First results of a combined soil-landscape model

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Introduction and motivation

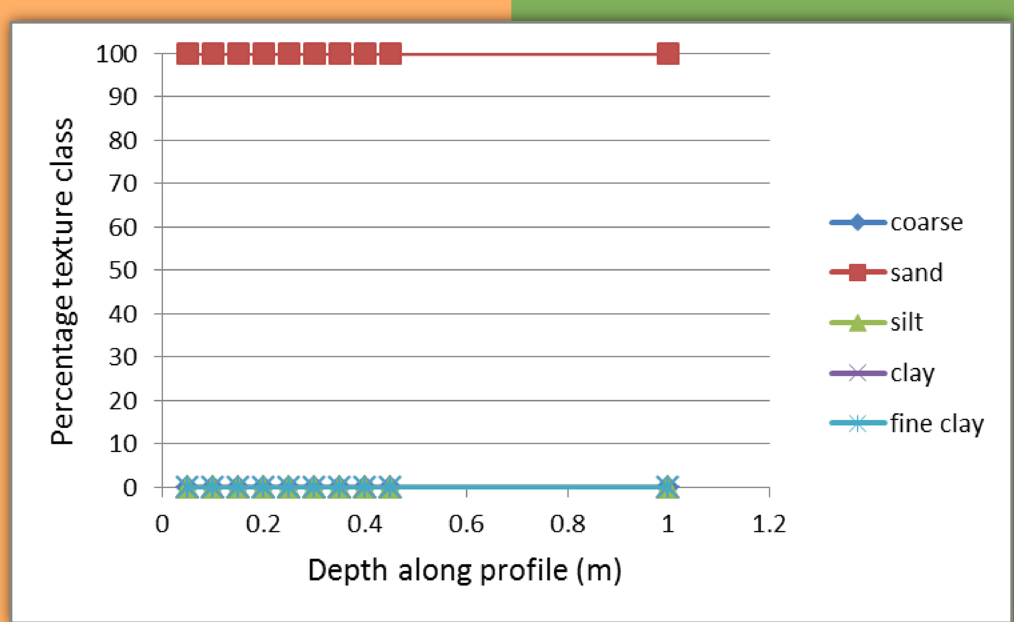
The formation of soils and evolution of landscapes over time are closely coupled. Erosion and lateral sediment redistribution impact soil profiles in hilly and mountainous areas and changes can be very rapid due to human-induced land use changes. On the other hand, key soil properties, such as depth and texture, are crucial for understanding the geomorphic response of landscapes. Also for understanding biogeochemical fluxes at the soil profile and landscape scale, a coupled approach is crucial. At present, it is hypothesized that many of these processes are controlled by thresholds and respond in a non-linear manner. There is therefore an increasing need for models that integrate both processes and mimic this complexity.

Here, we present a new coupled model of the co-evolution of soils and landscapes. This model is based on landscape evolution model LAPSUS and includes the soil forming processes represented in the model MILESD. The model allows the formation of a vertical soil profile with a user-specified number of layers. The soil forming processes included are soil formation from bedrock, physical and chemical weathering, bioturbation, clay neoformation and clay lessivage. Landscape evolution processes represented are water erosion, tillage erosion, landsliding, creep, solifluction and simplified tectonics.

