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Field Monitoring for LULUCF Projects

Timothy Pearson
Winrock International

Promoting Transformation by Linking Natural Resources, Economic Growth, and Good Governance

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Project Monitoring – Components:

- Carbon stocks
- Leakage
- Project Emissions
- Project implementation
  - Forest Establishment
  - Forest Management
  - Project Boundary

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Project Monitoring – Goals:

- Estimate GHG sequestration or avoided emissions by project
  - Estimate changes in carbon stocks
  - Estimate emissions caused by project
- Overall Goal:
  - Conservatively estimate changes with low uncertainty, minimizing errors

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Project Monitoring

- Detailed monitoring plan will need to be created for each component monitored
  - Standard operating procedures for collection
  - Excel data sheets and calculation tools
  - Frequency of collection
  - Tools to monitor and reduce error
  - Protocol for data storage
  - Project member responsible for data collection, analysis and storage

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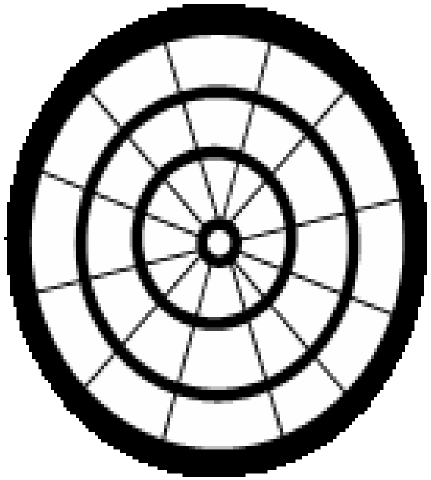
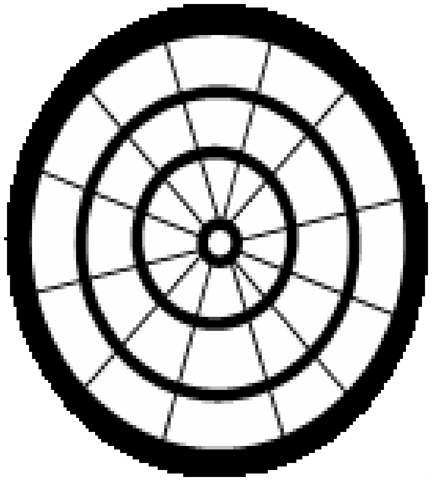
Accuracy and precision

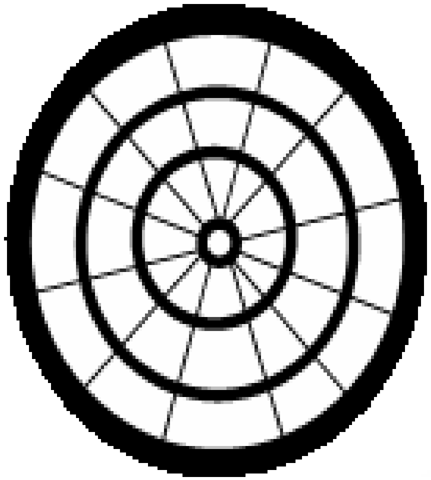
- Accuracy:
  - agreement between the true value and repeated measured observations or estimations
- Precision
  - illustrates the level of agreement among repeated measurements of the same quantity



Accurate
but not precise



Precise
but not accurate



Accurate and Precise

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True mean of forest carbon stock = 120 t C/ha

	Accurate but imprecise
	145
	95
	170
	110
	80
Average	**120**
95 % confidence interval	*45.8*

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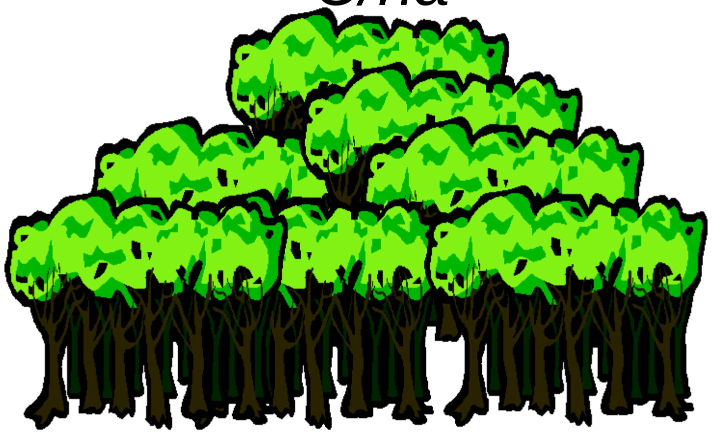
True mean of forest carbon stock = 120 t C/ha



	Accurate but imprecise	Inaccurate but precise
	145	180
	95	183
	170	177
	110	178
	80	182
Average	**120**	**180**
95 % confidence interval	*45.8*	*3.2*

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True mean of forest carbon stock = 120 t C/ha

	Accurate and Precise	Accurate but imprecise	Inaccurate but precise
	118	145	180
	123	95	183
	121	170	177
	118	110	178
	120	80	182
Average	**120**	**120**	**180**
95 % confidence interval	*2.6*	*45.8*	*3.2*

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Define project boundary

- For accurate measuring and monitoring, boundaries must be clearly defined from start of project
  - Also a requirement for project registration
- Monitor to show boundaries do not change through project due to encroachment, disturbance

Define project boundary

- Maximize the area for carbon credits
- Easy and efficient to monitor and verify using GPS
- Excludes areas that have little to no carbon benefit
- Excludes areas where baseline carbon stocks (and leakage) are more difficult to estimate than the potential carbon benefit warrants (e.g., villages)

