National Forest Inventories & REDD+

Livingstone, Zambia

25-28 Feb. 2014

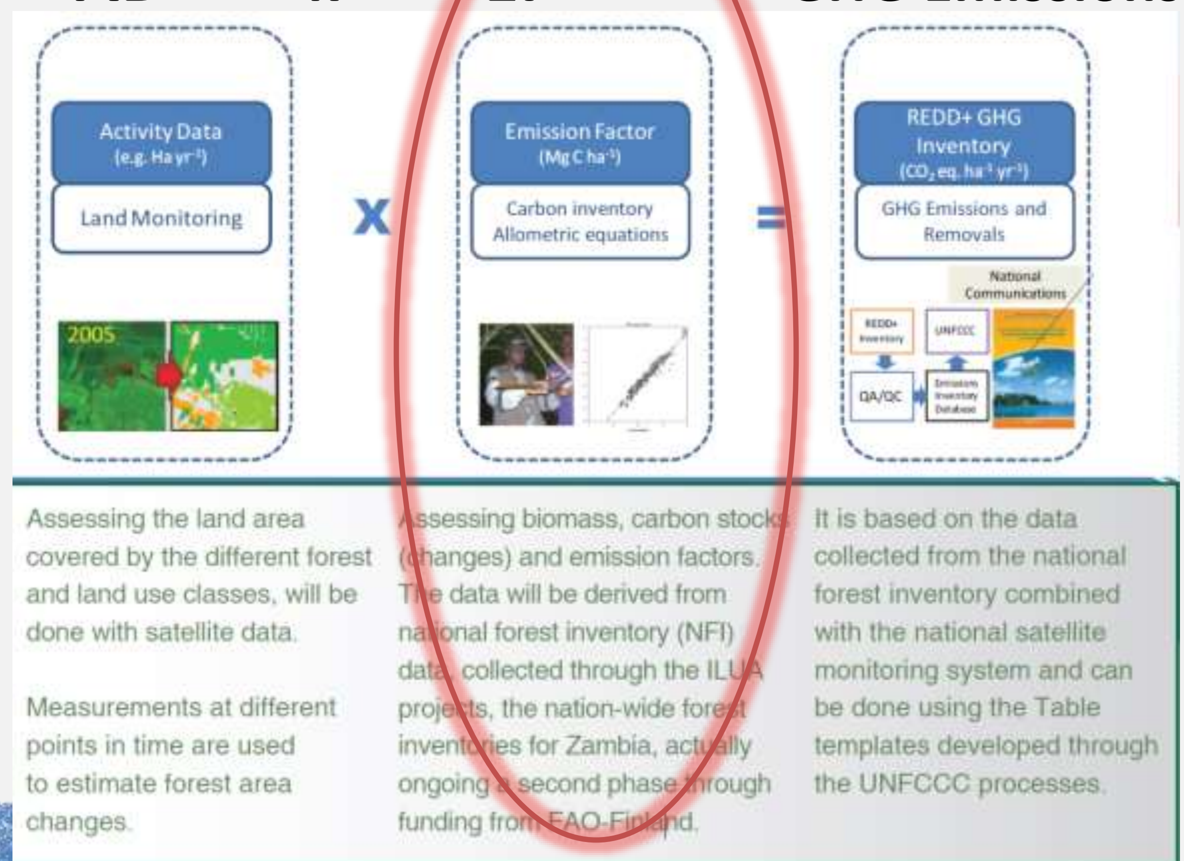
Background

- National Forest Inventory (NFI) data offer some potentials for use in calculating forest carbon stocks and stock changes for various land use types covered during inventories.
- According to UNFCCC decisions, countries are required to undertake ground-based forest carbon inventories that will be used to estimate or assess anthropogenic GHG emissions from various land use types.
- A National Forest Inventory (NFI) is actually one of the pillars of the National Forest Monitoring System (NFMS)

NFI and links to REDD+ _MRV

NFI data can be used to estimate emission factors for various land use types, then combine with Activity Data (AD) to produce emission factors as shown

AD x EF = GHG Emissions



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Limitations of Existing NFI Data for REDD+

- Traditional National Forest Inventories suffer from a number of weaknesses, including:

1. The fact that most inventories were limited to data collection for commercial species only, whereas forest carbon inventories are concerned with all tree species in the forest

2. Most forest inventories sample down to a minimum diameter limit (for ex. 10 cm, 20 cm etc.), whereas carbon inventories sample down to about 5 cm and below.

3. Inventories only estimate the volume of the main stem, whereas carbon/biomass inventories is concerned with several " pools" : stem, branches, roots, deadwood and litter.

Stages in Forest Inventory

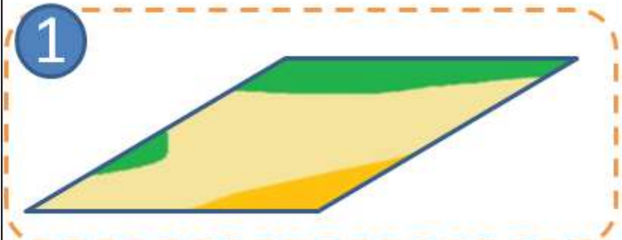
Basically 3 Stages:

1. **Stratification** into different forest types and/or land uses using remote sensing techniques (cf. **Activity Data**).

2. **Pre-sampling** involves field data collection from temporary plots to make preliminary estimation of tree/stand statistics & determine sample plot allocations to different strata.

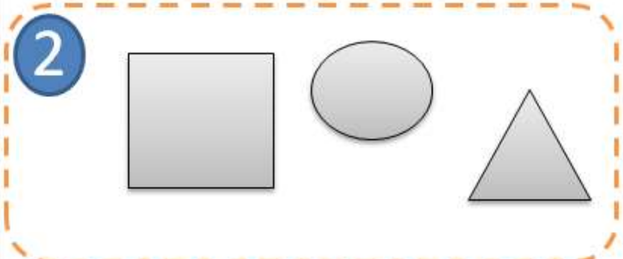
3. **Final sampling** in which a stratified sampling with optimal allocation of sample plots is determined, taking into account sampling cost and accessibility of each stratum. The distribution field sample plots (**TSPs** or **PSPs**) are made on a map.

Different Phases of NFI



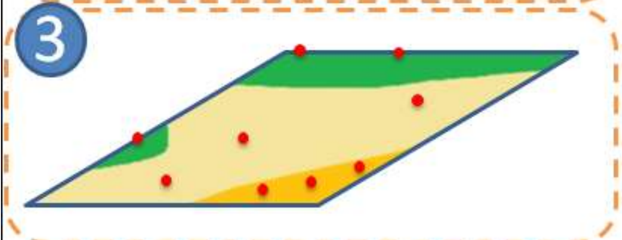
Stratification

Stratification of forest types into homogeneous and non-overlapping stratum, to reduce the uncertainty of estimates of the estimates.



