Estimating Forest Biomass Using Geostatistics Techniques: a case Study of Rondônia, Southern Brazilian Amazon

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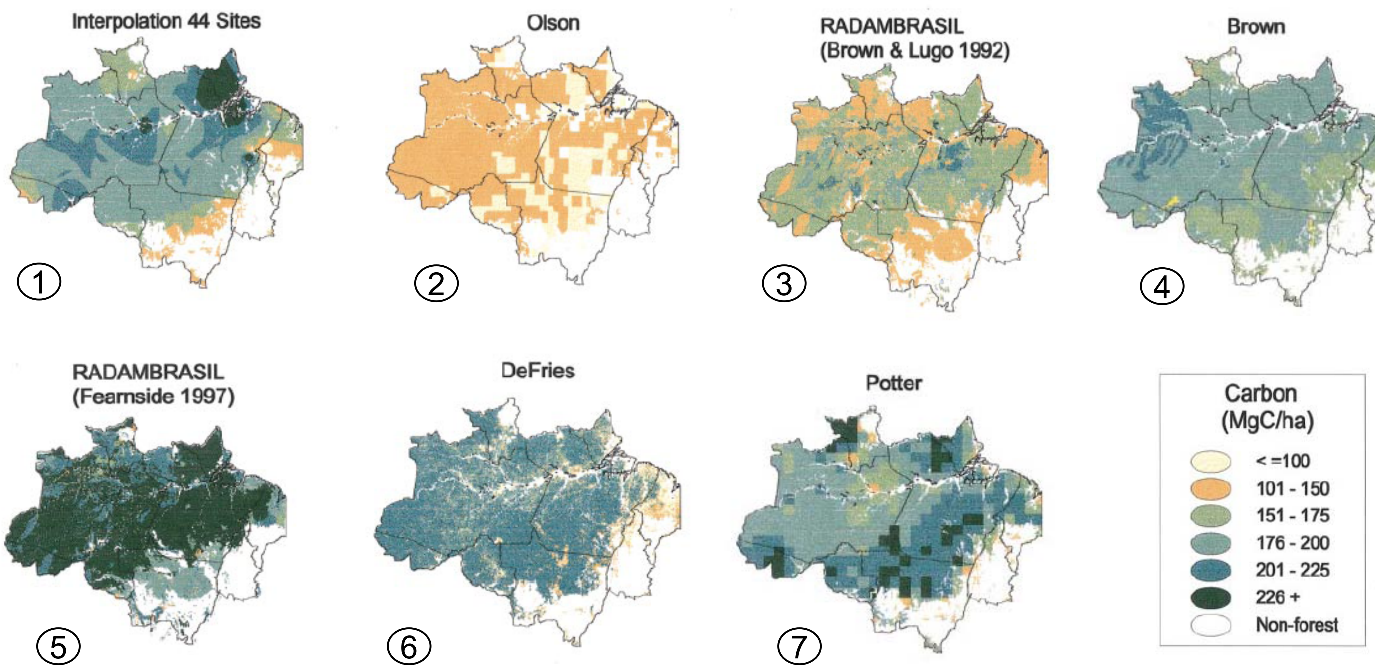
Biomass estimates diverge: (Houghton et al, 2001)



Approachs:

1- Interpolation.

2- Estimation on 44 forest ecossystems

3- Interpolation of field measurements.

4- Modeling

5- Interpolation.

6- Based on satellite data.

7- Purely Based on Satellite data.

Preview biomass estimates *

- Total biomassa ranged from 78 to 279 PgC.
- Resulting biomass profiles also differ.

* Picture modified from Houghton et al, 2001

Common Methods to Estimate Biomass

- Extrapolation of forest surveys;
- Estimates based on satellite data;
- Estimates based on models relating biomass on environmental parameters: (ex. vegetation type and soil);

