Landscape - Soilscape Evolution Modelling: LAPSUS

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Abstract
Landscape evolution modelling can make landscape evolution hypotheses explicit and theoretically allows for their falsification and improvement. Ideally, landscape evolution models (LEMs) combine the results of all relevant landscape forming processes into an ever-adapting digital landscape (e.g. DEM). These processes may act on different spatial and temporal scales. LAPSUS is an example of such a LEM. In multiple study cases different landscape processes have been included in LAPSUS: water erosion and deposition, landslide activity, creep, solifluction, weathering, tectonics and tillage. Besides properties of soils influencing landscape forming processes, vegetation effects can also be included. Process descriptions are kept as simple and generic as possible, ensuring wide applicability of the modelling approach. Interactions between processes are turn-based: soil redistribution caused by one process are calculated and used to adapt the DEM before another process is simulated. LAPSUS uses multiple flow techniques to model flows of water and sediment over the landscape. Though computationally costly, this gives a more realistic result than steepest descent methods. In addition, the combination of different processes may create sinks during modelling. Since these sinks are not spurious, the model has been adapted to deal with sinks in natural ways. This is crucial for several purposes, for instance when studying damming of valleys by landslides, and subsequent infilling of the resulting lake with sediments from upstream.

Key Words
Landscape Evolution Modelling, LAPSUS, soil redistribution, erosion.

Introduction
This short paper summarizes ongoing and completed work with the LAPSUS model and foreseen developments in the near future. LAPSUS is a landscape evolution model (LEM) that combines the effects of multiple landscape forming processes, including soil formation, into one dynamic landscape modelling framework. Spatial and temporal extent and resolution may vary from slope, catchment to basin, processed grid cells from 1 to 1000 m^2, timesteps of multiple events, seasons, years, decades and simulation periods from years to millennial time scales.

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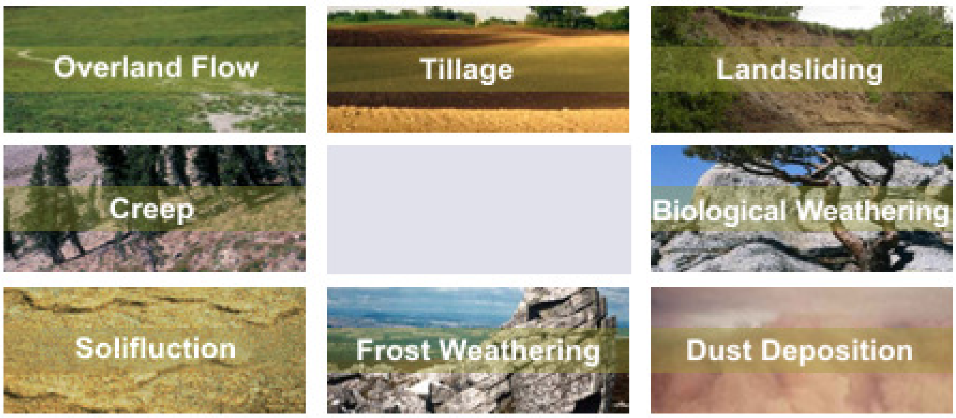

Figure 1. Overview of processes incorporated in the LAPSUS modelling framework (see also www.lapsusmodel.nl).

Besides properties of soils influencing landscape forming processes, vegetation effects can also be included. Process descriptions are kept as simple and generic as possible, ensuring wide applicability of the modelling approach. LAPSUS uses multiple flow routing techniques to model the flow of water and sediment over the landscape. This is computationally costly, but yields a more realistic result than steepest descent methods, especially when combining multiple processes over multiple timesteps.

The combination of different processes may create sinks during modelling. Since these sinks are not spurious, the model has been adapted to deal with them in a natural way. This is crucial when studying damming of valleys by landslides, and subsequent infilling of the resulting lake with sediments from upstream.

Results and discussion

LAPSUS has been used for erosion and landscape evolution studies in many landscapes in many countries over the last years. The development of LAPSUS started in 2000 with the programming, calibration and validation of the LAPSUS model and applications concerning land use in Spain and Ecuador (Schoorl *et al*. 2000, 2002, 2004, 2006; Schoorl and Veldkamp 2001, 2006). Later, the model has been extended in order to include soil redistribution by landsliding in New Zealand and Taiwan (Claessens *et al*. 2005, 2006a, 2006b, 2007a, 2007b). In addition, issues of DEM resolution and the treatment of sinks and pits in the landscape have been investigated (Temme *et al*. 2006, 2009a) as well as stretching the models time scale to landscape evolution time spans, for example in South Africa (Temme and Veldkamp 2009; Temme *et al.* 2009b). Different applications with individual processes have been developed, for example, the model has been used in regional nutrient balance studies in Africa (Haileslassie *et al*. 2005, 2006, 2007; Roy *et al*. 2004; Lesschen *et al*. 2005). The model has also been applied in desert environments in Israel (Buis and Veldkamp 2008);it has been used in combination with geostatistical tools and tillage in Canada (Heuvelink *et al*. 2006), and to investigate the faith of phosphor in the landscapes of the Netherlands (Sonneveld *et al*. 2006).
Recent developments and directions with the LAPSUS model are:

- Connectivity, agricultural terraces and land abandonment (Lesschen *et al*. 2007, 2009).
- Interactions and feedback mechanisms between land use and soil redistribution (Claessens *et al*. 2009).
- Effects of hydrological engineering on soil redistribution in large fluvial systems (Viveen *et al*. 2009)
- Erosion in a landscape evolution context, comparing event based and long term based models: LISEM and LAPSUS (Baartman *et al*. 2009).
- Refining the LAPSUS temporal resolution. Modelling daily sediment yield from a meso-scale catchment, a case study in SW Poland. (Coevert-Keesstra *et al*. 2009)
- Land sliding in mountainous areas. Landscape Dynamics: Calibrating landscape process modelling with Caesium-137 data, separating water driven erosion from landslides? See (Schoorl *et al*. 2009).
- 3D river gradient modelling. Quaternary tectonics, sea level and climate change: the case of the river Miño (Viveen *et al*. 2009).
- Coupling and interaction with TOA modelling. A novel site-specific methodology to assess the supply curve of environmental services (Stoorvogel *et al*. 2009; Claessens *et al*. in prep).

Conclusion

Landscape evolution modelling allows for confirmation, falsification or improvement of landscape evolution hypotheses and can make the consequences temporally and spatially explicit. Ideally, landscape evolution models (LEMs) combine the results of all relevant landscape forming processes into an ever-adapting digital landscape model These processes may act and interact on different spatial and temporal scales. The LAPSUS modelling framework is an example of a LEM that has embedded multiple landscape forming processes and their interactions in a generic tool that can be used to study many landscapes of the world at multiple temporal and spatial scales.

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