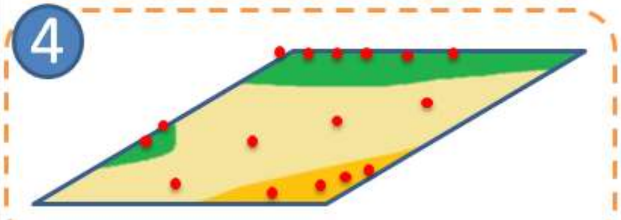
Design

Sampling strategy is designed, forest area is assessed, plot design and variables and methods identified



Pre-sampling

To allow assessment of the variance within stratum and of the costs of sampling. Then, optimum sampling allocation approach can be achieve.



Final-sampling

Sampling intensity achieved using carbon as the main variable but SFI will provide traditional forestry, biodiversity and socio-economic information.

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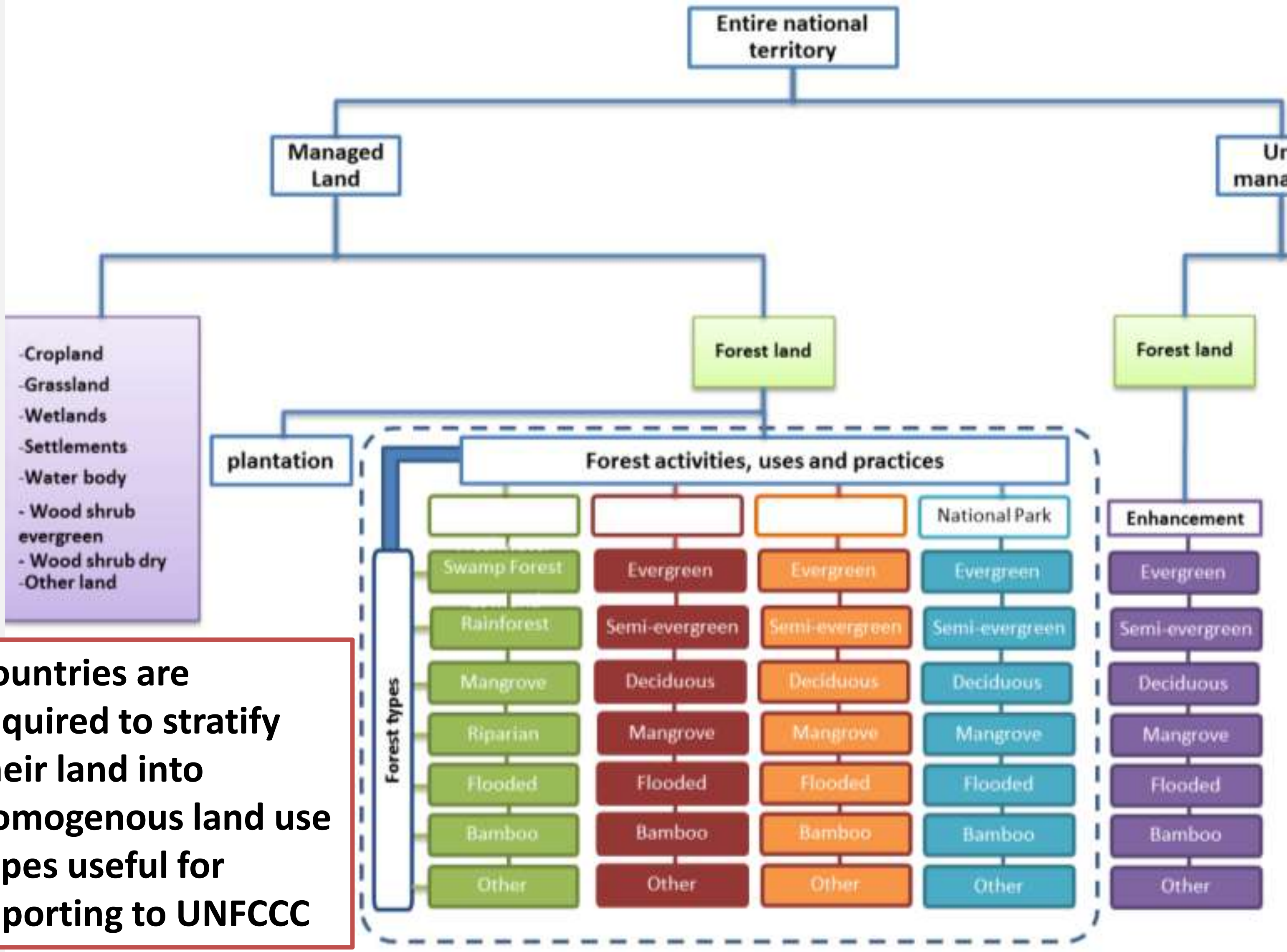
Example of Land Use Classification



LULUCF Land Use Categories (GPG2003)
Forest Land
Cropland
Grassland
Wetland
Settlements
Other Land

Countries are required to stratify their land into homogenous land use types useful for reporting to UNFCCC

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Sampling Designs

- Due to cost and time constrains, NFIs are implemented on a representative sample of the national territory
- Several sampling methods exist (e.g. simple random, systematic, stratified, cluster, multi-stage, multi-phase…) but in most cases, a systematic grid is overlaid over the entire territory (a stratified map) & a systematic sample selected; sometimes with varying intensities according to strata or land use categories.
- Sampling units (of different forms) are usually clusters of measurement units with nested subplots to collect various land use variables (tree measurements, land use change information, soil, litter, socio-economic data…)
- Sample plots can be Temporary (for one-off measurement) or Permanent (re-measurements for stock change estimation). e.g. NAFORMA (NFI Tanzania) has both **TSPs** (Temporary Sample Plots) & **PSPs** (Permanent Sample Plots).

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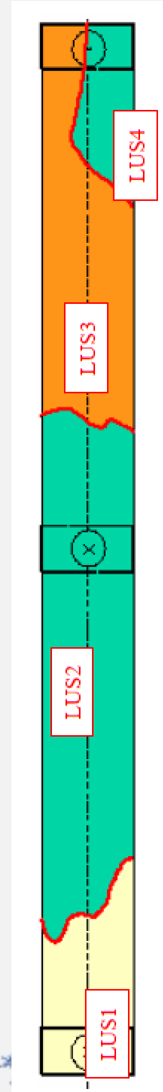
- Systematic Tract (1kmx1km) laid to cover entire country.
- Cluster of 4 rectangular plots established within the Tract
- Sub-plots nested within the rectangular plots for data collection
- Rectangular plot can be sub divided into land use sections (**LUS**) where land use changes occur, as assessed during inventory



