Module 2.7 Estimation of uncertainties

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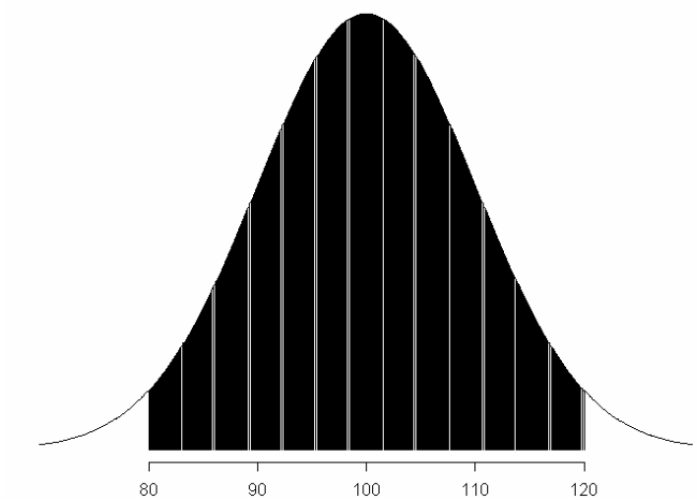

Source: IPCC GPG LULUCF

After the course the participants should be able to:

- Identify sources of uncertainty in the estimates of area change (activity data) and carbon stocks change (emission factor)
- Implement the correct steps to calculate uncertainties for estimates in area change and carbon stock change
- Understand the possible treatment of uncertainties in a conservative way

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GOFC-GOLD Global Observation of Forest and Land Cover Dynamics

FOREST CARBON PARTNERSHIP FACILITY

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Outline of lecture

1. Importance of identifying uncertainties
2. General concepts
3. Uncertainties in area-change estimates
4. Uncertainties in carbon stocks change estimates
5. Combination of uncertainties

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Uncertainty in IPCC and UNFCCC context

- GHG inventories consistent with "good practice" as those which "contain neither over- nor underestimates so far as can be judged, and in which uncertainties are reduced as far as practicable."

- Basic elements for the *identification*, *quantification,* and *combination* of uncertainties for the estimates of:

  - Area and area changes (the **activity data, AD**)

  - Carbon stocks and carbon stock changes (the **emission factors, EF**)

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Systematic errors and random errors (1/2)

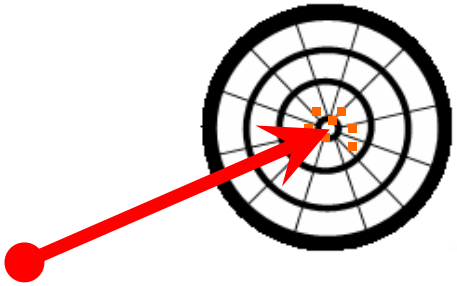
- **Uncertainty** consists of two components:
  - *Bias* or *systematic error* (lack of *accuracy*) occurs, e.g., due to flaws in the measurements or sampling methods or due to use of an EF that is not suitable
  - *Random error* (lack of *precision*) is a random variation above or below a mean value. It cannot be fully avoided but can be reduced by, for example, increasing the sample size.

Accuracy: agreement between estimates and exact or true values
Precision: agreement among repeated measurements or estimates