Problems of the Common Methods

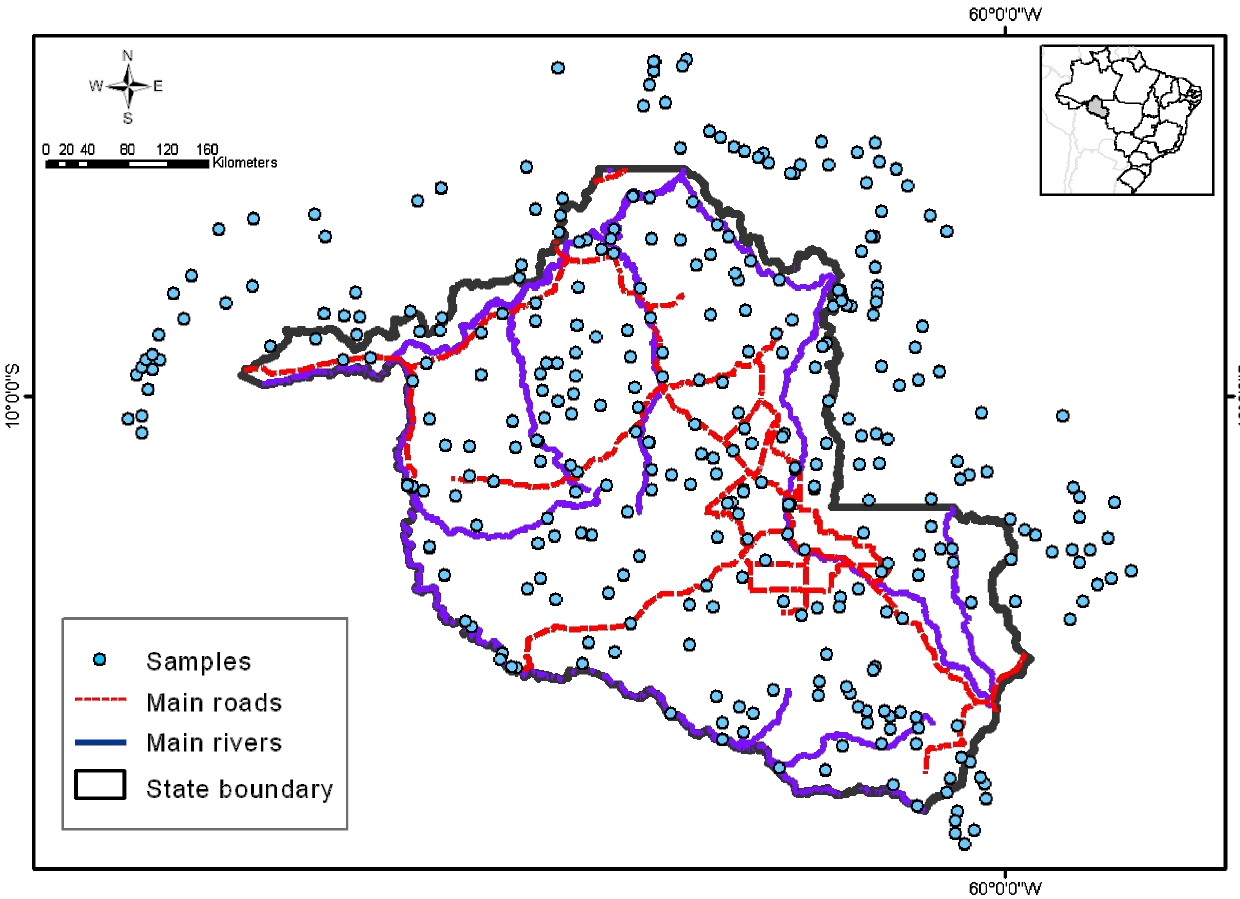
- Do not provide a measure of local uncertainty
- Do not account for spatial correlation

Objective

- Evaluate geostatistics to improve biomass estimation in the Amazon region
  - Takes into account spatial autocorrelation
  - Provides a measure of local uncertainty