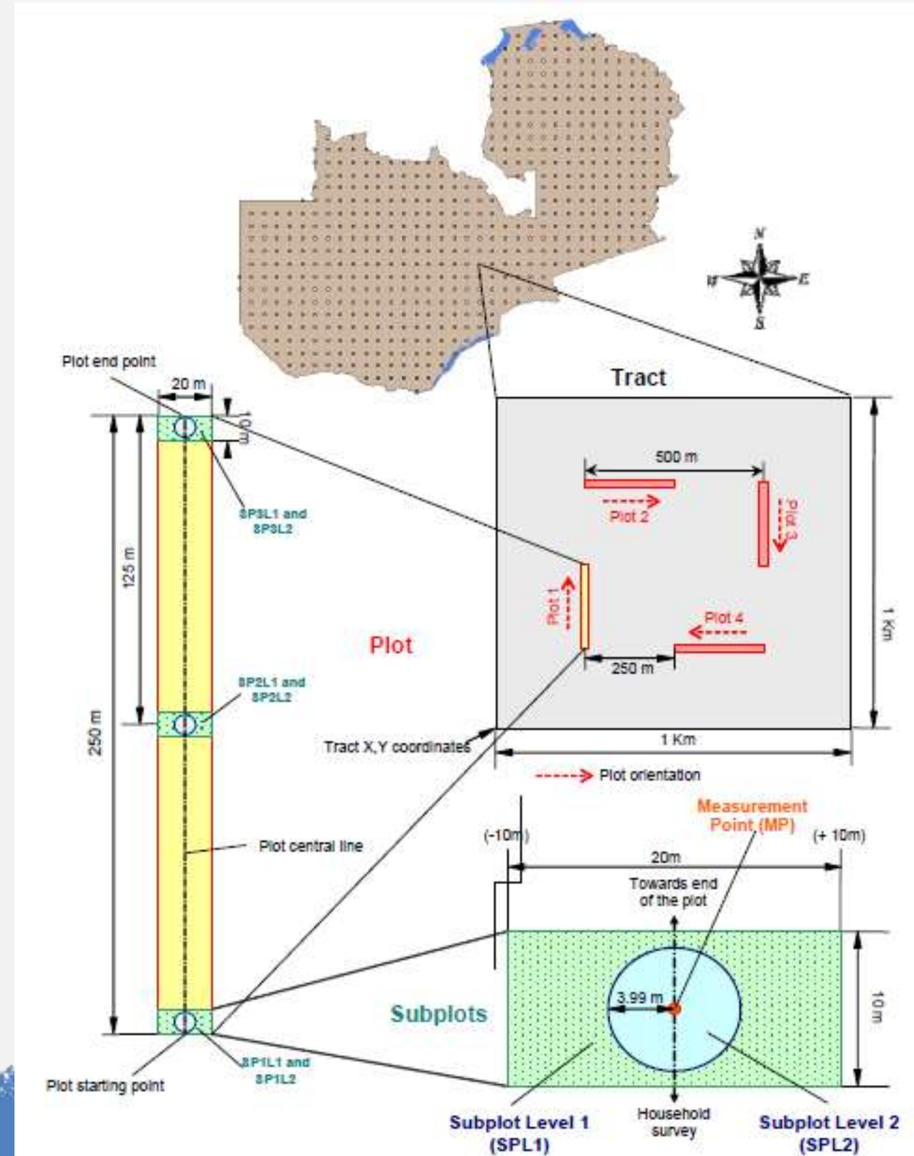


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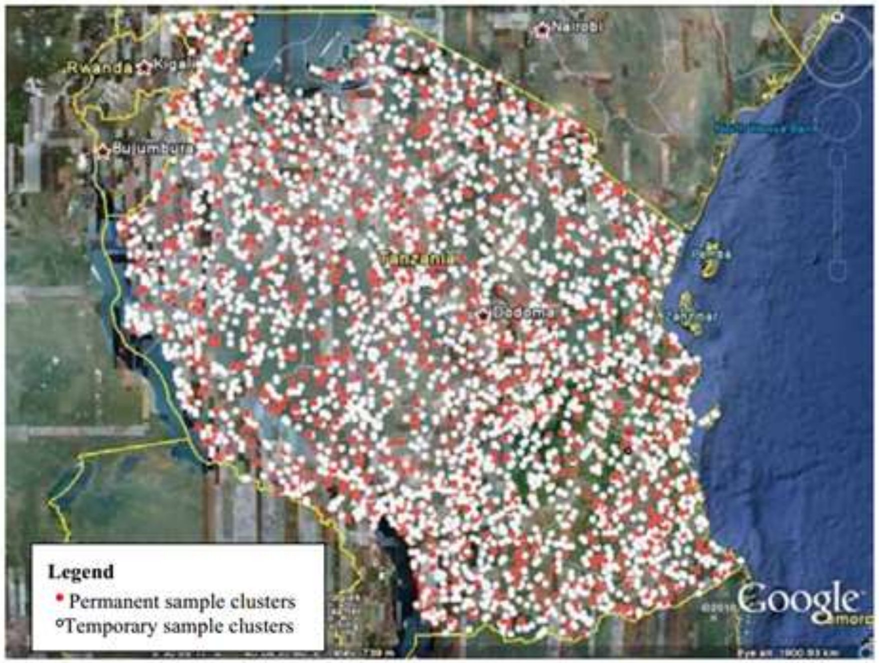
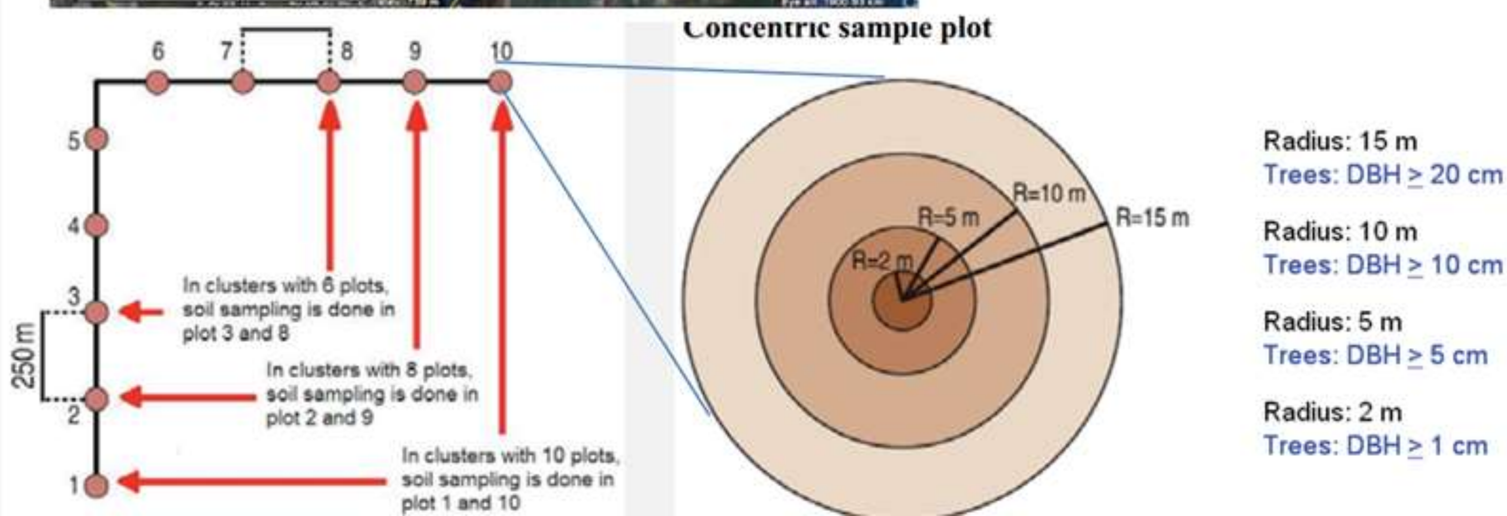
Illustration of sampling Design: Tanzania

