Newsletter 3 Spring 2017

IUSS-Working Group on modelling of soil and landscape evolution

WWW: soillandscape.org
contributions to: peter.finke@ugent.be

This issue

...after the permafrost

Editorial

2017 will be a year with good visibility for soilscape modelers. At two conferences we will be organizing hands-on demonstrations of soilscape models that have been (are being) developed.

First, at EGU2017 models at pedon scale, catena scale and landscape scale will be demonstrated in a short course. These models were applied in a large inter-university project Soils under Global change (SOGLO) to assess soil development, to reconstruct erosion and to link landscape development to C-sequestration. At this conference there will be various other workshops relevant for our working group members.

The same holds for the second, anniversary, Pedometrics 2017 conference . A full-day workshop is planned (conditional to sufficient subscriptions) in which 4 models will be used by the participants in a case study context.

In this 3rd newsletter you'll also find contributions from four young scientists describing their cutting-edge PhD-research. They were asked to comment on the topic of their PhD-research, the role of soilscape evolution models in their work and what they think is lacking right now in these models. Meet the modelers Marijn van der Meij, Benito Bonfatti, Saba Keyvanshokouhi and Andrea Román.

Hope to see you there, and enjoy reading. Peter Finke

Upcoming events

Vienna
23/4-28/4 2017

EGU 2017: A selection of relevant sessions:

Short courses

- Modelling soilscape development (Finke et al.)
- Soil mapping and process modelling at diverse scales (Pereira et al.)
- Open-source software for simulating hillslope hydrology and stability (Lombardo et al.)
- Introduction to Distributed Hydrologic Modeling with GSSHA (Downer)

Meetings

- ISMC International Soil Modeling Consortium (Van Looy)

Sessions

- Coevolution of soils, landforms and vegetation: patterns, feedbacks and ecosystem stability thresholds (Saco et al.)

- Coupling chemical weathering and physical erosion: Insights from geomorphic and geochemical studies (Scheingross et al.)
- Biogeomorphology: conceptualising and quantifying processes, rates and feedbacks (Larsen et al.)
- Modelling Earth surface processes and geomorphic flows: methods and validation (Deal et al.)
- Palaeoenvironmental evolution, connectivity and geomorphological dynamics in dryland areas: New approaches, challenges, pros and cons (von Suchodoletx et al.)

Wageningen 26/6-1/7 2017

Pedometrics 2017 (see here)

Workshop

- Hands-on modelling of soil - and soilscape development (26 june)

Programme not yet official, relevant topics are:

- Calibration and validation of soil-landscape evolution models
- Data fusion in soil mapping and modelling
- Scale issues in soil mapping and modelling
- Soil-landscape evolution modelling

PhD-students on soil and landscape modelling present themselves

Marijn van der Meij

Co-evolution of soils, landscapes and the hydrological system in Holocene hummocky postglacial landscapes

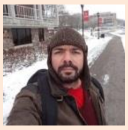
As all of you probably know, soil and landscape development are intertwined. The main driver of this development, water, is however often only implicitly considered in the pedogenic processes of soil-landscape evolution models. For example, this can be done by assuming an exponential decay of process rates with soil depth, to account for a decrease of temperature and soil moisture fluctuations. In soil landscapes with a more complex hydrological system this assumption does not hold, because the hydrological system co-evolves with the soils and landscape. This changes water redistribution both on the surface as in the subsurface, with changing rates, directions and types of soil and landscape forming processes. Examples of these feedbacks are changing hydraulic conductivities due to clay translocation, redoximorphic processes due to stagnating water and subsurface lateral transport of matter and solutes over stagnating layers. These processes show the need for including a more detailed hydrological system in soil-landscape evolution models, to improve our understanding of soil diversity in heterogeneous soil landscapes.

A landscape where complex hydrological behaviour can be expected is the hummocky postglacial landscape of northeast Germany. The landscape consists of closed kettle hole catchments, where water flow is oriented towards the centre of the depressions. The plateau and slope positions show a downward movement of water, while the depression experiences a net upward movement of water. The clayey glacial till is intersected with some sandy veins, which have a much higher hydraulic conductivity. Several changes in the boundary conditions over the Holocene have affected the formation of soils and landscape in this region. These changes include natural gradual changes like changing climatic conditions, but also, more importantly, abrupt changes of land use by humans in the form of deforestation or agricultural practices. The changing vegetation type affected evapotranspiration and therewith the water balance. Furthermore, the introduction of machinery introduced a new type of erosion, namely tillage erosion.

