# Training Seminar for BioCarbon Fund Projects

# Field Monitoring for LULUCF Projects

Winrock International

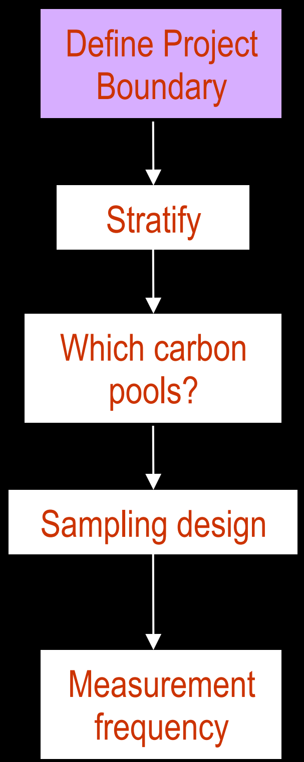
# IPCC GPG Chapter 4.3

- Provides good practice guidance for JI and CDM projects and includes guidance on:
  - defining project boundaries,
  - measuring, monitoring, and estimating changes in carbon stocks and non-$CO_2$ greenhouse gases,
  - implementing plans to measure and monitor,
  - developing quality assurance and quality control plans

# Developing a measurement plan

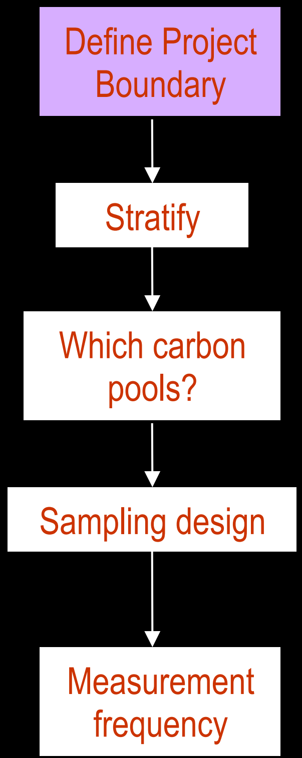
1. Define Project Boundary
2. Stratify project area
3. Decide which carbon pools to measure
4. Develop sampling design – plot type, shape, size, number, and layout
5. Determine measurement frequency

# Define project boundary




- For accurate measuring and monitoring, boundaries must be clearly defined from start of project
  - Also a requirement for project registration
- Define boundaries using features on map or coordinates attained using a global positioning system

# Define project boundary




- Project can vary in size:
  10's ha → 1000's ha
- Project can be one contiguous block OR many small blocks of land spread over a wide area
- One OR many landowners

# Carbon sampling

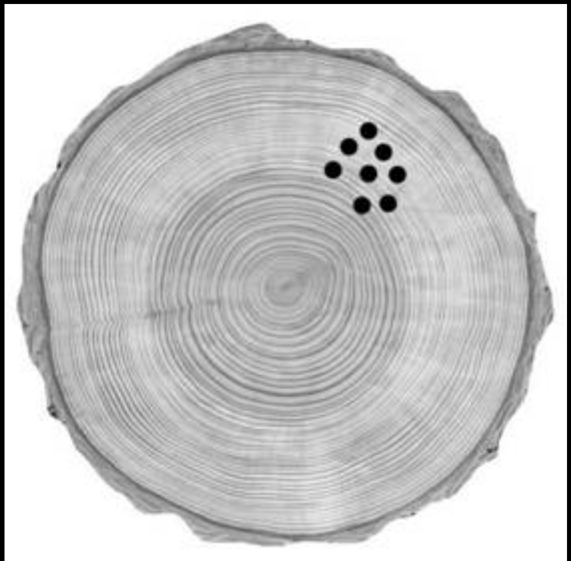
- Methods for measuring carbon credits are based on measuring changes in carbon stocks
- Not practical to measure everything - so we sample
- Sample subset of land by taking relevant measurements of selected pool components in plots
- Number of plots measured predetermined to ensure both ***accuracy*** and ***precision***

# Accuracy and precision

- Accuracy:
  - agreement between the true value and repeated measured observations or estimations
- Precision
  - illustrates the level of agreement among repeated measurements of the same quantity

Accurate but not precise

Precise but not accurate



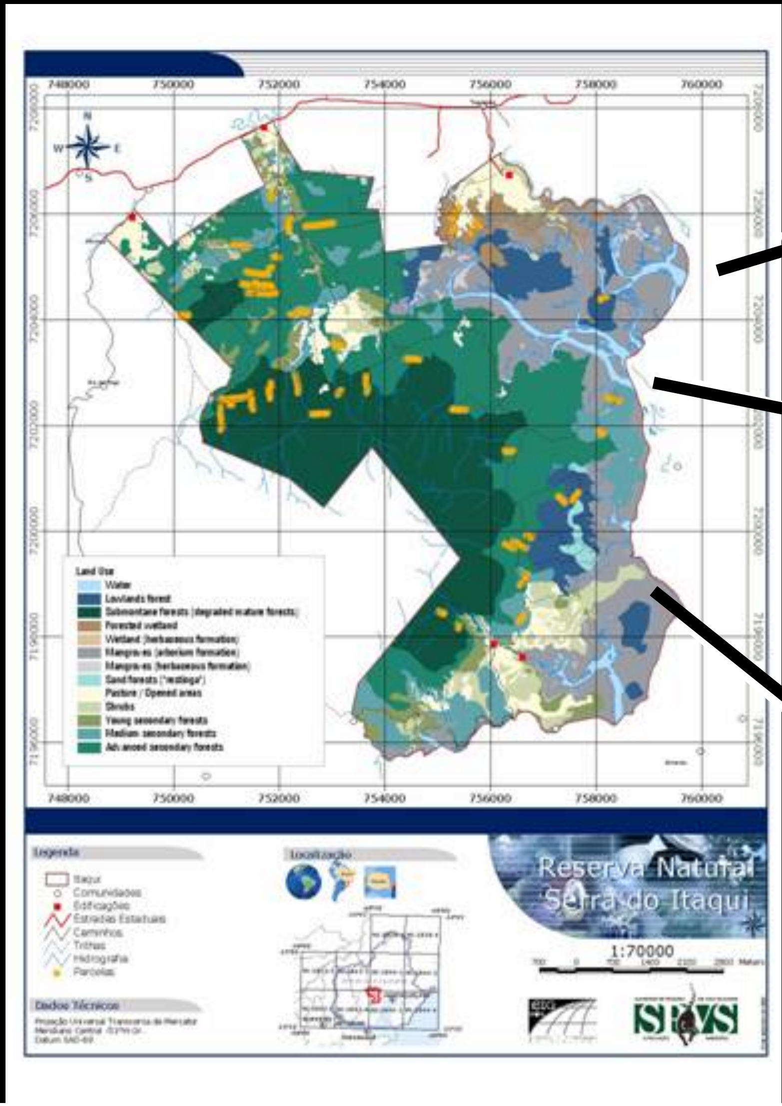
# Principles of monitoring carbon

- There is a trade-off between the desired precision level of carbon-stock estimates and cost
- In general, the costs will increase with:
  - Greater spatial variability of the carbon stocks
  - The number of pools that need to be monitored
  - Precision level that is targeted
  - Frequency of monitoring
  - Complexity of monitoring methods
- Stratification of the project lands into a number of relatively homogeneous units can reduce the number of plots needed.