Figure 4. Location of clusters in Tanzania



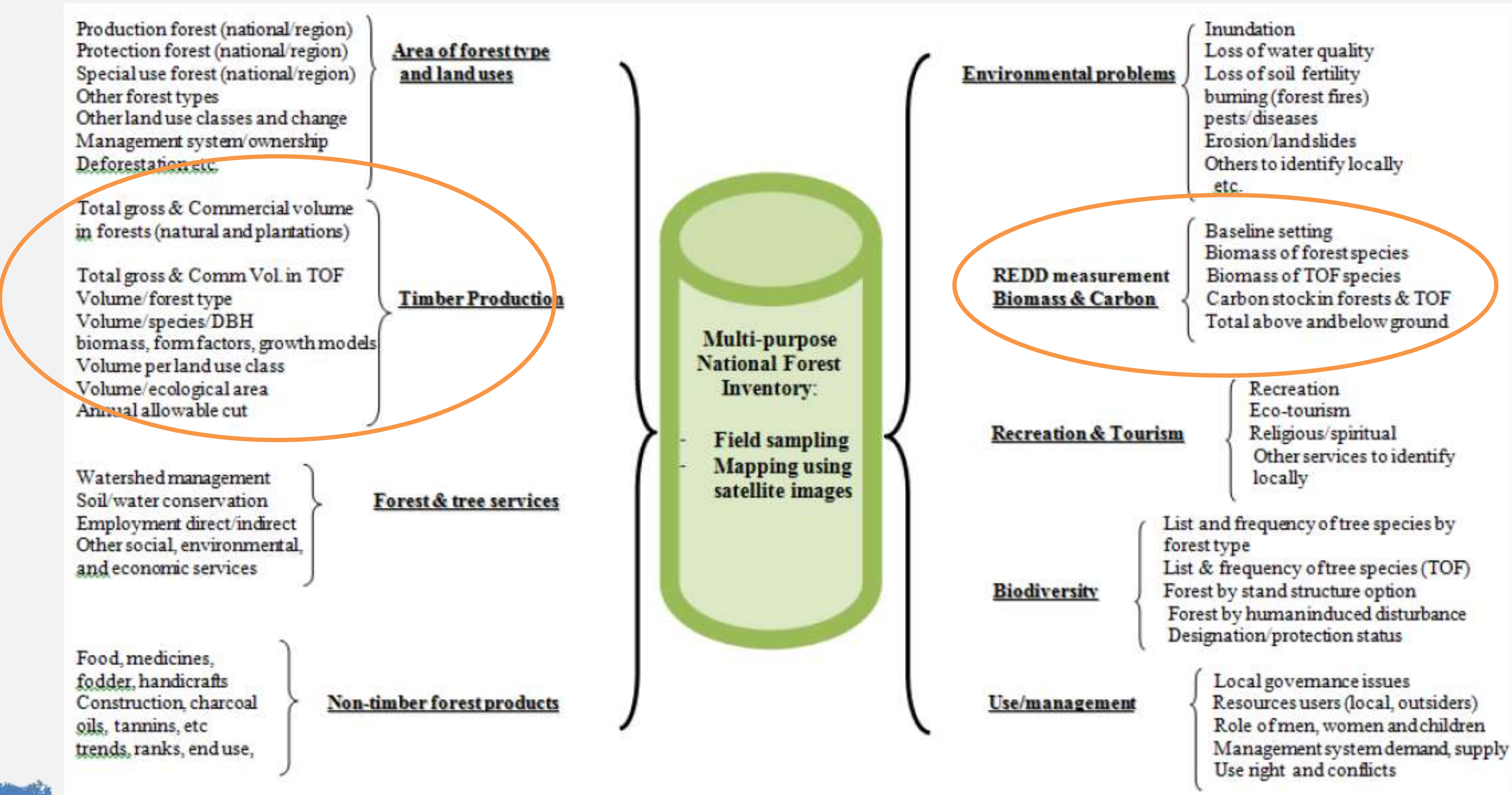
- In the case of NAFORMA (Tanzania), circular sample plots were used with nested sub-plots of varying radii

- A cluster of 10 plots (measurement units) are arranged in an "L" form



Field Data Collection

- Field data collection can vary from a few key parameters to several (e.g. multi-purpose inventories)



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NFI for REDD+ MRV

- REDD+ MRV System requires information on GHG emission factors (EF) for forest lands and each of the forest-related land use change types.
- National Forest (Carbon) Inventories are needed, including development of allometric equations and Conversion/expansion factors.
- The generation of EFs require extensive field-based data collection, and can be undertaken for specific ecological regions and land uses
- Estimates have to be made for different carbon pools

Forest Carbon Inventories

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- Requires the estimation of biomass and Carbon stocks from several "pools":
  1. Standing Live Trees
  2. Standing Dead trees
  3. Fallen Dead Trees
  4. Understory vegetation
  5. Forest Floor (Litter)
  6. Soil Organic Matter

NB: Only "**Key Categories**" should be estimated given the high cost of forest carbon inventories.

Above ground Biomass

- **Non-Destructive:** measure tree dbh & height of trees in plots (e.g during Forest Inventory); then apply allometric equations to estimate biomass & carbon

- **Destructive method:** Measure dbh, fell sample trees, separate into component parts, weigh and collect samples for Dry Weight estimation in laboratory.

Measurement of Bio-physical Parameters

Diameter at Breast height, above buttress or above Shoulder?

Tree Caliper or Egg Caliper ?

- The main bio-physical parameters measured in the field Basic are tree diameters and heights, as well as distances and plot dimensions, slopes etc.

- Tree diameter is measured over bark, at 1.3 m breast height above the ground (or above buttress) with the exception of particular cases mentioned below. Measurement may be carried out using the diameter tape or with the use of the caliper.

- Precautions should be taken when measuring double stemmed trees, leaning trees, trees abnormalities at 1.3 m etc..