Methods

Study area and data base

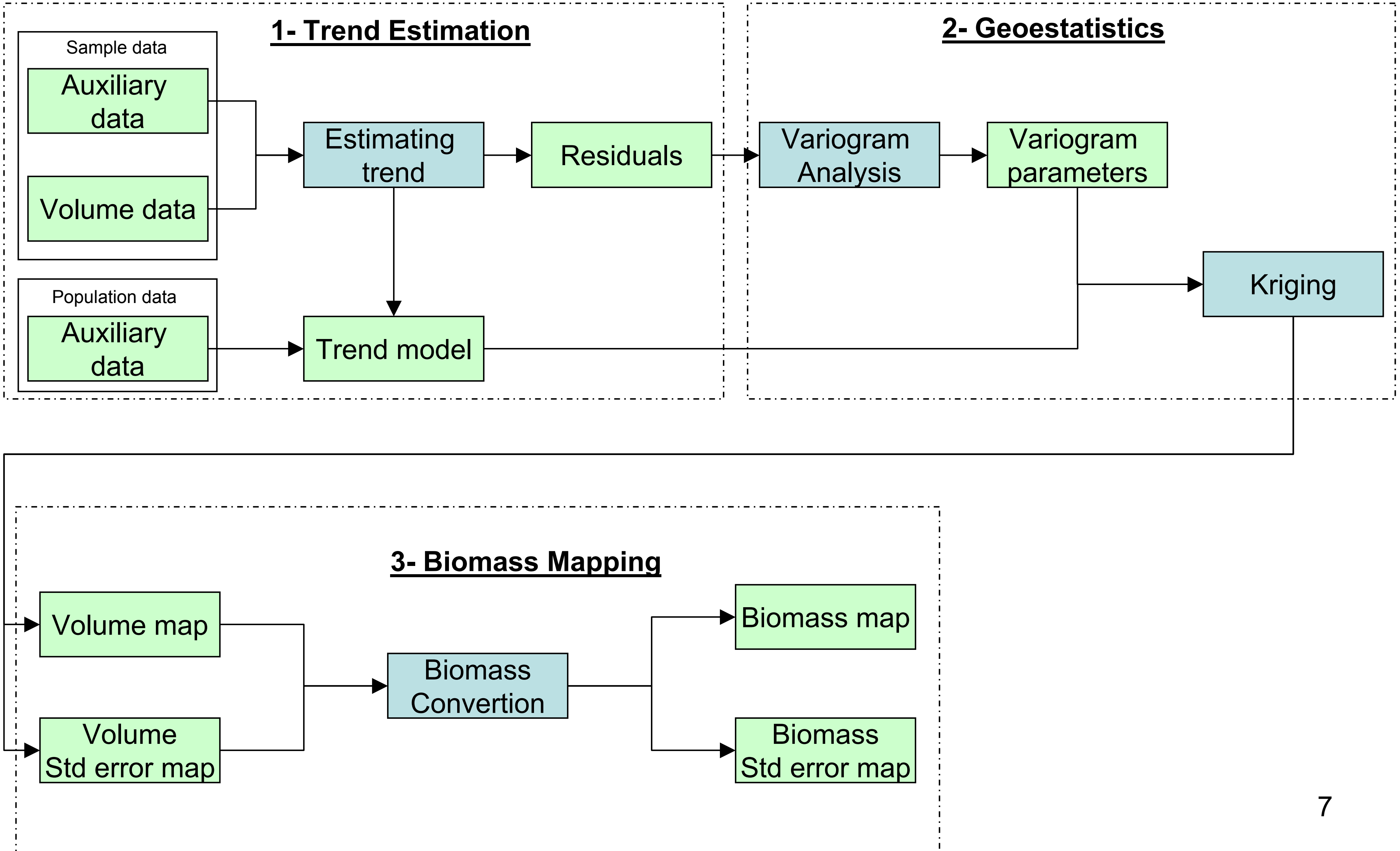


Origin: RADAMBRASIL

Data on timber volume from 330 samples inside and up to a distance of 100km around Rondônia.

RADAMBRASIL plots:
- 1 ha (20 m x 500 m).
- All trees which DBH≥45 cm.

Methods


1- Trend Estimation
Sample data
Auxiliary data
Volume data
Population data
Auxiliary data
Estimating trend
Residuals
Trend model
2- Geoestatistics
Variogram Analysis
Variogram parameters
Kriging
3- Biomass Mapping
Volume map
Volume Std error map
Biomass Convertion
Biomass map
Biomass Std error map

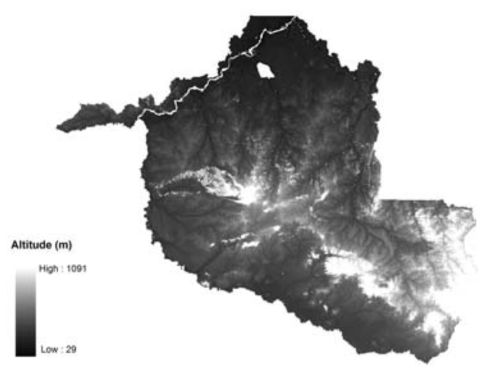
Methods

- Data Layers:

Soil Texture
(re-classified from IBGE’s Classification of Soils (1980)).

