RUNOFF AND EROSION MODELLING BY WEPP IN A BELGIAN AGRICULTURAL WATERSHED*

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Introduction

In recent decades several distributed parameters erosion models have been developed to estimate and analyse the impact of water erosion at watershed scale as well as the spatial and temporal distribution of soil loss. Among the physically-based models, the WEPP (Water Erosion Prediction Project, Nearing *et al.*, 1989) model, developed by the USDA since late '80, is supposed to have a wide range of applicability and therefore to be able to reduce the need for extensive field experiments and calibrations.

WEPP has been tested at plot, hillslope and watershed scales and widely applied around the world in different climatic conditions and under different land use scenarios (e.g. rangelands, burnt scrub areas, irrigated croplands, logged forest).

This paper aims at testing WEPP model prediction capability at event scale in a small agricultural watershed located in central Belgium under humid continental conditions.

Materials and methods

Main characteristics of the experimental watershed

The model was implemented using a database reporting hydrological, morphological, soil type and land use data collected at the Ganspoel watershed (Ganspoel database, 2007). The information about the database was drawn from the works by Steegen *et al.*, (2001) and Van Oost *et al.*, (2005), in which further details can be found.

The watershed covers about 110 ha between 60 and 100 m a.s.l. with an average slope lower than 10%. Soils (Tertiary sandy deposits covered by a loess sheet) are fairly homogeneous; the physical parameters are much more related to land use than to soil texture (Van Oost *et al.*, 2005). The watershed land use is mainly agricultural: the main crops are wheat, maize, sugar beet, potato; forested and pasture zones cover steep slopes as well as some thalwegs. Built zones are mainly located in north-western part of the watershed.

The climate of this area shows relatively dry summers and mild winters; annual precipitation varies between 700 and 800 mm. Precipitation is well distributed over the year, but high intensity rainfall events show a maximum in spring and summer.

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* Work carried out with equivalent contribution of the Authors

The hydrological database

The hydrological database was collected during a recording period of about 2 years (November 1996-February 1999). The pluviometric and flow/sediment measurement station was located at the outlet of the watershed. The rainfall events were recorded by a tipping-bucket rain gauge. Water depths were continuously measured by a flume equipped with a flowmeter, using a submerged probe level sensor. Water discharge was then calculated by a constant relationship between water depth and discharge. Suspended sediment concentration was measured by an automated water sampler.

Seventeen runoff events, corresponding to rainfall depths in the range 5.5-57.5 mm, were adequately sampled. The sampled events concerned low runoff volumes (15 with runoff depths lower than 2 mm); a runoff volume of 9.5 mm was recorded for the most intense event. Sediment yields varied between 1.9 and 604.5 kg ha^{-1}.

Model parameterisation

Morphological watershed discretisation

The water discretisation into sub-watersheds (groups of hillslopes) contributing to channels was carried out using the geospatial interface of the WEPP model (GeoWEPP, release ArcXXX 2005.1) (Renschler *et al.*, 2002) . Morphologic characteristics of each hillslope (i.e. length, width and slope) were automatically derived from a Digital Elevation Model (DEM) of the watershed, following the procedure implemented in GeoWEPP.

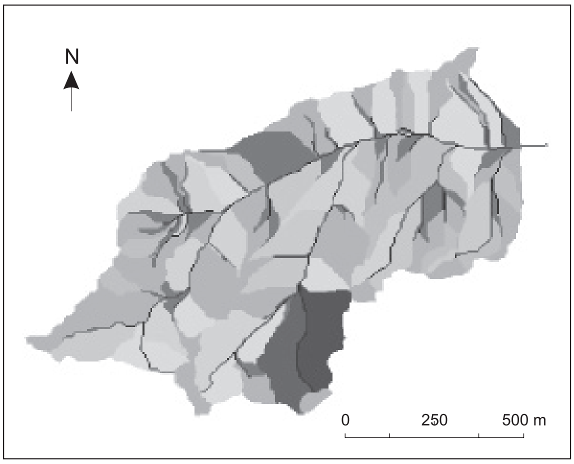

Figure 1. Layout of Ganspoel watershed discretisation in sub-watersheds and channels by GeoWEPP

In order to optimize the reproduction of the watershed morphology the CSA and the MSCL were set to 0.5 ha and 50 m, obtaining 155 hillslopes and 65 channels; about 20% of the modelled hillslopes was longer than 100 m (Figure 1).

Land uses and soil types were overlaid to each sub-watershed through the GeoWEPP interface according to a majority criteria. All channels were treated as ditches with a section width always set to 1 m.

Construction of input files

The Breakpoint Climate Data Generator (BCDG) was used to build the climate input file. As no meteorological information was provided with the available database, climatic data were collected at the close meteorological station of Bruxelles.

The whole watershed was modelled on an unique soil type (silt loam); an uniform soil profile was assumed. Input data related to vegetation cover and soil surface parameters (e.g. soil surface crusting and roughness) were collected during field surveys. The scarceness of information within the available database about some soil physical and hydrological parameters required by WEPP sometimes forced the modeller to turn to literature data, as for the soil saturated hydraulic conductivity (K_{sat}).

Six land uses were surveyed in the watershed (cereals, root crops, forest, meadow, fallow and urban areas).

Model performance evaluation procedure

Three simulation series were performed on a continuous basis using different sets of the soil effective hydraulic conductivity inputs. In simulation series *I*, the K_e values were internally calculated by WEPP.

In simulation series *II* the K_e values were assumed as 50% of K_{sat} (Bouwer, 1969). Then, trying to match the model simulations to the corresponding observations, in the simulation series *III* the K_e values were reduced up to 0.5% K_{sat} for each soil land use. Given that, as above mentioned, soil physical parameters were much more related to land use than to soil texture, six different values of K_{sat} (one for each soil land use) were input to the model.