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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
- Only includes lands that meet eligibility conditions

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Principles of monitoring carbon

- 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***

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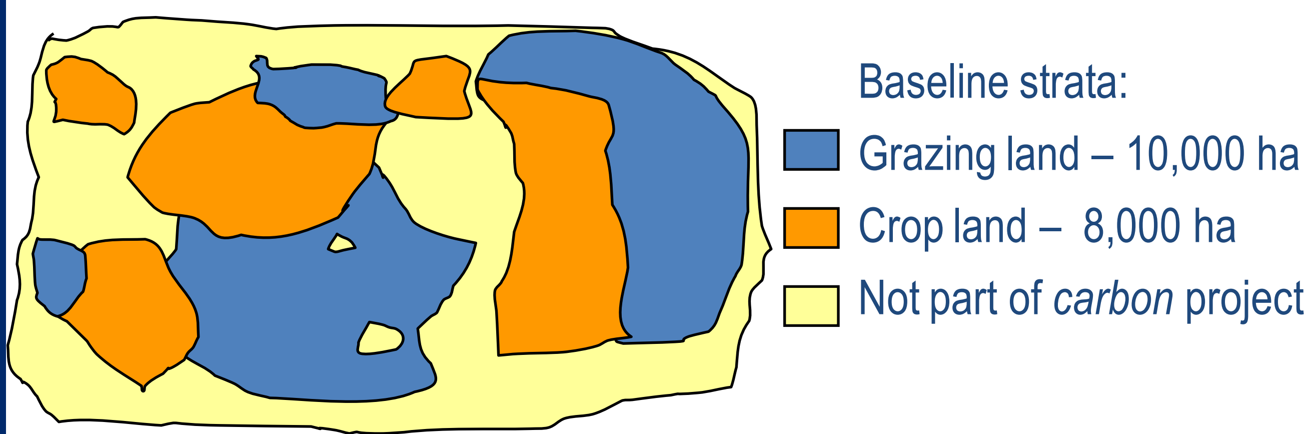
Principles of monitoring carbon

- 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.

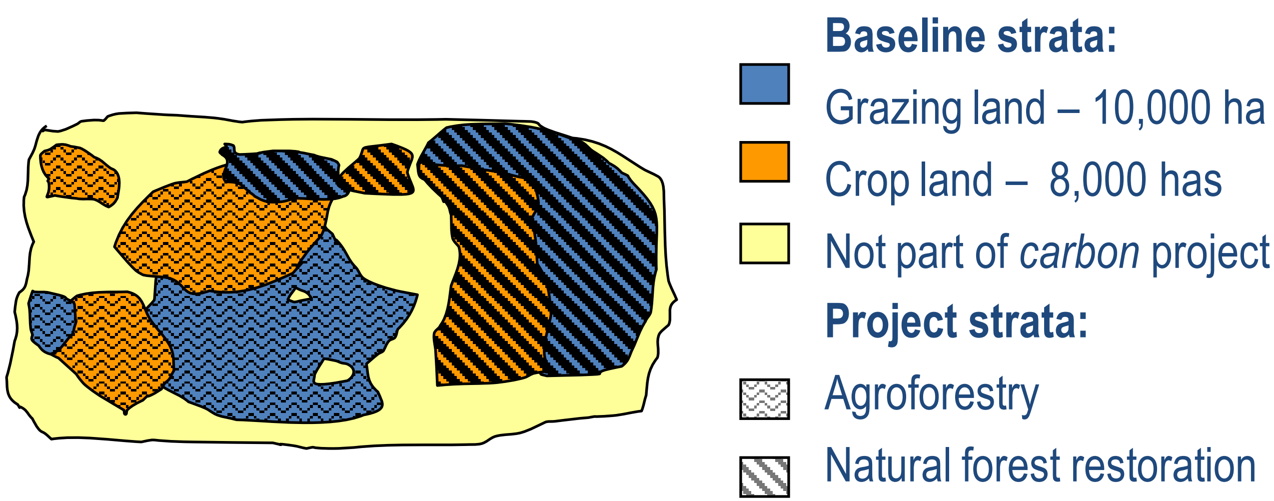
Stratify Project Area

- If different areas will contain different amounts of carbon, 'stratify' project = divide area into different 'strata'
- Stratify based on factors that will affect CARBON stock
- One stratum can be made up of one large block of land or several small blocks of land, as long all of the blocks have similar carbon stocks



Stratify Project Area

- Will most likely have separate strata for baseline and monitoring
- Must monitor area of each strata over project
- Area and number of strata may change over life of project



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Stratify Project Area

- Land use
- Slope
- Drainage e.g. flooded, dry
- Elevation
- Proximity to villages, towns
- Age of vegetation e.g. ‘cohort’
- Species composition, stand model

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Sampling Design: Type of plots

- Permanent plots
  - Statistically more efficient for measurements through time
  - Permit verification
  - Must mark trees to track ingrowth and mortality
- Temporary plots
  - Measurements made only one time
    - Preliminary data
  - Non-tree pools

Sampling Design: Number of plots

- 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
- Collect preliminary data to estimate variability of carbon stocks

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Sampling Design: Number of plots

- 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

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Sampling Design: Number of plots

- Non-tree biomass pools:
  - Above method can be used
  - OR: # 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

