

Modelling catchment soil erosion: a critique of Morgan-Morgan-Finney model and a revised approach

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Intensive agricultural practices have critically contributed to the global increase in soil erosion rates and sediment fluxes. In order to reduce the impact of these practices, models able to represent the effect of land use changes are needed. Conceptual erosion models allow simulation of soil erosion rates and catchment-scale sediment fluxes over multi-decadal periods or longer, while still retaining a general description of runoff and sediment generation processes. The Morgan-Morgan-Finney model (MMF) is a conceptual annual erosion model that retains the simplicity of RUSLE yet has a stronger physical base. MMF also enables representation of the effects of changes in land cover on soil erosion. However, the most recent versions of the model, namely the Revised MMF and the Modified MMF, contain several errors and limitations that have a large effect on model outputs. First, both model versions incorrectly apply the equation to calculate the kinetic energy of the leaf drainage. Second, ground cover is assumed to have a protective effect against runoff erosion only and not against rainfall erosion. Third, when the simulated annual runoff is very low or negligible, the equations to predict soil loss become independent of the runoff. Fourth, neither version of MMF takes into account seasonal variations in vegetation cover and climate.

We propose a revised approach to correct these limitations. This includes the following modifications: a) monthly computation to capture seasonal variability in climate and land cover, b) a new approach to simulate the ground cover protective effect, and c) a new representation of the catchment hydrology based on a soil moisture model and the delineation of contributing areas according to the topographic wetness index (TWI). The proposed model, called MMF-TWI, was applied in an agricultural catchment in the UK and performance compared to the previous version of the model. The Modified MMF simulated considerable sediment yields, despite producing negligible runoff, highlighting an important problem in the original model design. In contrast, MMF-TWI simulations produced levels of surface runoff consistent with sediment yields. MMF-TWI sensitivities to crop spatial arrangement and crop type were tested and it was found that seasonal variations in canopy cover, canopy height, ground cover and crop type and spatial arrangement have a significant influence on sediment yields. Our findings demonstrate: a) that the Modified MMF should not be used in its current form, b) the importance of the representation of seasonal changes in vegetation cover and climate, and c) the potential of the TWI as a methodology to delineate sediment contributing areas in catchments where saturation excess is the characteristic mechanism of runoff generation.