(A) Accurate but not precise

(B) Precise but not accurate

(C) Accurate and precise



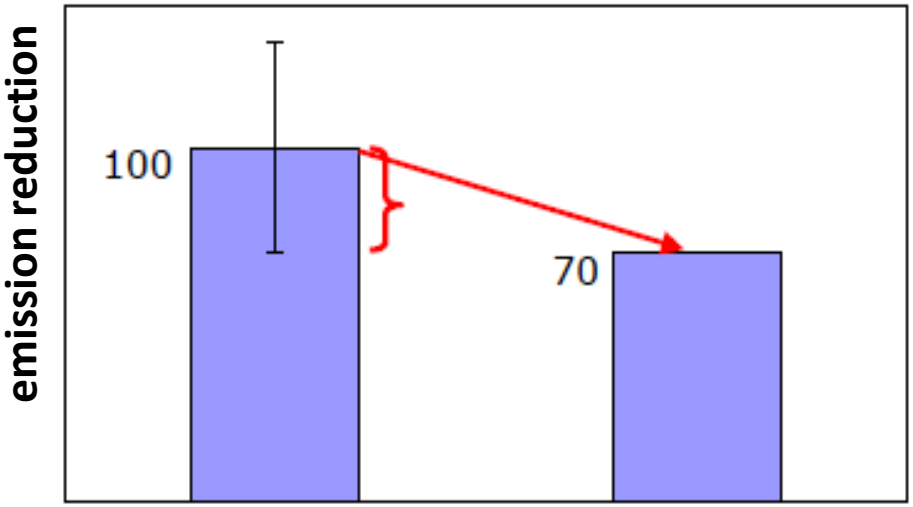
Trend uncertainty

- The *trend* describes the change of emissions or removals between two points in time.
- *Trend uncertainty* describes the uncertainty in the change of emissions or removals. Trend uncertainty is sensitive to the correlation between parameter estimates used to estimate emissions or removals for two points in time.
- Trend uncertainty is expressed as percentage points. For example, if the trend is +5% and the 95% confidence interval of the trend is +3 to +7%, we can say that trend uncertainty is ±2% points.

Conservativeness concept

The **conservativeness concept** (see Module 3.3 on reporting for more details) may be used to reduce the risk of overestimating the "true" value of emission reduction. To this aim, the value of uncertainty of emission reduction may be used to derive a conservativeness factor (i.e., a discount).

- The bracket in the figure indicates the risk of overestimating the true value, which is high if, for example, a Tier 1 estimate is used.
- Multiplying this estimate by a conservativeness factor (e.g., 0.7) means decreasing the risk of overestimating the true value.



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Accuracy assessment of land cover and changes (4/4)

For **land-cover changes**, additional considerations apply:

- It is usually more difficult to obtain suitable, multitemporal reference data of greater quality to use as the basis of the accuracy assessment, particularly for historical time frames.
- Since the changed classes are often small proportions of landscapes, it is easier to assess errors of commission (by examining small areas identified as changed) than errors of omission (by examining large area identified as unchanged).
- Other errors such as geo-location of multitemporal datasets and inconsistencies in processing/analysis and in cartographic/ thematic standards are exaggerated and more frequent in change assessments.

Addressing sources of uncertainty

Many of these sources of uncertainty can be addressed using widely accepted data and approaches:

- Suitable of satellite data: Landsat-type data, for example, have been proven useful for national-scale land cover changes for MMU of 1 ha
- Data quality: suitable preprocessing for most regions provided by some data providers (i.e., global Landsat Geocover)
- Consistent and transparent mapping: same cartographic and thematic standards and accepted interpretation methods should be applied transparently using expert interpreters