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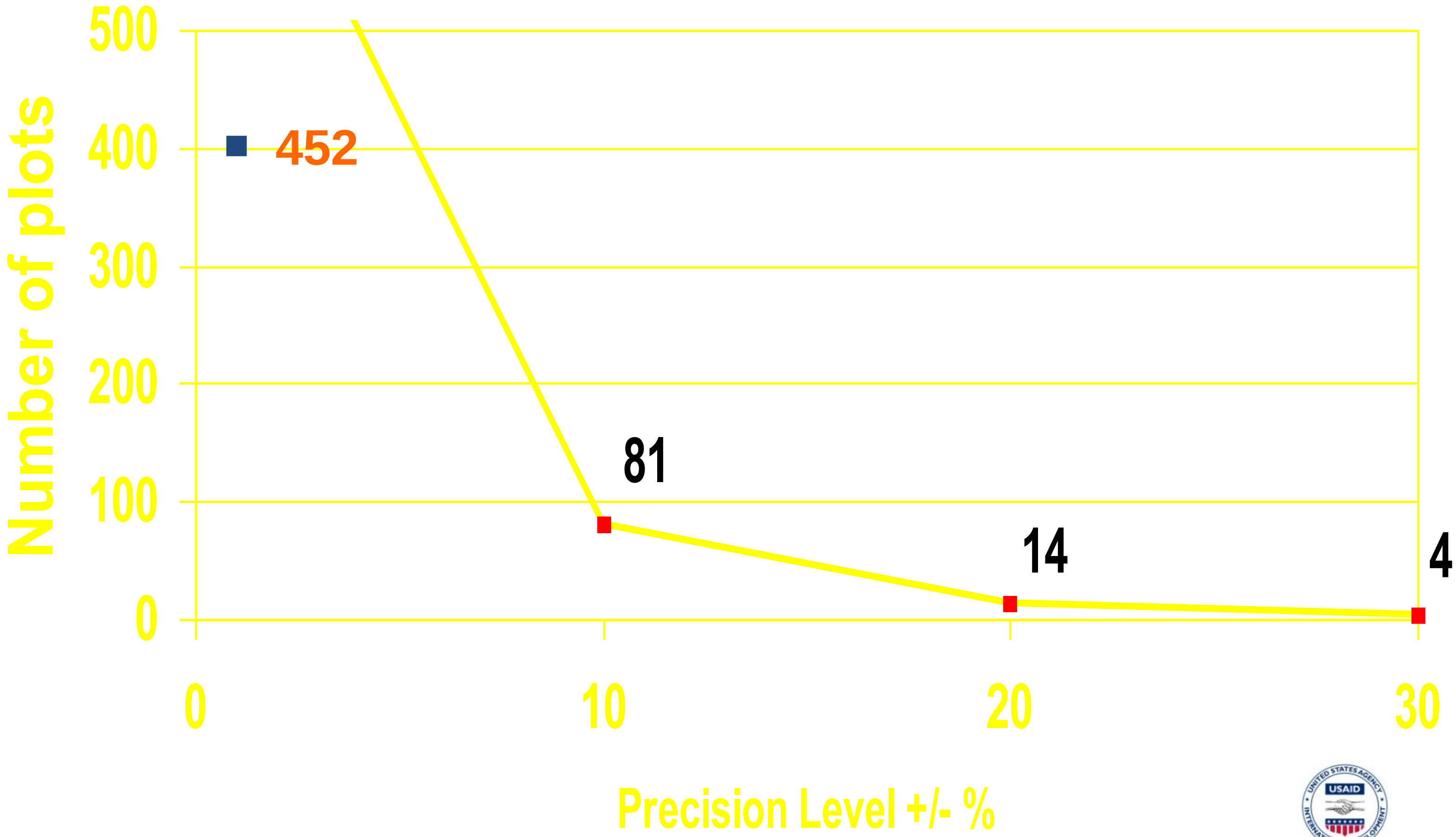
Achieving Precision – Noel Kempff