Forest type
(re-classified from IBGE’s vegetation classification).

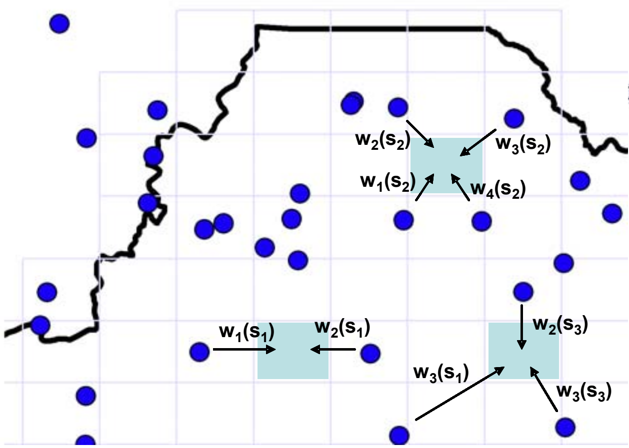
Topography
(SRTM)

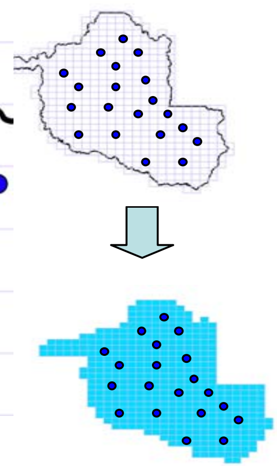


Data Analysis

Spatial Interpolation

Use information of neighbor samples to predict values at non-sampled locations





$$\hat{y}_s = w_1 y_1 + w_2 y_2 + \text{☺} + w_S y_S = \sum_i w_i y_i$$

$w_i(s)$: **Weighting factors of samples nearby location *s***

Ex.: Classical (inverse distance) interpolation:

$$w_i(s) = \frac{1}{d_i}$$

Geostatistical Interpolation (Kriging)

Choice of weighting factors $w_i(s)$:

$$w_i(s) = 1$$

$$Var\left(\hat{Y}(s) - Y(s)\right) = Var\left(\sum_i w_i Y(s_i) - Y(s)\right) = \min$$

Best Linear Unbiased Estimator!

Kriging Requires:

- **Volume values must be free of any trend (regression on external variables or coordinates)**
- **Estimation of variogram function (Variogram analysis):**

$$C(h) = Cov(Y(u), Y(u+h))$$

Data Analysis

Estatistical Model for volume:

$$\hat{Y} = m(s) + R(s)$$

- **In the samples:**

Trend Model Estimation

$$Volume_s = \underbrace{fortype + soiltext + topog + fortype,topog + soiltext,topog}_{m(s)} + R(s)$$