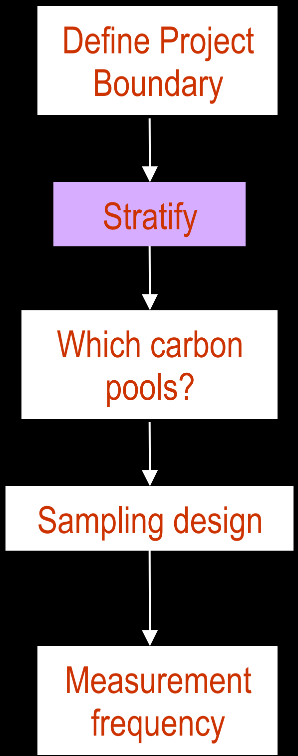
# Stratify project area

If the system is highly variable then splitting or stratifying it into definable units can reduce variation and consequently M and M costs

Define Project Boundary
↓
Stratify
↓
Which carbon pools?
↓
Sampling Design
↓
Measurement frequency




# Potential stratification options




- Land use e.g. forest, plantation, grassland, cropland etc.
- Vegetation species
- Slope e.g. steep, flat
- Drainage e.g. flooded, dry
- Elevation
- Proximity to settlement

# Decide which carbon pools to measure

Define Project Boundary

↓

Stratify

↓

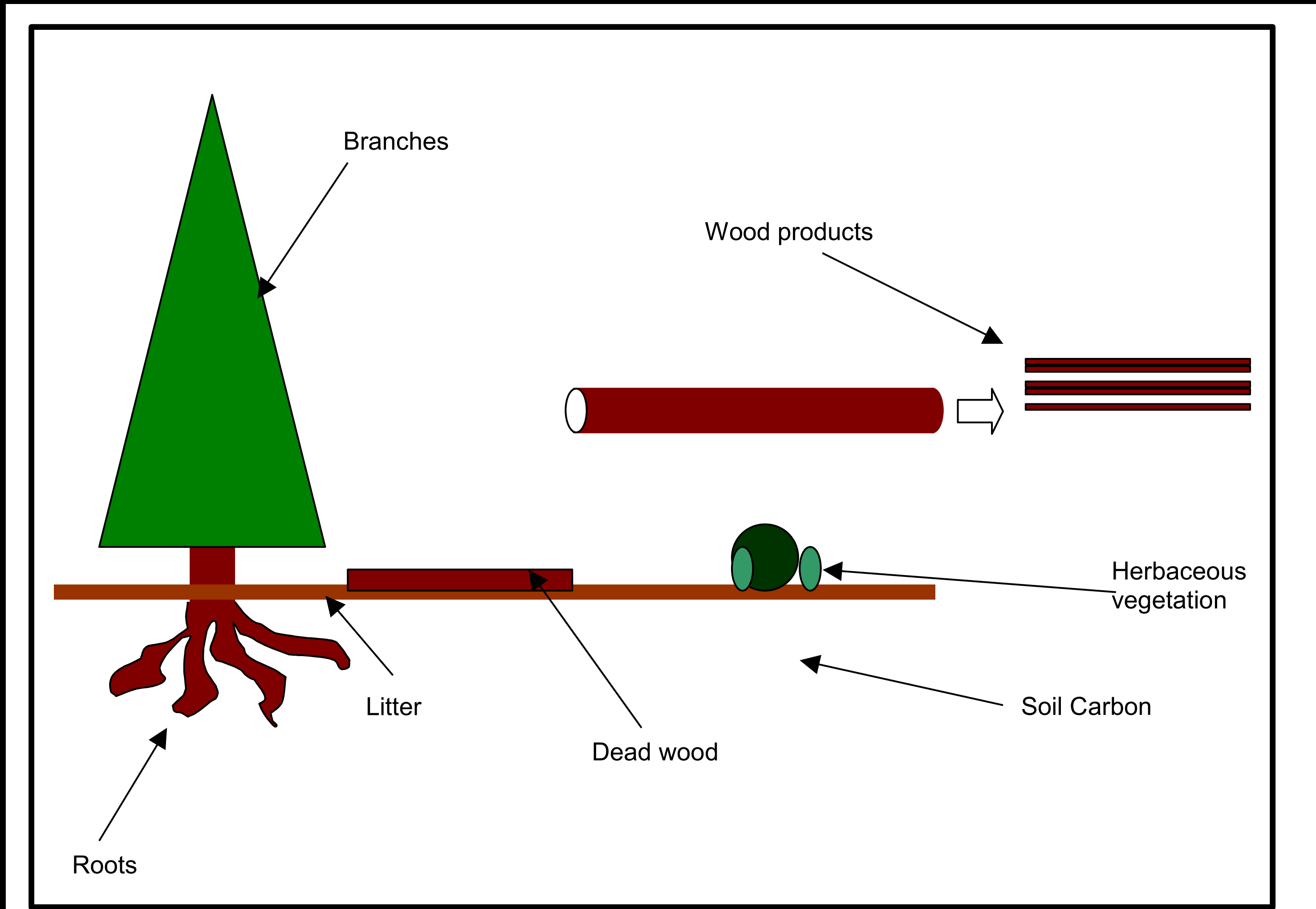
**Which carbon pools?**

↓

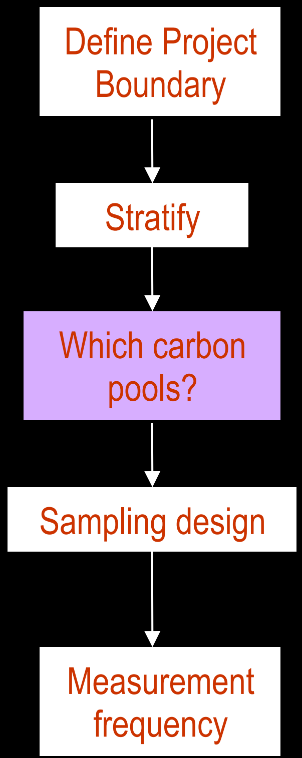
Sampling design

↓

