Uncertainty Modeling for Data from Remote Sensing Images Using Copula Based Indicator Approaches

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Introduction

- Indicator geoestatistic approaches have been used to estimate uncertainty models of environmental information as soil and hydrological properties, atmospheric and weather data, elevations, ...
- This work explores these approaches, that depend on the variogram (semivariogram) evaluations, to model the uncertainties of remote sensing image information.
- Bivariate copulas can be used to estimate variances (semivariances), instead of traditional mean variograms, to model the spatial variability of the considered attribute.
- Unlike traditional semivariograms, copula variograms represent dependence over the whole range of quantiles, including the extremes, and are not sensitive to outliers.

Objective

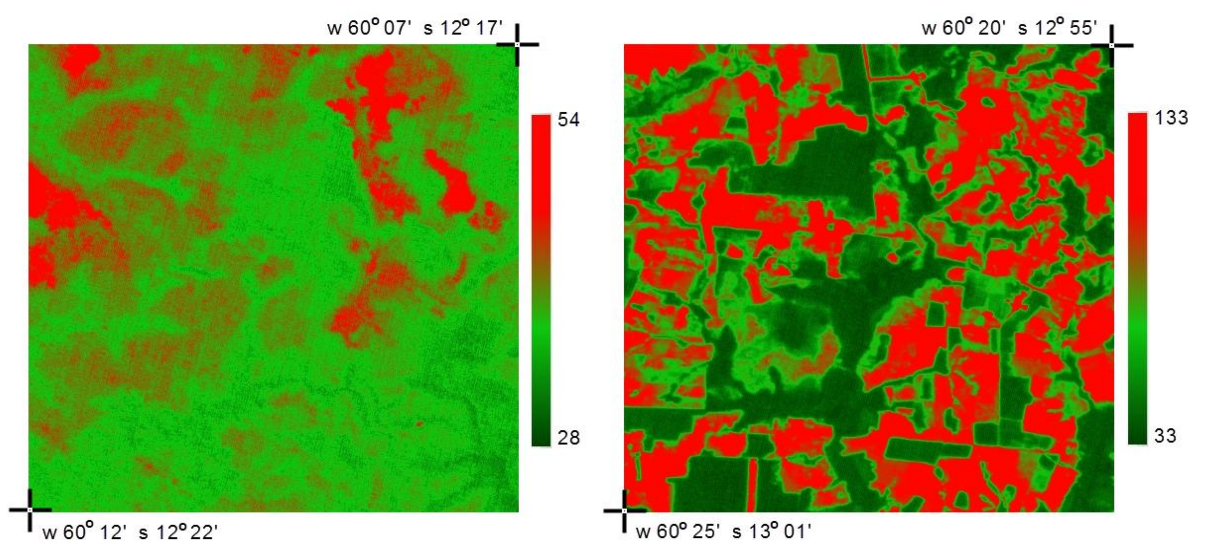
- Assess uncertainty models for remote sensing images using indicator approaches, kriging estimations and sequential simulations, based on bivariate copulas.

Considerations

- Indicator variograms are determined considering empirical bivariate copulas for various spatial distances values.
- The uncertainty models are used to perform spatial interpolation at image locations with missed or mislead information caused by clouds and shadows, for example.
- A case study is presented with China-Brazil Earth Remote Satellite (CBERS) images from the Brazilian Amazon forest considering forest and partially deforested regions.

Case Study

- Two small regions of a CCD CBERS Band3 image, patches of 171/114 path/row scene from the state of Rondônia, Brazil, acquired in September, 01, 2008.
- The image of region 1 (left) represents natural forest area while the image of region 2 (right) represents a partially deforested area.
- Each image has 20 m x 20 m spatial resolutions, 8 bits radiometric resolution and size of 500 rows x 500 columns.



