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Modeling spatiotemporal forest health monitoring data. (English) Zbl 1388.62093

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Summary: Forest health monitoring schemes were set up across Europe in the 1980s in response to concerns about air pollution-related forest dieback (Waldsterben) and have continued since then. Recent threats to forest health are climatic extremes likely due to global climate change and increased ground ozone levels and nitrogen deposition. We model yearly data on tree crown defoliation, an indicator of tree health, from a monitoring survey carried out in Baden-Württemberg, Germany since 1983. On a changing irregular grid, defoliation and other site-specific variables are recorded. In Baden-Württemberg, the temporal trend of defoliation differs among areas because of site characteristics and pollution levels, making it necessary to allow for space-time interaction in the model. For this purpose, we propose using generalized additive mixed models (GAMMs) incorporating scale-invariant tensor product smooths of the space-time dimensions. The space-time smoother allows separate smoothing parameters and penalties for the space and time dimensions and thus avoids the need to make arbitrary or ad hoc choices about the relative scaling of space and time. The approach of using a space-time smoother has intuitive appeal, making it easy to explain and interpret when communicating the results to nonstatisticians, such as environmental policy makers. The model incorporates a nonlinear effect for mean tree age, the most important predictor, allowing the separation of trends in time, which may be pollution-related, from trends that relate purely to the aging of the survey population. In addition to a temporal trend due to site characteristics and other conditions modeled with the space-time smooth, we account for random temporal correlation at site level by an autoregressive moving average (ARMA) process. Model selection is carried out using the Bayes information criterion (BIC), and the adequacy of the assumed spatial and temporal error structure is investigated with the empirical semivariogram and the empirical autocorrelation function.

MSC:

62G07 Density estimation
62H11 Directional data; spatial statistics
62M30 Inference from spatial processes
62P12 Applications of statistics to environmental and related topics
62C12 Empirical decision procedures; empirical Bayes procedures

Keywords:

pollution; climate; environmental monitoring; forest damage; spatiotemporal model; tensor product smooth; tree defoliation

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