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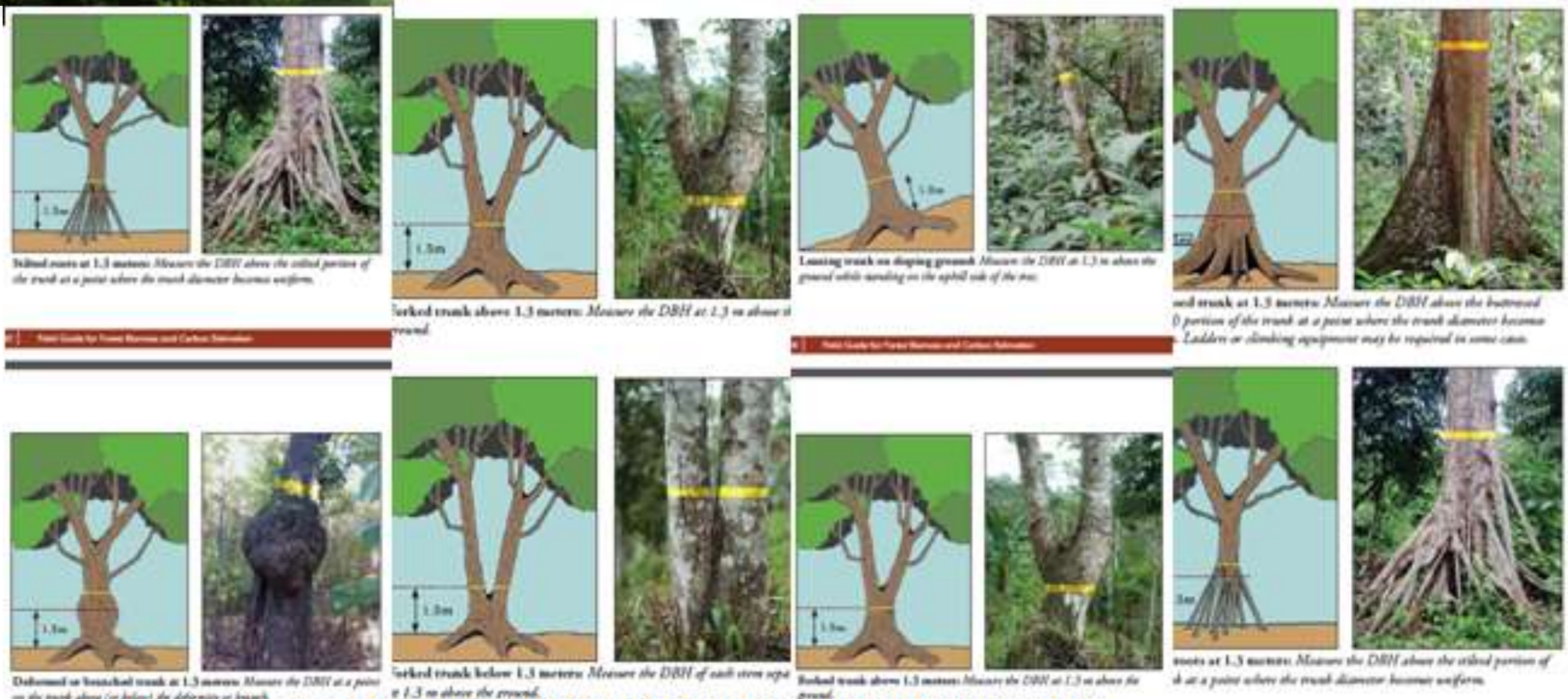
Measurements Diameters for Trees with Abnormalities



Source: Adapted from: Field Guide for Forest Biomass and Carbon Estimation. Woods Hole Research Center 2009.

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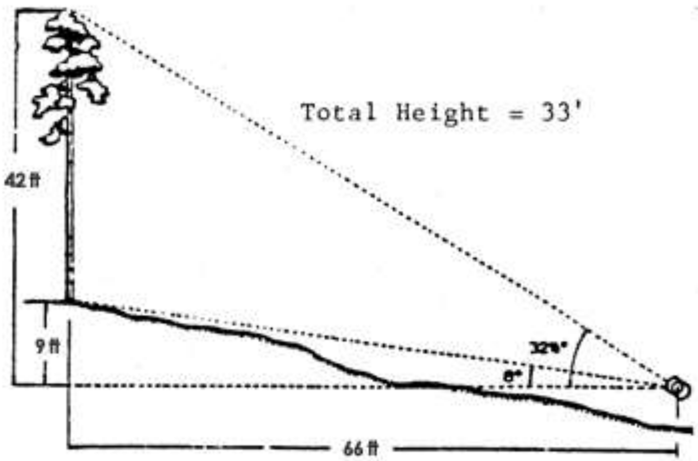
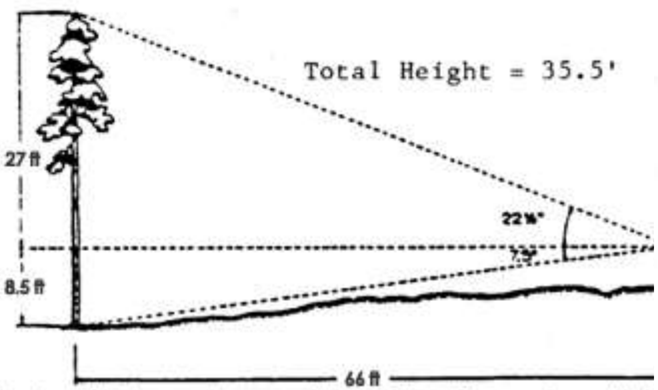
Tree height measurements

- Tree height measurement can be made using several hypsometers, including, the Blume-Leiss, Suunto, Haga, Bitterlich relascope , Vertex, Laser Rangefinder, etc.

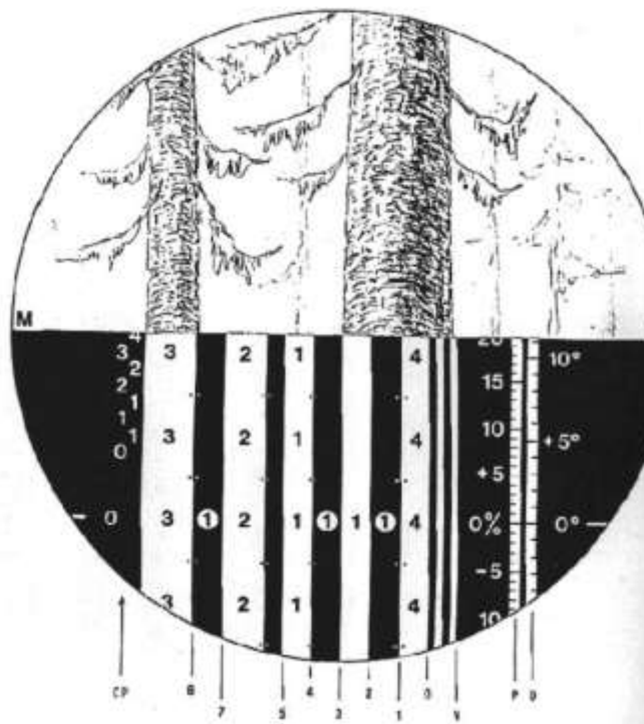
- the most common height measurement situations are shown below



Eye Level Below Base of Tree (Top - Base = Height)



Eye Level Between Base and Top of Tree (Base + Top = Hei



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Some Forestry Equipment

PDA

Figure 4.2: *Diameter tape (orange) and caliper (silver/blue).*

Diameter Tape

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Below Ground Biomass

- Non-destructive method: Use estimate of Above Ground Biomass and Root:Shoot Ratio to estimate BGB; or use allometric equations for root biomass (not common) to estimate BGB/Carbon.
- Destructive Method:
    1. Requires excavation (up rooting) of tree stumps and roots and undertaking measurements.
    2. Maybe very difficult to undertake for very large tropical trees.