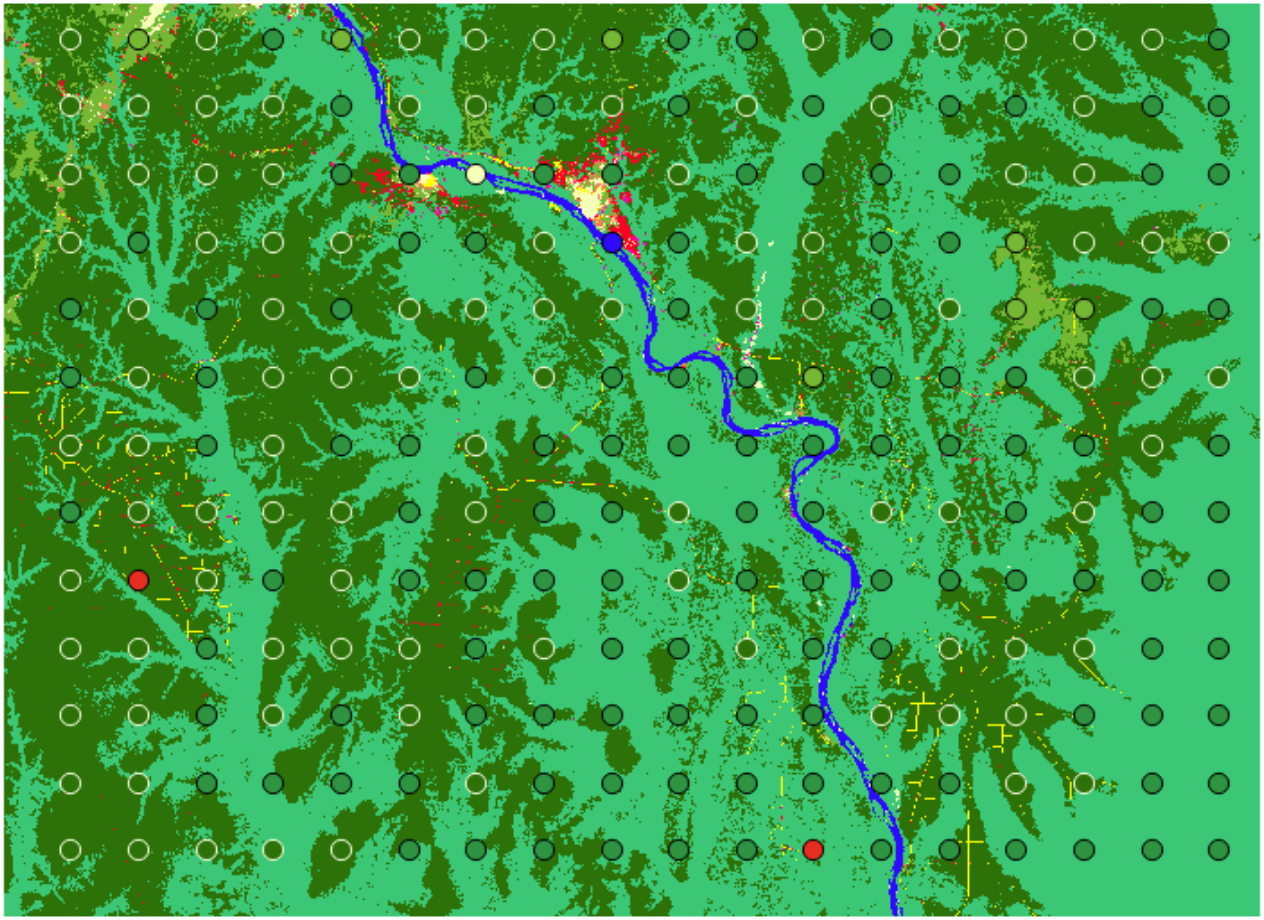
The accuracy assessment should provide measures of thematic accuracy and confidence intervals for estimates of activity data

