Spatial Uncertainty Analysis in Ecological Systems

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ABSTRACT

Uncertainty analysis is the part of risk analysis that focuses on the uncertainties in the data characteristics. Important components of uncertainty analysis include qualitative analysis that identifies the uncertainties, quantitative analysis of the effects of the uncertainties on the decision process, and communication of the uncertainty. (Funtowwicz & Ravetz 1990; Petersen, 2000; Regan et a1., 2002; Katz 2002). The analyses include simple descriptive procedures till quantitative estimation of uncertainty, and decision-based procedures. The analysis may be qualitative or quantitative, depending on the stage of analysis required and the amount of information available. When a neighbourhood structure lattice system is applied, a spatial connectivity between regions is defined where investigation of that structure includes modelling of the spatial homogeneity is introduced. Spatial investigation involves stochastic modelling especially in cases where the incomplete data involves hide information's. In this work a spatial analysis methodology was introduced and procedures to solve the problem with spatial variability are described.

Keywords: *Hierarchical Models, Markov Chains Monte Carlo (MCMC), Markov Random Fields, Spatial Modelling, Spatial Point Analysis, Uncertainty*

INTRODUCTION

Model evaluation assumes a certain general structure (e.g. multiple linear) and the model is built through adding terms (variables) which are significant and connected by using hierarchical modelling approaches. Parameter uncertainty is defined as a problem of estimation. These models are similar to models common to risk analysis, which often leads to deterministic approaches for the evaluation of the parameters. Stochasticity is often introduced through stochastic functions (e.g. weather) or random effects in parameter values.

Although the uncertainty analysis problem is similar to statistical problems, in application the uncertainty analysis problem is often more complex than many statistical problems. Models are used due to the complexity of the problem. The choice of the model is a choice that leads to structural uncertainty modelling (Katz, 2002; Stott & Kettleborough, 2002). Data may contain

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errors that result from problems with sampling, measurement, or estimation procedures (O'Neill & Gardner, 1979; Regan et al., 2002). Incomplete data are a common problem, especially in spatial modelling when the neighbourhood structure of the region is used for evaluation (Reckhow, 1994; Clark et al., 2001; Rypdal & Winiwarter, 2001; Katz, 2002).

The uncertainty in the lower level is used to estimate the uncertainty in the level of interest. The extrapolation method thus uses the variation in species sensitivity to calculate a concentration that is expected to be safe for most of the species present in the ecosystem. Extrapolation factors defined into the quantitative model used for uncertainty factors by developing a model to extrapolate from one level to another. To be effective, the method relies on three assumptions (Smith & Cains, 1993): 1. Ecosystems are protected if 100 (1-a) % of species are protected; 2. The distribution chosen to model variation in species sensitivities is correct; 3. The data are from randomly selected species and independent trials.

SPATIAL UNCERTAINTY ANALYSIS

Interactions between biological cells at different scales are characterized by their local dynamics and the emergent spatial patterns are the outcome of different processes. The development of specific new, applied statistical techniques can be explained by the emerging field of specific regions of human body, which focuses on spatial processes operating over various spatial extents biologists are trying to collect quantified information about spatial pattern in order to answer questions regarding the underlying processes (e.g. competition) (Turner, 1989; Wiens, 1989). Although different processes could be responsible in generating the same spatial pattern, its quantification may help to identify these processes. Complementary to answering causal questions about biological processes, quantification of spatial pattern can be used to analyze spatial dependences. However, the sometimes hidden spatial dependence in data can lead to violations of the assumption (Legendre, 1993). It must be noted that there is considerable variety of statistical methods that have been applied in the analysis of spatial variation in biological data. These include dispersal analysis, spectral analysis, wavelet analysis, kriging, spatial Monte Carlo simulations and many geostatistics methods (Zimeras & Matsinos, 2011).

Uncertainty in models can be divided in a similar way by statistical and systematic uncertainty. The statistical uncertainties arise from the variability of input variables and parameters where the variability is known. This variability can be described by probability density functions (PDFs) describing the variability of the input variables and the parameters (Zimeras & Matsinos, 2011). Systematic uncertainties arise from variability in input variables and parameters when variability is unknown. Also unknown processes in the model e.g. incorrect model structure contribute to the systematic uncertainties.

Scaling is the extrapolation of information from one scale to another in time or space or both (Wu, 1999). In the process of scaling, errors in data and models may be effects the results (Armstrong & Collopy, 1992). Thus, uncertainty analysis is an essential part of scaling because it provides critical information about the accuracy of scaling results (Katz, 2002).

Model uncertainty has two basic components, model structure and model parameters (O'Neill & Gardner, 1979; Jansen, 1998; Katz, 2002). Model structure uncertainty is caused by the modelling processes of simplification and formulation. Model simplification is essential to modelling and is the identification and selection of the relationships, and variables that are the most important to the modelling analysis.

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