Soil erosion modeling at small reservoir scale by WaTEM/SEDEM

Authors

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Scope

Reservoir siltation is an important "off-site" consequence of soil erosion. When fertile topsoil is eroded from hillslopes, it is transported downstream and ultimately accumulates in valleys and reservoirs. The loss of nutrient-rich topsoil can reduce the productivity of hillside agricultural systems, while siltation of small reservoirs lessens their functionality. This tool uses soil erosion models to simulate soil erosion and sedimentation rates at the catchment scale and to produce soil erosion hazard maps. These maps can help identify suitable locations for implementing soil conservation techniques.

Target group

Soil scientists, geographers, water resources planners

Requirements for application

- Digital elevation model; soil map; land use/cover map (e.g. based on vegetation cover classification by remote sensing images); flow network map; road map
- Climate data (rainfall amount and intensity)
- Computer facilities and erosion modelling software (WaTEM/SEDEM download for free: http://www.kuleuven.be/geography/frg/modelling/erosion/watemsedemhome/index.htm).

Description and application of the tool

The spatially distributed soil erosion and sediment delivery model WaTEM/SEDEM is a combined version of two empirically-based soil erosion modes, namely WaTEM (Water and Tillage Erosion Model; Van Oost et al., 2000) and SEDEM (Sediment Delivery model; Van Rompaey et al., 2001). Both models have been developed by the physical and regional geography research group at the University of Leuven, Belgium. They can be applied at small catchment, watershed and regional scale under a wide range of environmental conditions (e.g. Van Rompaey et al., 2005, 2007; Verstraeten et al., 2002, 2007; Verstraeten and Prosser, 2008). The main aim of the model is to predict sediment delivery to river channels and to simulate transport and deposition within a drainage basin. The model focuses on spatial variability and is useful in estimating the spatial patterns of soil loss and sediment flow across land units.

The model consists of two modules, a water erosion prediction component and a sediment delivery model.

The first module calculates soil loss related to water erosion based on an adapted version of the RUSLE (Revised Universal Soil Loss Equation, Renard et al., 1997).

$$A = R*K*LS*C*P$$

Where A: average annual soil erosion rate (t $ha^{-1}t\ y^{-1}$); R: rain erosivity factor (MJ mm $ha^{-1}h^{-1}y^{-1}$); K: soil erodibility factor (t h $MJ^{-1}mm^{-1}$); LS: topographical slope and length factor (dimensionless); C: crop management factor (dimensionless) and P: erosion control factor (dimensionless).

The individual factors for K, C, R and P are calculated using standard RUSLE procedures. The topographic factor LS is adjusted with a two dimensional routing algorithm (Van Oost et al., 2000) to account for interrill, rill and ephemeral gully erosion (Desmet et al., 1999).

The second module of the model, the sediment delivery approach, is based on calculations of mean annual transport capacity. The transport capacity depends on topography and land cover and is assumed to be directly proportional to the potential rill erosion (Van Oost et al., 2000):

$$TC = K_{TC}\ Ep_{rill}$$

Where TC: transport capacity (t $ha^{-1}m^{-1}$); K_{TC}: transport capacity coefficient (m) and Ep_{rill}: potential for rill erosion (t $ha^{-1}y^{-1}$).

Input parameter files were generated by the geographic software of IDRISI 32 (Figure 1). The topographical data (LS-factor) and river/flow topology were derived from a Digital Elevation Model, land cover data and crop erosivity (C-factor) were obtained from classified land cover maps from remote sensing images.