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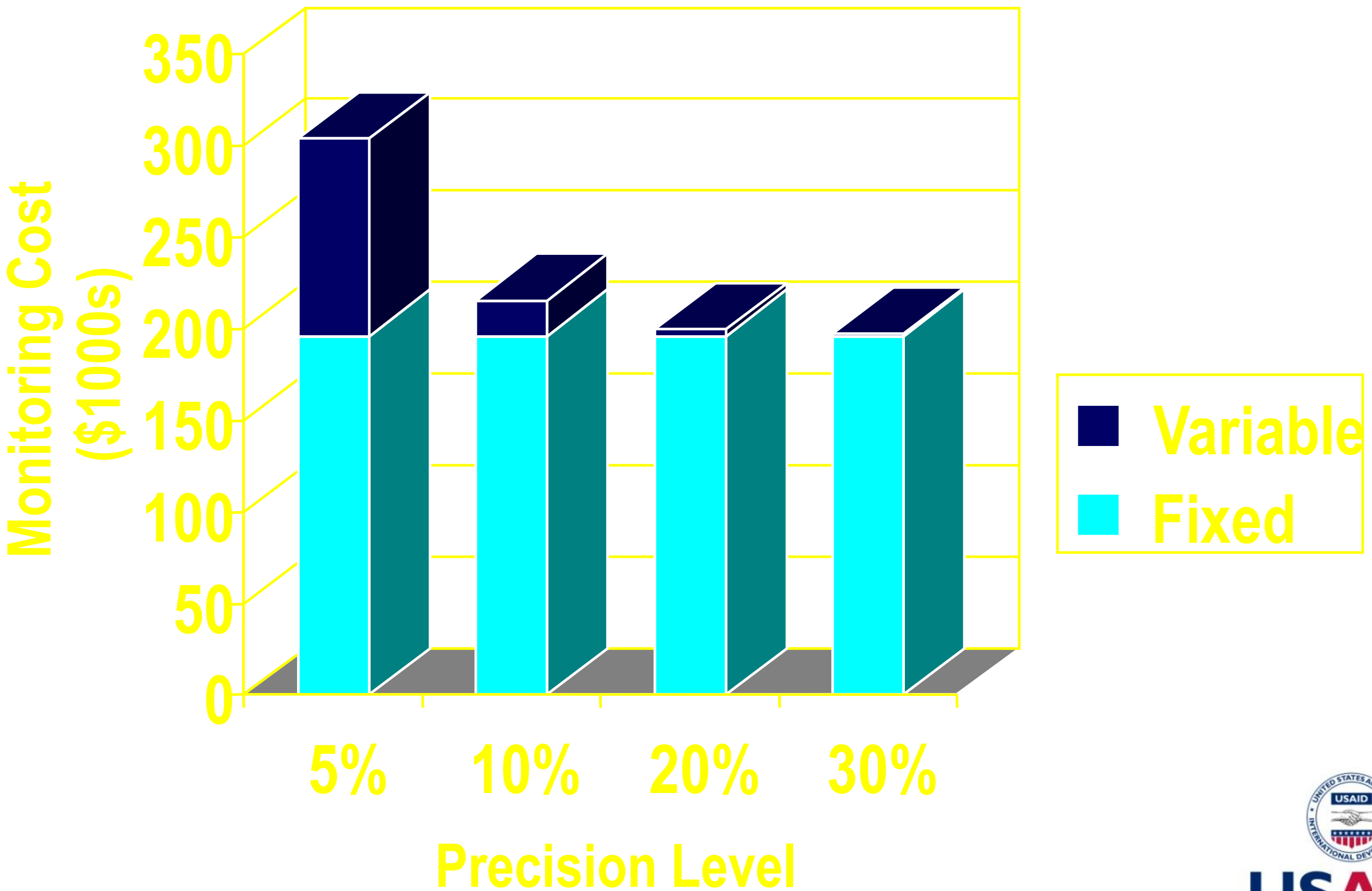
Cost of Precision – Noel Kempff



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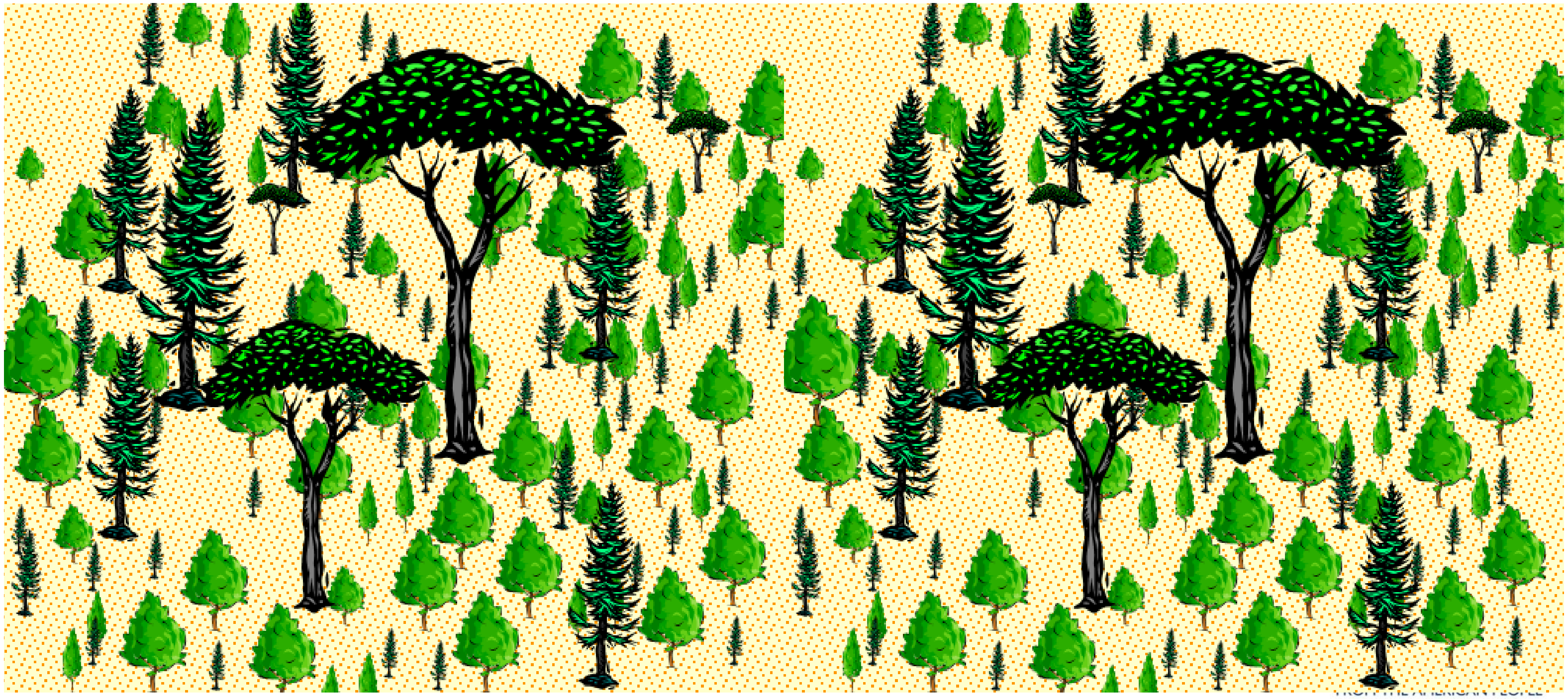
Sampling Design: Shape of plots

