University of Szeged

Department of Physical Geography and Geoinformatics

BUILDING A MODEL BASED ON THE EUROSEM SOIL EROSION MODEL

Theses

Károly Barta

Szeged

2004

1. Introduction

Water erosion on agricultural lands is a global problem. The natural erosion is only 0,1-0,3 t/ha as contrasted with the so called accelerated erosion caused by the permanent land use which can be 6-100 times greater. Erosion exceeding the rate of soil formation leads to serious economical and ecological problems. The direct measurement of erosion includes expansive and difficult methods therefore dozens of infiltration and erosion models are worked out which attempt to describe more or less exactly the erosional processes. Unfortunately the measurement of numerous input parameters influencing erosion comes up against difficulty and even if any parameters can be measured accurately, their spatial and temporal variability gives further uncertainty. It means that it is necessary to make standards for each models which include the typical values of parameters depending on soil texture or vegetation type. These tables based on thousand and thousand measured data have limited spatial usability, they can be used only in similar geographical environment where they were made. The basic condition to use the models in other areas is the adoptation of these tables, nomograms for local conditions as it is named the calibration of the model.

More and more models are adopted to different regions in order to estimate any changes in erosion conditions. There are some models (e.g. USLE, WEPP, EPIC) which were calibrated in Hungary and they have been used for many years in our country as well. My first aim was the calibration of the EUROSEM soil erosion model to Hungarian conditions. My choice ‘s reasons are the followings:

- it is an event based model so it is suitable to describe the effects of unsteady storms and long, steady rains as well,
- dynamic model, it means that you can get information not only the total amount of runoff and erosion but their temporal intensity as well,
- it is a plot scaled model with well defined and (“quasi-“) measurable input parameters.

In order to collect enough data for the calibration I ran different erosion measurement stations in the Velence Hills between 1998 and 2002. The measurements happened on plots and small catchments with different land uses (arable land with winter wheat and corn, forest, pasture, orchard and vineyard). The measurement methods were quite variable from the simple settling potholes to the automatic measurement stations. These last ones were developed by myself from former constructions applied for dropping and penetrating waters in caves.

During the process of the calibration I have shown that the EUROSEM has got some algorithmic, conceptional and other problems and they result that it is impossible to fit the modeled and measured data. So it has arisen the idea to make a new model based on the EUROSEM. The basic conception of the new model is that it should avoid the problems arisen in the EUROSEM but it should apply the usable part of the same model. It means that my modified aim is to build up a dynamic mathematical model which is suitable to model the effect of a rainfall event on a plot to the infiltration, runoff and erosion.

Connecting to the new model lots of further aims arise from that I consider the following ones the most important:

1. Comparison of the various measurement methods of saturated and unsaturated hydraulic conductivity
2. Creating conversional formulae between the different methods with help of the Darcy's low, Hortonian and Green-Ampt formulae
3. Testing the new erosion model with measured data
4. Calibration of the model in Hungarian test area.

The dissertation refers to the first subject from these ones, the others can be defined as further research aims.

2. Applied methods

2.1. Creating database for calibrating the EUROSEM

I ran various erosional measurement stations in the Velence Hills for five years (1998-2002). I tried to choose such plots and small catchments that are characteristic both in land uses (arable land with winter wheat and corn, orchard, vineyard, pasture and forest) and both in soil types (chernozems, brown forest soils and stony soils). The measurements can be divided into three periods depending on more and more growing technical opportunities:

1. Initial time of measurements: erosion and runoff were measured on four small catchments (1,3-14,5 ha) for nearly 7 weeks in 1998. Two of them were settled onto a cornfield near Pázmánd. Runoff water and sediment were collected in two pits with capacity 4 and 6 m^3. The other two stations operated in forest and on pasture near Pákozd. Runoff was measured by specially developed tip-scoops and the sediment was settled in 30 l volumed barrels here. Special data boxes stored the measured data which were downloaded every day.
2. For-year-long period with automatic stations: based on the technical experiences of the above described measurements we made work three automatic measurement stations between 1999 and 2002. We settled two stations on chernozem near Pátka in first step in 1999. One of them was on arable land with winter wheat and the other one was in orchard. Both of them collected runoff and sediment from 2x20 m large plots. In second step the number of the stations grew to three with initiating a 1,8x60 m large vineyard plot in 2001. It was on brown earth and it was worked until the autumn of 2002. All of these stations collected data in every 20 minutes – apart from some shorter periods – and their data boxes were downloaded about once a month.
3. Rainfall simulations: my aim was to get data with high temporal density. They took place on similar plots where the first two stations were found. Nominal rainfall intensity varied between 30 and 130

mm/h. The simulations were made by the University of Veszprém Georgikon Faculty of Agriculture, Department of Water Management and Melioration on 16-19 June 2000.

2.2. Steps of the EUROSEM's calibration

EUROSEM was tested and calibrated in United Kingdom, the Netherlands and Oklahoma so far. There are various methods to calibrate soil erosion models from that I applied the following one:

1st step: Sensitivity analysis

Its aim is to choose the so called sensitive parameters from the inputs. The variability of these sensitive parameters can cause high variability in outputs. They will be such parameters that play important role in the further model's calibration. I chose simple parameter analysis to complete the test:

1. The modeled plot was the wheat-field with parameters measured on 9 June 1999. These parameters were named as *basic inputs*. Some of them were established from standard or estimation.
2. The modeled rainfall event was an early summer storm on 15 June 1999.
3. I ran the EUROSEM to the above mentioned plot with the storm. The calculated results were named as *basic outputs*.
4. Each basic input was increased with 10 % – other input parameters were left invariable – and I ran the model again and again after every modification.
5. Similarly I decreased each basic input with 10 % and ran the model again.
6. I compared the new and the basic outputs and I defined sensitive parameters the inputs caused more than 10 % difference in *any* outputs. The studied outputs included the total runoff, total soil loss, time to runoff, peak flow rate and peak sediment discharge.

2nd step: Testing the model

The simulated values were compared with the measured data during the test. It lets us know whether the model can reflect the reality in given conditions. The test usually predicts the difficulties of the calibration.

3rd step: Calibration

This is the modification of the existing standards based on large amount of field measurements. The modified new standards are valid only in similar conditions where the calibration was made.

4th step: Validity test

This is the re-test of the calibrated model in order to decide whether the calibration was successful or not. If the calibration was good then the simulated and measured data are well fitting.

2.3. Building the new model

There was no building a new model in my original aims therefore its methodological problems did not arise. The creation of the model's algorithm happens on theoretical plain that means it can not be ordered any special methods to it. The implementation of the theoretical algorithm can be considered only technical and mathematical problems. Their most important factors inseparably interlock with the model concept itself.

3. Results

The results of my work can be summarized in the following points:

1. I elaborated a new method for measuring runoff and erosion. The automatic measurement station was developed from former equipment used for dropping and penetrating waters in caves. The main developments were the followings:
   - I constructed a new configuration of data boxes that have four channels for measuring water discharge (in two channels) and soil moisture (in the other two ones).
   - I made special tip-scoops with 1,08 l capacity for one of the discharge channel. It is suitable to measure runoff even minute by minute.
   - I constructed rain-gauge for the other discharge channel. Its sensitivity can be set optionally and it can measure even minute by minute also.
   - I used big barrels with 30 l capacity for settling the eroded sediment. The barrels were sunk into the soil, under the measurement equipments.

2. I have created database about the erosional conditions of the typical soils and land uses in the Velence Hills. The database includes runoff and erosion records of both natural rainfalls and both rainfall simulations. The results were measured on 12-108 m^2 plots under winter wheat, orchard and vineyard. They can play great role in the regional planning in the future.

3. I have shown the limit of the applicability of the EUROSEM model and I have given proofs of the model's mistakes. I have drawn up the suggestions to avoid these mistakes.