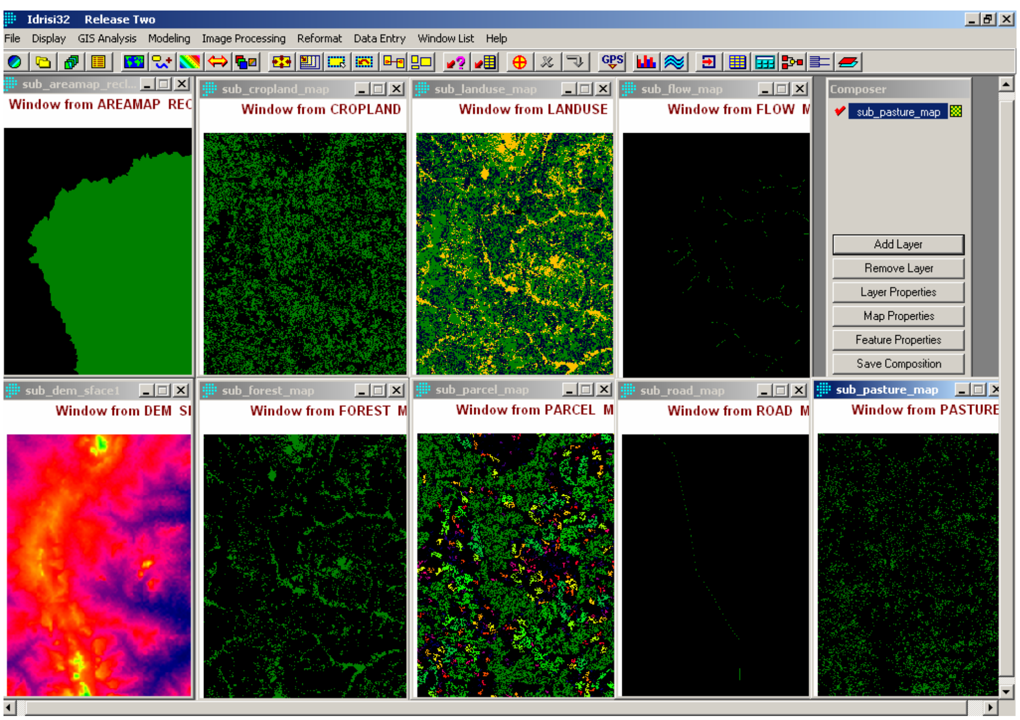

Figure 1 Input files for WaTEM/SEDEM generated by IDRISI

The soil erodibility factor (K-factor) was calculated from soil maps and the rainfall coefficient (R-factor) was generated from weather station rain gauges. Additionally, road maps and pond maps were digitized based on remote sensing images and topographical maps of the area. (For further information about input parameter procedures and data requirements see also WaTEM/SEDEM Manual, version 2006 by Notebaert et al., 2006).

Based on these input parameters, sediment production, sediment deposition and sediment export out of the catchment are calculated. A soil erosion/deposition map is produced showing redistribution rates at each point of the catchment. The example in Figure 2 shows soil erosion rates of up to 2.5 t ha^{-1} for a small catchment in southwestern Burkina Faso. Net deposition occurs mainly in lower areas and depressions. The flow network clearly identifies sediment deposition areas, where eroded soil from upslope areas accumulates. Here maximum net deposition rates reach approximately 2.3 t ha^{-1}.

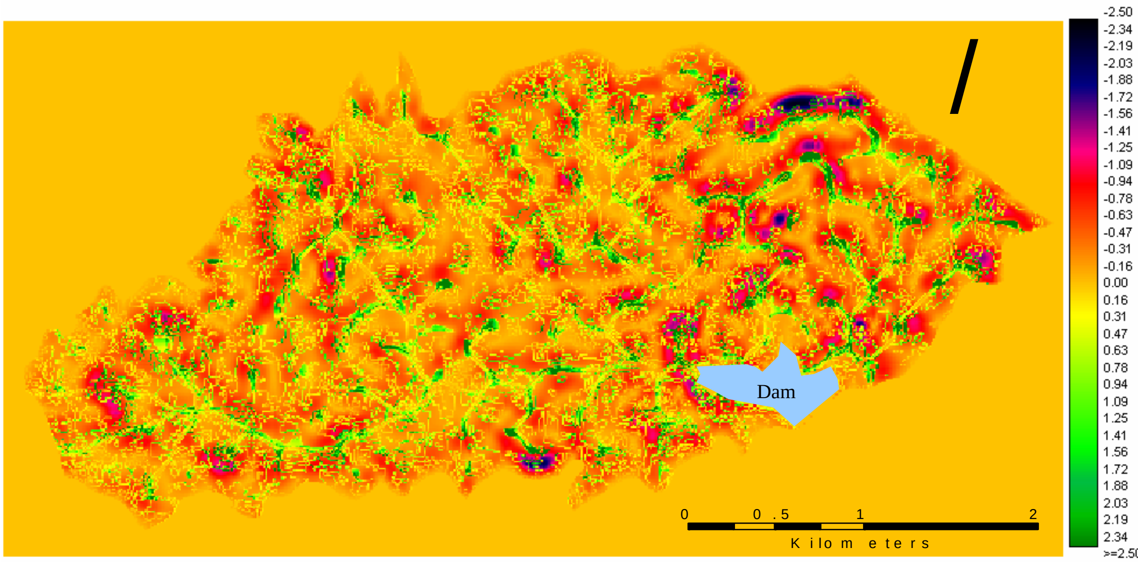

Figure 2 Erosion rates (t/ha) simulated by WaTEM/SEDEM for a small reservoir in southwestern Burkina Faso (positive values refer to net sediment deposition, negative values to net erosion).

The model can be calibrated by adjusting the transport capacity coefficient, using information about the sediment storage of the dam, which can be obtained from a bathymetric survey or sediment retrieval (see Toolkit: "Bathymetric survey by depth-sonar and lake sediment coring by Beeker sampler to identify sediment budgets and siltation rates of small reservoirs" by Brunner). The model should be validated either by model application in similar environments or by measured erosion/sedimentation data from plot studies or ^{137}C-measurements (see Toolkit: "Quantitative assessment of soil erosion and deposition rates by 137Cs measurements" by Brunner).

Lessons learned and recommendations

For soil erosion predictions in West African context, the WaTEM/SEDEM model was found adequate to represent the spatial distribution of soil loss and soil deposition. Although the model is based on the revised universal soil loss equation, some major improvements have been made, including a raster-based structure and topographically-driven calculations. One of the most important pre-requisites for reliable prediction is a high resolution digital elevation model. Adequate information on land cover is also necessary. The use of this tool may be inappropriate when a high resolution digital elevation model or information about land cover is lacking.

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