$fortype$: Set of dummy variables for forest classes

soiltext : Set of dummy variables for soil texture classes

topog: Topography

R: Regression residuals

- **In the population:**

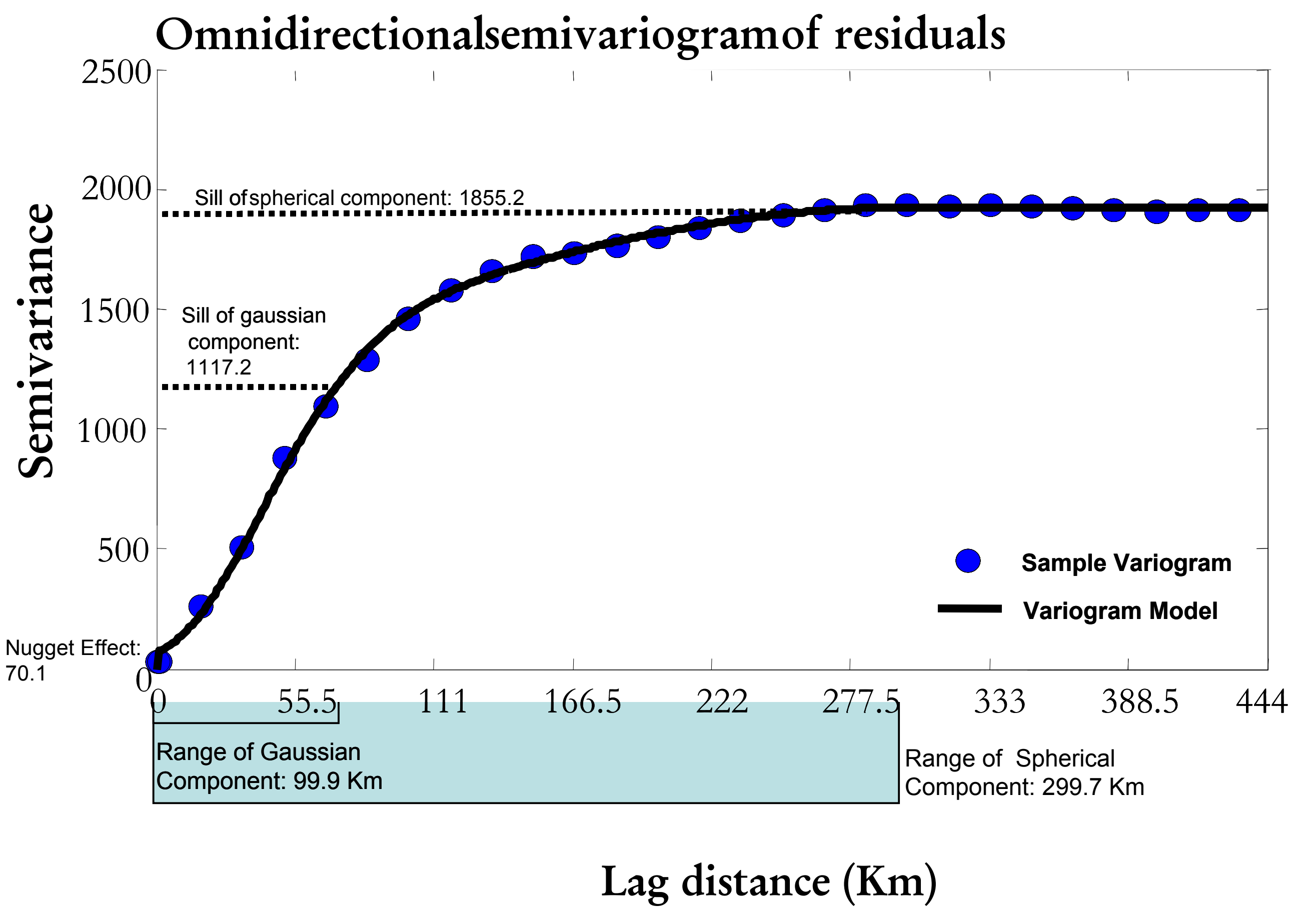
Trend Model Application

•Rondônia was divided in a 1km x 1km grid

•Trend model applied using data layers

Results

Variogram Analysis of Residuals



Sample residual variogram

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left(y(u_i) - y(u_i + h) \right)^2$$

Variogram Model:

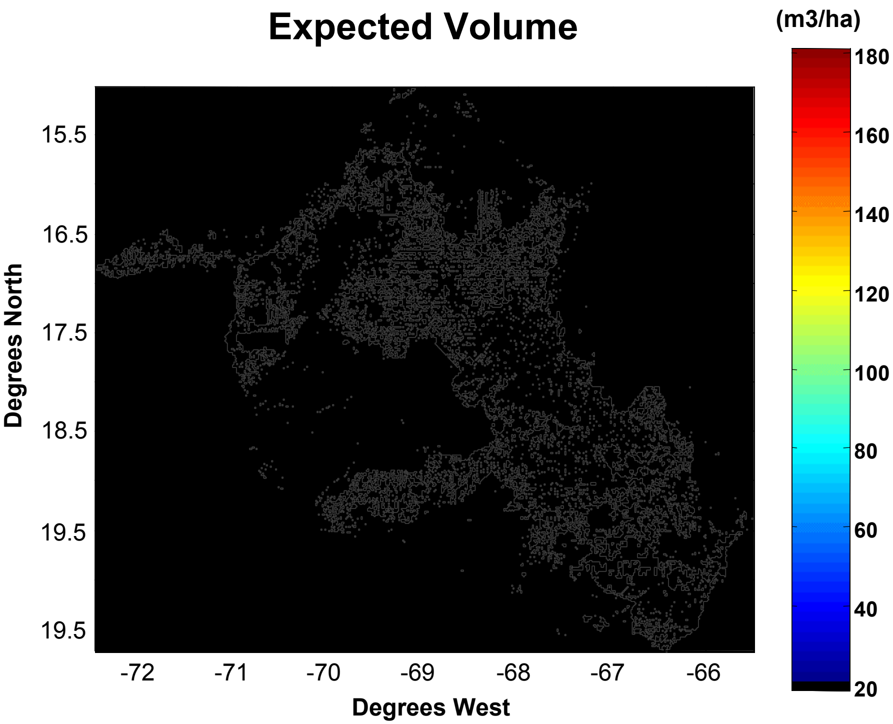
Nested Structure: nugget+gaussian+spherical