Elements for a robust accuracy assessment

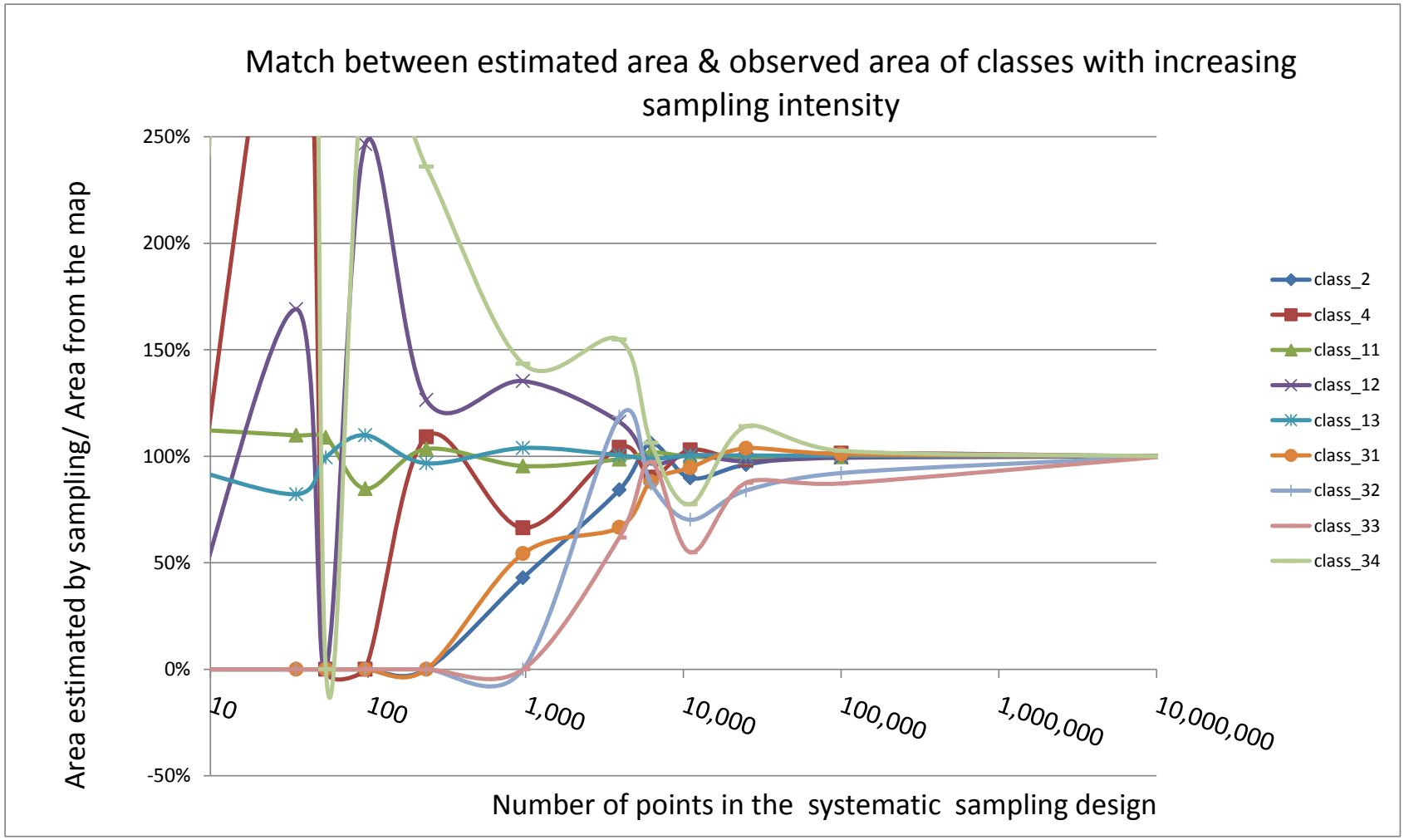
For robust accuracy assessment of land cover or land-cover change maps and estimates, statistically rigorous validations include three components:

- Sampling design
- Response design
- Analysis design

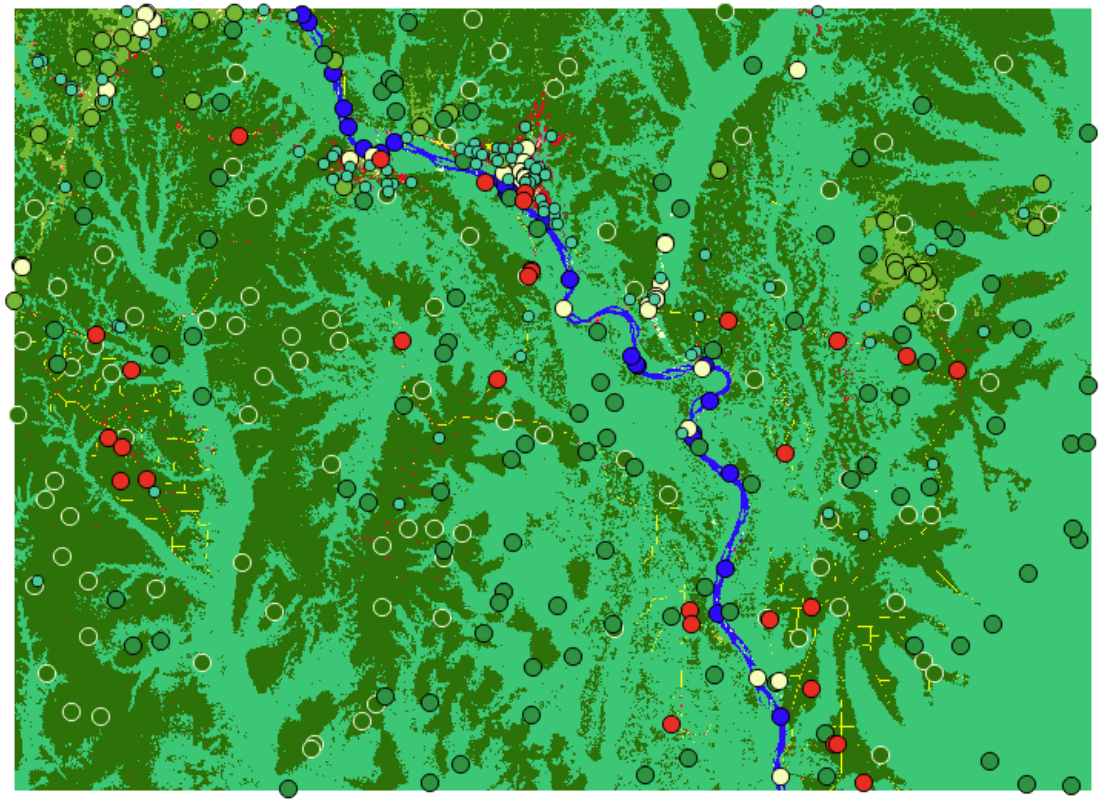
Visual interpretation of points provides very accurate estimates but….



