Modelling of soil and landscape evolution, state of progress. 14-9-2015, Cordoba

Go to:

Workshop program	*Workshop discussion*	*Proposed follow-up*

Workshop program

10:15	10:30	Opening and scope of the day / *Peter Finke*
Presentations on soil-landscape evolution models		
10:30	10:45	Model for the interaction between landscape evolution and soil development (**MILESD**) / *Tom Vanwalleghem*, Uta Stockmann, Budiman Minasny, Alex McBratney
10:45	11:00	**LORICA**: Soil-landscape co-evolution model / *Arnaud Temme*, Tom Vanwalleghem
11:00	11:15	Mathematically modelling the dynamics of soil profile evolution, its coupling with erosion and landform evolution, and potential applications in better defining environmental processes **(mARM3D)** / *Garry Willgoose*, Dimuth Welivitiya, Greg Hancock, Sagy Cohen, Natalie Lockart
11:15	11:30	Soil landscape modelling: **Speros-C/LT** mechanistic 3D landscape model /*Samuel Bouchoms*, Kristof Van Oost
11:30	11:45	Modelling soil profile evolution under global change with **SOILGEN** / *Peter Finke*
11:45	12:00	The international soil modelling consortium ISMC / *Jan Vanderborght*, Andrea Schnepf, Harry Vereecken
Model demo's		
13:45	14:15	**SOILGEN** / *Emmanuel Opolot*
14:15	14:45	**mARM3D** / *Garry Willgoose*
14:45	15:15	**LORICA** / *Arnaud Temme&Tom Vanwalleghem*
15:15	16:00	**Discussion:** What are challenges given the current status of soilscape modelling?

Model demos are accessible via http://soillandscape.org/model-downloads-and-demos/

The discussion was structured around a number of questions that are related to the issues raised in review paper http://dx.doi.org/10.1016/j.earscirev.2015.07.004

Summary of discussions and conclusions

CHALLENGES 1: PROFILE MODELS

i. Quality of process descriptions?

Conclusion(s)

The quality of process descriptions is a concern of the modeler but end-users of the model will likely put emphasis on functional properties of the soil as can be deduced post-processing, e.g. available water, filtering, etc. Having model outputs converted to for example ecosystems services would be of great interest, and the accuracy of such results needs to be high. Thus there is need to have contact and work with ecosystems services experts.

ii. Process coverage?

Q: How are situations with changing subsurface hydrology dealt with in SoilGen (e.g. changing water table depths)

A: They can be dealt with via an input of the average water table depth in a particular year, which is converted by the model to a layer of low hydraulic conductivity, with water stagnating on top of it. Normal boundary condition is free drainage.

Q: Is simulation forward or backward in time? What is the target, only the final state? Because patterns along the timeline could also be of interest.

A: it is forward and yes certainly patterns are important.

Conclusion(s)

After discussion it is concluded that process coverage is important to increase. As an example was mentioned the fate of "deep" carbon such as may occur in Podzol soils, thus (de-) podzolisation processes should be included.

iii. Calibration options?

Q: When calibrating the model are you also thinking about validating it?

A: Yes but both for calibration and validation, the major issue is that data for comparison usually reflect the present situation. There is usually limited information about past system states and therefore one tunes model parameters to arrive at the present situation. This may produce parameter estimates that are do not represent intermediate stages. So it is indeed more of a data problem. What is probably of interest to the modeling community is that luminescence data and radioactive nuclide data are increasingly available and could be incorporated in profile models and help to calibrate some processes e.g. bioturbation.

However we should also be aware that there are lots of assumptions behind the radionuclides and OSL data interpretation. One could also look at elemental concentration (such as Al, Si, Ti, Zr) which now can be measured using a portable XRF instrument.

Conclusion(s)

Data used for calibration/validation should cover the time domain as much as possible, and this puts emphasis on sampling of chronosequences, and simulating additional parameters that can be measured (luminescence, radionuclides) and that are actually integrators over time. Thus the temporal "depth" of the calibration is extended. Perhaps the Pedometrics sampling/monitoring communities can contribute to progress here.

iv. How to go 3D?

Q: What processes slow for example the 3D models?

A: Water erosion, mass balancing processes. While in 1-D models water flow is the time-limiting process. Will coupling result in the worst of both worlds? Faster computers are increasingly becoming available and could solve the computational costs involved with coupling 1D and landscape models, but there also data demands that increase (e.g., lateral hydraulic conductivity).

Conclusion(s)

This could be possible by simplifying some processes. Which processes then depends on the question that is addressed and what processes are important in that respect.

Another possibility is rasterization. This also depends on the type of coupling needed.

A third possibility is running 1-D models distributed across a landscape, and material transport linked with a landform evolution model.

v. Data scarcity problems

Q1: A lot of inputs appear to be needed for detailed profile models, how does it affect the application of the model to new areas, how to solve the data problem?

A1: Initial data may not be that of a problem when the run covers a long period, at least for many soil parameters, because the sensitivity of the model to initial soil data may be limited. However this is not always the case. In principle realistic reconstructions of the initial situation could solve the initial data problem (e.g. by sampling parent materials). Here is potentially a link to the Critical Zone Observatory (CZO) network, which mainly focuses on detailed measurement at sites. Thus CZO may provide highly useful data for profile models. As little emphasis is on spatial variation, CZO-data have less potential for landscape and soilscape evolution models.