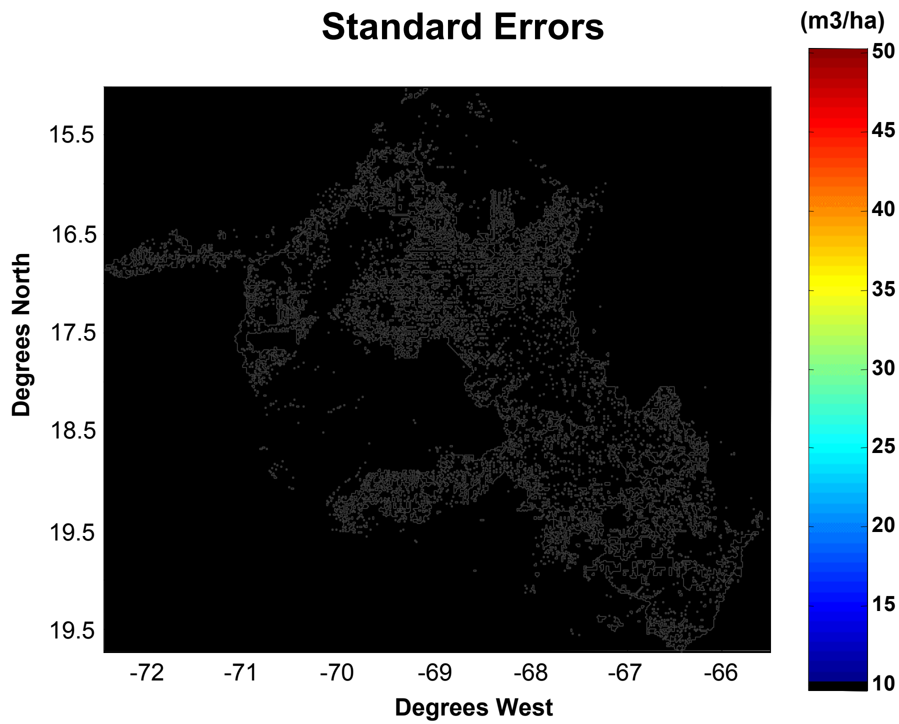
Model Parameters:

Component	Sills	Ranges
Nugget:	70.1 (0.04)	-
Gaussian component:	1117.2 (0.60)	99.9 Km
Spherical component:	1855.2 (1.00)	299.7 Km

Kriging Results

Volume Estimates





Deforestation up to 2003

Converting volume to biomass Fearnside, 1997:

Biomass = SB x BEF x CF

SB = Volume x VEF x WD: Stemwood biomass

Volume Expansion Factor = 1.25 for dense forests
= 1.5 otherwise.

