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# Identification of prevailing processes in soils using nonlinear statistics

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A big challenge in soil science is the identification and quantification of prevailing processes in soils. The more complex the interplay between single processes, the larger the size of the required data set will be. Soil monitoring yields such large data sets. For the identification of the prevailing processes, as well as the identification of the spatial patterns or temporal trends, mostly linear approaches are used. But linearity often is more an exception, rather than the rule in ecological data sets. Numerous studies show that nonlinear analyses of ecological data revealed higher efficiency. However, nonlinear approaches in soil science are still very rarely used today.

Here, a nonlinear approach, Isometric Feature Mapping (Isomap), was applied and compared to the established linear Principal Component Analysis (PCA) to a data set from a long-term monitoring program in the forested Lehstenbach catchment (Fichtelgebirge, Germany). The data set comprised more than 4000 soil solution samples with 13 solutes being determined from four different sites within the catchment. The samples were collected at different depths, for different periods and from different soil types (Sapric Histosol, Dystric Arenosol and two Haplic Podzols).

The nonlinear Isomap approach achieved better results than the linear procedure.

More than 94% of the variance of the given data set was explained by the first five components. The calculated components can be interpreted and assigned to specific processes. The different processes can be quantified. As most relevant processes we identified the impact of long-term atmospheric deposition, soil acidification, a long-term shift of deposition chemistry, interactions of soil matrix and soil solution and decomposition of organic matter. Thus, long-term deposition was identified as the most important factor influencing soil solution chemistry in different ways, being responsible for nearly 60% of the dataset variance. The decomposition of organic matter (1.6% of the variance of the data set) only plays a secondary but still detectable role.

Time series of component scores were investigated with respect to long-term trends, as well as to effects of single extreme events. For example, effects of extreme cold periods or heavy rainfall events could be traced down to >100 cm depth, having an impact on e.g. the redox conditions, interactions of soil matrix and soil solution and the relevance of decomposition for soil solution chemistry.

Additionally calculated variable loadings offer the possibility to identify processes which dominate the concentration dynamics of single variables. For the DOC-dynamics acidification turned out as the most important process, actually more important than decomposition.

The nonlinear Isomap approach gave insight into the interplay between different processes and solutes. Thus, the effects of different processes on single solutes could be differentiated, which is important to know when modeling. The chosen approach proved to be a powerful tool to elucidating the non-linear interplay of different processes at different time scales.