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Relevance of anisotropy and spatial variability of gas diffusivity for soil-gas transport

Helmer Schack-Kirchner, Anke Kühne, and Friederike Lang
Chair of soil ecology, Albert-Ludwigs Universität, Freiburg, Germany (helmer.schack-kirchner@bodenkunde.uni-freiburg.de)

Models of soil gas transport generally do not consider neither direction dependence of gas diffusivity, nor its small-scale variability. However, in a recent study, we could provide evidence for anisotropy favouring vertical gas diffusion in natural soils. We hypothesize that gas transport models based on gas diffusion data measured with soil rings are strongly influenced by both, anisotropy and spatial variability and the use of averaged diffusivities could be misleading. To test this we used a 2-dimensional model of soil gas transport to under compacted wheel tracks to model the soil-air oxygen distribution in the soil. The model was parametrized with data obtained from soil-ring measurements with its central tendency and variability. The model includes vertical parameter variability as well as variation perpendicular to the elongated wheel track.
Different parametrization types have been tested:

i) Averaged values for wheel track and undisturbed.

ii) Random distribution of soil cells with normally distributed variability within the strata.

iii) Random distributed soil cells with uniformly distributed variability within the strata.

All three types of small-scale variability has been tested for

j) isotropic gas diffusivity and

jj) reduced horizontal gas diffusivity (constant factor),

yielding in total six models.

As expected the different parametrizations had an important influence to the aeration state under wheel tracks with the strongest oxygen depletion in case of uniformly distributed variability and anisotropy towards higher vertical diffusivity. The simple simulation approach clearly showed the relevance of anisotropy and spatial variability in case of identical central tendency measures of gas diffusivity. However, until now it did not consider spatial dependency of variability, that could even aggravate effects. To consider anisotropy and spatial variability in gas transport models we recommend a) to measure soil-gas transport parameters spatially explicit including different directions and b) to use random-field stochastic models to assess the possible effects for gas-exchange models.