

Modelling the genesis of Luvisols in late Weichsel loess

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Abstract

Many soils in the western European loess belt have in common (i) a parent material deposited in the late Weichsel period (up till about 15,000 BP), (ii) a mineralogical composition with some 10-15% calcium carbonate, some 12-18% clay minerals dominated by montmorillonite and most of the silt-sized fragments dominated by quartz minerals. As far as soil genesis is concerned, there are often indications of decarbonisation followed by clay migration. Clay migration may no longer be an active process in semi-natural environments, when pH drops to levels at which Aluminium and Iron enter the soil solution and keep the clays flocculated, while in agricultural environments liming may have favoured a re-start of clay migration, often in combination with organic materials. Knowledge as summarized above has come from mineralogical and soil chemical analysis and is supported by soil morphological observations. Most of the underlying processes are now understood quite well and can be modelled.

Decarbonisation is driven by CO_2 production in the soil and a precipitation surplus. Rates of decarbonisation were approximated as $2.5 \text{ mol CaCO}_3/\text{m}^2$, year at a precipitation surplus of 1000 mm/year (Egli and Fitze, 2001), which translates to approximately 1/3 mm of loess soil depleted of CaCO_3 yearly in western European circumstances. Carbonate chemistry is part of quite a number of soil chemistry models.

Clay migration or, more generally, the migration of soil colloids is progressively better being understood as the combination of the effects of film straining, air-water interface capture and soil-water interface deposition. The effect of ionic strength on the thickness of double layers contributes to the air-water interface and soil-water interface capture, as does the type of colloid. Recently, Denovio et al. (2004) formulated an advection-dispersion equation for soil colloid transport and elaborated on its terms, thus outlining a model for soil colloid transport in the unsaturated zone.

The formulation of a model incorporating unsaturated flow, soil and colloid chemistry and transport should therefore theoretically allow for the reconstruction of the formation of Luvisols. This study is a first attempt.

The proposed model starts from an existing soil chemistry model LEACHC (Hutson and Wagenet, 1992), simulating unsaturated water flow by a finite difference approach to the Richards' equation and solute transport by the Convection Dispersion Equation. The model also includes carbonate chemistry and sorption of cations to the exchange complex. The intention is, to couple this model to a colloid transport model based on the Denovio paper on a yearly basis, both models sharing the LEACHC hydrology. Each timecycle, also the effect of (i) bioturbation in the topsoil, (ii) changed porosity near the CaCO_3 dissolution front and (iii) clay eluviation and illuviation on bulk density will be simulated. Simulated bioturbation will via partial mixing affect the distribution of soil components in the next timecycle. The effect of changes in porosity and clay content on soil physical characteristics relevant to water flow will be accounted for by a module that re-estimates on a yearly basis these characteristics by pedotransfer functions. Boundary conditions will be generated on reconstructed climate data from the early Holocene to present.

The paper will show the first results of this attempt to model the genesis of Luvisols. Focus will be on the simulation of decalcification in combination with bioturbation. Special attention will be devoted to the calibration of the model, since only the start situation (C-material of the loess) and the current situation are available for reference.

References

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