Pilot course "MRV and Monitoring for REDD+"
FAO Rome 1-3 March 2011

Basic forest statistics - accuracy, precision & bias – or: do we need to be afraid/ashamed of errors ?

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Background

Forest ecosystems and the forest resource are highly complex → it is impossible to understand the system without systematically generated data and information.

→ Sound MRV and monitoring are a theoretical prerequisite for good policy formulation.

→ "Sound monitoring" means from a scientific point of view: on statistical grounds, along methodologically acknowledged paths.

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Objective of this talk

- Characterize some elements of statistical sampling and monitoring from a methodological perspective.
- Clarify some basic terminology.
- Make clear that the basics are not overly complicated nor “beyond reach”.

Expected output

- You are more familiar with the terminology and concepts in statistics regarding “uncertainty”.
- You know what questions to ask from a methodological point of view, when you read forest statistics and are interested in their credibility.

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A brief intro to relevant basics of statistics and statistical sampling

Situation:

- We are interested in knowing quantitative details of the forest resource.
- Because of the complexity and extent of the resource, we can not measure /observe everything.
- We need to devise an assessment system which efficiently combines data sources and efficient assessment techniques
  → such that the target data can be generated.

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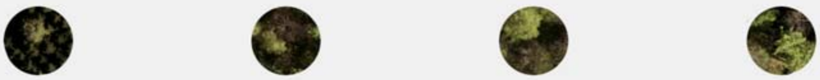
A brief intro to relevant basics of statistics and statistical sampling

Major data sources used

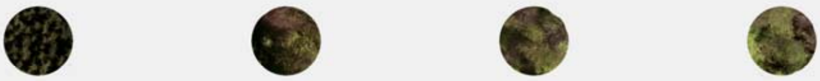
- Field data
- Remote sensing
- Existing data and maps from prior studies
- Models

Major methods applied

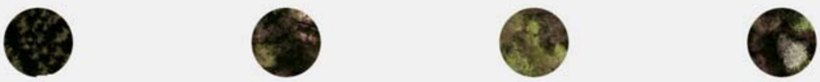
- Statistical sampling
- Remote sensing image analysis
- Modelling



Sampling is like „looking through small windows into a population of interest and then draw conclusions about it“.



It is obvious that there need to be very clear rules for such „drawing conclusions“ in order to make such a procedure transparent and credible – and verifyable



Statistical sampling

These rules are defined in science by the principles of statistical sampling.

In most forest inventories, sampling plays a central role:
Sampling (planning/implementation/presentation) determines largely how credible and/or reliable the results are.

Important questions to be dealt with:

- How many samples ?
- How to select the samples ?
- How to take what observations ?
- How to calculate the estimates ?

Sampling studies are designed such that they

- *achieve best precision* (budget is fixed)
  or
- *cause minimum cost* (precision is defined).

In practice: What is more common?

Some guiding principles in forest inventors sample design planning

- Conformity with objectives (regarding variables assessed and their precision).
- Statistical soundness.
- Economical and logistical feasibility.
- Sustainability (be useful for future assessments).
- Overall credibility.

→ Keep it simple (KIS)
Keep it short and simple (KISS)
...

- There are no GPG so far for forest inventories.

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Statistical sampling

- Statistical sampling provides methodologically sound (and defendable!) results.
- Randomization is the *only generally accepted* selection "philosophy" for the class of sampling techniques that we deal with here (introduced by Sir RA Fisher in the 1920/30s).
- Concepts like "fairness", objectivity", "represen-tativeness" should not be used as a general basis for sample selection.
- Guided subjective or arbitrary selection is not statistical sampling!
  We may not apply statistical analysis techniques to such samples!

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"Statistical estimations"

Two types of estimations:

- estimations of the variable(s) of interest (= point estimates)

- estimations of the precision of the point estimates (interval estimates)

Example:

Volume = 200 m³/ha ± 15%

200 m³/ha ± 30 m³/ha

That is either the standard error of half the width of the confidence interval.

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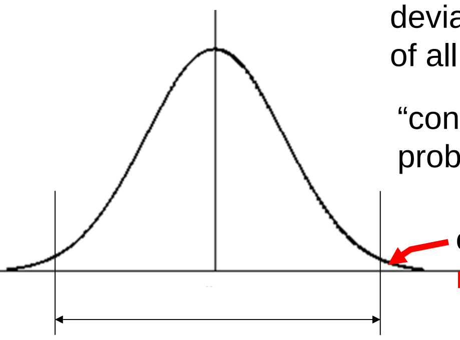
"Statistical estimations"

What does "standard error" and "confidence interval" mean?

→It is a **probability statement** and gives important insight into the distribution of all possible outcomes of such sampling study.

"Standard error" = standard deviation of this distribution of all possible estimates.

"confidence interval" = probability interval



error probability – needs to be defined !

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"Statistical estimates"

Every (!) result from a sampling study is an estimate.

Also the "precision of estimation", that is the "standard error", is estimated!

The sampling based statement
"*changes in above ground biomass are xx Mg/ha/a*"

is to be understood as

"*changes in above ground biomass are estimated to be xx Mg/ha/a*"

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The conservativeness priniciple

→ using conservative estimates ...
- for the investor to be on the safer side
- for the contry to have an incentive to produce precise estimates.

