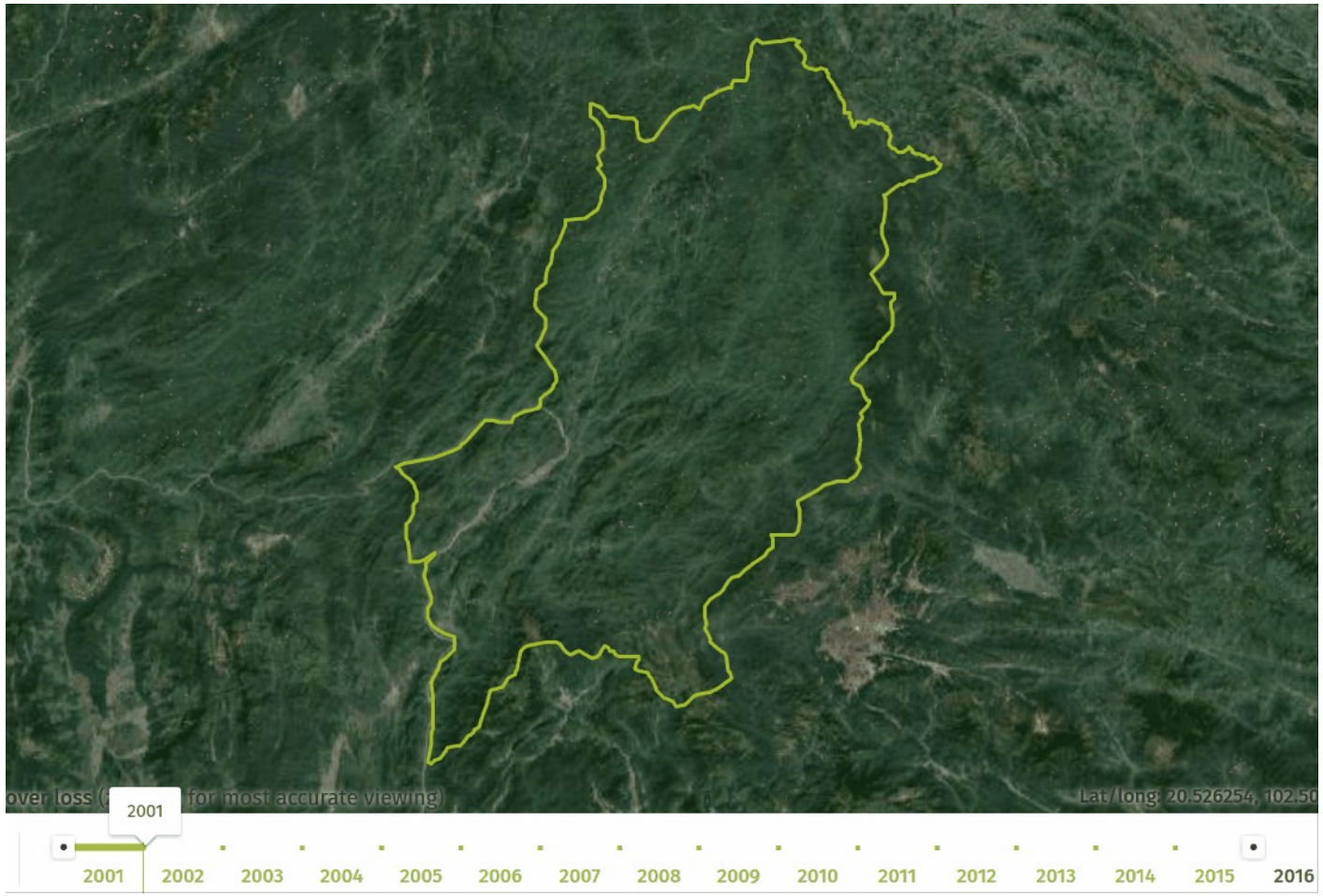
# Different group, different sampling

# Inventories: Field course

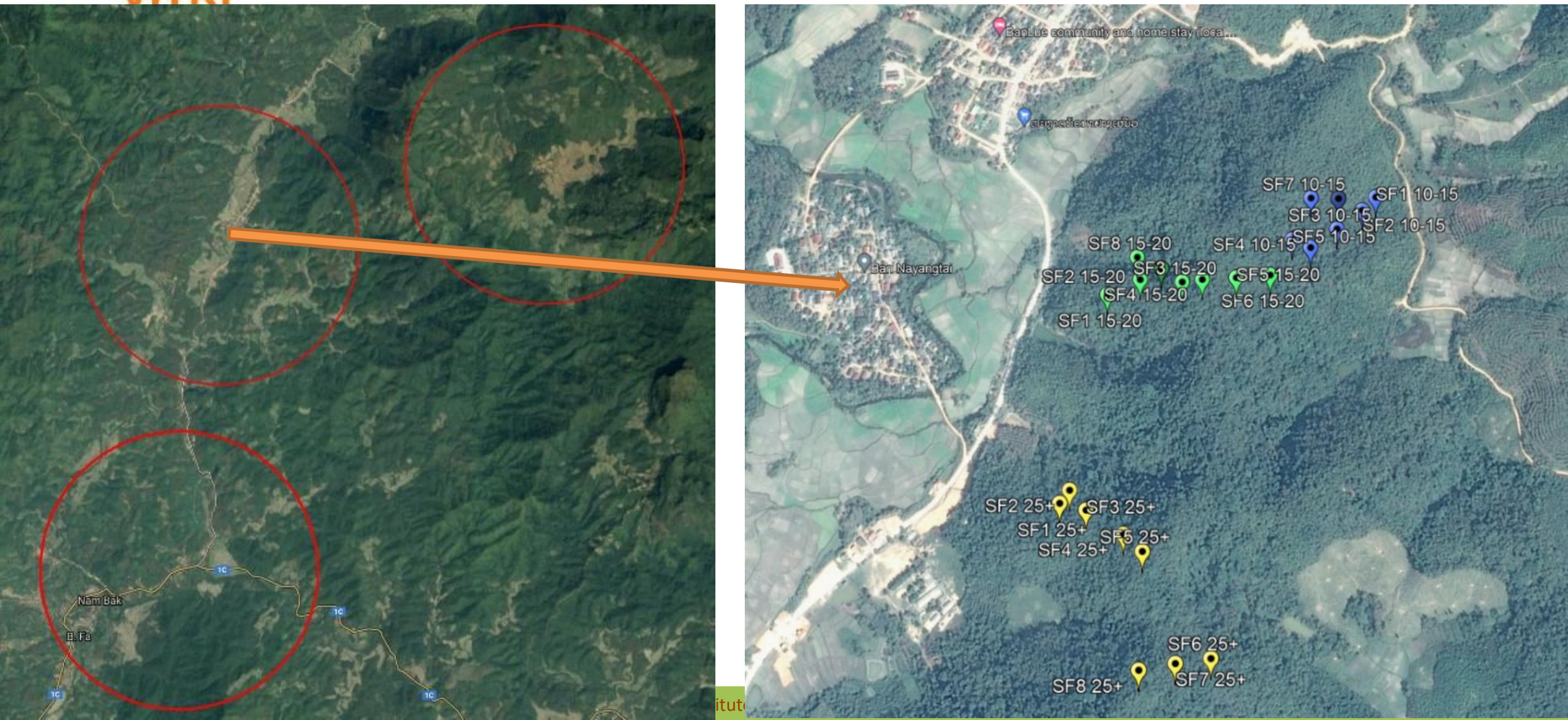
- Plots in old grow forest and secondary forest



# Inventories: Last field course



# Secondary forest of different ages & old grow forest



# Secondary forest of different ages & old grow forest

# Secondary forest of different ages & old grow forest

# Secondary forest of different ages & old grow forest