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Title: Spatial+: a novel approach to spatial confounding

Abstract:
In spatial regression models, collinearity between covariates and spatial effects can lead to significant bias in effect estimates. We encounter this problem, known as spatial confounding, modelling forestry data to assess the effect of temperature on tree health. Reliable inference is difficult as results depend on whether or not we include spatial effects in the model. The mechanism behind spatial confounding is poorly understood and methods for dealing with it are limited. We propose a novel method, spatial+, a modified version of the spatial model. Using a thin plate spline model formulation, we are able to analyse the asymptotic behaviour of effect estimates to provide a theoretical explanation for why spatial confounding happens and why spatial+ works. These results are also demonstrated in a simulation study. Spatial+ is straight-forward to implement using existing software and standard model selection criteria can be used for comparing models. Another advantage of the method is that it extends to models with non-Gaussian response distributions. Finally, while our results are derived in a thin plate spline setting, the spatial+ methodology transfers naturally to other spatial model formulations.