Modification of the Revised Morgan–Morgan–Finney model for estimating sediment yield in large river basins

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1. The RiNux model

The RiNux model has been developed to simulate and predict monthly nutrient fluxes from land to coastal waters under various scenarios of global change. The RiNux model consists of different modules for simulating the hydrology, sediment transport, and nutrient transport within river basins at a 3 km resolution using available global data sets for input variables.

The sediment transport module simulates the supply of sediment from the hillslopes to and transport through the river network. It accounts for sediment detachment and transport capacity on hillslopes, transfer to and transport in the river channel network, conveyance losses due to sediment deposition in lakes and reservoirs, and overbank sedimentation on floodplains (Fig. 1).

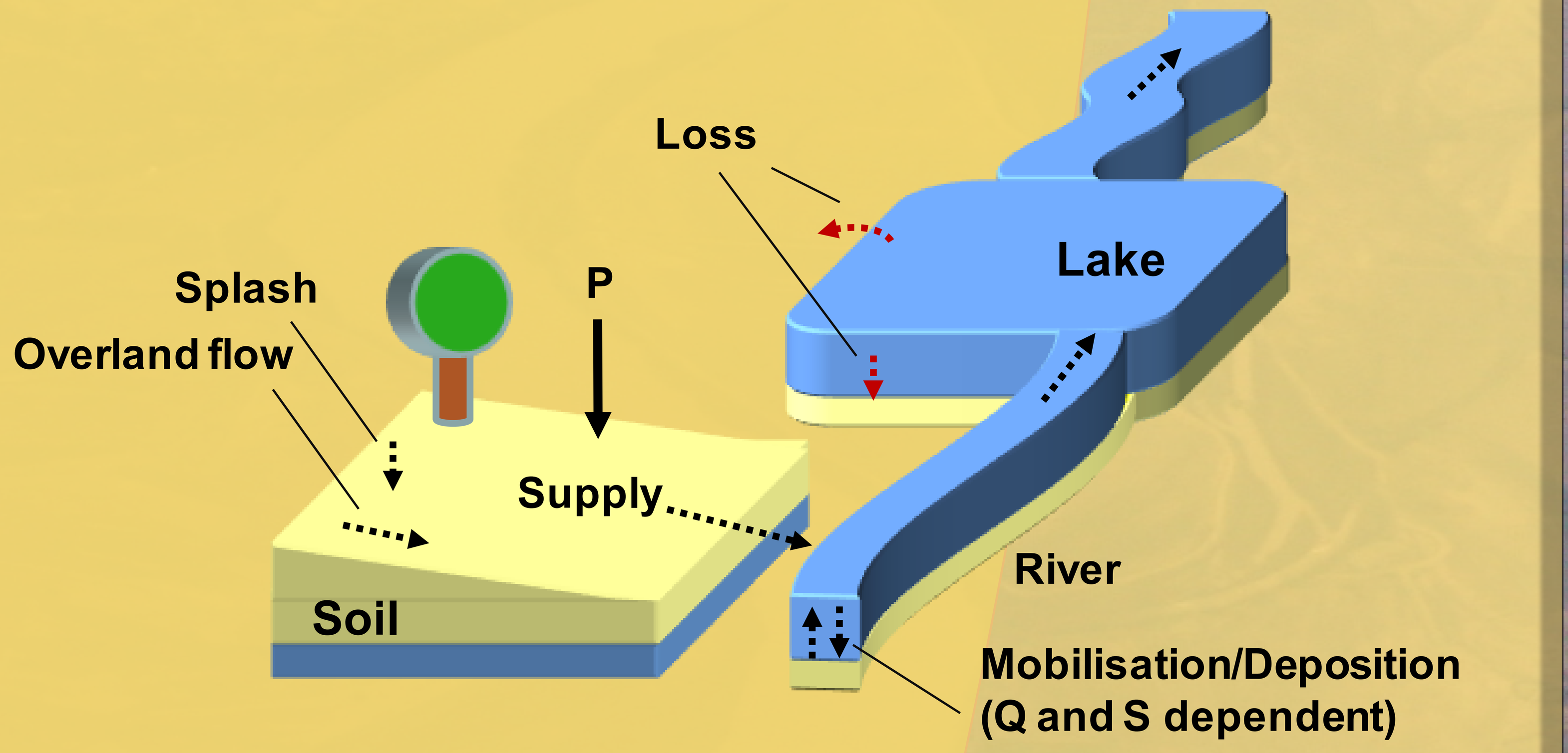
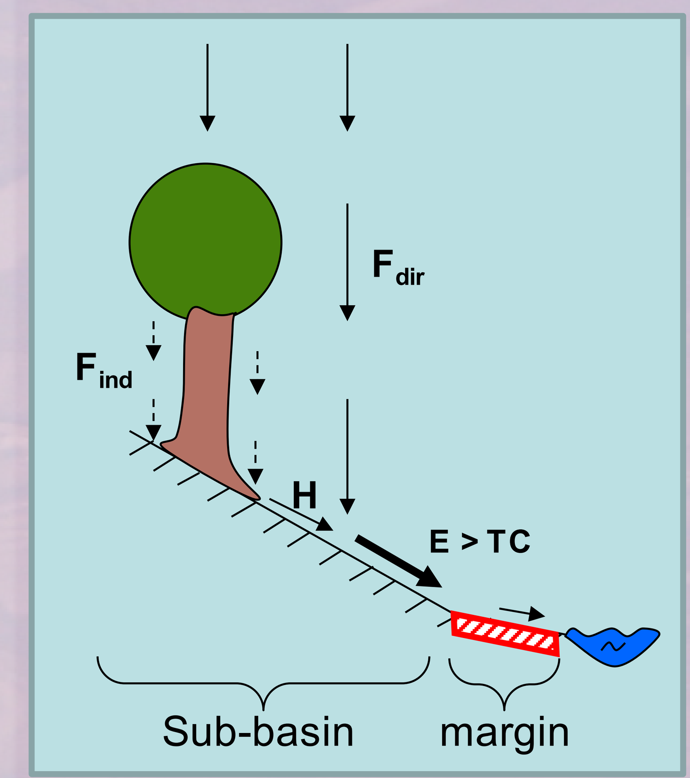