Measurement frequency

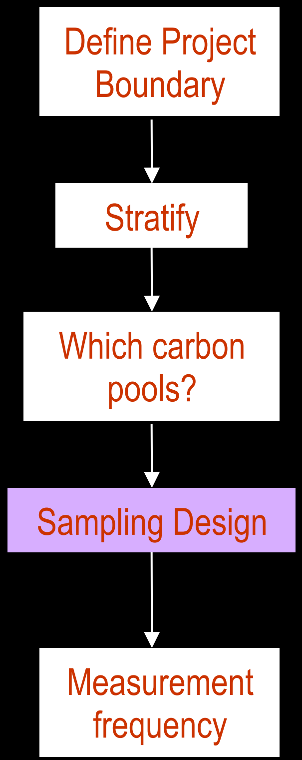


# Decide which carbon pools to measure



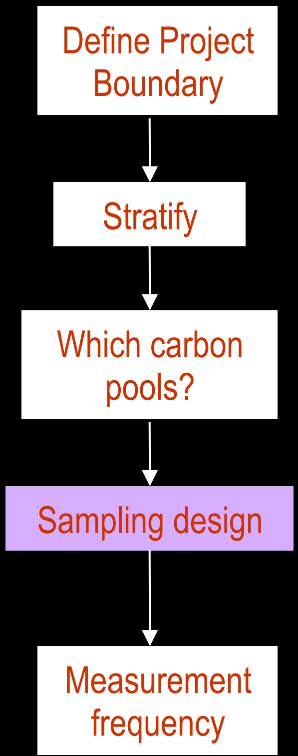

- Selection of pools depends on:
  - Expected rate of change
  - Expected magnitude and direction of change
  - Availability of methods, accuracy and cost of methods to measure and monitor
- For afforestation and reforestation over < 60 years it is always most economic and efficient to measure live tree biomass (above and belowground)

# Determine type, number, shape, size of plots, and layout



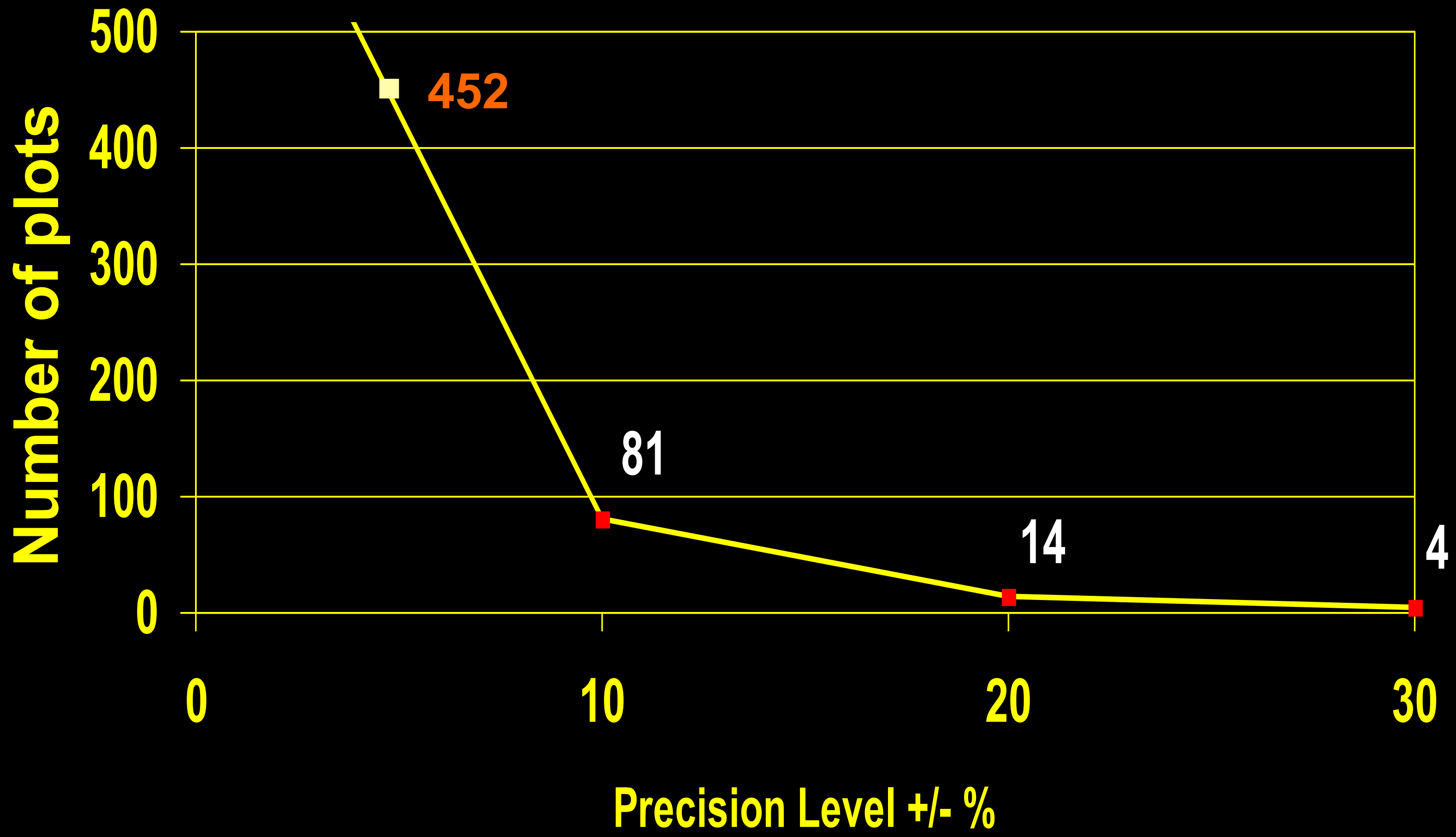

- Permanent plots statistically more efficient for measurements through time
- Also permit verification
- Must mark trees to track ingrowth and mortality

