Catena 91 (2012) 47–55

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

# Parameterization of the EROSION 2D/3D soil erosion model using a small-scale rainfall simulator and upstream runoff simulation

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ARTICLE INFO

*Keywords:*
Rainfall simulator
Infiltration
Resistance to erosion
Surface roughness
Tillage practices

ABSTRACT

The specific parameters of soil erosion models as resistance to erosion, hydraulic roughness etc., are usually determined by simulated rainfall experiments. Due to the required plot length of usually 22 m, these experiments can only be carried out with an enormous effort of time and manpower. This study presents a runoff feeding device, which is able to multiply the plot length virtually by supplying sediment loaded runoff from upstream. Thus it is possible to restrict the plot length to 3 m and nevertheless simulate flow conditions similar to those using standard plots. The described method has been already tested successfully under laboratory conditions (Parson et al., 1998; Römkens et al., 2001; Schmidt, 1996). In the present study, this method is used to determine input parameters for the soil loss and deposition model EROSION 2D/3D under field conditions. Based on the model parameters “skinfactor, soil resistance to erosion and surface roughness” the experimental approach is described exemplarily. The experimental results show that results from large-scale rainfall simulations with the plot's length of 22 m can be reproduced successfully.

## 1. Introduction

### 1.1. Motivation

In order to estimate soil loss by water, physically based erosion models require specific parameters describing the decisive processes involved e.g. the infiltration of rainwater into the soil or the detachment of soil particles by raindrop splash and surface runoff.

In the mid 1990s, Michael (2000) carried out an extensive rainfall simulation campaign in order to provide a comprehensive database of model parameters for the routine application of the EROSION 2D/3D model in the German Federal State of Saxony. For this campaign, a large-scale rainfall simulator was used, covering plots of 22∗2 m in size, so called USLE-plots (Wischmeier and Smith, 1978).

At the time of the first field campaign conservation tillage practices were only implemented for a short period of time on a few plots, non-tillage practices were missing completely. Since some of the parameters used by the EROSION 2D/3D model are very sensitive to tillage practices, additional plot experiments were needed to keep the EROSION 2D/3D database up to date. However, at present the large-scale rainfall simulator is not available anymore so that an alternative method for plot experiments had to be developed.

Since the use of large-scale rainfall simulators implicate a great effort of time, manpower and space (Kainz et al., 1992), most soil erosion experiments using rainfall simulators were conducted on plots of rather small sizes. Nearly 50% of the 229 rainfall simulators examined by Cerdá (1999) are $<1.5\ \mathrm{m}^2$ in size. Rainfall simulations of that size are predominantly used to examine specific processes like soil crusting, splash and interrill erosion (Alves Sobrinho et al., 2008; Martínez-Mena et al., 2002; Seeger, 2007; Stroosnijder, 2005; Vahabi and Nikkami, 2008). However, from the authors' point of view, small sized plots (0,15 m² resp. 0,063 m²) as used by Assouline and Ben-Hur (2006) and Romero et al. (2007) are unsuitable for the comprehensive simulation of soil erosion processes since slope length is directly related to the surface runoff as well as the soil detachment and transport. This has been confirmed by experiments carried out by Panini et al. (1997) and Gómez and Nearing (2005). The important role of the plot size is also pointed out by Knapen et al. (2007b). Therefore, this study aims to develop a time and cost-efficient method for simulating rainfall and surface runoff on small plots which delivers results comparable to large-scale plot experiments. The paper presents methodological details and first results.

### 1.2. Theoretical background

EROSION 2D/3D (Schmidt et al., 1999) is a field-tested, process based computer model for predicting surface runoff and soil erosion by water on agricultural land. The application of EROSION 2D/3D requires raster-based information on relief, soil and rainfall conditions. Most of these variables are commonly accessible except the following model-specific parameters: skinfactor, surface roughness and resistance to erosion.

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doi:10.1016/j.catena.2011.01.007

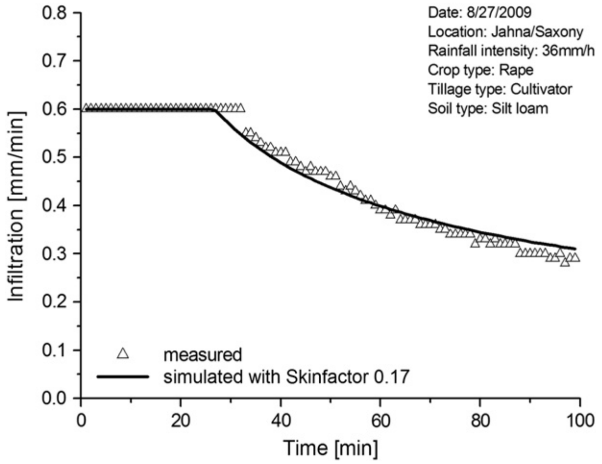

**Fig. 1.** Measured infiltration rates and simulated infiltration curve as calibrated by the skinfactor parameter of the EROSION 2D/3D model.

Since the experimental determination of these parameters is the subject of this paper, some theoretical considerations shall be presented first.

### 1.2.1. Skinfactor

The runoff subroutine of EROSION 2D/3D uses a modified Green & Ampt infiltration equation in order to calculate rainfall excess (Weigert and Schmidt, 2005):

$$i = k_s \cdot g + k_s \cdot \frac{\Psi_{m0}}{\sqrt{\frac{2k_s \cdot \Psi_{m0} \cdot t}{\rho_f \cdot (\Theta_s - \Theta_0)}}} \qquad (1)$$

where $i$ is the infiltration rate [kg/(m² s)], $k_s$is the saturated hydraulic conductivity [(kg s)/m³], $g$ is the gravity [m/s²], $\Psi_{m0}$ is the matrix potential related to the initial water content $\Theta_0$[N m/kg], $t$ is the time [s], $\rho_f$ is the fluid density [kg/m³], $\Theta_s$ is the saturated water content [m³/m³] and $\Theta_0$ is the initial water content [m³/m³].