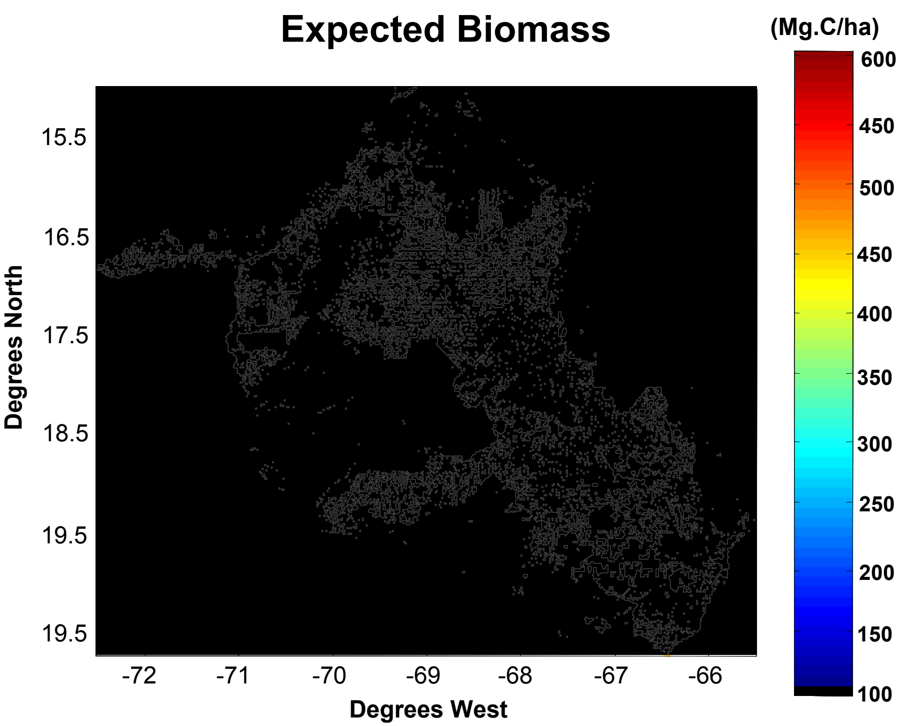
Wood Density = 0.404 for savanas (Barbosa & Fearnside);
= 0.68 otherwise (Nogueira et al, 2005).

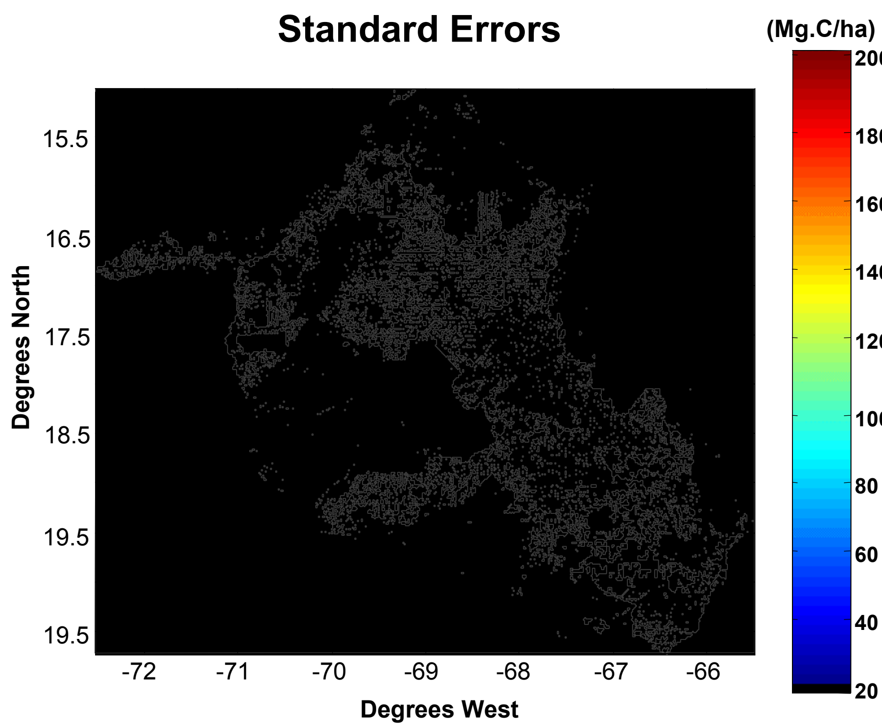
BEF = exp(3.213-0.506 ln(SB)) if SB<190
= 1.74 o.t.c

CF = 1.68: Sum of correction factors for lianas, non-trees, belowground biomass, trees <10cm DAP, trees with 30<DAP<31.8 cm DAP, hollow trees, bark and palms.