Methodology

- Define the image sensor and bands to be considered (CBERS - Band3);
- Create a random sample set, of 10000 points, from the images, to be used for representing the spatial radiometric variation;
- Determine a set o cutoff values (β_i) to represent the uncertainty model;
- Calculate empirical bivariate copulas for the defined cutoffs and for different distance values **h**;
- Considering the cutoffs and the distance values, evaluate empirical indicator semivariograms using empirical bivariate copulas by the following relation, (Bardossy, 2006):

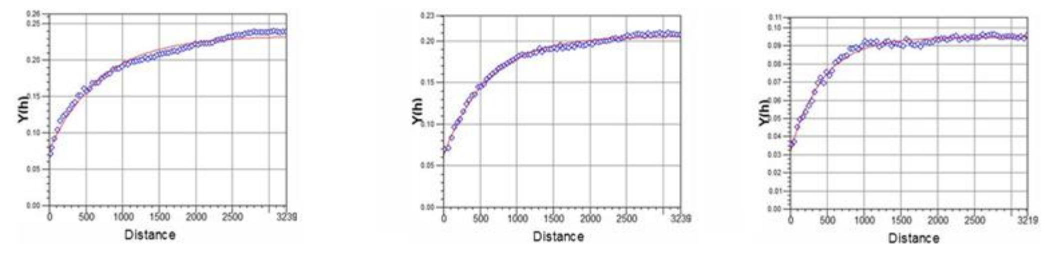
$$\gamma_{\beta}(\mathbf{h}) = F_z(\beta) - C_S(\mathbf{h}, F_z(\beta), F_z(\beta))$$

- Fit the empirical indicator semivariograms with theoretical models;
- Run indicator kriging estimations or sequential simulations on image locations or areas with missed or mislead information.

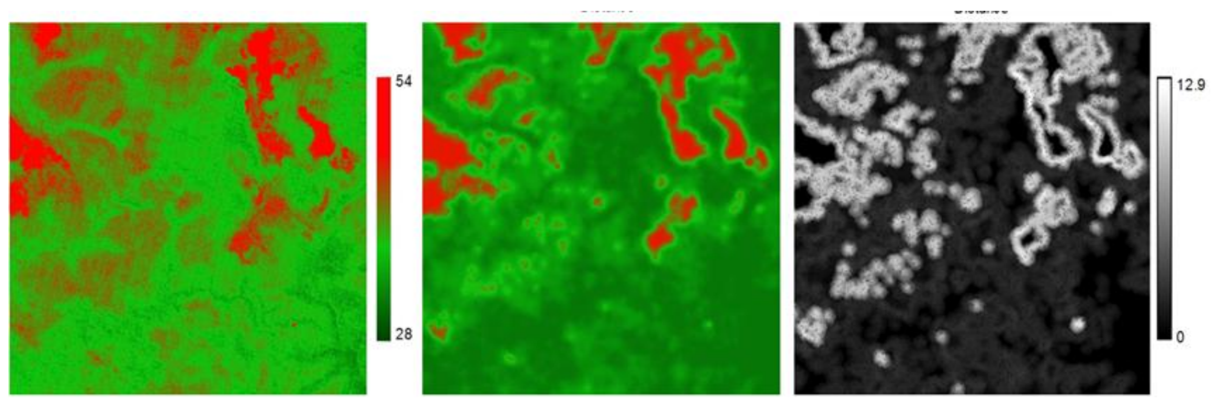
Results / Analysis

Semivariograms and Estimations in Region 1

- It was considered 3 cutoffs (33, 34 and 35) closer to the quartile values to evaluate the copula based semivariograms.

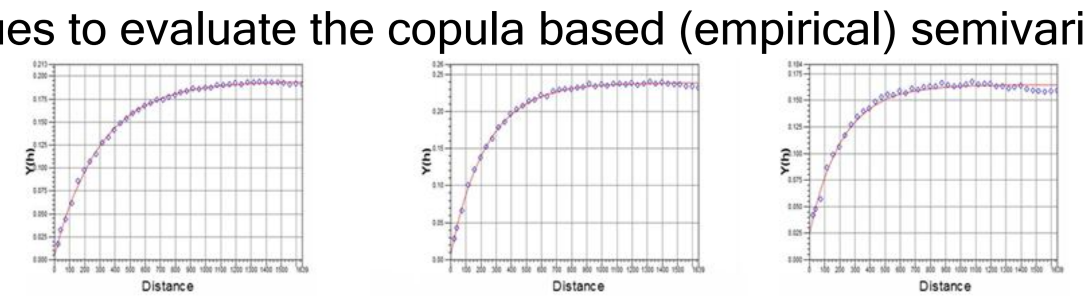


- The nugget effect were high mainly due to the low variability of the band 3 data in the region. Exponential models adjusted the empirical semivariograms with low Akaike Criterion values.
- The samples of the original image (left) and the semivariograms above yielded expected visual results for the kriging estimates (middle) along with their standard deviation uncertainties (right).