   3.1. The maximum interception storage of the vegetation is meant as an intensity and not as a storage capacity filling up once at the beginning of the rainfall. This results that even theoretically it is not possible to fit the measured and modeled data. It is possible to demonstrate it to run the model for a few-hour-long rainfall event with the alteration of the maximum interception storage and the vegetation cover. The calculated runoff is systematically less with the product of the above mentioned two inputs than the difference between the rainfall intensity and the saturated hydraulic conductivity (Fig. 1).

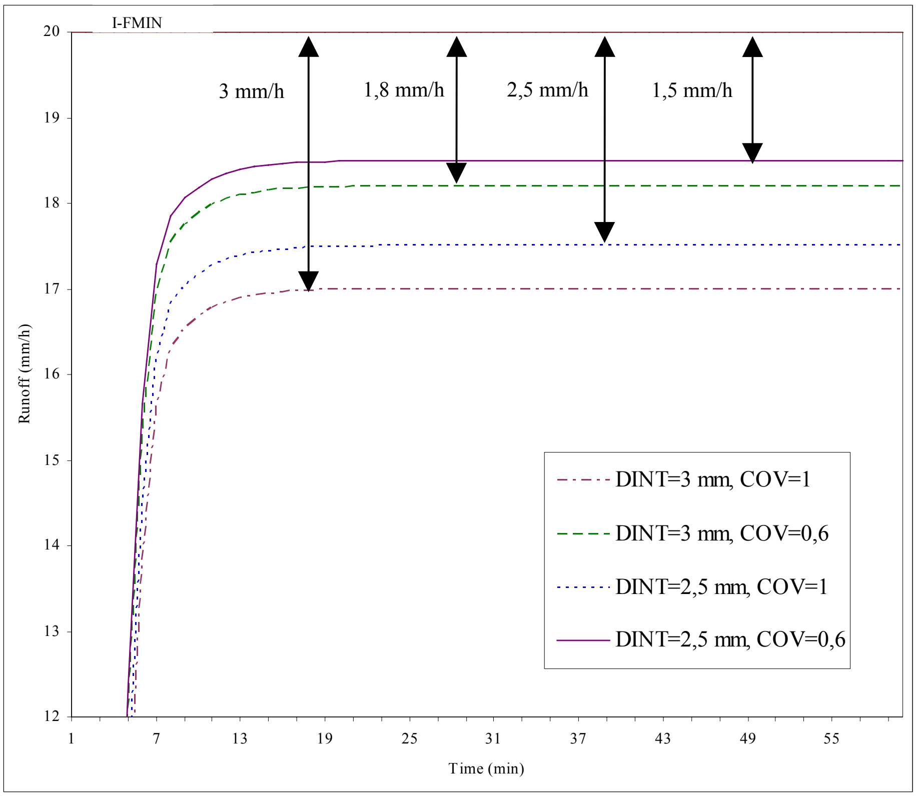

Fig. 1: The effect of plant cover (COV) and maximum interception storage (DINT) to the hydrographs (I: rainfall intensity, FMIN: saturated hydraulic conductivity)

3.2. There is no reference in the user's guides whether the maximum interception storage applies to 100 % vegetation cover or to the cover conditions suggested by the standard. We can know that it applies to 100 % cover from only the above described model test.

3.3. In the opinion of the model parallel to increasing the proportion of surface covered by impermeable materials (PAVE) and percentage basal area of the vegetation (PBASE) the infiltration increases as well and it is just opposite of the measurement experiences.

3.4. There is no importance of the porosity and the direct values of the initial and maximum soil moisture in the model. It can use only the difference between the maximum and the initial soil moisture. Its practical consequence is that it is enough to measure this difference and it is not necessary to record all of the soil hydraulic and physical parameters.