Fig. 1. Processes accounted for in the RiNux sediment transport module.

2. Spatial and temporal scaling

To estimate sediment supply from hillslopes to the river network, we employed an adapted version of the Revised Morgan–Morgan–Finney (RMMF) model (Morgan, 2001). The RMMF model is intended for the prediction of annual soil loss in small-scale catchments.

Therefore, we accounted for the difference in scales between the RMMF and RiNux models by introducing appropriate scaling parameters for both spatial upscaling (from the original approximately 100 m resolution to the 3 km RiNux model resolution) and temporal downscaling (from an annual to a monthly resolution) (Fig. 2).



F= splash erosion; H= overland flow erosion; E = total erosion; TC = transport capacity

$$H = \alpha_1 \cdot \alpha_2 \cdot A \cdot \frac{1}{0.5 \cdot COH} \cdot Q_{subcatchment}{}^{\lambda} \cdot \sin S$$

$$TC = \alpha_1 \cdot \alpha_2 \cdot C \cdot A \cdot Q_{subcatchment}{}^{\lambda} \cdot \sin S$$

where H = flow detachment (kg month^{-1}); TC = transport capacity (kg month^{-1}); A = average area of the subcatchments draining into the channel wihin a model grid cell (see Fig. 3) (m^2); $Q_{subcatchment}$ = average discharge (mm month^{-1}); λ = exponent (λ = 1.5 for H and λ = 2 for TC); S = average slope gradient in the subcatchments; C = a crop factor; a_1 and a_2 are scalings parameters for spatial upscaling and temporal downscaling, respectively:

$$a_1 = n_{unit}{}^{1-\lambda} \quad \text{and} \quad a_2 = 12^{\lambda-1}$$

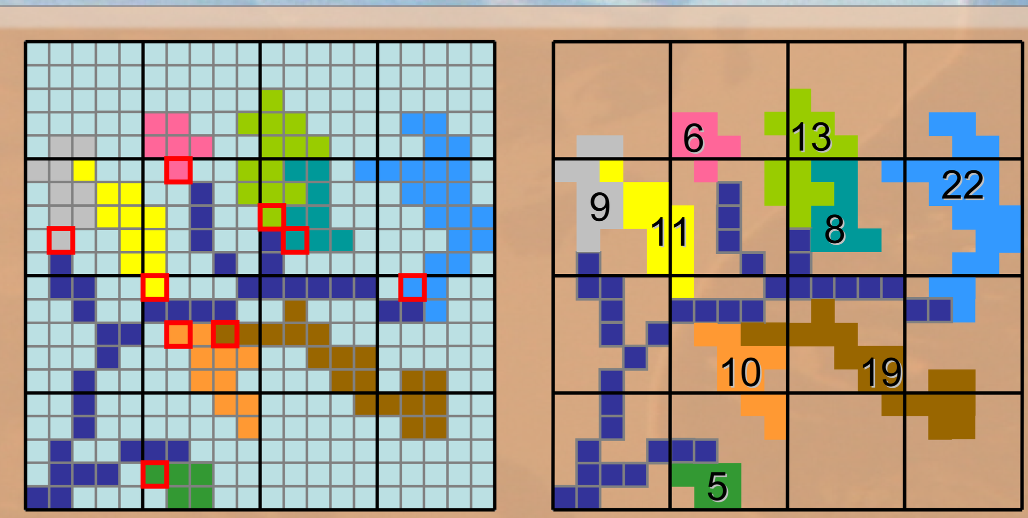
where n_{unit} is the average the number of ~100 m resolution units (e.g.SRTM grid cells) in the subcatchments draining into the channel wihin a model grid cell.