The aim of my project is to quantify the relative contributions of variation in initial soil and landscape properties, changing boundary conditions and internal feedbacks on present soil and landscape diversity in hummocky NE Germany. For that I will reconstruct climate, land use and erosion history and the initial topography of my study area named CarboZALF-D, located 100 km north of Berlin. Furthermore, I'm developing a reduced-complexity hydrological soil-landscape evolution model to simulate how soils and landscape have evolved under influence of the changing boundary conditions. The soil hydraulic properties will be dynamically linked to soil physical properties. The main challenge lies in finding the balance between required model complexity and calculation time. I'm currently looking into modelling with dynamic time steps to distinguish between normal hydrological behaviour and extreme events.

marijn.vandermeij@wur.nl

Wageningen University, Netherlands & Leibniz Centre for Agricultural Landscape Research (ZALF) Germany



Benito Bonfatti

Benito defended his thesis at Universidade Federal do Rio Grande do Sul, Departamento de Solos. Porto Alegre, RS. Brazil on February 15, 2017

Empirical and mechanistic models applied to digital mapping of soil attributes

The thesis that I was working aimed to present and evaluate different models which can be used in digital mapping of soil attributes. Firstly, different techniques from empirical models to predict and mapping were discussed. In sequence, techniques from mechanistic models were also evaluated. Two studies were presented. The first study involved an empirical model to predict and map soil organic carbon content and stocks. The objectives were to quantify and understand the spatial variation of SOC concentration by depth through digital soil mapping, and to assess the uncertainty, to quantify and map SOC stocks, and to estimate SOC changes due to land use change The second study used a mechanistic model to predict soil thickness and to evaluate the change in soil thickness over time. Different scenarios were developed and tested and the results were validated using measured soil thickness data. It was conducted in two steps. Firstly, we evaluated four different combined soil production – landscape evolution models to predict soil thickness. In the second step, soil thickness evolution was analyzed, by using the predicted soil thickness as input in a LEM. The studies were conducted in Vale dos Vinhedos, RS, Brazil. The empirical models depended from soil samples and results varied conform the method chosen, the soil samples number and representativity. The mechanistic models showed complexity and it was important to identify soil attributes tendencies, despite the impossibility to model all the phenomena involved during the pedogenesis. It was less dependent from soil samples and allowed a better understanding about the elements behavior involved. The change in soil thickness over time depended of the landscape position and the best function considered the moisture available varying spatially. Empirical and mechanistic models can be used in digital mapping of soil attributes, considering their advantages and respecting each technique limitations.

The potential of a soilscape evolution model appeared when combined a soil production function with a landscape evolution model to predict soil thickness or the soil thickness change over time, using a mechanistic model. The results showed that using the SPF and LEM to predict soil thickness is promising. Despite unknown processes at short time scales and uncertainty involving soil formation, the model showed trends in soil thickness variation over a catchment. However, the model has limitations. To predict soil thickness, the model needed to consider a soil thickness steady state condition, but in places with sediment deposition this condition does not appear. The influence of depositions could be modelled if we have a DEM of the past. Some studies tried to predict a DEM to the past, but it had several limitations.

The main functionalities lacking in the model are how to use a DEM representing the landscape in the past and how to estimate uncertainty. To know a past DEM would permit the estimation of several soil properties influenced by sediment deposition, using a landscape evolution model combined with different types of soil production functions. The uncertainty estimation could bring more confidence to the predictions. We developed our own model in R and soil management, land use evolution, original bedrock topography, flooded areas, terraces, correct uplift rates are factors that could be incorporated in future models.

benito.bonfatti@ufrgs.br
Universidade Federal do Rio Grande do Sul
Brazil

Bonfatti, B. R., A.E. Hartemink, E. Giasson, C.G. Tornquist, K. Adhikari. 2016. Digital mapping of soil carbon in a viticultural region of Southern Brazil. Geoderma, 261: 204-221.

