Using remote sensing data for model-based and model-assisted forest resource assessment

Göran Ståhl

Professor of Forest Inventory, SLU

Outline of presentation

- About forest resource assessments
- Use of remote sensing data in forest surveys
- Statistical frameworks
  - Model-assisted estimation
  - Model-based prediction
- Conclusions

Disclaimer: Despite today's date I have not included any deliberate delusions in the presentation…

Why do we conduct forest resource assessments at all?

Examples of reasons

- Forest owners need information for planning sustainable forestry
- Regional and national agencies need information for development and follow-up on forest and environmental policy and legislation
- International agreements demand reports from Parties, for follow-up on progress towards targets

  - Whereas historically there has always been some demand for forest information, these demands have increased considerably due to the UNFCCC and CBD conventions
  - Within UNFCCC, forests play a major role in the LULUCF sector

Uncertainties…

- It is important to assess not only the target quantities of interest, such as the average biomass within a given area, but also…
- The reliability of the information!
- For example, IPCC requires reported figures to be ”neither over-, nor underestimated”
- And the precision of estimates (e.g. variances) should be reported as well

⇒This requires statistically sound approaches for forest resource assessments!

The traditional approach

- Field-based!
- Either by forest stands, or through using sampling principles across the entire forest area of interest
- National forest inventories have a very long tradition of field-based surveying following statistical principles


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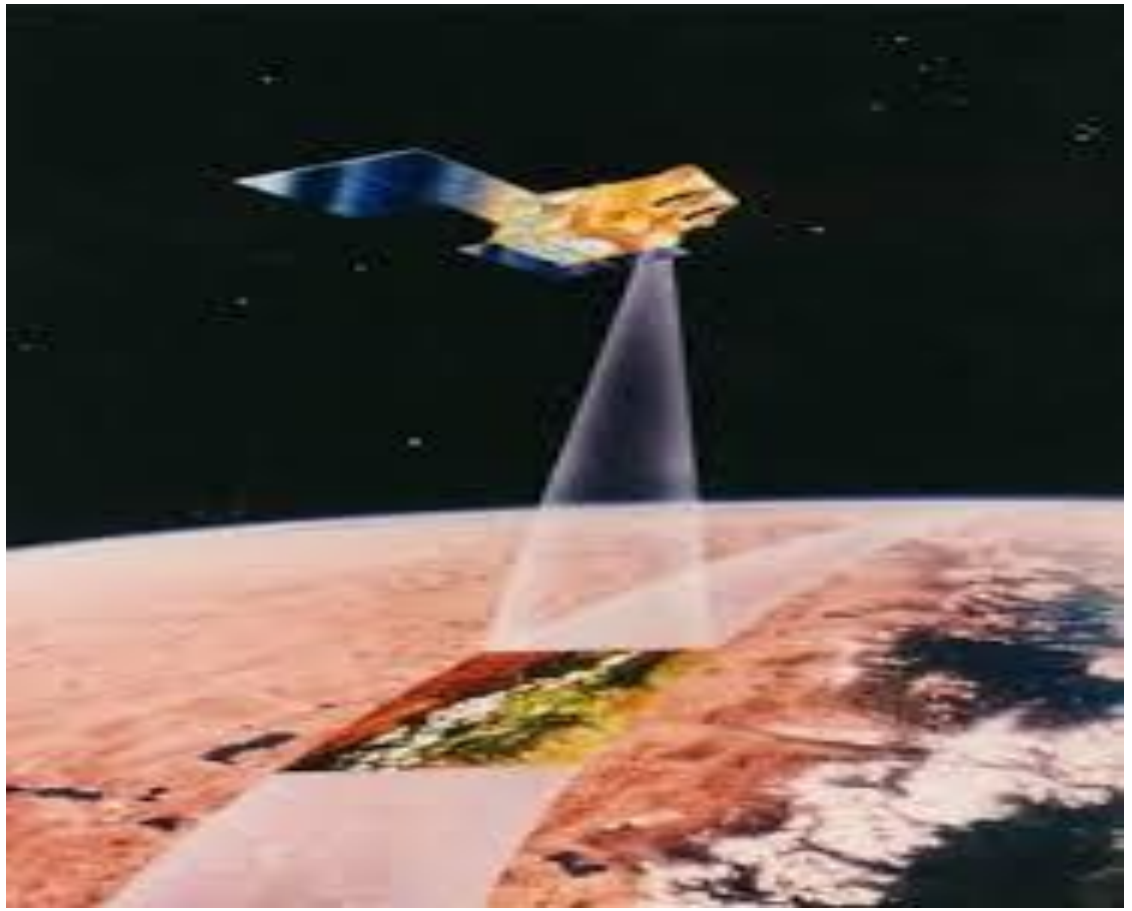
Detailed measurements on each plot…