Applied to estimation: the lower bound of the confidence interval is being reported and evaluated.

Then, an appropriate error probability needs to be defined. What are the criteria ?

... in forest inventory reporting, we are used to state both point and interval estimate. Then, the reader can draw his/her won conclusions ...

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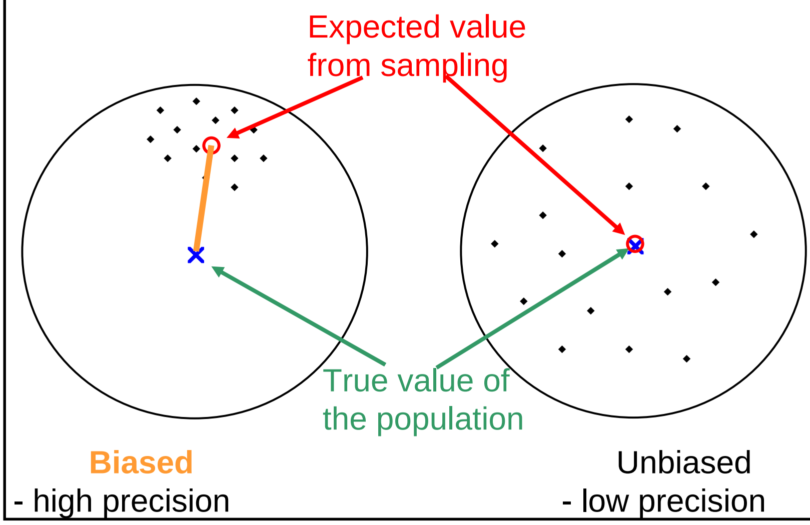
Precision and (estimator) bias

„Precision“ is clearly defined in sampling statistics.
„Accuracy“ is a lesser clear term.



More formally: Unbiasedness

- An estimator is unbiased, if it produces on the average estimations that equal the population parameter. Formally: $E(\hat{\theta})=\theta$. If this is not the case, then there is a bias $B=E(\hat{\theta})-\theta$
- Using an unbiased estimator:
  If we would repeatedly and frequently apply the **same** sampling to the same population, then the mean of all individual means (= the *expected value*) would finally be equal to the true population value.

More on bias ...

- Distinguish: - estimator bias,
  - *selection bias,*
  - *observer bias*.
- How much does bias matter?
- Can bias be quantified?
- **An estimator bias will not disappear with increasing sample size !**
- If precision is high, a relatively small bias may be acceptable (e.g. for cost reasons) -- However, where possible we prefer unbiased estimators
- *Ease of application is a weak counterargument, then ! Example: k-tree sampling*

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Factors that influence in precision of estimation

In practice, we will employ a statistically sound sampling approach, where precision is high.

With unbiased estimators precision is a function of

- Sample size
  (NOT sampling intensity !!)
- Sampling design (ancillary variables ?)
- Plot design
- (Estimation design)

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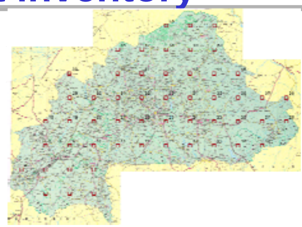
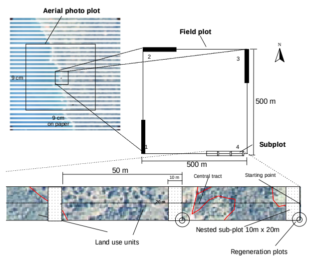
A look on the methodological structure of a large area forest inventory



Sampling design: *How to select "sampling objects" ?*

- systematic sample grid;
- sample size varies;
- stratification where useful.



Plot design: *What to measure (and how) on the selected objects?*

- cluster plots of dis-joint sub-plots
- combining nested plots of different plot types
- including remote-sensing based sub-plots.

Estimation design: *How to produce estimates ?*

(formulae = estimators) Long tradition in forestry of adhering to rigorous statistical sampling; much research to develop unbiased estimators.

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It is sample size, not sampling intensity, that counts !

Not the fraction in % of all samples is important, but the absolute number of samples

Statements like „you need to sample at least 5% of the population to obtain good results" are not helpful.

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Example: sampling intensity vs. sample size

TUCKER, C.J. and TOWNSHEND, J.R.G., 2000. (Strategies for monitoring tropical deforestation using satellite data. International Journal of Remote Sensing, 21, 1461-1471) stated, that a satellite image based 10% sample (as employed by FAO in FRA) is not sufficient to estimate tropical deforestation. Rather, a full coverage is required.
Evidence presented: simulation study in Bolivia, where 4 images were taken out of 41.

Czaplewski, R. 2003 (International Journal of Remote Sensing Volume 24, Number 6/March 20, 2003 pp. 1409 – 1412) responded with a simulation study, creating from the Bolivia data set new data sets (by simply “repeating” the 41 images so that a “global coverage” with exactly the same characteristics was produced).