… systematic point sampling can't capture small change



Stratified sampling targets small change



AA process : corrects for the biases and quantifies the uncertainties

Weighted confusion matrix

Table 8: Matrix which gives correct classification, omission (under detection) and commission (over detection) errors expressed in corresponding map area (ha)

2000- 2013	classes	Reference				
		FL	FG	SF	SNF	Map area
Map data	Forest Loss (FL)	88,616	8,862	53,170	221,540	**372,188**
	Forest Gain (FG)	824	7,003	24,306	7,827	**39,960**
	Stable Forest (SF)	195,164	139,403	14,581,519	7,109,536	**22,025,622**
	Stable Non Forest (SNF)	907,955	90,795	7,536,026	83,441,064	**91,975,841**
	Adjusted area	**1,192,559**	**246,063**	**22,195,021**	**90,779,968**	

Building confidence in estimates

Information obtained without a proper probability sample design can still be useful to build confidence in the estimates, e.g.:

- Spatially-distributed confidence values provided by the interpretation
- Systematic qualitative examinations of the map and comparisons (qualitative / quantitative) with other maps
- Review by local and regional experts
- Comparisons with non-spatial and statistical data

Any uncertainty bound should be treated conservatively to avoid producing a benefit for the country (overestimation of removals or of emissions reductions)

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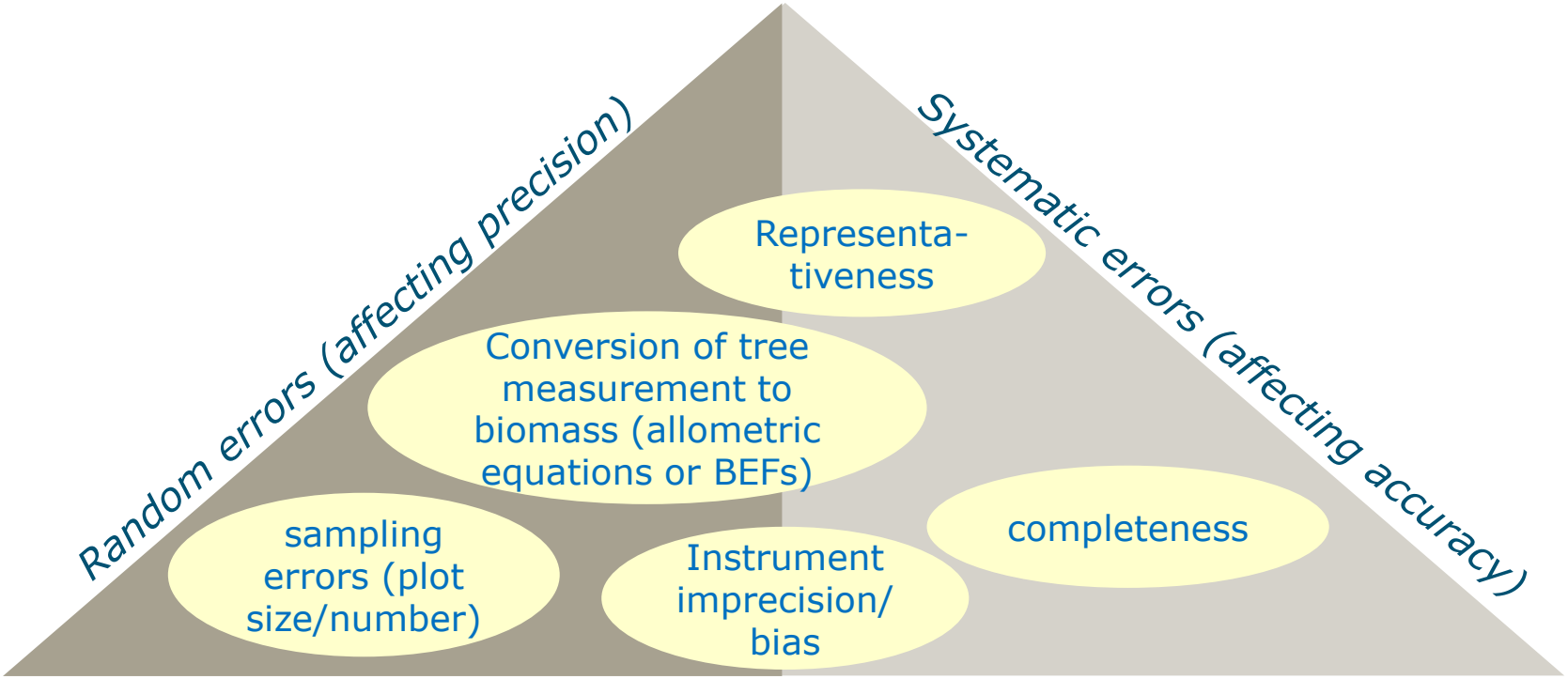
Random errors and systematic errors

