Including the effect of tillage-induced roughness in simulated runoff patterns: The Tillage-Controlled Runoff Pattern model.

1. Introduction

Oriented roughness on tilled fields often directs runoff along the tillage lines instead of in topographic direction (Ludwig et al., 1995; Desmet and Govers, 1997; Souchère et al., 1998; Takken et al., 2001). In addition, borders between fields may act as water collectors and water flow may be routed along linear features, such as lynchets or roads, even if these are oriented more or less parallel to the contour lines. Therefore, the actual runoff pattern can be very different from the runoff pattern that would be predicted from topography alone. Due to the fact that the runoff pattern defines the locations where water will concentrate, as well as the effective slope gradient (ea. the slope in flow direction), this also has an important effect on erosion patterns and rates. At present, the runoff pattern used in distributed soil erosion models is based on topography only and is often calculated by the steepest descent algorithm (e.g. Desmet and Govers, 1996).
Takken et al., 2001c propose a methodology that can be used to create a runoff pattern whereby the effect of tillage-induced roughness is taken into account. The methodology is only shortly summarised here and the PC-Raster model scripts can be downloaded. For a more detailed description of the model procedures and the obtained results we refer to Takken et al., 2001a and b.

2. Description of the methodology

The methodology to create the runoff pattern includes four steps. First, a topographically controlled runoff pattern is created using the standard single-flow, steepest descent algorithm. Next, a tillage-determined runoff pattern is created, i.e. a runoff pattern based on the assumption that water will always flow in the tillage direction (TCRP model, Takken et al., 2001a). Then, decision rules are applied to determine for each cell whether the water will flow in the tillage direction or in the topographic direction (Takken et al., 2001b). Finally, a flow direction map can be generated by combining the topographically determined runoff pattern with the tillage-controlled runoff pattern (Takken et al., 2001b).

2.1. Creation of a tillage-controlled runoff pattern (TCRP model)

The model used to create a tillage-controlled runoff pattern (TCRP model) requires a digital elevation model (DEM), a land use map, and the major tillage direction on each field as input. In the model the flow lines corresponding with the tillage orientation are defined first. Subsequently, the flow direction within these lines is defined by choosing the direction that corresponds with the downstream tillage direction. When flow convergence occurs, e.g. in thalwegs (low places), the flow is routed in the topographic direction. Flow directions along field borders are defined separately. Hereto, the direction of the field border is defined, based on the land use map. The flow direction along the field border is then defined based on the slope gradient along the field border. This TCRP

model automatically creates headlands along field borders that are not parallel to the tillage orientation. The runoff pattern that is created may contain some errors: it is possible that crossing flow lines occur, e.g. when ditches are present or at field borders. It is also possible that some of the grid cells have no outflow direction (e.g. circular flow). Procedures were developed to correct these errors.
The TCRP model is described in detail by Takken et al., 2001a. The correction procedures to remove pits and crossing flow lines are described in the TCRP model manual.

2.2 Decision rules to determine flow direction

The TCRP model creates a runoff pattern based on the assumption that water will always flow in the tillage direction on tilled fields. However, flow is not always in the tillage direction; water often breaches through tillage ridges and continues to flow in the direction of the steepest slope. Therefore, decision rules are required that can be used to determine when flow will be in the tillage direction and when flow will be in the topographic direction.

Takken et al., 2001b developed two logistic regression equations that can be used to predict whether water will flow in topographic or in tillage direction. These equations are based on a wide range of fields data collected in an agricultural catchment in the Belgian Loam Belt (Takken et al., 2001b). The first logistic regression equation uses topographic slope, the angle between the tillage and aspect direction, and the degree of oriented roughness as input (Eq. 2). In the second model, the effect of discharge on the flow direction is also considered using unit-contributing area as a substitute variable (Eq. 3):

$$\mathrm{logit}(p) = -5.92 + 0.133 \cdot S + 0.102 \cdot \alpha - 0.417 \cdot R_o \qquad (2)$$

$$\mathrm{logit}(p) = -9.50 + 0.177 \cdot S + 0.113 \cdot \alpha - 0.470 \cdot R_o + 1.578 \cdot \log(A_u) \qquad (3)$$

where p is the probability that the flow will be in the topographic direction, S = slope (%), α = angle (°), R_o = oriented roughness (cm) and A_u = unit contributing area (m^2). If a probability exceeding 0.5 is predicted, it was assumed that flow was predicted to be in the topographic direction. Takken at al., (2001b) show that flow directions could be well predicted using Equation 2. The improvement made by including the unit contributing area within the model (Eq.3) was limited, while the application of such a model is complicated and error-prone. Therefore, it may be better to predict flow directions without taking discharge into account.

3. Model scripts

The model is constructed in the PCRaster computer language (Van Deursen, 1995; Karssenberg, 1996).

References

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