Sample size calculations for natural resource surveys assuming zero-inflated beta distributions and AR1 time dependence

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Abstract:
In order to perform sample size calculations for natural resource surveys, prior estimates of population variance and temporal dependence are needed. Natural resource surveys typically use an areal sampling frame representing the entire land area within a predefined region (e.g. land or continent). These surveys also have multiple objectives such as the estimation of land cover (change) for multiple land cover types.
We consider the case where sampling units contain a mix of land cover classes. Depending on the size of the sampling unit and the detail of the land cover classification, a substantial proportion of sampling units in a sample may be empty for a particular land cover class. This proportion will be determined by the (unknown) proportion of land covered by the particular land cover type and its spatial distribution. In addition, when a particular land cover class is present, it will cover a proportion of the total area of the sampling unit. To estimate the spatial or population variance, we therefore need a distribution that reflects both sources of variability. We show that zero-inflated beta distributions, with the zero-inflated part modelling the absence of a land cover type and the beta part modelling the areal proportion within sampling units when present, fulfil these needs. Land cover classes tend to be persistent features and consequently change in land cover tends to be rare. This can be modelled through a first-order autocorrelated process.
We demonstrate the estimation of realistic spatial variance and temporal dependence using data from five monitoring cycles of the United Kingdom Countryside Survey (UK CS). In turn, these estimates allow us to calculate required sample sizes to detect trends and estimate the area of a land cover class at reasonable quality levels to evaluate similar natural resource surveys at the design stage.