4. I have built up a new runoff and erosion model (Fig. 2). For the theoretical base of the model I have chosen the most typical situation on arable land, namely we can apply the model on soils with two different layers: the cultivated topsoil and the more compacted plough-pan beneath. This first version of the model can be used only in the case of permanent rainfall intensity and deep soil water table with no effect to the infiltration. The model consists of four sub-models:
   1. The vegetation sub-model describes the way of the rainfall until the surface (interception, leaf drainage, throughfall, stemflow). The newness of this part of the model is that it can rids the main algorithmic problem of the EUROSEM, it takes the maximum interception storage of the vegetation in good sense. The sub-model's output parameter is the "net rainfall intensity".
   2. The infiltration sub-model can show the temporal distribution of the net rainfall between the infiltration and runoff. It is built up on absolutely new bases. The most important features of the sub-model are the followings:
      - The infiltration is determined by the characteristics of the *different* soil layers, for e.g. saturated/unsaturated hydraulic conductivity, soil moisture, different water capacities.
      - I have used almost only such soil parameters as input data that are possible to measure or calculate exactly.
      - I have fixed and ordered the measurement methods to each applied parameters.
      - The hydraulic conductivity for each soil layer is described by Hortonian function.
      - Based on the Hortonian equation I have characterized the saturation and infiltration of the different soil layers with mathematical functions.

      The processes of the modeled infiltration are realized through the following steps:

      1. The topsoil is filled up until its field capacity.
      2. The plough-pan starts to shallow water.
      3. Parallel to it water is dammed back into the topsoil.
      4. After the topsoil reaches its maximum soil moisture the infiltration rate of the plough-pan will determine the surface runoff.

      All intervals between these moments can be ordered different functions of infiltration and runoff. The sub-model can compute with equalizing the water amounts needed to fill the soil layers until field capacity and maximum soil moisture with definite integrations derived from the Hortonian equation. The above mentioned moments are the upper limit off the integrals as the unknown parameters of the equations. The sub-model's output parameter is the "surface rainfall excess".
   3. The runoff sub-model describes the runoff intensity in space and time. It is based on the EUROSEM's equations.
   4. The erosional part of the model was adopted from the EUROSEM also. The sediment yield is given by the product of the water runoff and the sediment concentration.