# Determine type, number, shape, size of plots, and layout

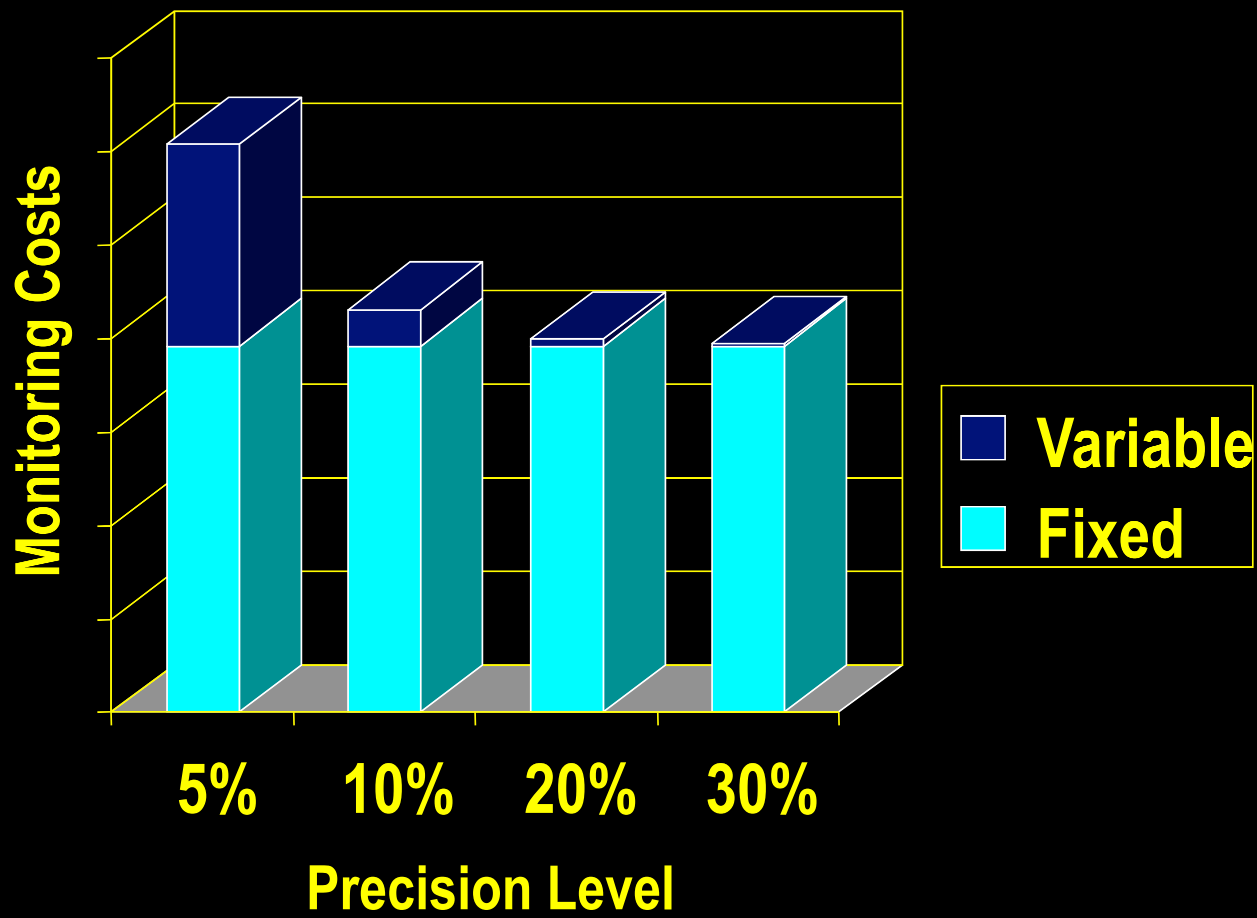



- Number of plots:
  - Identify the desired precision level
    - ±10 % of the mean is most common
      but as low as ±20 % of the mean could be used

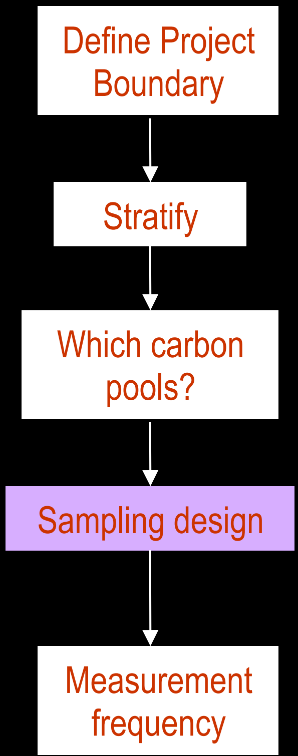
# Achieving Precision – Noel Kempff



# Cost of Precision – Noel Kempff

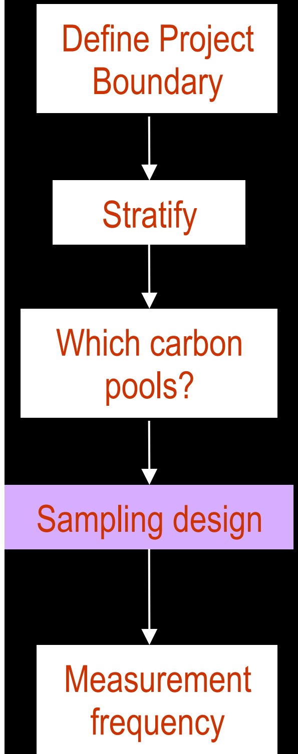


# Determine type, number, shape, size of plots, and layout




- Identify an area to collect preliminary data
  - Randomly sample approx. 10 plots within land cover type expected at end of project period
    - Trade-off between precision in young forest and measurement costs
- Could use data from the literature if available for project area

# Determine type, number, shape, size of plots, and layout




- Estimate carbon stock and variance from preliminary data
- Calculate the required number of plots using equation provided

**Single stratum:**

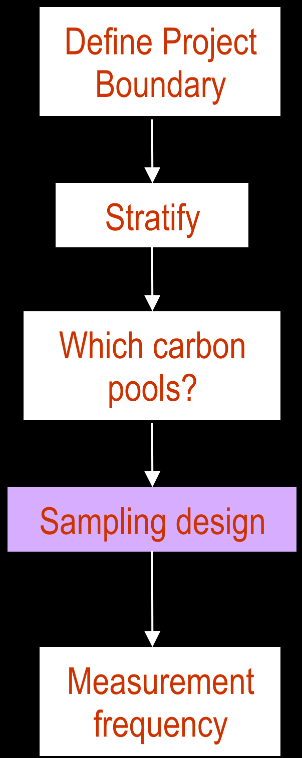
$$n = \frac{(N * s)^2}{\frac{N^2 * E^2}{t^2} + N * V}$$

**Multiple strata:**

$$n = \frac{(N_1 * s_1)^2 + \ldots.. + (N_n * s_n)^2}{\frac{N^2 * E^2}{t^2} + N_1 * V_1 + \ldots.. + N_n * V_n}$$

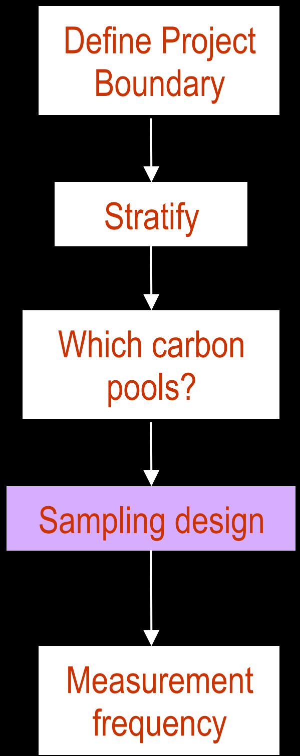
s = standard deviation
V = variance
N = # of sampling units in population
t = sample statistic from the t-distribution for the 95 % CI
E = ½ width of the confidence interval