According to Campbell (1985) the saturated hydraulic conductivity can be estimated by applying the following empirical function:

$$k_s = 4 \cdot 10^{-3} \cdot \left(1.3 \cdot 10^{-3} / \rho_b\right)^{1.3 \cdot b} \cdot exp(-0.069 \cdot T - 0.037 \cdot U) \qquad (2)$$

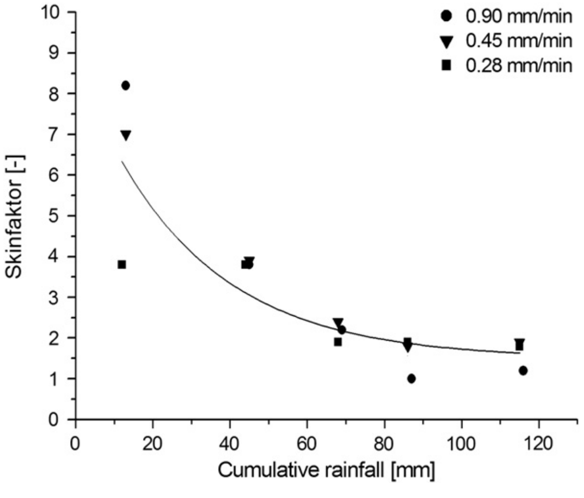

**Fig. 2.** Skinfactor as a function of cumulated rainfall.

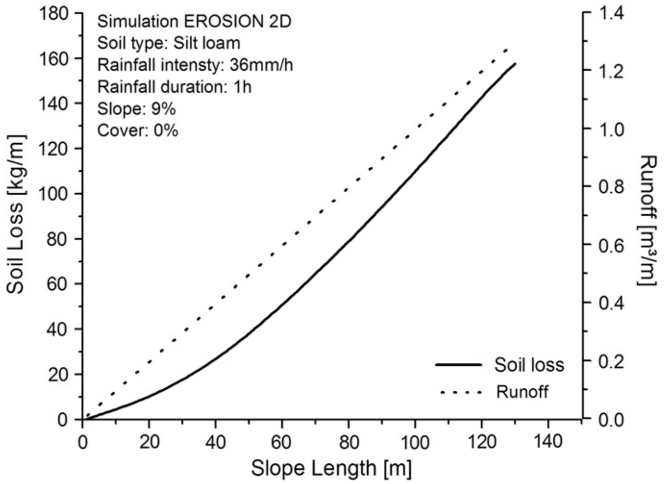

**Fig. 3.** Simulated soil loss and runoff as a function of slope length referring to a straight slope.

where $k_s$ is the saturated hydraulic conductivity [(kg s)/m³], $\rho_b$ is the bulk density [kg/m³], $T$ is the clay content [kg/kg], $U$ is the silt content [kg/kg], $b$ is a parameter [−]. with

$$b = \left(10^{-3} \cdot D\right)^{-0.5} + 0.2 \cdot \delta_P \qquad (3)$$

where $D$ is the mean diameter of soil particles [m] and $\delta_P$ is the standard deviation of the mean diameter of soil particles [−].

Because Campbell's equation presupposes a rigid soil matrix, the temporal variability of soil structure due to tillage, slaking and sealing, shrinking and swelling, biological activities etc., has to be considered by an additional empirical parameter which allows for calibrating the saturated hydraulic conductivity $k_s$ on the basis of measured data. In the EROSION 2D/3D model this parameter is called the skinfactor which is determined by iterative calibration of simulated infiltration rates. The skinfactor adjusts infiltration rate by multiplication with saturated hydraulic conductivity. Values of skinfactor $<1$ reduces the simulated infiltration rate, in order to take the effects of soil slaking and sealing as well as the anthropogenic compaction into account. Values of skinfactor $>1$ causes a positive correction of infiltration rate, e.g. for the consideration of an increased infiltration in macropores due to soil shrinking, biological activity or tillage impact. If skinfactor $=1$ infiltration rate is obviously not affected by either slaking and sealing or macropores. Related to sealed soil conditions, Fig. 1 shows exemplarily

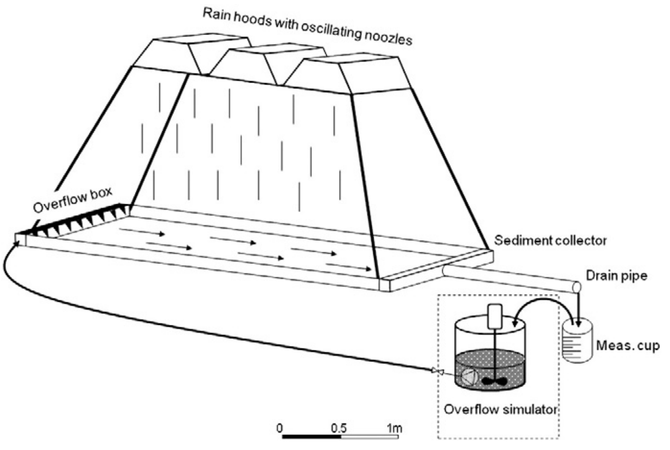

**Fig. 4.** Field rainfall and runoff simulator.