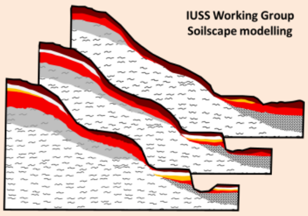
Newsletter 1 Spring 2015

IUSS-Working Group on modelling of soil and landscape evolution



Chair: Peter A. Finke
Vice Chair: Tom Vanwalleghem

A new IUSS-working group

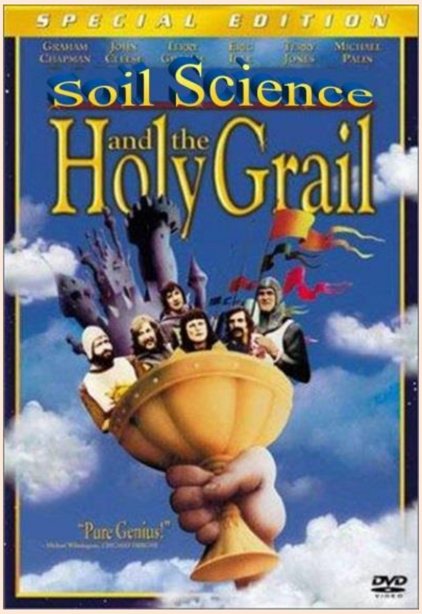
The proof of the pudding is in the eating. For a scientist this means that testing available knowledge is best done by its application. When this knowledge is about soil and landscape processes, this implies building models and confronting these to the real world. In recent decades we see a strong development of both landscape and soil development models, by some colleagues coined “Holy Grails” of their disciplines. It is therefore no surprise that IUSS asked for a working group that would bring together both groups to progress modelling of soilscape development. In IUSS-bulletin 124 and at the 2014 IUSS-congress at Jeju, Korea the working group on modelling of soil and landscape evolution was announced and here we are.

So what’s the plan. Besides some structural activities, like this newsletter and a website soillandscape.org to keep you informed and get your feedback, the WG-activities will be organic and depend on opportunities. This means that we will start (co-)organizing topical sessions and workshops in larger conferences such as the EGU and Pedometrics (examples in this newsletter). Furthermore we will stimulate review papers on the state of progress in the discipline of soilscape modelling, produce an overview of the capabilities of existing soil and/or landscape models and identify what’s missing today in models and knowledge on soilscape evolution.

The success of all of this will depend on efforts, ideas and support of all interested colleagues. Enjoy the pudding!

Peter Finke

This issue



Info

WG initiators:

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Recent meetings

Vienna
27/4–2/5 2014

EGU 2014: session on *Dynamic Soil Landscapes: coupling soils, landscape evolution and biogeochemical cycles*. Info here. Several oral papers on interactions and feedbacks between soil development, surface processes and weathering in a modelling context.

Bonn
29/9-2/10 2014

TERENO: session on *Transferring local Understanding of Vadose Zone Processes to the Landscape Scale.* Presentations here. Several orals on relations between landscape, soil properties and their combined evolution. Various contributions on model tuning in a landscape context by data assimilation methods.

Las Vegas
26/10-31/10 2014

RAISIN 2014: *Soil-Forming Processes and their Rates, with excursion in Mohave desert*. Report here. Mostly presentations on field- and lab estimates of soil formation rates and their indicators in desert environments. Emphasis on sampled chronosequences in various presentations and during the excursion.

pls send us meeting reports

Upcoming events

Vienna
12/4-17-4 2015

EGU 2015: Relevant sessions:

- *Linking evolution of landscapes, soils and biogeochemical cycles through models, novel approaches and soil records*. Conveners: Arnaud Temme, Tony Reimann, Peter Fiener, Tom Vanwalleghem, Kristof Van Oost. read this;
- *Coevolution of soils, landforms and vegetation: patterns, feedbacks and ecosystem stability thresholds*. Conveners: Patricia Saco, Mariano Moreno de las Heras, Jose Rodriguez, read this.

Córdoba
14/9-18/9 2015

PEDOMETRICS 2015: Information here.

- Introductory workshop of IUSS-working group on modelling of soil and landscape evolution (14-9-2015). Conveners: Peter Finke and Tom Vanwalleghem. Focus on developments in different research groups, model demonstrations and discussions. A program will be announced soon after the abstract deadline of April 15; We now have confirmed presentations and demonstrations on the models Lorica, mARM3D and SoilGen and are expecting more.
- One of the topics of the Pedometrics conference itself is on Soil-landscape modelling (mechanistic and empirical).