# Determine type, number, shape, size of plots, and layout




- More variable C stocks → more plots needed for precision level
- If a stratified project area requires more plots than an unstratified area → remove 1+ strata
- If strata analyzed together → C stocks in each strata cannot be reported separately but fewer plots needed to attain precision level

# Determine type, number, shape, size of plots, and layout



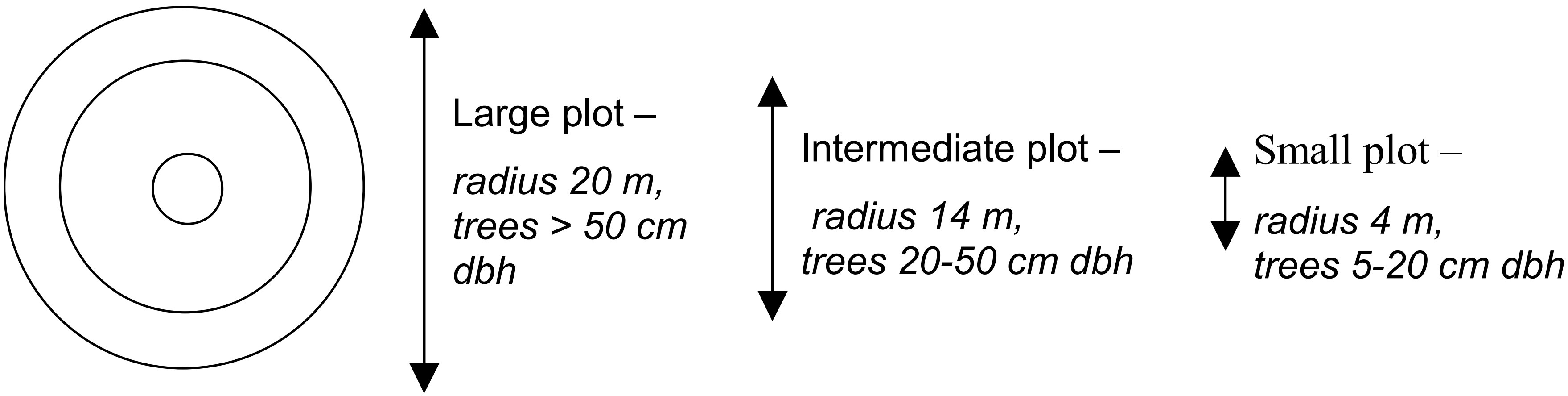

- Non-tree carbon pool:
  - Above method can be used
  - However, size of non-tree carbon pool most likely small in reforestation/afforestation project
  - Alternatively, measure non-tree pools in proportion to # tree plots

    For example:
    - For every tree plot, sample:
      - Single 100 m line transect for dead wood
      - 4 sub-plots for herbaceous, forest floor, soil
  - May result in large variance, but overall amount small in comparison to tree carbon stock

# Determine type, number, shape, size of plots, and layout

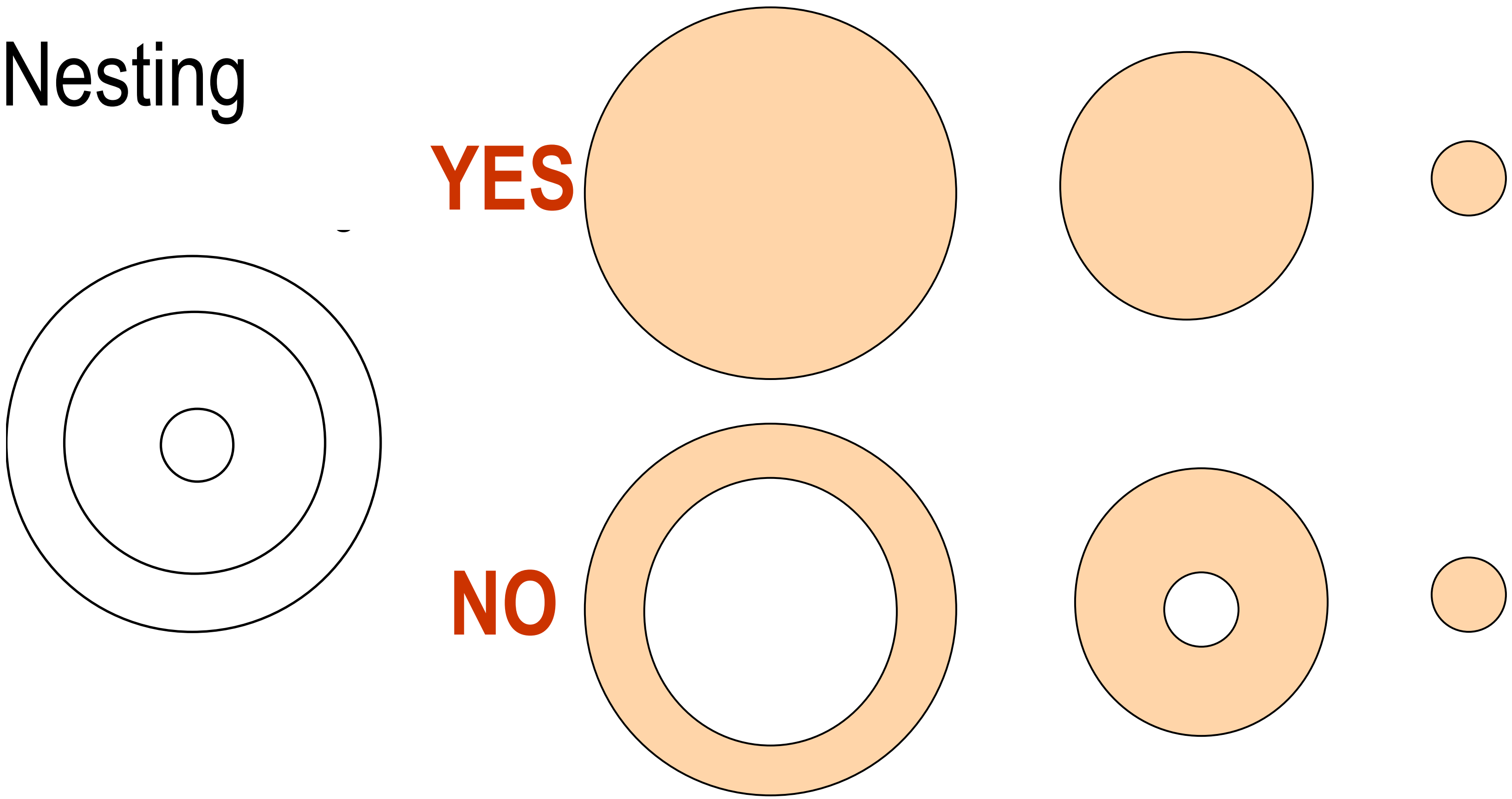
- Nested plots
  - efficient for regenerating forests with trees growing into new size classes
  - Plots can be either circular or square
  - ~10 stems per strata 'rule of thumb' to determine plot size

The schematic diagram below represents a three-nest circular sampling plot.