- Trees
  - Large trees: few, very spread out
  - Small trees: many, close together

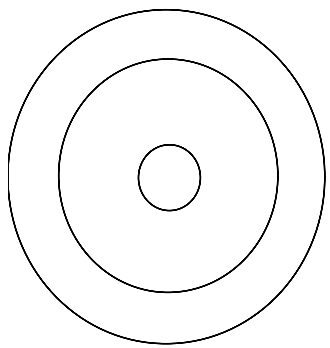


Sampling Design: Shape of plots

- 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
- Single size plots
  - Requires lower expertise
  - can be efficient where trees will be planted and will be single-aged

Sampling Design: Shape of plots

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



Large plot –

radius 20 m, trees > 50 cm dbh

Intermediate plot –

radius 14 m, trees 20-50 cm dbh

Small plot –

radius 4 m, trees 5-20 cm dbh

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

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Field Measurement Techniques

Carbon vs Biomass

Generally:

Carbon = 50% of Biomass

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Create Plot

- **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

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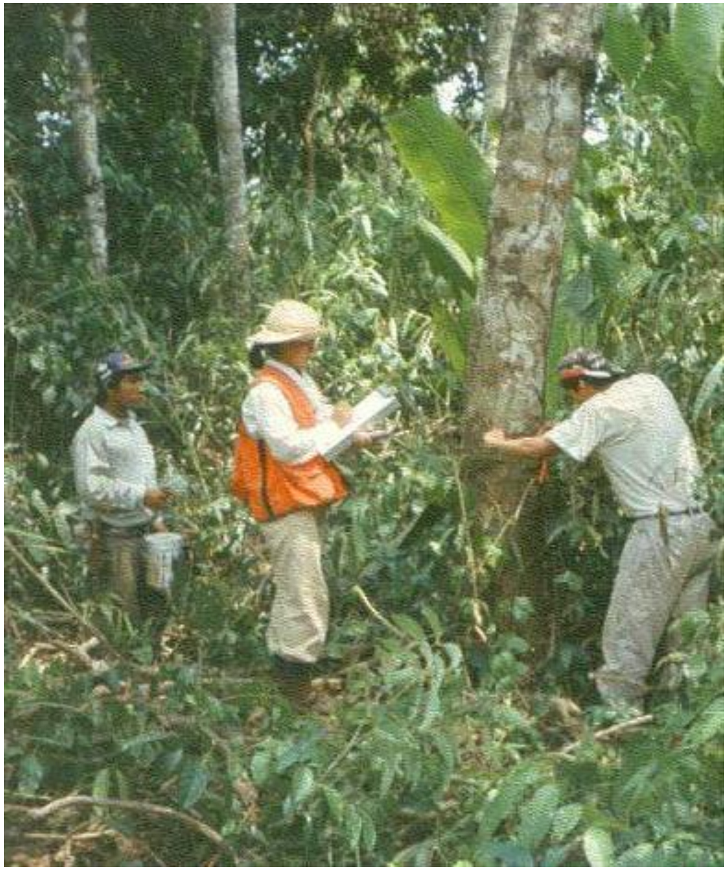
Estimate carbon pools - tree biomass



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

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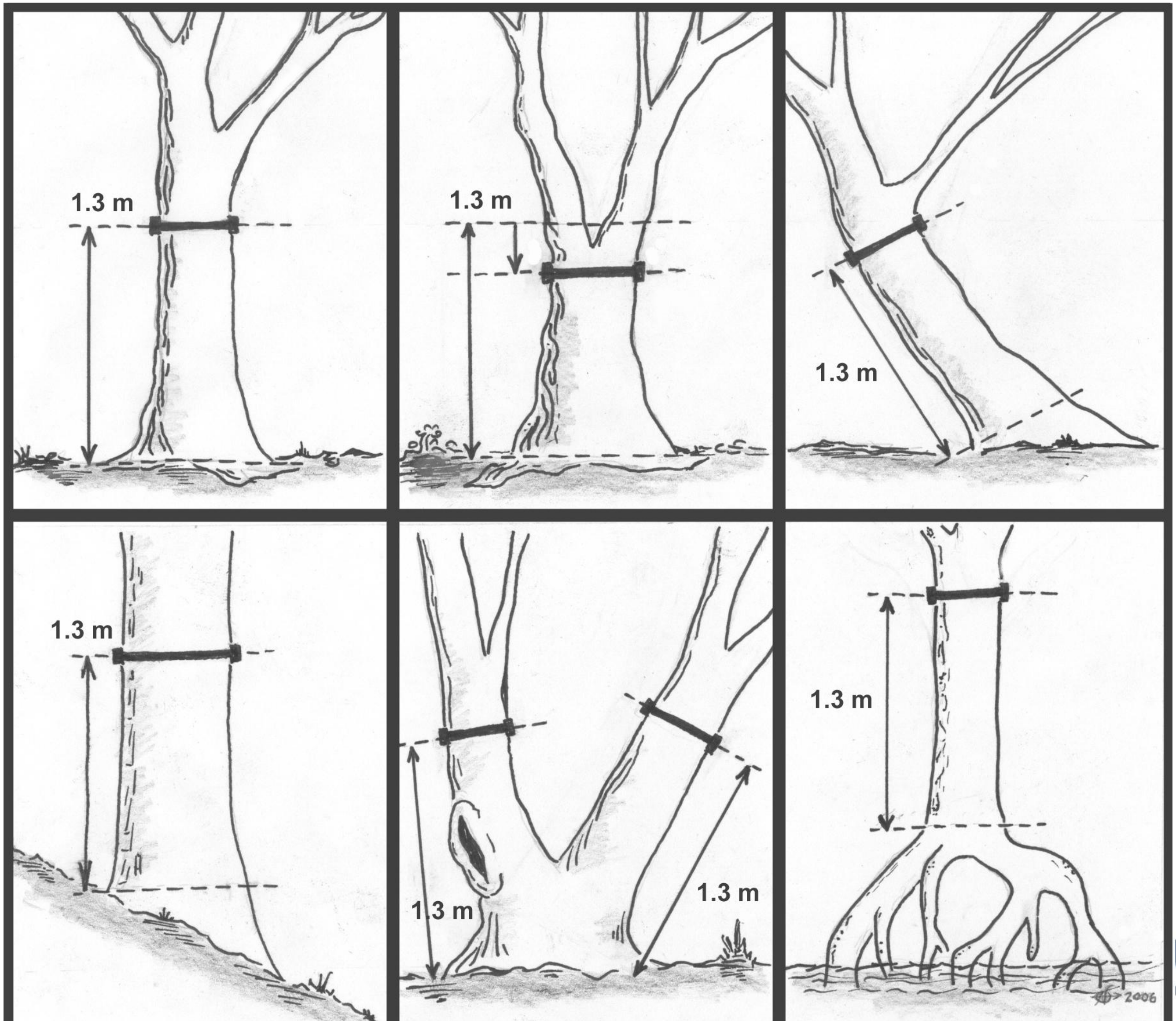
Measurement of trees