Freudenstadt
21/9-24/9 2015

FRONTIERS: Workshop on *Terrestrial systems - frontiers of our understanding*. Conveners: Kurt Roth, Hans-Jörg Vogel, Ute Wollschläger, Olaf Ippisch. The main goal is “to perform a thorough analysis of the current state of our understanding of terrestrial systems” by a series of invited discussion contributions. More information here.

pls send us coming events

Suggested readings

In this first WG-newsletter it seems appropriate to put focus on review papers on soil and landscape modelling. Most of the publications listed below focus either on soil (pedogenesis) modelling or on landscape modelling, with the notable exception of Stockman et al. (2011). This suggests that the research groups are still largely unaware of each other's work, or at least that there is still limited experience with integrated or coupled soil-landscape models. We are aware that this gap is already being filled with case studies and that at least one integrative review paper is underway. In a next issue we will focus on recent papers attempting to integrate soil and landscape modelling.

- Hoosbeek, M.R., Bryant, R.B., 1992. Towards the quantitative modeling of pedogenesis: a review. Geoderma 55, 183-210. DOI

  A classical paper suggesting that mathematical simulation of dynamic pedogenetic processes should be pursued, integrating soil physical, chemical and ecological processes.
- Coulthard, T. J., 2001. Landscape evolution models: a software review. Hydrol. Process., 15, 165–173. DOI

  Review of the landscape evolution models SIBERIA, GOLEM, CASCADE, CHILD and CAESAR in terms of underlying processes (hydrology, tectonics, erosion, mass wasting), spatial discretization (grid/TIN, resolution) and runtime performance.
- Samouëlian, A., Cornu, S., 2008. Modelling the formation and evolution of soils, towards an initial synthesis. Geoderma 145 (3/4), 401-409. DOI

  A review of the different approaches in deterministic modelling of pedogenesis, with emphasis on the choice between only modelling the solid phase or modelling geochemistry, water and solute flow in combination. The paper discusses advantages and limitations of each approach.
- Minasny, B., McBratney, A.B., Salvador-Blanes, S., 2008. Quantitative models for pedogenesis: a review. Geoderma 144, 140-157. DOI

  An overview of quantitative models that model pedogenesis starting from bedrock. Factorial, energy and mass-balance based models are distinguished and criteria are discussed for pedogenetic models at pedon and landscape scales.
- Tucker, G.E., Hancock, G.R., 2010. Modelling landscape evolution. Earth Surface Processes and Landforms 35(1), 28-50 DOI

  Models are presented as instruments to focus thinking on processes and observable characteristics. The paper reviews landscape theory precipitated as numerical models of drainage basin evolution and identifies current knowledge gaps and future computing challenges.
- Stockmann, U., Minasny, B., McBratney, A.B., 2011. Quantifying pedogenesis processes. Advances in Agronomy 113, 2-67. Download here

  Review paper discussing conceptual models for pedogenesis, soil weathering and soil production, mixing processes and mass balance based models at pedon and landscape scale.
- Temme, A.J.A.M., Schoorl, J.M., Claessens, L., Veldkamp, A., 2013. Chapter 2.13. Quantitative Modeling of Landscape Evolution. In: John, F.S. (ed.), Treatise on Geomorphology. Academic Press, San Diego, pp. 180-200. DOI

  Book chapter reviewing quantitative modelling approaches towards landscape evolution based on the function of the model, which may be either experimentation, understanding, reconstruction or prediction. 117 case studies were analyzed and attributed to these categories. There is ample attention for the future of landscape evolution modeling, with emphasis on complexity, predictive studies and uncertainty analysis, process definition and integration with other scientific fields..
- Chen, A., Darbon, J., Morel, J.-M., 2014. Landscape evolution models: A review of their fundamental equations. Geomorphology 219, 68-86. DOI

  The physical laws behind landscape evolution models of increasing complexity are reviewed, the most complex containing water, bedrock, suspended sediment and regolith. The simplest and most general physically consistent set of equations is given. Three issues regarding the downslope water transport equation, detachment-limited erosion (on hill slopes) versus the transport-limited sediment transport (on river beds) and associated mass conservation are discussed and systematized.

- Opolot E., Y.Y. Yu and P.A. Finke. on line. Modeling soil genesis at pedon and landscape scales: achievements and problems. Quaternary International. DOI

  An overview of the state of progress in pedogenetic modelling at the pedon scale, with reference to process coverage and to options to move to landscape scale

What's missing in soilscape modelling? A literature scan.