Use of remote sensing data in forest surveys

- Remote sensing data have been applied for a long time, but to a limited extent (mainly aerial photos, since the 1920s)
- From the 1970s onwards, there has been a very strong technological development in ”civil” remote sensing

Optical satellite images



Digital airphotos

Laser scanning data

Remote sensing data can be used for..

- Facilitating the field work
- Producing maps
  - While maps provide nice overviews, in most cases they do not provide the information required for analysis, planning and reporting
- Improving field sampling designs
- Improving estimates by combing field and remote sensing data

⇒Due to time constraints we will focus on the last issue!

A plethora of estimation methods are available for making use of remote sensing data in forest surveys

$\Rightarrow$But only some of them can be considered statistically rigorous!

Two main cases

- Model-assisted estimation
- Model-based prediction

$\Rightarrow$Both of them require that field data are available in combination with the remote sensing data

Model-based prediction

- Relies on statistical principles within the framework of model-based inference
- Uses model relationships between the remote sensing data and the variable of interest (e.g. biomass on a plot)
- Known for a long time but seldom formally applied in forest resource assessments
- ”Rediscovered” in connection with greenhouse gas emissions reporting and currently gaining increased interest due to limited requirements for field plots

Model-based prediction – the super-crash course

1) Estimate a model for predicting the variable of interest at the level of a plot (pixel)
2) Apply the model to every piece of forest (pixel) in the study area
3) Sum up to obtain a prediction of the total (or mean)
4) Assess overall uncertainty by realising that the major uncertainties are due to:
   - Model specification and range of application
   - Model parameter estimation uncertainty
   - Residual error uncertainty

⇒The two latter components can usually be estimated and the MSE for the model-based prediction estimated

Model-assisted estimation

- Relies on statistical principles within the framework of design-based inference
- Basic theoretical developments in the 1980/1990s, and several large-scale case studies in the 2000/2010s (e.g. Norway, Alaska, …)
- A fairly straightforward way of utilising auxiliary data and models without leaving the paved path of design-based inference
- Requires fairly large samples of field data, in addition to the remote sensing data

Model-assisted estimation – the super-crash course

1) Apply a model to estimate a total or mean, as in model-based prediction
   - But in this case we do not need to trust the model fully!
2) Select a random sample of field plots
3) Compare the model predictions with the field measurements at the level of plots, and estimate (following sampling theory) the total (or mean) of the differences between predictions and measurements in the population
4) Model-assisted estimate = Model-based prediction + correction term
5) Uncertainties are assessed according to ”standard” sampling theory

Some further notes

- Model-based predition and model-assisted estimation rely on quite different statistical principles, which tends to cause confusion
- Both methods are statistically rigorous, but the risk of failure is much larger in the case of model-based prediction compared to model-assisted estimation.
- A common problem is that models are applied widely outside the range in which they can be trusted. Model-assisted estimation adjusts for this but model-based prediction does not!

Conclusions

- Forest resource information is demanded for a wide range of purposes, ranging from local to global
- In forest resource assessments it is important to assess not only the target quantities, but also their reliability
- Remote sensing data are currently being widely introduced for making forest resource assessments more efficient
- Model-based prediction and model-assisted estimation are two statistically rigorous methods for combining field and remote sensing data in forest resource assessments.
- Model-based prediction requires less field data than model-assisted estimation, but since model-assisted estimation corrects for any potential model mis-specifications it is a ”safer” method to apply.

Thank you for listening!