Soil development | Landscape development

Isolated simulation | Combined simulation | Isolated simulation

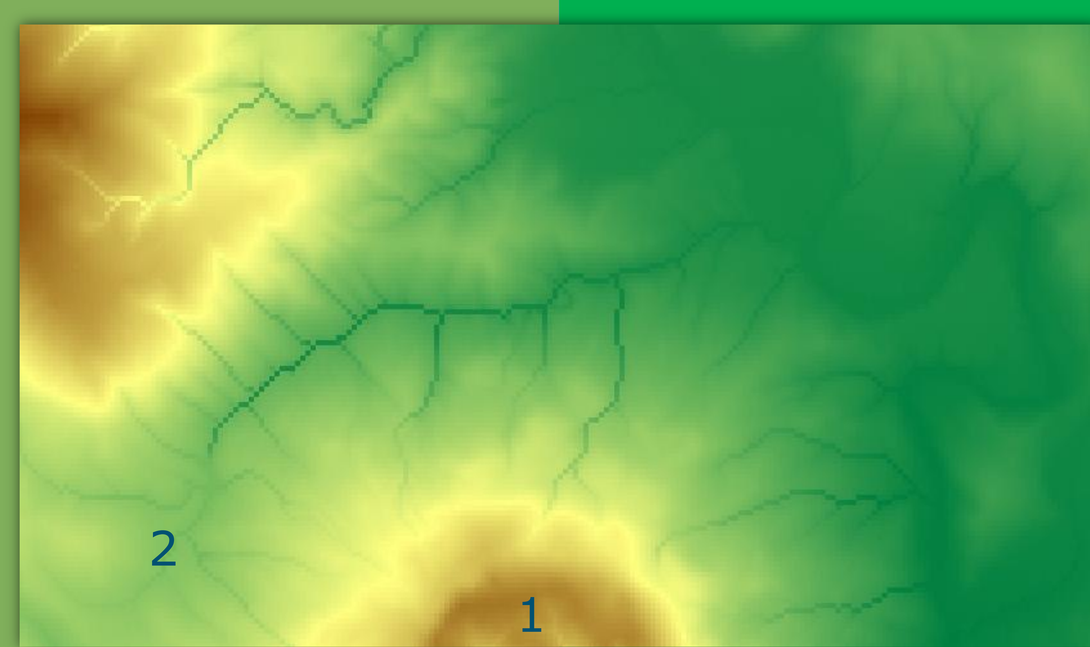
Inputs



A 1m deep, pure sand soil, uniform over the study area

Climate:
700 mm rainfall
150 mm infiltration
350 mm evaporation

Control parameters:
5k years
10 soil layers
Defaults for processes



A 25m resolution DEM from SE Spain (214 * 128 cells)
Soil development was recorded at locations 1 and 2.

Processes

(**bold** were activated)

Soil development:

Rock weathering (Dietrich et al ,1995)
Physical weathering (Salvador Blanes et al, 2007)
Chemical weathering (Vanwalleghem et al, 2013)
Clay neoformation (Vanwalleghem et al, 2013)
Clay e- and illuviation (Legros, 1982)
Bioturbation (Yoo et al, 2011)
Carbon cycle (two classes, Minasny et al, 2008)

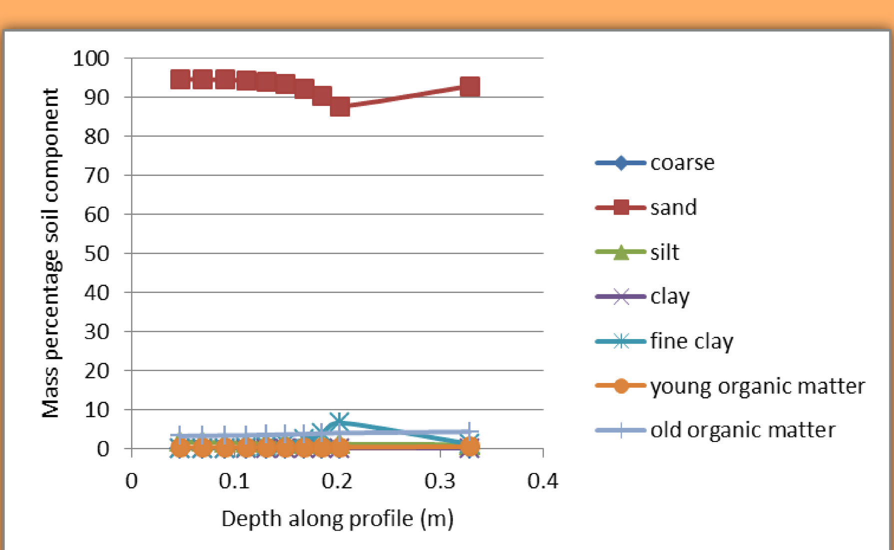
Model structure:

User defined number of layers, thinner at the surface
Layers contain soil material, have bulk density and change their thickness (within limits) as processes change them. Layers are combined when too thin, split when too thick. If needed, the two most similar layers are combined to avoid loss of information