Peter Finke

The title question "What's missing" should be preceded by another question "What should be there". For soilscape development models the second question did not get a proper answer yet in literature. Most people will probably agree that a complete soilscape development model should be able to reconstruct (or predict) the redistribution of matter in the landscape, both in a vertical sense (soil profile development) as in a lateral sense. It should therefore be a 3D-model and include the factor time. What "matter" such model should include is less clear. From the 1980's onwards, may topical leaching models have been developed describing transport of nutrients, biocides, salts and colloids, and many landscape evolution models have been developed describing erosion and mass wasting processes at the soil surface in terms of the solid phase of the soil.
The degree to which soil profile models have evolved beyond topical leaching models can be assessed by the process coverage in relation to soil genesis. Bockheim and Gennadiyev (2000) have defined 17 soil-forming processes that relate to the taxa in Soil Taxonomy and World Reference Base via their diagnostic horizons, properties and materials. To these, we could add 5 processes (erosion, deposition, physical weathering, chemical weathering and bioturbation) that may not be diagnostic for soil classification but do change soil properties over time and cause variation in the landscape. The resulting list of 22 soil processes (Table) explains the genesis of soil types occurring worldwide and can therefore be considered a proxy for the ideal process coverage of a soil profile model.

Table. Processes of soil formation. *Italic* terms refer to processes named by Bockheim and Gennadiyev (2000).

Soil process	**Description**
Erosion	Removal of topsoil material
Sedimentation	Addition of material on the topsoil
Physical weathering	Reduction in grain sizes due to fragmentation of particles
Chemical weathering	Breakdown of primary minerals and -possibly- formation of secondary minerals
Bioturbation	Mixing of soil layers by faunal, floral or human activity
Melanization	Accumulation of well-humified organic matter within the upper mineral soil
Argilluviation	Movement of clay (lessivage)
Calcification	Accumulation of secondary carbonates and gypsum
Base cation leaching	Eluviation of base cations (Ca, Mg, K, Na) from the solum under extreme leaching conditions
Biological enrichment of cations	Vegetation-induced cycling of base-cations
Ferralitization	Residual enrichment of Al and Fe and loss of Si by weathering of primary and secondary minerals
Anthrosolization	Effects of human activities such as deep working, intensive fertilization, additions of materials, irrigation with sediment-rich waters, and wet cultivation
Gleization	Development of reductimorphic or redoximorphic features
Silification	Secondary accumulation of Si
Paludization	Deep accumulation of organic matter (peat formation)
Vertization	Shrinking and swelling of soils, evident at the landscape, pedon, and microscopic scales
Andosolization	Domination of fine earth fraction by amorphous (Fe, Al) compounds
Podzolisation	Movement of organic matter possibly complexed with Fe and Al compounds

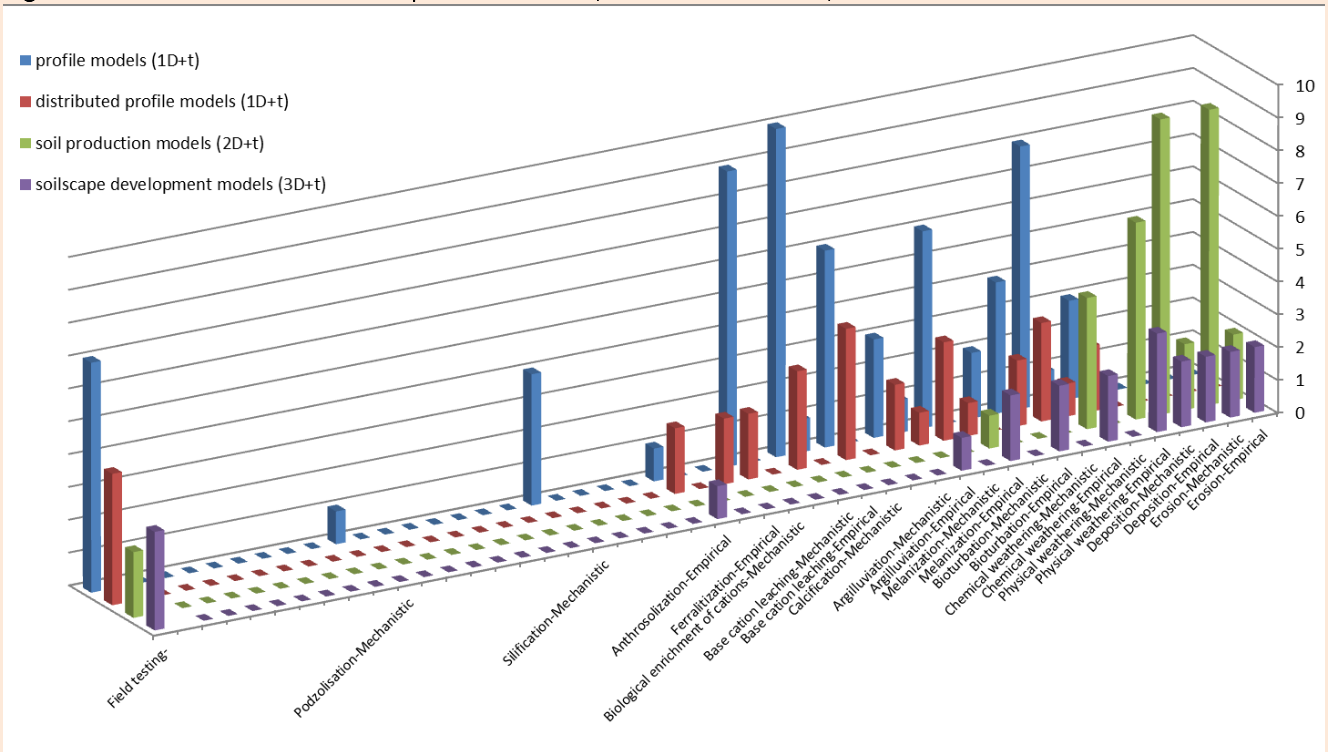
Cryoturbation	Frost stirring of soil horizons and components under (near-)permafrost conditions
Salinization	Accumulation of soluble salts of Na, Ca, Mg, and K as chlorides, sulfates, carbonates, and bicarbonates
Solonization	Leaching of excess soluble salts and dispersion of Na-dominated colloids in soils with a strongly alkaline reaction
Solodization	Leaching (argilluviation) of dispersed Na-dominated colloids