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Litter Biomass

•.Litter refers to all dead organic surface material on top of the mineral soil. Some of the material (e.g. dead leaves, twigs, dead grasses and small branches) could still be recognizable, while some might have decomposed. All deadwood with dbh<10 cm is included in this category.

•Procedure:

1. Place a square frame (≈ 30 cm x 30 cm) on the site (plot location)
2. Collect all litter inside the frame. Use knife to cut pieces that fall on the frame border.
3. Place all collected litter on a tarpaulin
4. Weigh the sample immediately on-site,
5. take to laboratory & oven dry to constant weight and determine total dry mass.

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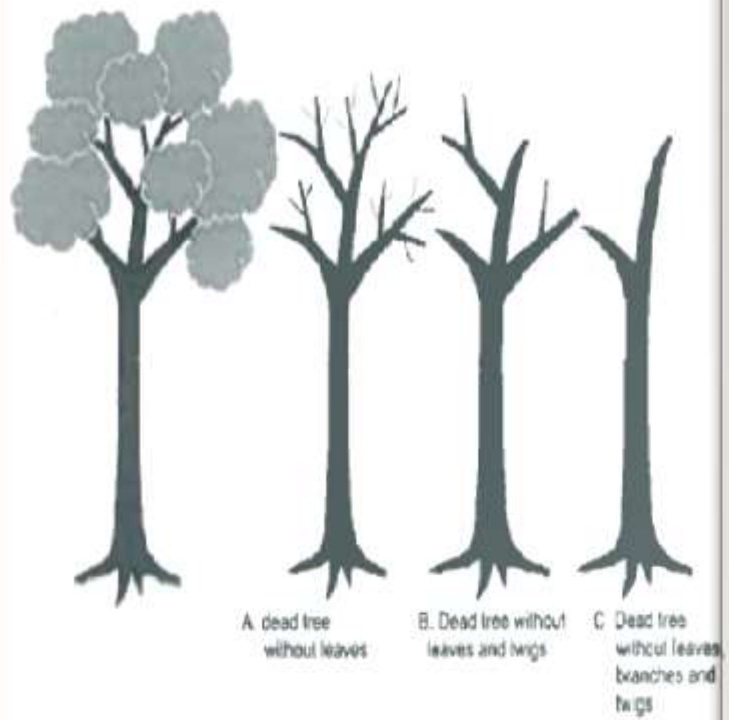
Standing Deadwood

- Measure dbh and ht as for standing live trees.
- Determine decomposition class:
  - 1- if branches and twigs are still on it;
  - 2- if signs of decomposition exist, including loss of twigs, branches & crown)
- For decomposition class 2, density of decomposing stem needs to be determined, and used for biomass estimation.
- Estimate biomass using allometric equations or BCEF as for live trees (for decomposition class1).



Remarks:
A. Intactness level with a correction factor of 0.9
B. intactness level with a correction factor of 0.8
C. intactness level with a correction factor of 0.7

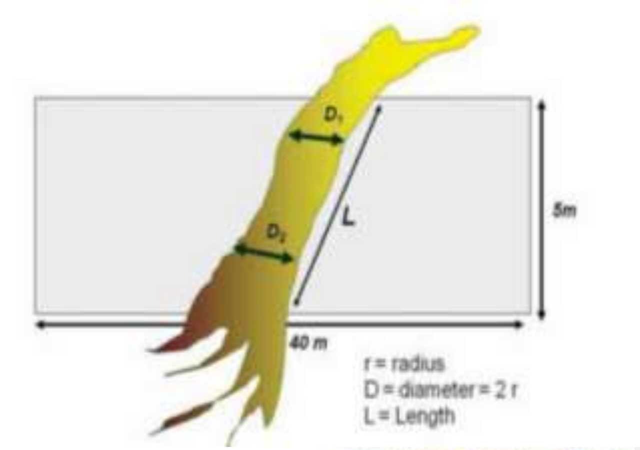
Figure 4 – Intactness level of dead trees

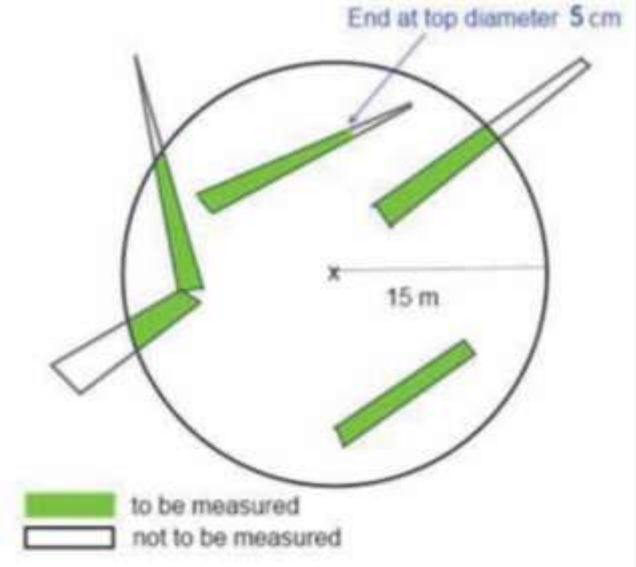
Down (Lying) Deadwood

- Use line transect method (Harmon & Sexton 1996) in which two – 50 m lines are established bisecting each sample plot and diameters of lying deadwood (≥ 10 cm) intersecting the lines are measured.

- Assign deadwood to one of three density states (sound, intermediate & rotten) using the "**Matchete Test**" as recommended by IPCC GPG LULUCF (2003).

- Volume estimated using equation by Warren and Olsen (1964) as modified by Van Wagner (1968).





Soil Biomass & Carbon

- Complicated to undertake and requires specialists in soil sampling and laboratory analysis for soil organic matter/ carbon
- NAFORMA has an elaborate methodology on this carbon pool.