Results

Biomass Estimates

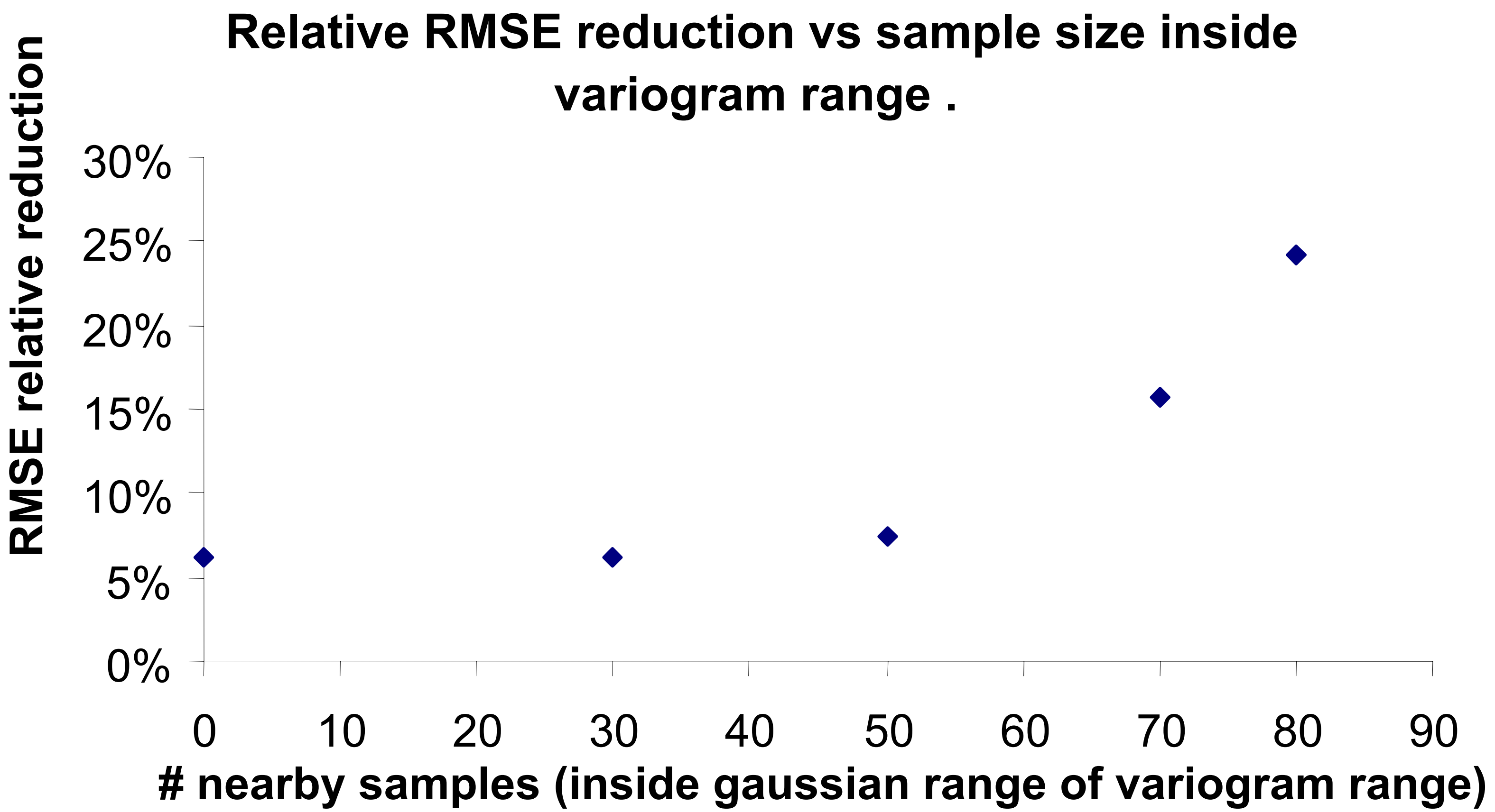




Deforestation up to 2003

Results

Validation



Conclusions

- Biomass estimation has to take into account the spatial correlation.

- The volume in 1 ha plots is spatially correlated up to 100 km.

- Kriging improves estimation at locations with high samples density.

- The maps can be used to generate confidence intervals for the expected local mean biomass /ha.