Q2: And how can one account for the effect of multiple processes, can one recognize the overprinting effect?

A2: Yes, in principle one can see overprinting effects by evaluating time-depth diagrams. Ref to a case in Finke and Hutson 2008 where land use change would induce a second phase of clay migration (resulting in further depletion of E-horizon and growth of Bt horizon). Correctness of such outcomes could be checked by thin section analysis. Usually such evaluations need to be qualitative.

CHALLENGES 2: LANDSCAPE EVOLUTION MODELS

i. What are essential soil processes?

Response: The formulation of erosion processes can be improved via formulations of infiltration and relation to vegatation.

Conclusion(s)

Particularly the infiltration process as affected by soil structure has hardly been modelled, in fact no model explicitly models soil structure untill now. There is need to incorporate this mechanism in our soil models however simple it may be. Someone has to get started!

Vegetation also needs to be taken into account seriously in landscape models. Vegetation process influences several soil processes influencing the water balance such as water uptake, development of soil structure (through OM input), interception evaporation etc.

ii. **How to improve process parameterization?**
(no notes / no discussion)

iii. **Static or dynamic boundary conditions?**
(no notes / no discussion)

iv. **What feedbacks to other ecosystem components are needed?**
(no notes / no discussion)

CHALLENGES 3: SOILSCAPE EVOLUTION MODELS

i. **What boundary conditions for GC-ready soilscape evolution models?**

Conclusion(s)

Temperature and moisture dynamics should be represented explicitly (as well as land use dynamics). Soil moisture dynamics / water flow should be included in these models. Major difficulty is that spatio-temporal reconstructions are very complex and remain associated with uncertainty. Including the above processes will allow simulation of processes like clay illuviation, decalcification etc. in soilscape evolution models.

ii. **Performance issues:**

How to manage trade-off between complexity and process coverage, how to optimise model code performance?

Conclusion(s)

A partial answer might be in focusing modelling efforts on deriving appropriate time steps or -scales. Time steps might either be fixed or flexible. There clearly is a link with the question to be answered and the associated main processes and its dynamics.

Another approach may be to structure the model in such way that, during runtime, the model keeps track of the position in parameter space and retrieves results from a database where simulation results of a previous visit to this position in parameter space are stored.

iii. **Link to / integrate with other areas (vegetation models, climate models…)**

Linkage to work on land surface models (c.f. Jed Kaplan's work) is needed.

iv. **What are the main drivers of spatial heterogeneity?**

Conclusion(s)

From a research perspective, covariation between simulated parameters should be systematically identified to find such driver, because it is not always due to landscape position only.

Several drivers are mentioned (and incorporation of these drivers will allow for a better representation of developing spatial heterogeneity):

- Vegetation variation and associated feedback mechanisms, e.g., high OM, high infiltration because of improved soil structure can cause heterogeneity to develop. Similarly, soil chemical status could respond at the same spatial scale, thus affecting vegetation and litter/OM input and eventually its associated feedbacks.
- Variations in runoff processes could also be responsible
- More generally, spatial heterogeneity could be initiated by non-linear response to events (or the crossing of thresholds) e.g. cultivation, treefalls etc.

v. Process coverage

Process coverage should be widened. Still, in soilscape evolution models, not all the processes cited in the classical paper from Mike Kirkby, 1976 are yet covered. Special reference is made to the geochemistry which appears to have been adequately formulated in this paper already at that date.

CHALLENGES 4: MODEL CALIBRATION AND VALIDATION

i. **How to optimize sampling/monitoring for calibration?**

Conclusion(s)

Sampling in terraces, chronosequences. Although it is a difficult task to get good /quality data. See also Challenge 1, discussion point iii.

ii. How to increase the temporal depth of model testing?

See also Challenge 1, discussion point iii.

iii. How to tailor methods for sensitivity analysis and calibration (models with fast / slow runtimes)?

Conclusion(s)

In soilscape models, focus should be on stable landscape components for calibration and application of derived parameter values elsewhere. Sensitivity analysis and Calibration should take a limited sample of parameter space (e.g., Latin Hypercube sample) in case simulation time is limiting, if this is not the case then Monte-Carlo or Bayesian approaches are feasible. The fact that this is not done yet, illustrates that it is still challenging.

Proposed follow-up activities of the IUSS-working group on modelling of soil and landscape evolution

Given the major discussion points and conclusions, further activities of the WG could focus on:

1. increasing the user community
2. increasing process coverage of soil profile and soilscape evolution models
3. increasing focus on options and data for calibration and validation

Ad 1: A proposal is to organize an international PhD-course on soil-landscape modelling in the fall of 2016 (October or November). Partly talks, partly hands-on modelling activities.

Ad 2: This could be a topic for EGU sessions in future years, or pedometrics 2017

Ad 3: Options and data for calibration and validation of soilscape models could be a theme in the Pedometrics conference 2017 (June 26– July 1 Wageningen). Announce timely so that we trigger some case studies.