The hydrological and erosion components of WEPP model were evaluated in logical order according to the input dependencies on each other. Runoff volume, peak flow as well as sediment yield predictions were assessed at event scale by using the 17 events of the Ganspoel hydrological database recorded from May 1997 to February 1999. The period from January to April 1997 was used to initialise soil conditions (e.g. soil moisture).

The different components of the model were quantitatively evaluated by statistics (mean and standard deviation of observed and simulated values) as well as a combination of both summary and difference measures: coefficients of determination (r^2); coefficient of efficiency (E, Nash and Sutcliffe, 1970) and its modified form (E_1, Legates and McCabe, 1999); and coefficient of residual mass (CRM, indicating a prevalent model over or underestimation of the observed values, Loague and Green, 1991).

Results and discussion

In all the simulation series the coefficient of regression was always close to 0.90 for runoff volume predictions. The model efficiency *E* gave acceptable results just for the simulation series *I* and *II* (0.54 and 0.83 respectively), where, however, WEPP runoff volume predictions met the observations only for the most intense event. Fifteen events with observed runoff less than 2 mm were underestimated up to two orders of magnitude, simulated runoff being zero in many cases. Also mean and standard deviation of simulated runoff volumes were in a poor agreement with observed values. Further runs carried out by reducing K_e up to 0.5% of saturated hydraulic conductivity (simulation series *III*) let the runoff volumes simulated by WEPP to be closer to the observed values for most events, even though poor model efficiency (E = -3.25) was achieved due to the significant overprediction of some observed runoff volumes (CRM = -1.17). Four events (corresponding to rainfall depths lower than 6.5 mm) resulted in zero runoff simulations (Figure 2).

The regression analysis of observed versus simulated peak flows gave r^2 in the range 0.48-0.55 with coefficients of model efficiency (*E* and E_1) always negative in all simulation series. Observed peak flows were modelled as zero values for most of the rainfall events in simulation series *I* and *II*. By decreasing the values of the effective hydraulic conductivity (simulation series *III*), the WEPP model performance worsened (E and E_1 << 0).

The poor performance achieved for runoff volume and peak flow simulations affected sediment yield predictions. In all simulation series model simulations gave r^2 always greater than 0.59; model efficiency, poor in the simulations series *I* and *III*, was instead satisfactory in the simulation series *II* (E = 0.58), due the closeness

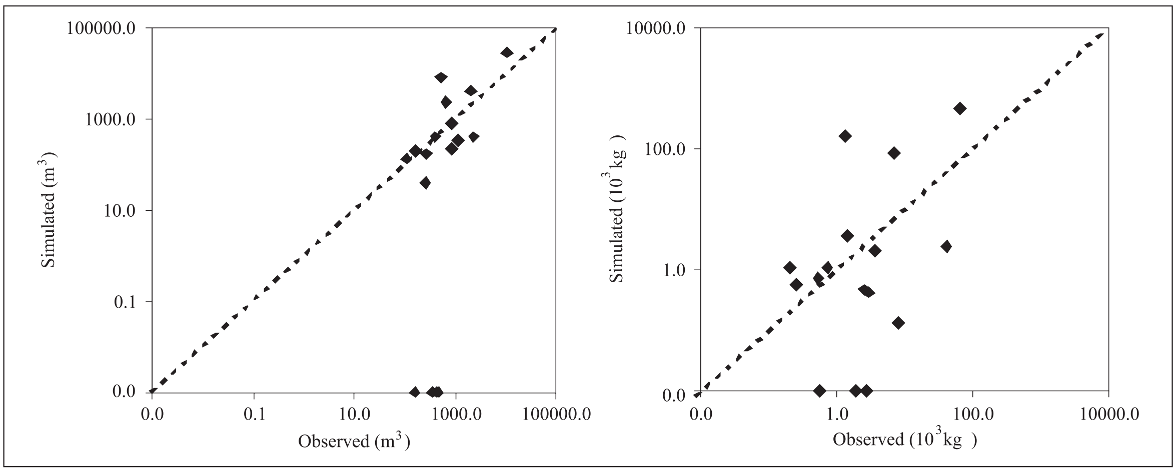

Figure 2. Comparison between observed and simulated runoff (left) and sediment yield events (right) for WEPP implementation in the Ganspoel watershed (simulation series III: Ke = 0.5% Ksat)

of the sediment yield prediction to the observed value of the most intense event. In the simulations series *I* and *II* WEPP provided zero sediment yield for many observed events.

On the whole the poor prediction accuracy shown by the WEPP model in the experimented watershed may depend on: i) the great number of small runoff events within the available database, which in many cases are not well reproduced by WEPP, as found by other Authors (Soto and Diaz-Fierros, 1998, Grønsten and Lundekvam, 2006; Licciardello *et al.*, 2006); ii) the lack of model calibration processes, able to compensate for the errors due to model parameterisation and modelling of hydrological processes; iii) the above mentioned scarceness of information about some soil physical and hydrological parameters within the available hydrological database; iv) the inadequacy of the WEPP model in modelling existing erosion sources as gullies within the watershed; v) the land use heterogeneity and crop schedule complexity of the Ganspoel watershed, also highlighted by Nearing *et al.* (2005).

The above mentioned limitations of the available database do not allow to exclude the possibility to simulate runoff and erosive events at small watersheds in humid continental conditions by WEPP. A more concrete attempt of calibration (and successive validation) of the hydrological submodel (and consequently of the erosive subroutine) will be opportune, when a wider and more complete hydrological and geomorphologic database will be available.

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