Geophysical Research Abstracts
Vol. 14, EGU2012-1139, 2012
EGU General Assembly 2012

A hybrid design-based and model-based sampling approach to estimate the temporal trend of spatial means of soil and hydrological variables

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This paper launches a hybrid sampling approach, entailing a design-based approach in space followed by a model-based approach in time, for estimating temporal trends of spatial means or totals. Sampling locations are selected by probability sampling, whereas this is not required for selecting sampling times. The underlying space-time process that generated the data is only partly described, viz. by a linear mixed model for the temporal variation of the spatial means. The model contains error terms for model inadequacy (model or process error) and for the sampling error in the estimated spatial means. The linear trend is estimated by Generalized Least Squares. The covariance matrix is obtained by adding the matrix with design-based estimates of the sampling variances and covariances of the estimated spatial means and the covariance matrix of the model errors. The model parameters needed for the latter matrix are estimated by REML. The error variance of the estimated regression coefficients (fixed effects) can be decomposed into the model variance of the errorless regression coefficients and the model expectation of the conditional sampling variance.

In a case study on forest soil eutrophication and acidification in the Netherlands, concentrations of ammonium, nitrate and pH in the soil pore water were measured in a rotational panel sample at three depths (de Gruijter et al, 2006). There were four sampling times, separated by one year. Each time 20 locations, selected by simple random sampling, were sampled. The matching proportion was 50 percent which means that 10 locations of a given time were revisited the subsequent time, and each time 10 new locations were selected. Results were compared with the design-based approach in which the linear trend is defined as a population parameter and only the sampling error in the estimated spatial means is accounted for in quantifying the uncertainty in the estimated trend (Brus and de Gruijter, 2011). Inclusion of the model error led to a considerable increase of the error variance for most variables. In the topsoil the contribution of the process error to the standard error of the estimated trend was much larger than that of the sampling error. For pH the contribution of the model error was negligible. Important advantages of the presented approach over the fully model-based approach in which the trend is estimated using a full space-time model (Ter Braak et al., 2008) are its simplicity and robustness to model assumptions.

References

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