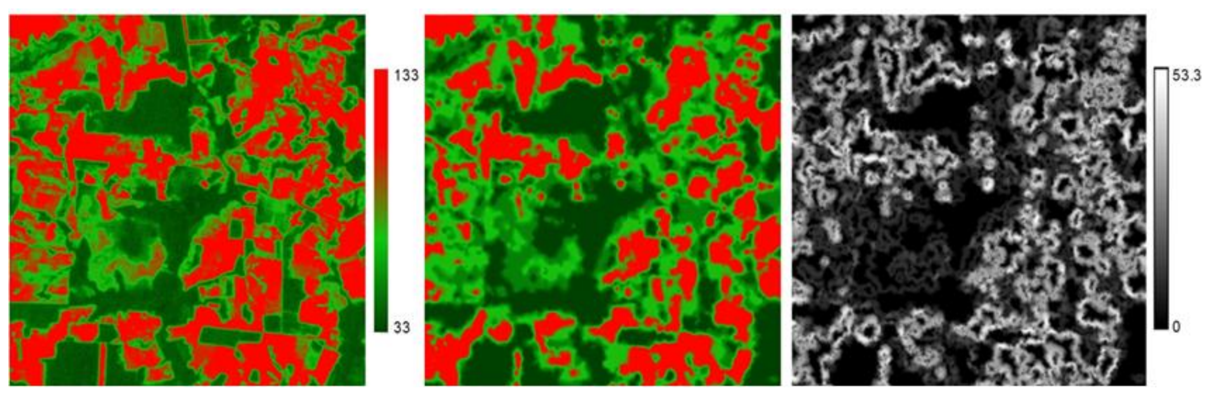


Semivariograms and Estimations in Region 2

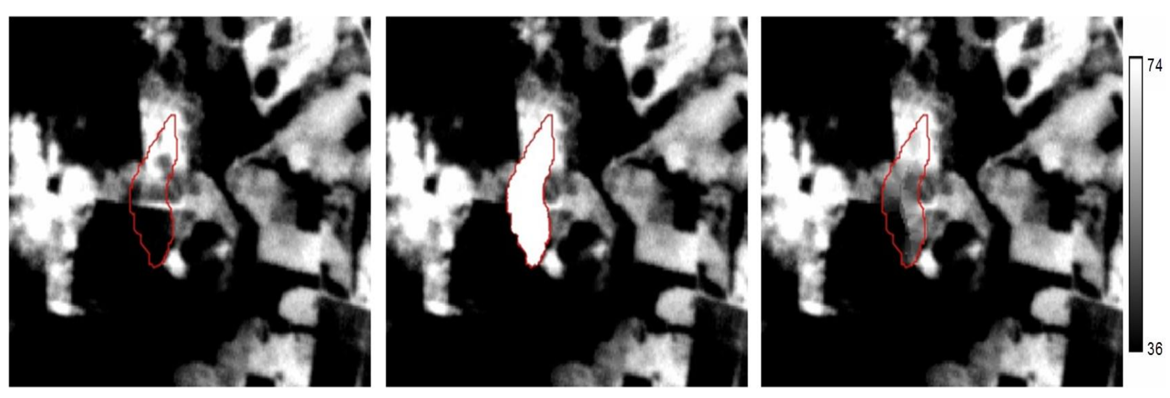
- It was considered 3 cutoffs (39, 50 and 60) closer to the quartile values to evaluate the copula based (empirical) semivariograms .



- Exponential models adjusted the empirical semivariograms with low Akaike Information Criterion (AIC) values.
- The samples of the original image (left) and the semivariograms above yielded expected visual results for the kriging estimates (middle) along with their standard deviation uncertainties (right).



*Application for missing/*mislead *values (an example)*



Conclusions

- This work showed that is feasible to model uncertainties for remote sensing image data using copula based semivariograms along with indicator approaches, including sequential simulations.
- The copula based semivariograms of this work were shown to be representative of the variability of the image data.
- Qualitative visual analysis showed high similarity between the original and the estimated information. Uncertainty maps can be used to qualify the estimations.
- The random sample set was used to generate the semivariograms while the estimates was done directly from image information closer to the area of interest.
- Future researches should be done to get more qualitative and quantitative results in the presented methodology and making use of other source data set.

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