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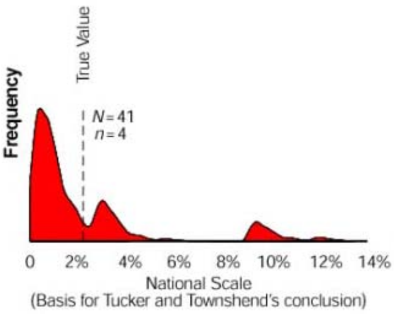
Sampling intensity vs. sample size

Result of the simulation study (Czaplewski), selecting 10% of the population each from populations of different sizes :



Source: Czaplewski, R. 2003

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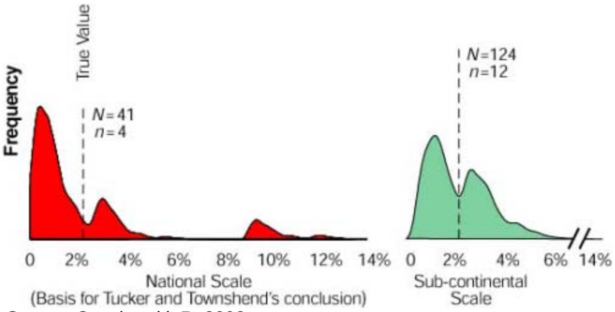

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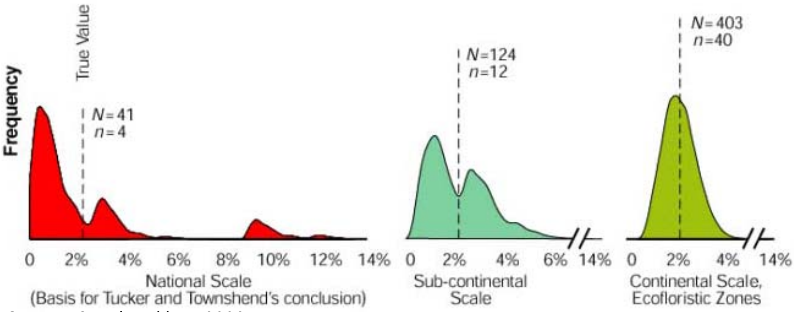


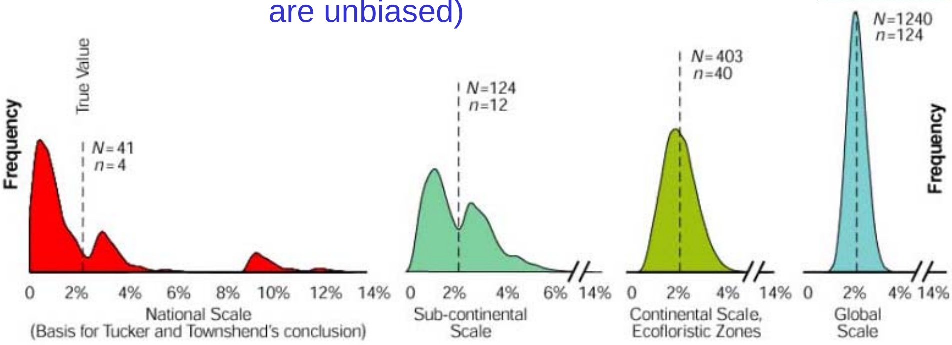
Source: Czaplewski, R. 2003

Sampling intensity vs. sample size

Result of the simulation study (Czaplewski), selecting 10% of the population each from populations of different sizes :

→ it is absolute sample size that counts !

Obs →all estimates (from *n*=4 to *n*=1200 are unbiased)



Source: Czaplewski, R. 2003

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Sample size vs sampling intensity

Usually, large area forest inventories work with extremely low sampling intensities – but often very high sample sizes!

For example, the sampling intensity in the German NFI is about 0.001% - sample size is in the order of magnitude of n = 20000.

Precision of estimation for volume and forest area is about 0.8-1% !!

Sampling intensity is usually not a value that merits reporting, because it looks confusing.

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What is a good precision ?

- Good question
  - to the decision makers,
  - to the investors.
- Examples of forest area and biomass precisions of estimation (simple standard error):
  Germany NFI: area 1%, biomass 0.8%
  Costa Rica NFMA: area 7%, biomass 12%
  Burkina Faso (res.): area 20%, biomass: 20%
- Precision of estimation in forest inventory has much to do with a well designed statistical approach …
  … **but much more with the resources allocated.**
- Good question – no clear answer (as of yet) …

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… resources are commonly scarce

- The question is: where in the entire estimation process to allocate more resources to achieve the best improvement of precision per €:
  - More field observations.
  - Better measurement devices.
  - Higher resolved remote sensing imagery?
  - Lidar everywhere?
  - Better biomass models (based on more measurements)?
  - Better co-registration between RS and field plots?
  - ….?
- Interesting research question – with far reaching significance in practice.

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So: do we need to be afraid or ashamed of errors ?

Of course not: errors are normal elements of empirical studies that involve measurements, models, estimation.

Nobody can produce error-free results in forest monitoring.

The art is to keep the errors small.

If errors are not sincerely reported, the report is incomplete.

AWF

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