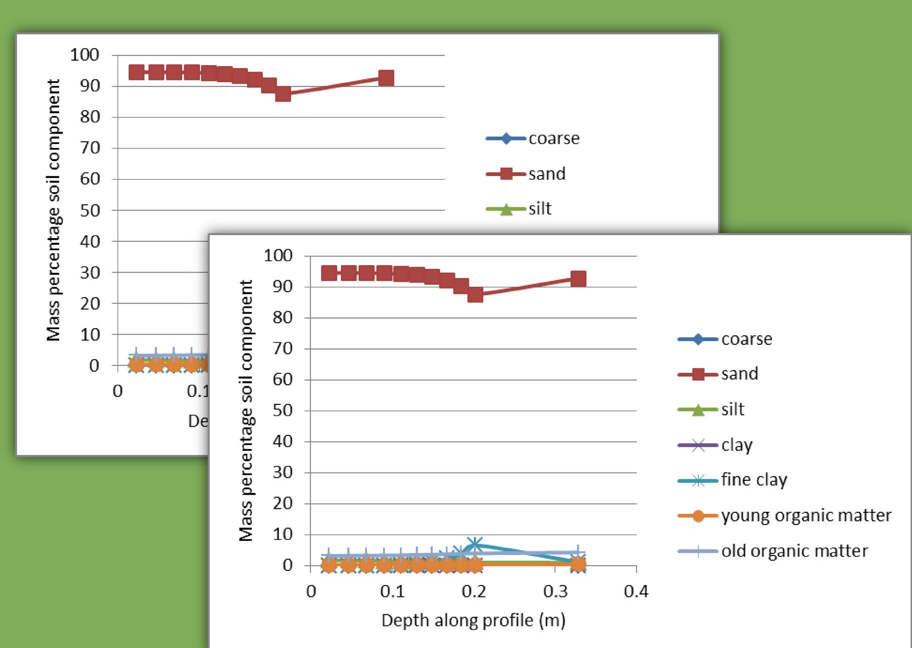
Landscape development:

Water erosion and deposition (Schoorl et al ,2002)
Tillage (Govers et al, 1996)
Creep (Follain et al, 2006)
Landsliding (Claessens et al, 2007)
Solifluction (Temme et al, 2009)
Tectonics (tilting, uplift

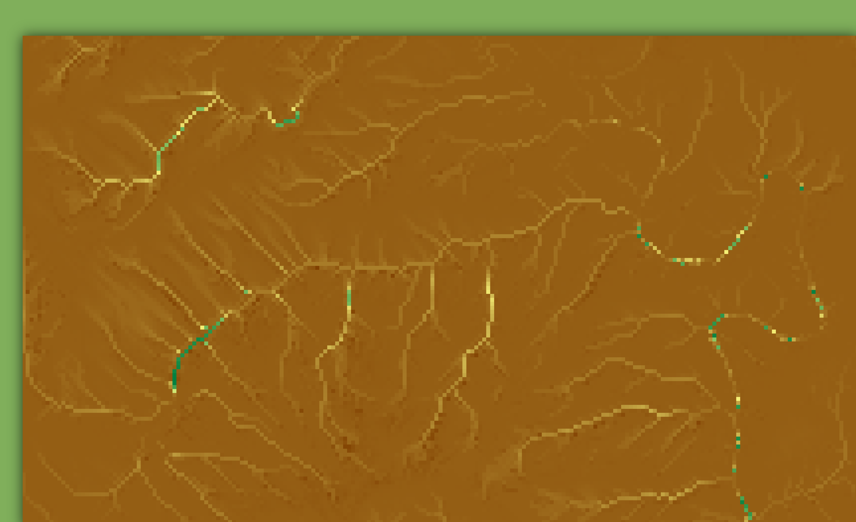
Outputs



After 5k years, uniformly over the study area, incipient weathering of sand, production and transport of fine clay to a depth of about 0.2m. Without geomorphic activity, a soil dominated by clay illuviation is likely to develop over time. Old organic matter is accumulating. Soil has thinned during simulation and layers have adapted to thinning.



In the combined simulation, soil development is very similar to that without geomorphic activity. Differences are in the order of mass percentages after 5k years. Apparently, in this early state of development and with this remarkable initial soil, landscape development is more sensitive to soil development than vice versa.



In the combined simulation, the weathering products of the sandy soil (silt and clays) are easier to erode. After 5k years, more erosion is Visible along the smaller drainage lines. Maxima (+- 10 cm) and minima (zero) remain the same. Total erosion from the catchment has increased.

After 5k years, erosion is significant along the drainage lines (+- 10 cm). Most other areas are only weakly affected (brown colours indicate near-zero values for erosion). Deposition is absent given the detachment-limited settings.

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