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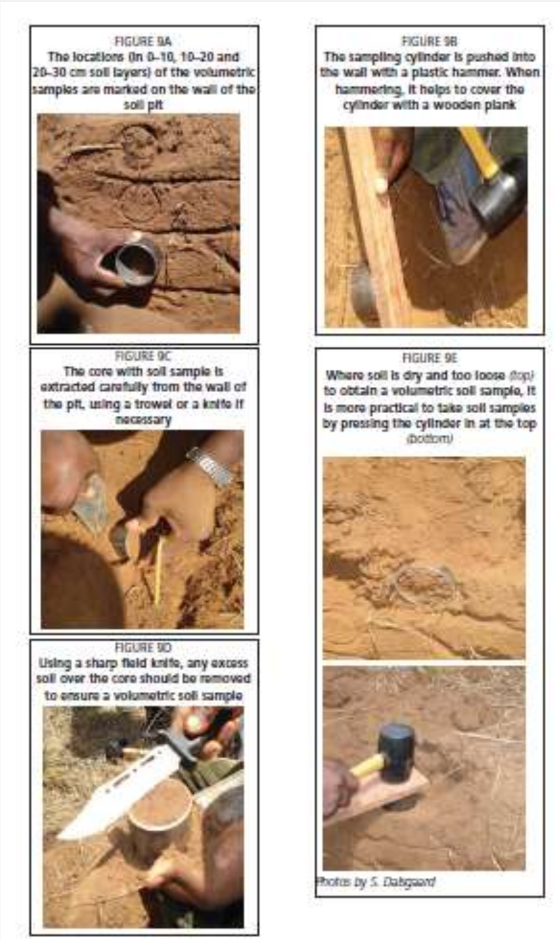
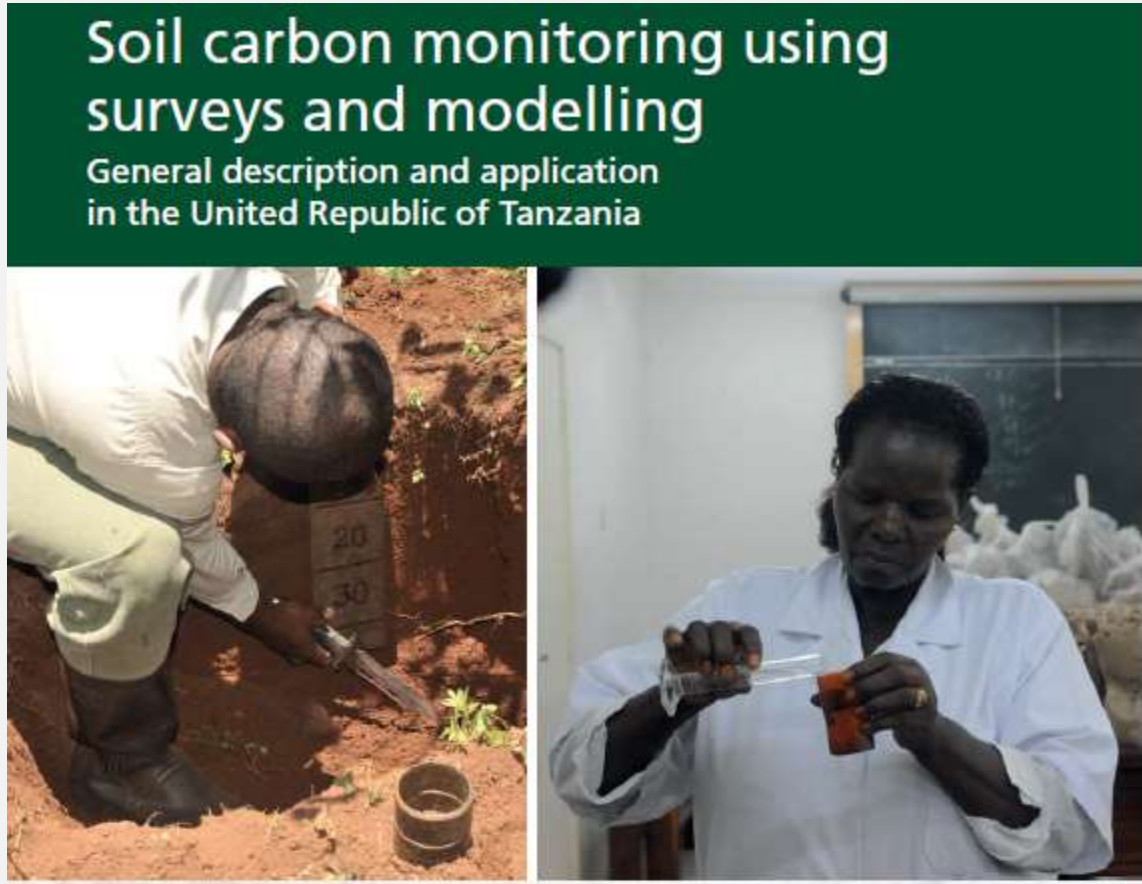
Soil Sampling: NAFORMA





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Thank You

Website: http://www.un-redd.org

Joint approach to Monitoring land use change & Carbon Stock changes

- Estimate land use changes between Time 0 and Time1 using Remote Sensing Techniques
- Build a land use change matrix
- Estimate Carbon stock changes between Time 0 and Time 1 to give Emission Factors for each Land use category

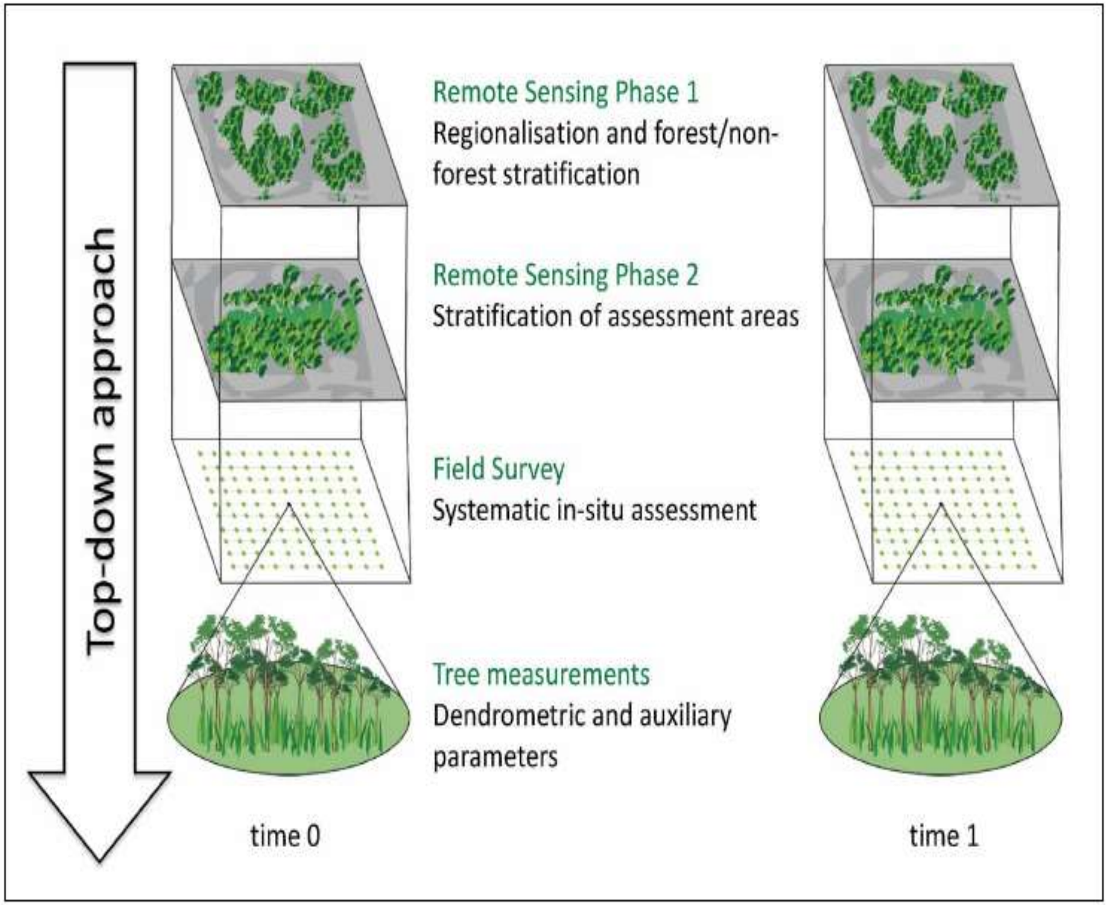

FIGURE 1. Top-down approach for a combined inventory on national scale.