To evaluate the process coverage of existing models, I did a literature scan of 29 published case studies of pedogenetic soil models at the profile scale as well as the landscape scale, checking process coverage according to the table. Distinction was made between 1D-profile models, 1D-models applied in a spatially distributed manner, 2D-soil production models (that have no vertical discretization but do have soil depth as a spatio-temporal variable) and 3D-soilscape models that do have vertical discretization over the landscape. Differences between empirical and mechanistic process formulations were noted. For an overview of the inventory have a look here.

Soil profile models

The scan revealed that process coverage is currently higher for soil profile models than for landscape models, but is still incomplete (Figure). The case studies may not have reported all included processes in the applied models, and may not fully describe (or confine) the model application ranges in terms of parent material, climate range, vegetation type, relief, etc. The soil profile models by Kirkby (1977, 1985) and Sommer et al. (2008), and the models Orthod (Hoosbeek and Bryant, 1994), HP1 (Jacques et al., 2008), and SoilGen (Finke and Hutson, 2008) are water flow driven, whereas the WITCH model (Goddéris et al., 2006) needs an external water flow model and the energy model (Rasmussen et al., 2005) does not consider water flow. SoilGen, WITCH and the energy model have been applied as spatially distributed models to generate results at the landscape scale, but these studies excluded lateral interactions (by erosion/deposition/mass wasting or by non-vertical fluxes of water). Most of the soil profile model case studies contain confrontations between simulated and measured data, and thus give an indication of the confidence that can be attributed to the results, and most of the process descriptions are mechanistic or functional in the terminology of Hoosbeek and Bryant (1992).

Figure. Presence of soil formation processes in 1D, 2D and 3D models, counted in 29 case studies



Soil production and soilscape genesis models

The 2D-soil production models and 3D-soilscape models generally show a lower process coverage than the profile models (Figure) and lack formulations of water flow. These models concentrate on the fate of the solid phase. Lateral interactions occur at the soil surface as erosion and mass wasting processes. Most of the process descriptions are functional or empirical, with depth in the soil and time as process drivers, acting as proxies for temperature, moisture and "evolution". Thus, the linkage to the factors of soil formation is less direct than that of the soil profile models. Only in few cases simulations are confronted to measurements.

So, what's missing?

The inventory shows that process coverage is incomplete in most models, but it remains to be seen if "completeness" is necessary for the envisaged soilscape model applications of today. Soilscape models applied in a global change context (this automatically includes both soilscape reconstruction studies and predictions of soilscape development) would need a closer linkage to external forcings such as climate and human activities. An important factor therefore seems to be the inclusion of water flow on and in the soil. 2015 will see some review papers on these issues, so this discussion is far from closed! We expect the workshop on 14-9-2015 (Pedometrics, Córdoba) to feed the discussion.

Case study list

Baartman et al., 2012; Brantley et al., 2008; Cohen et al., 2010; Dietrich et al., 1995; Finke, 2012a; Finke and Hutson, 2008; Finke et al., 2013; Follain et al., 2006; Goddéris et al., 2006; Goddéris et al., 2010; Hirmas et al., 2010; Hoosbeek and Bryant, 1994; Jacques et al., 2008; Kirkby, 1977; Kirkby, 1985; Minasny and McBratney, 1999; Minasny and McBratney, 2001; Minasny and McBratney, 2006; Rasmussen et al., 2005; Rasmussen and Tabor, 2007; Rosenbloom et al., 2006; Saco et al., 2006a; Salvador-Blanes et al., 2007; Sauer et al., 2012; Sommer et al., 2008; Van Oost et al., 2003; Vanwalleghem et al., 2013; Yu et al., 2013; Zwertvaegher et al., 2013