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Estimate carbon pools - tree biomass– Allometric equations

- Local regression equations 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– Allometric equations

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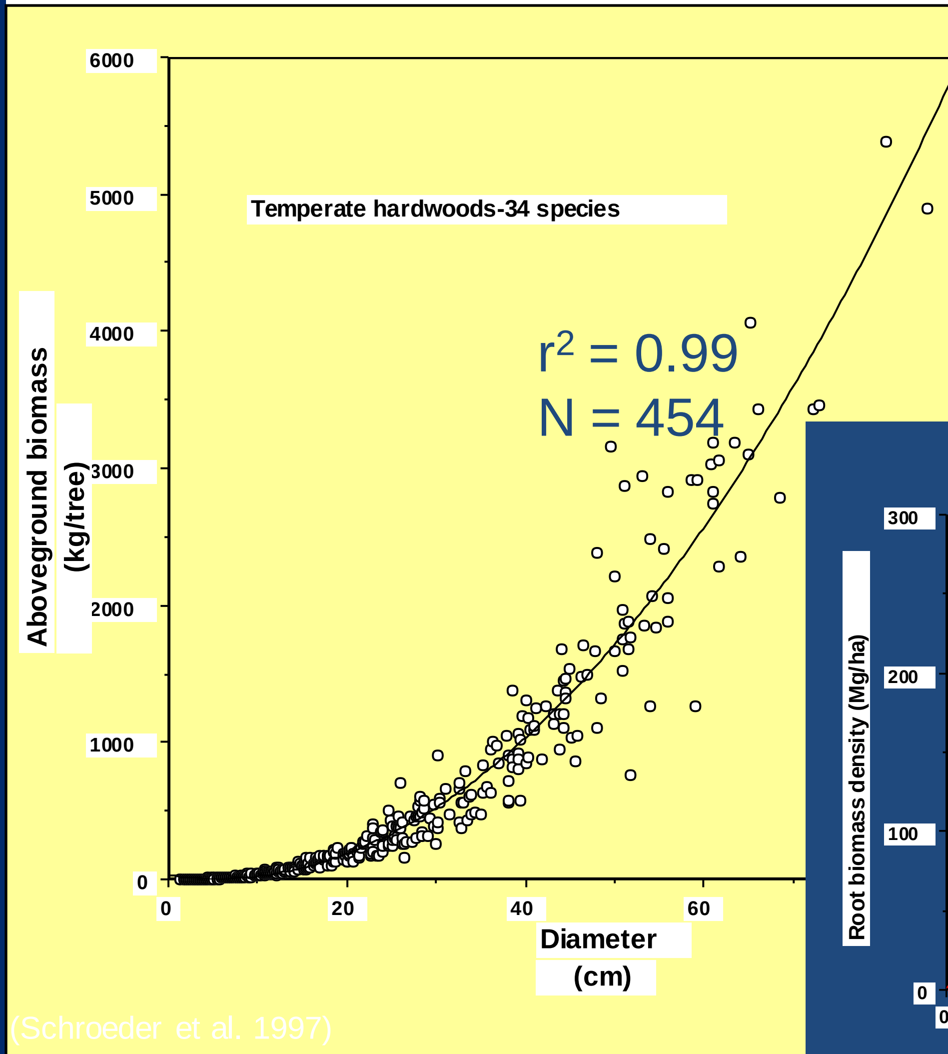
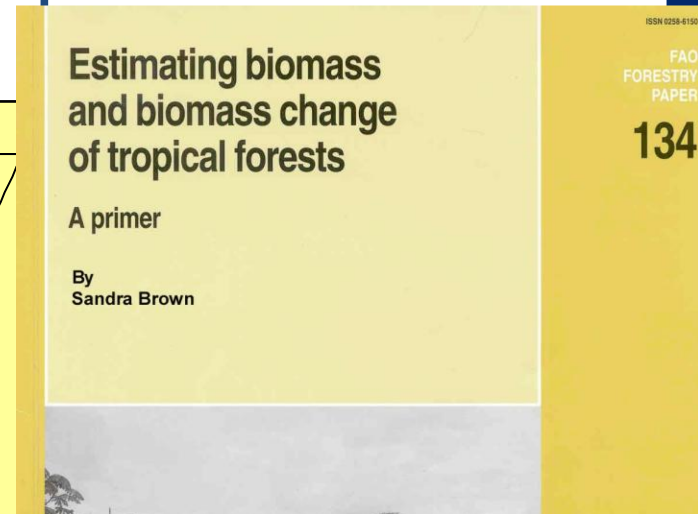
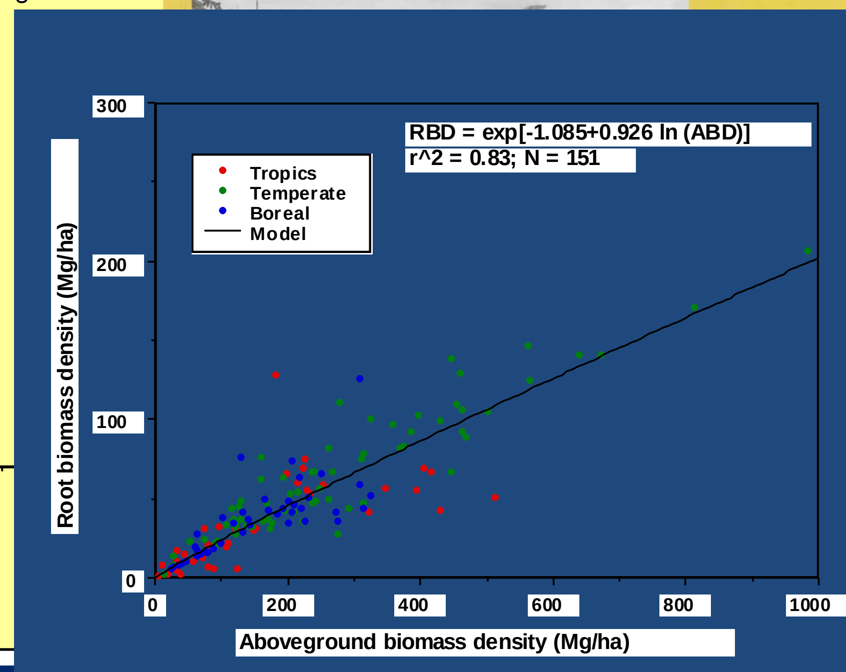