Stock Change Estimation Methods

- Two methods can be used:
  1. The Gain-Loss (IPCC 2006 Default) Method: involves estimation of gains in carbon stock of the pools due to growth and transfer of carbon from one pool to another (e.g from live-biomass to dead organic matter due to harvest or disturbance); as well as deductions of losses in carbon stocks due to harvest, decay, burning…
  2. Stock Change methods requires the estimation of carbon for each pool at two points in time (e.g. PSP data); from which the annual difference is estimated. Method more suitable for carbon mitigation and land conservation & development projects.
- Gain-Loss method is difficult to apply: apportioning annual transfers of biomass/carbon into litter, deadwood etc.., and estimating losses due to extraction, fires, decay etc.. requires more effort.
- With Stock-Difference approach, it is easier to account for changes in stocks of all relevant pools, and changes if time series measurements exist .
- Stock difference method can also provide growth rate (increment) and losses data needed for the Gain-Loss Method.

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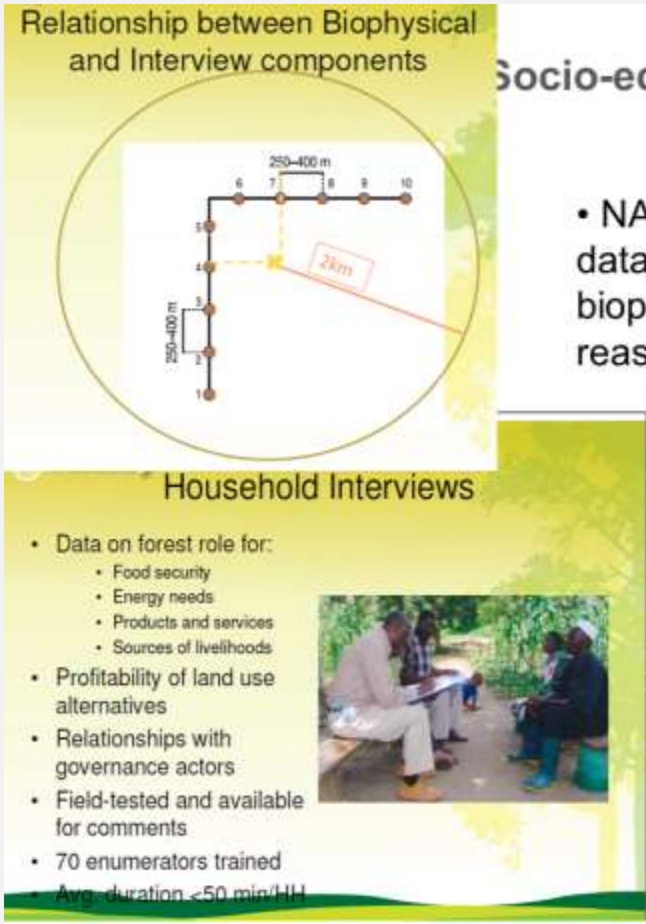
Socio-economic surveys & links with Biophysical studies (cf. NAFORMA)



Socio-economic surveys & links with Biophysical studies (cf. NAFORMA)

- NAFORMA's sampling design for socioeconomic data follows the design for the collection of biophysical data because of two important reasons:
  1. It allows for a close analytical link between biophysical and socioeconomic data, which in turn will strengthen the explanatory power and policy relevance of the data.
  2. It will result in an unbiased sample of the population of interest since the biophysical sampling design is stratified according to predicted variability of biomass volumes (meaning that areas with forests will have more sample points).
- Socioeconomic data (Household and key informant interviews) is collected in 50% of the clusters.

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Emission & Conversion Factors: Definitions

- In order to calculate carbon stocks and changes from merchantable volume (e.g. from inventory data) we need use of conversion and expansion factors such as:
  1. Biomass expansion factor (BEF) is a multiplicative factor that expands (converts) commercial round wood (in m^3) to total above ground biomass (in tonnes). This expansion takes into account the non-merchantable biomass components such as branches, and foliage.

  2. Wood density (*D*) is used to convert above ground volume to above ground biomass (Wood density data bases exist e.g. ICRAF, …) that can be used as defaults.
  3. Biomass Conversion and Expansion Factors (BCEF) combines the conversion (*D*) and expansion factors (BEF), and transforms in one single multiplication growing stock, into above-ground biomass(t). Mathematically, BCEF = BEF ● D

  4. Root-to-Shoot ratio (*R*) is a coefficient used to estimate below ground biomass from above ground biomass (≈ 0.37 for tropical rainforest; see IPCC 2006 for default values)

  5. Carbon fraction (CF) is a value used to convert biomass to carbon (deault≈0.47;

Converting stem Volume to Biomass

- Where stand volume estimates exist from inventories, they can be converted to biomass and carbon using biomass expansion factors.

- Stand volume per ha (VOB) is first converted to biomass (BV) using wood density (D) as follows: BV=VOB*D.

- Biomass expansion factor (BEF) is the relation between the total tree biomass and the stem biomass. It is used to indirectly estimate the total tree biomass using stem biomass, which is easy to measure directly or which can be calculated from the stem volume data. Brown (1997) provides an equation for estimating BEF from BV as follows:

  BEF = Exp{3.213 - 0.506*Ln(BV)} for BV < 190 t/ha

  1.74 for BV>=190t/ha

  (where: BV = biomass of inventoried volume in t/ha, calculated as the product of VOB/ha (m^3/ha) and wood density (t/m^3))

- **Note** that for a mixed forest we need to calculate a weighted wood density based on each species volume in the stand.

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Use of Biomass Expansion Factors (BEF)

- In some situations where tree measurements have been done down a diameter limit above 10 cm 920 cm, 25, 30..) we can use a volume expansion factor that converts the VOB to a value at 10 cm or less (VOB10) (cf. Brown 1997).

- Volume expansion factor (VEF) is defined as the ratio of inventoried volume for all trees with a minimum diameter of 10 cm and above (VOB_{10}) to inventoried volume for all trees with a minimum diameter of 25-30 cm and above (VOB_{30}).

(Eq. 3.1.5),

$$VEF = Exp\{1.300 - 0.209*Ln(VOB_{30})\} \text{ for } VOB_{30} < 250\ m^3/ha = 1.13 \text{ for } VOB_{30} > 250\ m^3/ha$$

(sample size = 66, adjusted $r^2 = 0.65$)

- The general formula for estimation carbon stocks from inventory data (VOB) is : ***C=[VOB*D*BEF]*[1+R]*CF***. and ***CO_2 eq.=C*(44/12).*** See calculations on next slide.