From micro pores to ecosystems - ecological gradients as components of environmental analysis and mangement

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In this paper we present a theoretical approach to better understand the processes, structures, and dynamics in soil systems and whole ecosystems. Several examples are used to demonstrate the significance of ecological gradients on different interacting scales – reaching from soil micro-pores to landscapes, and the potential of this approach to improve environmental management is discussed.

The theoretical basis of the gradient principle originates in ecological thermodynamics. It is described basing on the following set of propositions:

A. Ecosystems are self-organized systems. Throughout their development they create spatial and temporal concentration profiles.

B. These emerging environmental gradients are basic determinants of ecosystem structures, processes and functions, because gradients provide the basic potentials for ecological flows.

C. Ecosystems are hierarchical systems. The created gradients operate at different, interrelated spatio-temporal scales.

D. Gradients are basic components of ecosystem development. They can be used to indicate developmental stages in ecosystems and their components.

E. Ecosystem utilization modifies the environmental gradient systems. The scales of human perturbations and the affected gradients determine primary effects, while the overall impacts are due to the interrelations between different gradient systems.

F. As human-environmental interactions can also be assigned to a hierarchy of gradients, gradient adaptation can lead to an optimized landscape management.

These theses are illuminated and tested with different data sets from ecosystem analysis, landscape ecology, and soil science. There is a distinction of structural and functional gradients.

The *structural gradients* define the spatial distribution patterns of ecosystem elements, which can be assigned to long-term processes. They provide an “environmental envelope” for rapid ecosystem processes. Structural gradients will be demonstrated, taking into account landscape features, abiotic ecosystem features and biotic distribution patterns. These characteristics as a whole determine the heterogeneity and biodiversity of ecosystems.

The *functional gradients* refer to the short-term ecological flows that operate between specific storage compartments. These processes will be exemplified with reference to

the energy balance (energetic gradients), the water balance (hydrological gradients), and the nutrient balance (chemical gradients).