(Schroeder et al. 1997)





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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
- For standing dead trees estimate biomass using regression equations or volume from detailed measurements

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Measuring Dead Wood

- Two Types of Dead wood:
  - Standing Dead trees
  - Lying dead wood
- Will use two different methods
- For both methods, need to estimate density of dead wood
- Will use density to calculate biomass

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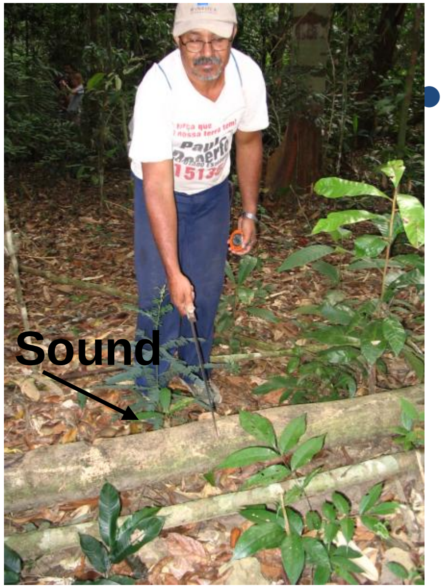
Dead Wood Density



- All dead wood is classified into three density classes:
  - Sound: Machete does not sink into the piece (bounces off)
  - Intermediate: Machete sinks partly into the piece, and there has been some wood loss
  - Rotten: Machete sticks into the piece if there is more extensive wood loss, and the piece is crumbly

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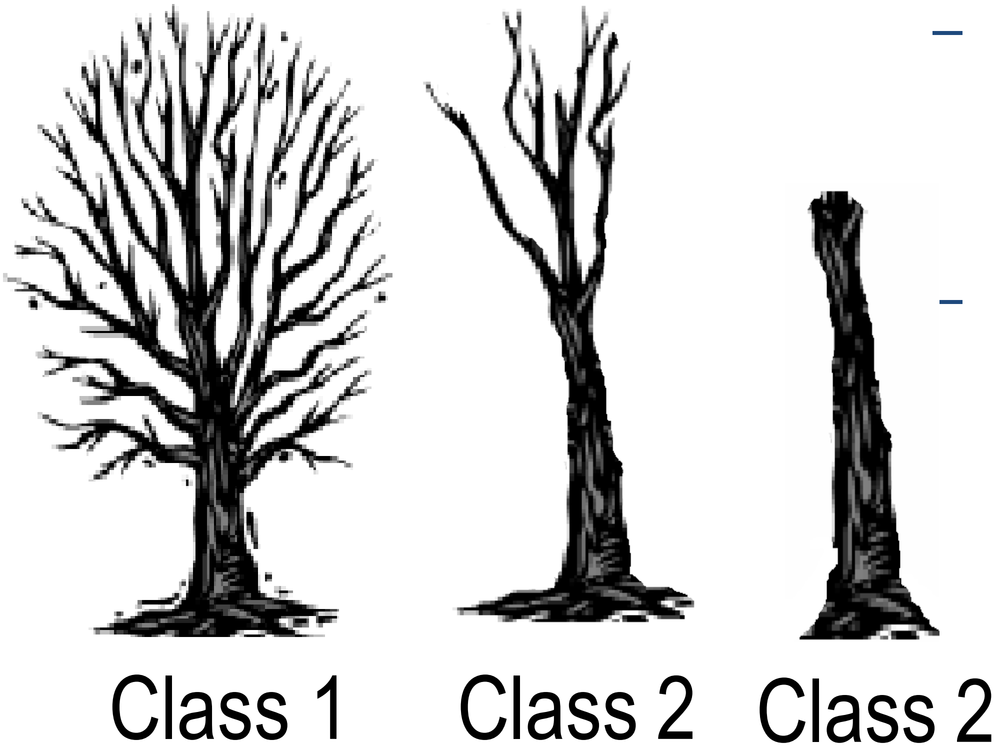
Standing Dead Wood