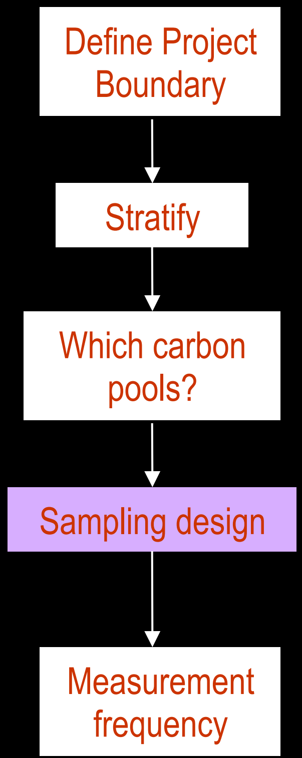


# Determine type, number, shape, size of plots, and layout

Nesting

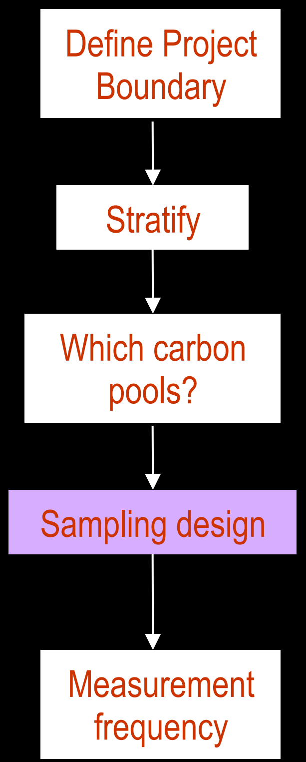


# Determine type, number, shape, size of plots, and layout



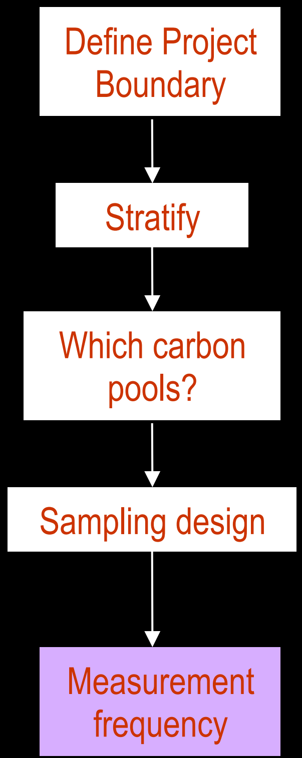

- Where an even-age distribution of trees can be expected single plots can be used instead of nested plots
- The size of a single plot is a trade-off between adequately sampling large trees late in the project and high effort and cost for sampling small trees initially
  - This trade-off is avoided with nested plots

# Determine type, number, shape, size of plots, and layout




- Decide if plots to be distributed:
    - Systematically
        - Overlay grid on map
        - Allocate plots in regular pattern across strata
    - Randomly
        - Generate random number for bearing and distance for each plot or randomly allocate in GIS
    - Post-stratify
        - Where highly variable but difficult to stratify

# Frequency of measurement




- For CDM, verification and certification must occur every five years
- It is therefore logical to re-measure at this time
- However, for slowly changing pools such as soil it will be necessary to measure less frequently

# Field Measurement Techniques

# Carbon versus Biomass

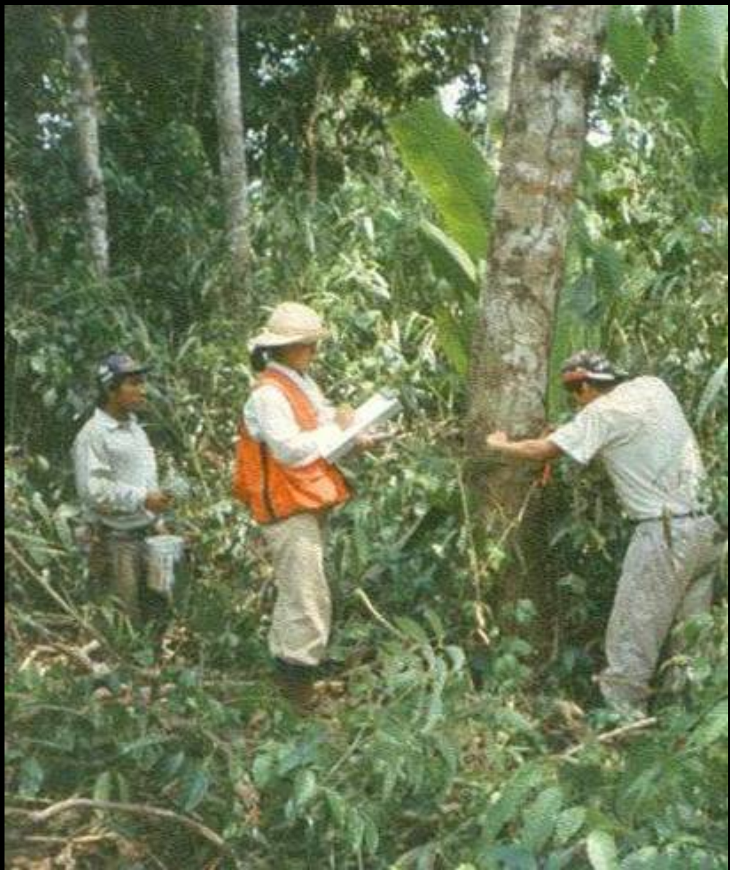
- Carbon is generally taken to be equal to: ½ Biomass
- Alternatively, the proportion of carbon contained in a biomass pool can be measured on a project by project basis
- The proportion of carbon in soil will not be 50 % and if soil monitored proportion will need be measured

# Permanent plots

- **Install permanent measuring and monitoring plots in a standard design**
  - Permanently mark plot center and locate with a GPS