- Uncertainty of carbon stocks can be caused by both *random errors* and *systematic errors,* but sometimes it may be difficult to distinguish between the two.



Conversion of tree measurement to biomass

- Allometric model or biomass expansion factors (BEFs):
  - Selection of best-fitting allometric model for respective forest type → ≈ 20% error of tree AGB estimate
- Overall:
  - Uncertainties on plot level (at 95% CI*): 5% to 30%
  - Average range of AGB of IPCC: -60% to +70%

*CI = confidence interval.

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Combination of uncertainties

- The uncertainties in individual parameters can be combined using either:
  - *Error propagation* (IPCC Tier 1), which is easy to implement using a spreadsheet tool; certain conditions have to be fulfilled so that it can be used.
  - *Monte Carlo simulation* (IPCC Tier 2), based on modelling and requiring more resources to be implemented; it can be applied to any data or model.

Tier 1 level assessment (3/3)

Examples of combination of uncertainties with Tier 1

Multiplication

	Mean value	Uncertainty (% of the mean)
Area change (ha)	10827	8
Carbon stock (t C/ha)	148	15

Thus the total carbon stock loss over the stratum is:

10,827 ha* 148 tC/ha = 1,602,396 t C

And the uncertainty = $\sqrt{8^2 + 15^2} = \pm 17\%$

Addition

	Mean	95 % CI
	t (C/ha)	
Living Trees	113	11
Down Dead Wood	18	3
Litter	7	2

therefore the total stock is 138 t C/ha and the uncertainty =

$$\frac{\sqrt{(11\% * 113)^2 + (3\% * 18)^2 + (2\% * 7)^2}}{|113 + 18 + 7|} = \pm 9\%$$

The total uncertainty is ±9% of the mean total C stock of 138 t C/ha

https://www.reddcompass.org/mgd-content-v2/dita-html/en/s5_3.html#s5_3

In summary (1/2)

- Assessing uncertainty is fundamental in the IPCC and UNFCCC contexts.
- Uncertainty consists of two components: *systematic errors* and *random errors.*
- The *conservativeness concept* may be used to reduce the risk of overestimating the "true" value of emission reduction.
- *Accuracy assessment* of land cover and changes is used to characterize the frequency of errors (omission and commission) for each class and the overall accuracy of the map using an independent reference dataset.

In summary (2/2)

- Assessing uncertainties of the estimates of C stocks and C stocks changes is usually more challenging due to different types of random and systematic errors.
- The uncertainties in individual parameters can be combined using either error propagation (Tier 1) or Monte Carlo analysis (Tier 2).