- Within live tree plots, standing dead trees should also be measured and classified into two classes:
  - **Class 1**: Tree with branches and twigs and resembles a live tree (except for leaves)
  - **Class 2**: Trees ranging from those containing small and large branches to those with bole only



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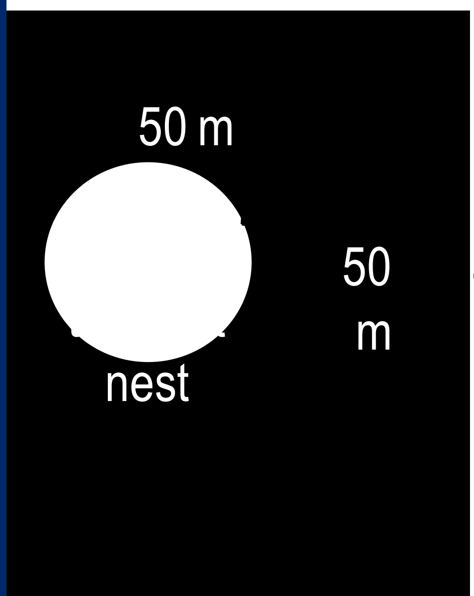
Lying Dead Wood

- Defined: All woody material ≥10 cm diameter
- Smaller diameter pieces measured in litter clip plots
- Use 'Line Intersect Method'
  - If no tree plots, determine location randomly
  - From center of plot (or GPS location if in nonforest area) using watch and compass, walk to edge of plot in randomly determined direction
  - Lay out transects totally 100 m. For example, lay out two 50 m lines at right angles at the edge of your plot



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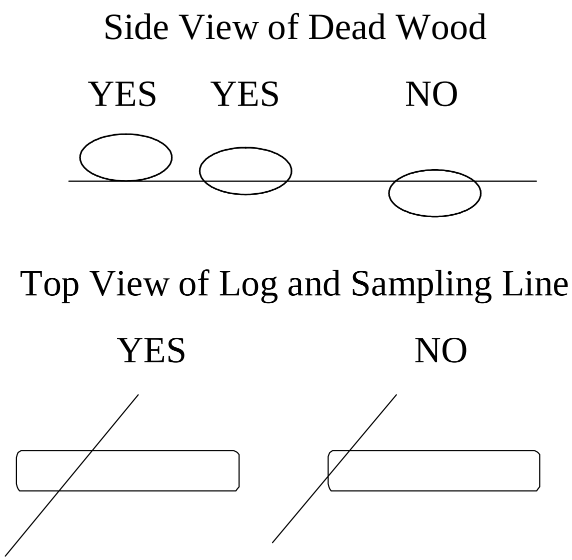
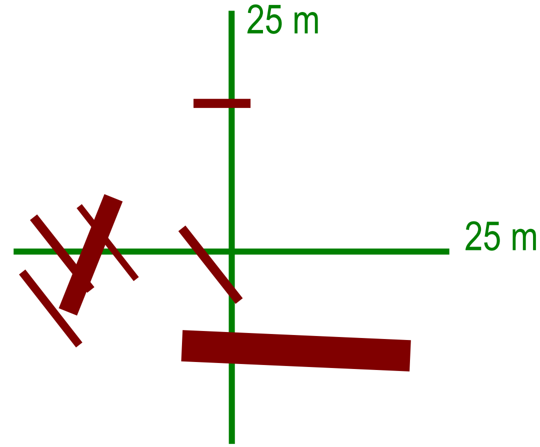
Lying Dead Wood

- Measure wood if:
  - ≥50% of the log is aboveground
  - Line crosses ≥50% of diameter





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Estimate carbon pools– Understory / Herbaceous vegetation and litter

- **Use small frames**
- **Frame placed on ground**
- **Place in new location on repeat measurements**

Aluminum or PVC frame of ~60 cm^2 is placed on the ground

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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

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Monitoring Project Emissions

- Tracking:
  - Vehicle and machinery use
  - Use of fertilizers
  - Use of fire
  - Incidental fires
  - Livestock emissions

Monitoring Leakage

- All projects
  - Monitoring vehicle use
- Some projects
  - Activity shifting
    - Tracking individuals
    - Tracking livestock
    - Tracking wood fuel use
- All require good organization and good database skills

Minimizing Project Errors

- Errors will arise through:
  - Poorly chosen methods
  - Poorly applied methods
  - Insufficient sampling
- Errors can be predicted and minimized to decrease project costs and maximize claimable credits

Sources of error in estimating carbon pools

- For estimating carbon stocks, three main sources of error 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"

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Quality Assurance/Quality Control plans

- Monitoring requires provisions for quality assurance (QA) and quality control (QC) to be implemented via a QA/QC plan
- = How to guarantee that methods are applied correctly
- The 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.

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