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Spatial correlation of soil properties in the artificial catchment "Chicken Creek" at an early phase of ecosystem development

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Biotic and abiotic processes cause characteristic spatial (and temporal) patterns in terrestrial ecosystems. Such patterns often manifest themselves as a scale dependent variation of some state variables of the system. Studying them is one way to learn about processes dominating energy and matter fluxes and interactions between organisms within an ecosystem. One method to investigate spatial patterns is the analysis of variance of data collected in surveys in which the sampled locations are spatially hierarchically nested.

We used such a nested sampling design to elucidate the spatial scales of variation of chemical and physical soil properties in the 6 ha catchment “Chicken Creek” that was artificially constructed in the Lusatian lignite mining landscape near Cottbus, NE Germany in 2004/2005. The assumption was that soil properties varied without much spatial structure in the newly constructed catchment. Spatial patterns were thought to evolve in the course of ecosystem development as the result of processes such as erosion, formation of preferential drainage paths on the surface and within the soil, non-uniform chemical weathering, uneven colonization by organisms, etc.

Topsoil was sampled in 2008 at 192 locations using a balanced nested design involving six spatial scales (0.2 to $>$60 m) and analysed for particle size, organic matter content, pH, soluble P, and various fractions of selected metals. The nested sampling survey did not really capture the state of the ecosystem at time zero, although still at a very early stage of its development. Variance components, associated with the spatial scales of the nested design, were estimated by restricted maximum likelihood. We used likelihood ratio tests and likelihood based confidence regions for inference about the spatial autocorrelation patterns.

Likelihood ratio tests showed that all variables were spatially autocorrelated, some variables even strongly, but the allocation of the variance to specific spatial scales was highly uncertain. For most variables, at least one variance component could not be precisely identified because the profile likelihood surface was flat. 95%-likelihood joint confidence regions for accumulated variance components showed that the shape of the variograms was poorly defined for most variables. For some variables, a variogram with a dominant nugget (increase of semivariance only up to 0.2–0.6 m) and a variogram, implying an unbounded increase of the variation up to the largest spatial scale ($>$60 m) seemed equally consistent with the data.

Our results suggest that the development of the ecosystem in the “Chicken Creek” catchment did not start from a spatially unstructured soil. For most variables, we found substantial spatial variation — the coefficients of variations ranged from about 15 % to more than 70 % — and strong autocorrelation three years after the construction of the catchment. While the spatial distribution patterns of some of the analysed variables may have changed during the first three year of its development, e.g. the organic matter content, soluble P, etc., substantial change in spatial patterns is rather unlikely for others, (e.g. total contents of metals). It is likely that the spatial structures are primarily related to initial heterogeneities deriving from the construction process. However, in spite of the sound evidence for autocorrelation, we could not reliably attribute variance components to specific scales.