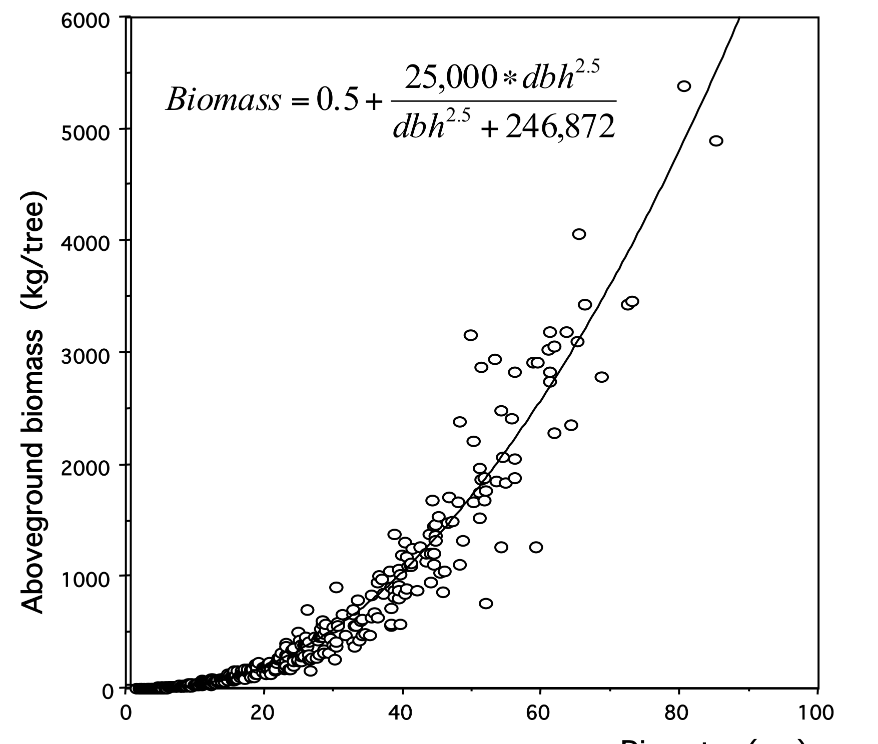
Plots marked with rebar and PVC, trees marked with aluminum nails and tags

# Estimate carbon pools - tree biomass



- In each strata, measure DBH of appropriate size trees
- DBH measured at 1.3 m above the ground with a DBH tape

# Estimate carbon pools - tree biomass– Allometric equations




Taken from: Schroeder *et al* 1997

- Relationship between tree diameter and mass ('biomass') of tree
- Many equations published for forests worldwide
- Local regression equations may exist in literature
- Verify applicability of equation(s) through limited destructive sampling or volume and wood density estimations
- If no equations exist, need to harvest and measure a representative sample of trees to develop equations

# Estimate carbon pools - tree biomass
## Developing allometric equations

*Step 1:* Select the dominant tree species

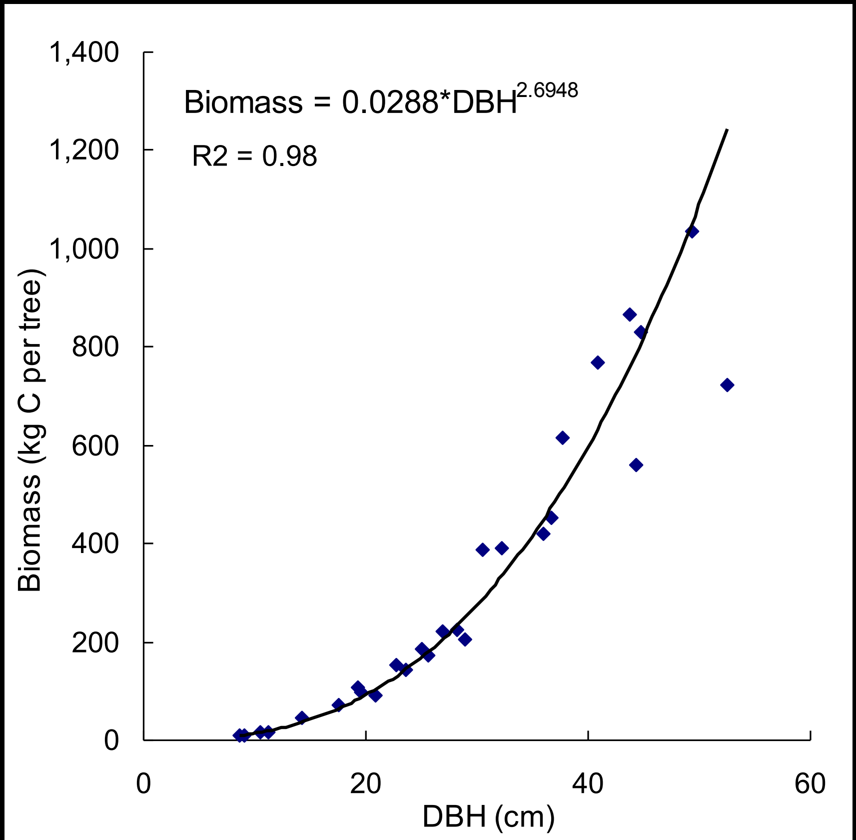
*Step 2:* Select about 30 trees randomly to represent the full range of diameter classes existing or expected

*Step 3:* Measure DBH and height of each tree

*Step 4:* Harvest the selected trees to the ground

*Step 5:* Estimate mass of tree

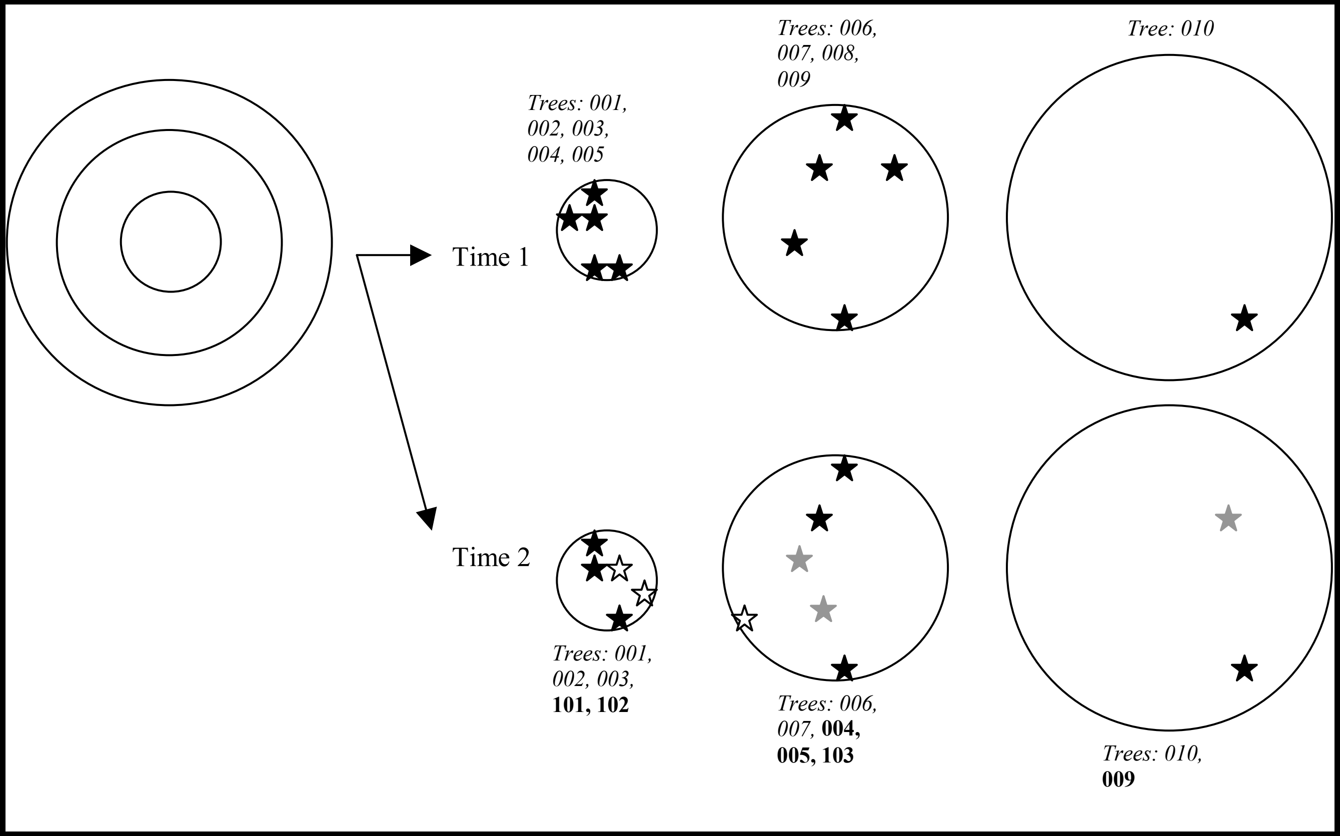
# Estimate carbon pools - tree biomass
## Developing allometric equations