Saba Keyvanshokouhi

Chasing soilscape modelling down the rabbit hole

If soilscape modelling in its ultimate form is the 3D reconstruction of processes that form the land, I am sitting on a small spot of this evolving landscape and looking down the rabbit hole, a pedon of soil.

How did I end up there?

The basic question to address in my PhD research is how does the soil evolve in response to the changing environmental factors, notably climate and land use.

This question can be approached using soil evolution modelling to allow, finally, soil change projections. This requires modelling efforts sensitive to the variations of the environmental factors and including the feedback mechanisms among physical, chemical and biological processes. Recent literature reviews (Opolot et al., 2015; Minasny et al., 2015) have shown that among all the available models, SoilGen (Finke, 2012) by far, is the only model that covers a wide range of all three process categories while simulating the flux of water and matter redistribution explicitly. These characteristics make SoilGen a good candidate to study the evolution of soil and project this evolution according to the predicted global change scenarios. However, SoilGen is a 1D, soil formation model and has never been used for projection means so far.

The sensitivity analysis and precision evaluation of this model proved its suitability and shed light on its limitations (Keyvanshokouhi et al., 2016; Opolot et al., 2015) such as:

- 1D Spatial domain: ignoring lateral processes and mechanisms
- Limited applicability depending on the soil parent material: including limited primary minerals in chemical weathering process and lacking the formation of secondary minerals
- Constant soil volume assumptions: ignoring the volumetric changes from strains
- Non-dynamic plant system: ignoring the effect of climate change and soil properties on plant growth and net primary product

To provide an environment to take steps toward the improvement of the model and communicate with other modelling communities (climate and ecology) to address the initial question, the model was implemented in a soil modelling platform, Vsoil.

Vsoil modelling platform (Lafolie et al., 2015), offers a mean to clearly define processes, provides tools to represent each process with various numerical definitions and automatically connects the processes to the selected modules to create a model consists of multiple processes, taking into account the feedbacks between them.

Providing these characteristics, and having modularity as its major feature, Vsoil platform is expected to facilitate addition/substitution/alteration of processes/modules inside complex models. Implementation of SoilGen model in such an environment provides opportunities for further investigation of the modelling needs as well as flexibility for improvements.

The comparison of two models and inter-comparisons in terms of runtime, sensitivity and functionality in response to different scenarios, soil compartment thickness and time step are examples of model investigation opportunities feasible through the platform.
Providing a modular environment to couple several models describing distinct processes to characterize a more complex system, in the case of SoilGen, coupling the model with a more sophisticated weathering model (WITCH; Godderis et al., 2006), and a more dynamic plant development module are some examples of model improvement opportunities.

Further on, platform features on grid definition (customised, non-uniform initial definition; variable through the simulation years), facilitate the remediation of constant volume constraint, which is a common limitation in most of the soil models today.
Overall, this implementation can be a start of investing more and more on modelling platforms such as VSoil which could provide an efficient tool to eventually connect the rabbit holes and make the 3D global view to address critical questions such as predicting the evolution of soil due to global change.

References:

Finke, P.A, 2012. http://dx.doi.org/10.1016/j.quaint.2011.10.016

Goddéris, Y., François, L. M., Probst, A., Schott, J., Moncoulon, D., Labat, D., Viville, D., 2006. http://dx.doi.org/10.1016/j.gca.2005.11.018

Keyvanshokouhi, S., Cornu, S., Samouëlian, A., Finke, P, 2016. http://dx.doi.org/10.1016/j.scitotenv.2016.07.119

Lafolie, F., Moitrier, Ni., Balesdent, J., Bruckler, L., Cousin, I., Maron, P.A., Moitrier, Na., Mollier, A., Nouguier, C., Pot, V. and Richard, G., 2014. The VSoil Platform: a tool to integrate physico-bio-geo-chemical models in soils at the local scale. Geophys. Res. Abstr 17. EGU General Assembly 2014, Vienna, Austria. 27 April - 2 May, 2014, ID. 3925.