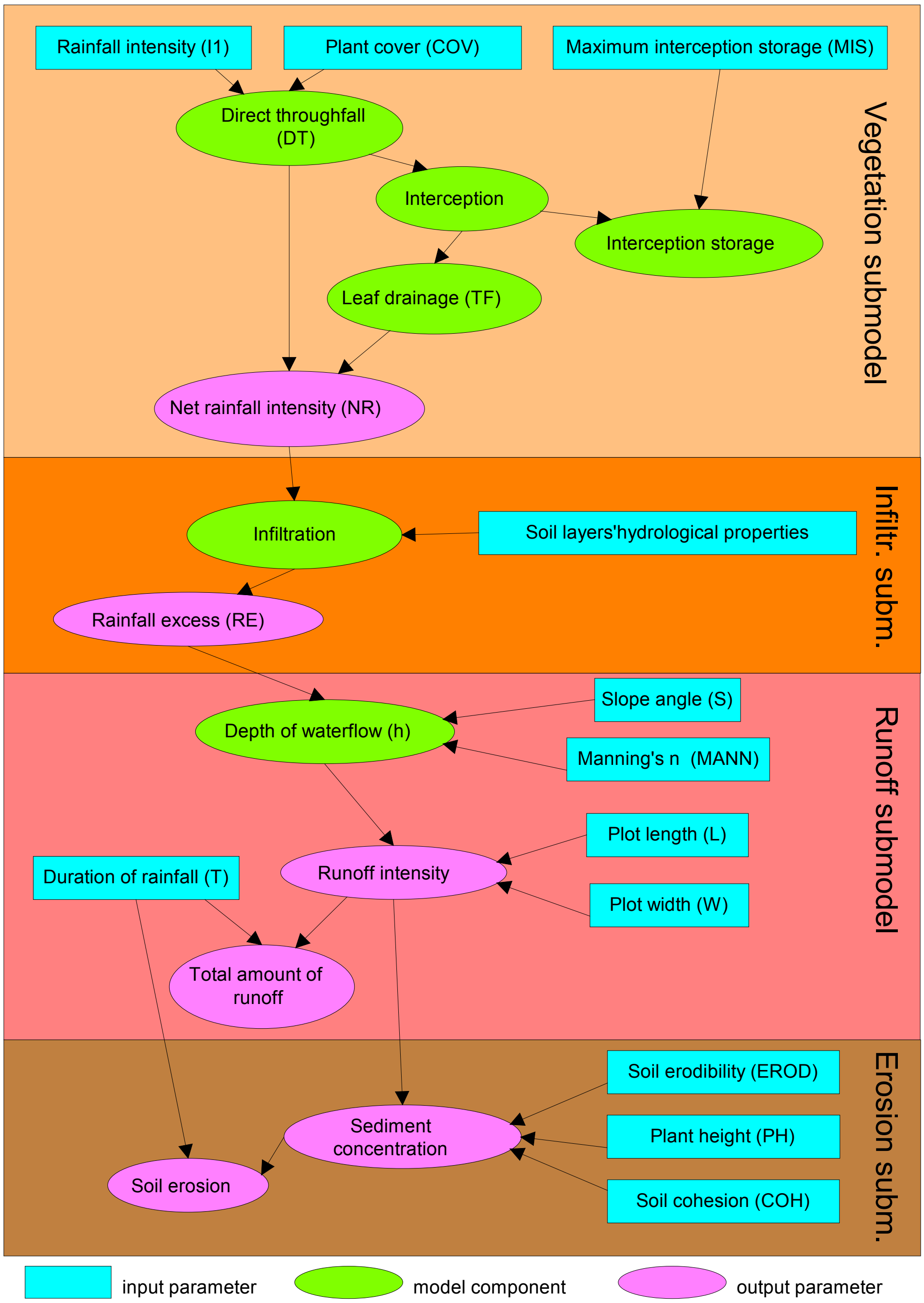

Fig. 2: The algorithm of the new model

The first two sub-models were programmed in Maple 8 and the output rainfall excess can be transported to the EUROSEM's rainfall file as its input parameters.

5. I have made an overall comparison of the infiltration measuring methods used in Hungary.
It gives us possibility to develop formulae for converting the results measured with different methods to each others.

4. Publications in the subject of the dissertation

BARTA K. - FARSANG A., 2000: The effect of structural changes in agriculture on soil degradation processes (case study in Hungary). In: Abstracts Book. Man and Soil at the Third Millennium. 28 March - 1 April, 2000. Valencia. p. 63.

CSATÓ SZ. – **BARTA K.** – FARSANG A., 2000: Az elmúlt húsz év tájhasználati változásai és azok hatásai velencei-hegységi mintaterületen. In: A táj változásai a Kárpát-medencében a történelmi események hatására (szerk: Füleky Gy.). Budapest – Gödöllő. pp. 222-227.

BARTA K., 2001: A EUROSEM talajeróziós modell tesztelése hazai mintaterületen. In: A földrajz eredményei az új évezred küszöbén. Magyar Földrajzi Konferencia. Szeged, 2001. október 25-27. (CD)

BARTA K., 2002: Runoff Modelling in large scale. ECO-GEOWATER EuroWorkshop „GI and Natural Hazards". Milano, November 2002. Abstracts of Presentation. pp.13.

BARTA K., 2003: Infiltration and runoff modelling on arable land. COST 623 Final Meeting and Conference. Books of Abstracts and Field Guide. 5-8 July 2003, Budapest Hungary. p. 35.

BARTA K., 2003: Modeling runoff and infiltration on arables. Acta Geographica Szegediensis 38. Szeged. (in print)

BARTA K., 2003: A szántóföldi beszivárgás-lefolyás modellezése. Földrajzi Értesítő (in print)

TILLMANN, A. – **BARTA K.,** 2003: Comparison of the effect of various land uses on soil erosion processes by different erosion models. Journal of Soil and Water Conservation. (in print)