Fig. 2. Scaling of the RMMF soil loss in the RiNux model

3. Transport capacity in the riparian zone

In addition, the RiNux sediment module accounts for the limitation of the transfer of sediment from the hillslopes to the river channel due to the generally low slope gradients in the riparian zone.

For this, we introduced an additional transport capacity parameter for the riparian zone, which was estimated taking into account the sub-grid variability using the SRTM digital elevation model (~ 90 m ×90 m). The transport capacity of the riparian zone was calculated from the average slope gradient corrected for slope concavity/convexity in the SRTM grid cells adjacent to the river channel cells (Figs. 2 and 3).



0	0	0	0
9	6	11	0
0	14	0	22
0	5	0	0

SRTM (90 m) DEM (3 km) mean area *(A)*

Fig. 3. Upscaling subgrid (SRTM) information to the model grid cells.

4. Model results

Test runs for three large river basins in contrasting climate zones (Mississippi River, Rhine River, and Mekong River) showed that the sediment module is capable to reproduce the seasonal pattern of sediment fluxes at various locations within these river basins and to predict the absolute sediment fluxes within a factor of 3 (Fig.4).

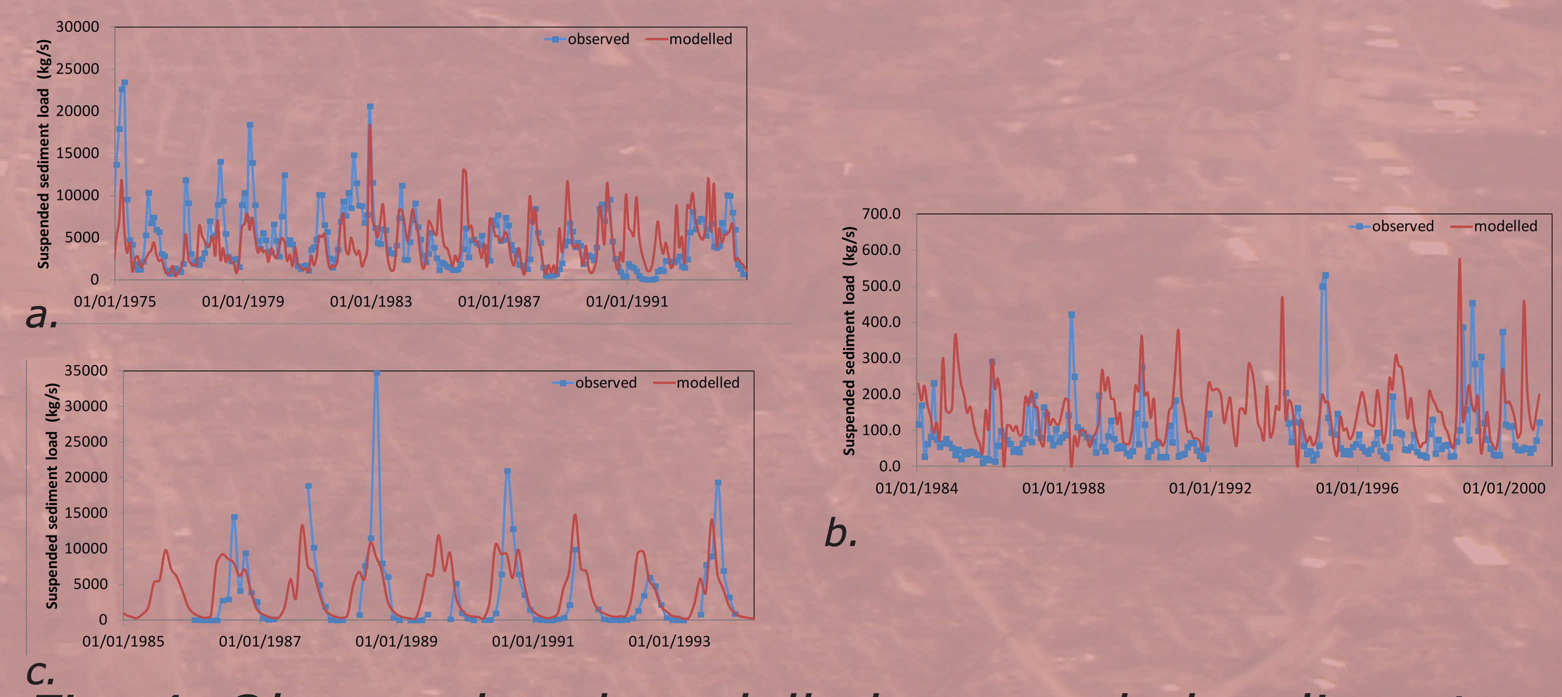


Fig. 4. Observed and modelled suspended sediment loads for the a) Mississippi River (Vicksburg), b) Rhine River (Lobith, and c) Mekong River (Pakse)..

Reference

Morgan, R.P.C., 2001. A simple approach to soil loss prediction: a revised Morgan–Morgan–Finney model. *Catena* **44**, 305–322.

Source: D. Searls / Flickr