Minasny, B., Finke, P., Stockmann, U., Vanwalleghem, T., McBratney, A. B., 2015. http://dx.doi.org/10.1016/j.earscirev.2015.07.004

Opolot E., Yu, Y. Y., Finke, P.A, 2015. http://dx.doi.org/10.1016/j.quaint.2014.02.017

saba.k.shokouhi@gmx.com
Cerege, Université Aix-Marseille & Ghent University
France & Belgium

Andrea Román

Evaluation of agricultural sustainability through long-term erosion and soil formation modelling

The main aim of this study is to model and quantify the different soil formation processes in a granitic area in Sierra Morena in South of Spain. We first analyzed the spatial variability of soil properties based on field sampling and traditional geostatistics. We then analyzed and quantified bioturbation and erosion-deposition. Next, we determined physical and chemical weathering patterns comparing different landscapes positions. Finally, we plan to integrate this information in a soilscape model like MILESD or LORICA. Currently, many soilscape models are missing field data for the validation.
The role of soil properties, especially organic carbon, in soil forming has been explored in a 2.7 km2 watershed. There is high heterogeneity in the spatial distribution of pools of soil carbon attributed to high spatial variability of stoniness and bulk density in mountainous areas. In this study, the samples analyzed were collected in 67 points up to 30 cm at 6 depths. Stoniness, bulk density and organic carbon were related with solar insolation, elevation, slope, curvature, TWI, TPI, SPI and NDVI. A random forest model was used to evaluate these relations. The results show NDVI and solar radiation as controlling factors in the spatial distribution of carbon stock with 4.38 kg m^{-2} on average and more than double on north facing than south facing slopes. The model validation

shows low correlation between these variables and, therefore, the spatial distribution of the carbon stock cannot be explained only with the vegetation and the topography, attributed furthermore to distribution bulk density and the stoniness depending on slope. (Román-Sánchez, A., et al., 2016)

Bioturbation is a crucial factor in the control of soil formation although poorly understood. We reconstructed the vertical and lateral soil movement in four soil profiles along a hillslope in our study area. Luminescence techniques were used for this purpose employing feldspar single-grain Infrared stimulated measurements (IRSL and post-IR IRSL). In this study, we selected feldspar because has a higher labour-efficiency and more luminescence sensitivity than quartz. (Reimann et al. 2017 submitted). This technique assesses the last time that the sample was exposed to the surface. A total of 15 samples were collected in all soil profiles at 5 cm, 20 cm, 35 cm and 50 cm. This study not only calculates the burial age of the soil samples, but also the effective soil mixing based on the proportion of grains that lead the soil mixing or grains that have been exposed to the surface (non-saturated grains). Furthermore, this allows objectively establish the boundary between the mobile regolith and saprolite. This work was carried out in collaboration with Dr. Tony Reimann and Dr. Jakob Wallinga, Soil Geography and Landscape group & Netherland Centre for Luminescence Dating (NCL), Wageningen University.

In order to quantify the bioturbation and erosion-deposition rates along the hillslope, we used an analytical model employing the diffusion-advection equation to fit our age-depth results in each soil profile. A global sensitivity analysis was performed to evaluate the importance of the diffusivity constant and erosion-deposition term in the model. An uncertainty analysis was carried out to determine the degree of uncertainty in parameter estimation.

The vertical particle size distribution was sampled in 10 soil profiles in our study area. We then fitted this data to a vertical particle size distribution model to stablish the patterns that govern bedrock weathering in collaboration with Dr. Garry Willgoose, Centre for Climate Impact Management, University of Newcastle, Australia.

The chemical weathering was analyzed in 10 soil profiles and the results reveals different patterns depending on the soil landscape position.

Finally, we plan to use all this information in soilscape models (MILESD, LORICA) or in a new model integrating also the paleoclimate to help estimating better the long-term soil formation processes.

References:

Román-Sánchez, A., et al., Controls on soil carbon storage from topography and vegetation in a rocky, semi-arid landscapes, Geoderma (2016)

Reimann, T., et al., Getting a grip on soil reworking; single-grain feldspar post IR IRSL as a novel tool to quantify soil reworking rates. Quaternary geochronology (submitted 2017)

aromansanchez@gmail.com
Universidad de Córdoba
Córdoba, Spain