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Spatial Uncertainty Assessment in the Reconstruction of Presettlement Forest Patterns in Western NY, USA

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1. Introduction

A spatially continuous representation of presettlement forest patterns has broad applications, including local and landscape-scale vegetation reconstruction, landscape change, and analysis of effects of human impact on land use change. Typically, presettlement vegetation patterns are reconstructed using historical survey data in the form of Geographical Information Systems (GIS) layers using a variety methods, i.e., environmental modeling and spatial interpolation techniques [Wang and Larsen, 2006]. Given that historical data processing involves aggregation of spatial data obtained from multiple sources and types, landscape pattern reconstruction is inevitably accompanied by uncertainty originating from data transformation and representation errors. It is therefore essential to provide a model of uncertainty associated with predicted values at locations where survey data are unavailable, as well as to evaluate the impact of such uncertainty on the consequent analysis and classification results.

Despite the increased interest in characterizing and quantifying uncertainty originating from aggregating spatially explicit information for landscape reconstruction, there is limited literature regarding uncertainty analysis on reconstructed surfaces. Even those limited efforts have focused only on various aspects of classification uncertainty; for example, Bolliger and Mladenoff [2005] proposed a method to quantify spatial classification uncertainty using fuzzy approaches whose main focus was on a measure of uncertainty associated with classification procedures, while taking for granted uncertainty arising in the data pre-processing procedure.

In the current paper, we propose a geostatistical framework to quantify uncertainty associated with a set of tree species occurrence probability at a set of unsurveyed locations, and assess the impact of the uncertainty associated with the reconstructed map of presettlement forest patterns on the overall uncertainty regarding the classification results.

2. Proposed Approach

In the geostatistical framework, the presence/absence of individual tree species at a location is viewed as a realization of a binary random variable that is partially characterized by the proportions of individual tree species and a measure of their spatial structure, i.e., the spatial indicator covariance model. Given the spatial information contained in tree records, soil conditions, and a model of the spatial correlation for each individual tree species, we model spatial uncertainty regarding the conditional probability that an unsurveyed location belongs to a specific type of tree species by generating multiple and equally probable realizations of

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joint distribution of individual tree species via a stochastic simulation. More specifically, uncertainty analysis conducted in the current paper proceeds in the following steps:

First, bearing tree records from the Holland Land company township survey of c. 1800 are transformed into mutually exclusive and collectively exhaustive categories using two classification approaches, i.e., a rule-based and a statistically clustering approach, adopted in a prior study [Wang, 2007]. These classification-derived categorical attributes at survey corner locations are used to infer the indicator covariance for each species as well as the indicator primary indicator values.

Then several probability maps of presettlement forest occurrences are generated using sequential indicator simulation with indicator Kriging, accounting for all information available, e.g., global proportion of each tree species, the primary indicator values at surveyed locations, soil drainage data, and spatial correlation model within expected fluctuations. In the current study, the soft indicator data (soil drainage information known throughout at survey and prediction locations) are used to update the posterior probability at a prediction location as a local indicator mean. We exclude a 5% subset of the primary indicator data randomly selected from the total survey locations to serve as reference values in the uncertainty assessment.

Once posterior probabilities of individual tree species occurrence are derived at all prediction locations, they are converted to vegetation-association classes using the two classification approaches mentioned above [Wang, 2007]. For comparability, we applied consistent classification schemes for survey data transformation as well as post-processing of simulated probabilities.

As a measure of location-specific uncertainty associated with the reconstructed vegetation association classes, we calculate local entropy, local prediction error variance, and a measure of classification inaccuracy (the risk of misclassification) at each prediction location [Goovaerts, 1997]. The other measure of uncertainty is reported as a form of accuracy statistics based on the differences between the tree species derived from simulated posterior probability map and the known tree species type at a set of reference locations [Kyriakidis et al., 2001]. The overall accuracy as well as individual species-specific accuracy is reported. This comparison allows us to evaluate the degree of spatial uncertainty that may occur for each different tree species and vary across geographic areas.

3. References

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