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

Sibren Loos¹, Marcel van der Perk², Ludovicus P.H. van Beek² & Hans Middelkoop²

¹Deltacs, P.O. Box 177, 2600 MH Delft, The Netherlands; email: sibren.loos@deltacs.nl
²Department of Physical Geography, Utrecht University, P.O. Box 80115, 3508 TC Utrecht, The Netherlands; email: m.vanderperk@uu.nl

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 network, conveyance losses due to sediment deposition in lakes and reservoirs, and overbank sedimentation on floodplains (Fig. 1).

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).

\[ H = a_1 \cdot a_2 \cdot A \cdot \left( 0.5 \cdot \frac{Q_{subcatchment}}{C} \cdot \sin S \right) \]
\[ TC = a_3 \cdot a_4 \cdot C \cdot \left( A_{subcatchment} \right) \cdot \sin S \]

where \( H \) = flow detachment (kg/month); \( TC \) = transport capacity (kg/month); \( A \) = average area of the subcatchments draining into the channel within a model grid cell (see Fig. 3) (m²); \( Q_{subcatchment} \) = average discharge (mm/month); \( A \) = exponent (\( A = 1.5 \) for \( H \) and \( A = 2 \) 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 \( a_3 \) and \( a_4 \) are scalings parameters for temporal downscaling, respectively.

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 x 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).

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 x 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).

Reference