*Step 6:* Develop biomass equations linking tree biomass data to DBH alone, or DBH and height.

Can be done in EXCEL by plotting biomass against DBH (or DBH and HEIGHT) and fitting a regression line

# Calculating change in tree biomass




(Σ increments of trees remaining in subplot size class) +

(Σ increments for outgrowth trees [= Σ max biomass for size class – biomass at time 1]) +

(Σ increments for ingrowth trees [= Σ biomass at time 2 – min biomass for size class†])

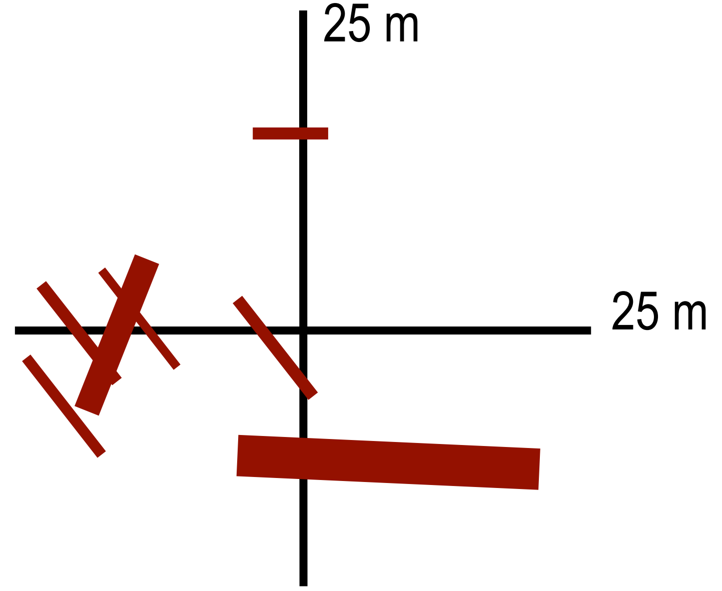
*† Minimum biomass for each size class is calculated by entering the minimum dbh for that size class into the regression equation (5 cm for the small plot, 20 cm for the intermediate plot and 70 cm for the large plot)*

# Estimate carbon pools – Dead wood

- Dead wood can be a significant component of biomass pools
  - Particularly in mature forests – not eligible in first reporting period

# Estimate carbon pools– Dead wood

- Standing dead trees
  - Estimate biomass using regression equations or volume from detailed measurements
- Down dead wood
  - Measure with line intersect and classify into density classes
  - Sample dead wood for density estimates
  - Change location of lines on repeat measurements




$$Volume \cdot (m^3) = \pi^2 * \left[ \frac{\left(d_1^{\,2} + d_2^{\,2} \cdots\cdots d_n^{\,2}\right)}{8L} \right]$$

$$Biomass = Volume\ x\ Density$$

# Estimate carbon pools– Understory/herbaceous vegetation

Aluminum frame of 60-cm diameter is placed on the ground

- Use small circular frames
- Frame placed on ground
- Cut all herbaceous vegetation within the frame
- Weigh entire sample

# Estimate carbon pools– Understory/herbaceous vegetation

- Collect a sub-sample for moisture determination
- Place sub-sample in bag and weigh it
- Repeat the process for litter
- Sub-samples dried and weighed for determination of dry biomass
- Place in new location on repeat measurements

# Estimate carbon pools - Mineral soil carbon

- Expose mineral soil surface
- Collect 4 samples, mix and sieve for C analysis
- Collect samples for bulk density in each plot

# Sources of error in estimating carbon pools

- Three main sources are:
  - Sampling error—number and selection of plots to represent the population of interest
  - Measurement error —e.g. errors in field measurements of tree diameters, laboratory analysis of soil samples
  - Regression error — e.g. based on use of regression equations to convert diameters to biomass
- All these sources can be quantified and "added"

# Uncertainty

- Two methods for determining uncertainty in estimates
  - Error Propagation

  e.g.

  - **Monte Carlo Analysis** (commercial software available)
    - Complex but should be used if there are strong correlations between datasets or if error >100 %
    - Correlations will exist between various measured carbon pools and between estimates at different times

# Quality Assurance/Quality Control plans

- Monitoring requires provisions for:
  - Quality Assurance (QA)
  - Quality Control (QC)
- The QA/QC plan should become part of project documentation and cover the following procedures:
  - collecting reliable field measurements;
  - verifying methods used to collect field data;
  - verifying data entry and analysis techniques;
  - data maintenance and archiving.

# QA/QC field measurements

- Develop a set of Standard Operating Procedures (SOPs)
- Thorough training of all field crews in procedures, followed by:
  - Hot Checks - supervisor visits crew in field and verifies measurements
  - Cold Checks - supervisor revisits plots after the departure of crew and reviews recorded measurements
  - Blind Checks - supervisor re-measures a proportion of plots with no knowledge of data recorded by crew

# QA/QC for laboratory measurements, data entry, and archiving

- Laboratory measurements
  - check equipment and measurement with known quantity samples added blindly
- Data entry
  - test of out of range values
  - recheck proportion for errors
- Archiving
  - off-site storage of data

# Acknowledgements


- Team at Winrock International
  - Including Sandra Brown, Ken MacDicken, David Shoch, Matt Delaney and John Kadyszewski
- Funding agencies
  - Including TNC, USAID, USFS, UNDP and World Bank