Modeling soil erosion by water on agricultural land in Cenei, Timiş County, Romania

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Abstract: This paper aims to present soil erosion by water on agricultural land with low slope up to 5%. In the study were analyzedthe agricultural land of Cenei, in Timiş County, Romania, on part of drainage systems Răuți – Sânmihaiu German and Checea – Jimbolia, and on the course section of river BegaVeche. The model analyzes soil erosion by water and sediment transport on the main drainage channels and the course section of river BegaVeche.

*Key-Words:*soil erosion by water, sediment transport, drainage system, earth channels,hydrographic area, low slope erosion.

1 Introduction

Through the water cycle in nature appears the phenomenon of soil erosionby water on agricultural land. This phenomenon affects the condition of the drainage systems by clogging the channels section.
Due to this problem it is brought to discussion the possibility of analysis of soil erosionby water on agricultural land with small slopes.
The model analyzes agricultural land of Ceneiwhich is located in Timiş County, on western part of Romania[1].
Agricultural land in the territorial area ofCenei overlaps with parts of drainage systems Răuți – Sânmihaiu German and Checea – Jimbolia administered by the National Agency for Land Reclamation, Timis Branch. Both drainage systems were designed and built in the '70s, and consists in main drainage channels, secondary channels and tertiary channels. Themain channels are named CPE and they transport water to the drainage pumping stations, SP Uivar and SP Cenei, located on the left and right bank of the river BegaVechewhich flows beside Cenei.[2][3]

2 Problem Formulation

The sediment formation consist of processes in which soil particles are detached and transported on soil surface by external dynamic agents (precipitation, wind) and deposited at different distances from the detachment place. [4]

In order to evaluate the soil erosion by water on the studied surface due to the small slope of surface,which is up to 5%., for the analysis was used a modelling program -WEPP (Water Erosion Prediction Project) [5]
WEPP is software for the prediction of erosion processes in watersheds, developed by USDA Forest Service, Agricultural Research Service, Natural Resources Conservation Service, Department of Interior's Bureau of Land Management and Geological Survey from USA, now days, the most used model in numerous countries. WEPP has been under a permanent development process since 1985.
The WEPP model may be used in both hillslope and watershed applications. The model is a distributed parameter, continuous simulation and erosion prediction, implemented as a set of computer programs for personal computers.
The hillslope component of the WEPP erosion model requires a minimum of four input data files to run: climate file, slope file, soil file and plant/management file.
The watershed component requires a minimum of seven input data files: each hillslope information file, structure file, slope file, soil file, management file, climate file and channel file.
WEPP considering the hillslope consist in numerous parallel rills; the surface erosion occurs on interrill surfaces and the dislocated soil particles are

transported downhill by rill flow (rill erosion is also considered in calculus).

WEPP produces many different kinds of output, in various quantities, depending upon the user's needs. The basic output contains the runoff and erosion summary information, which may be produced on a storm by storm, monthly, annual or average annual basis. The time – integrated estimates of runoff, erosion, sediment delivery and sediment enrichment are contained in this output, as well as the spatial distribution of erosion on the hillslope (fig.1).

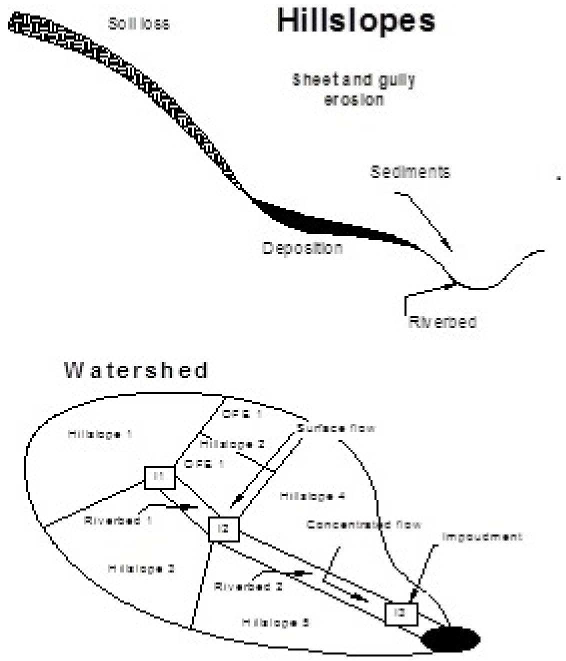

Fig.1 WEPP Model

The model has two basic components:

Erosion component

It is based on the continuity equation:

$$\frac{dG}{dx} = D_r + D_i \quad (1)$$

where: G – sediment load (kg/s.m)

x – distance downslope (m)

D_r – rill erosion rate (+ for detachment, - for deposition)

D_i – interrill sediment delivery (kg/s.m^2).

For the calculus of D_i following relation is used:

$$D_i = K_{iadj} I_e \sigma_{ir} SDR_{RR} F_{nozzle} \left[\frac{R_S}{w}\right] (2)$$

where: K_{iadj} – interrillerodibility

I_e – effective rainfall intensity (m/s)

σ_{ir} – interrill runoff rate (m/s)

SDR_{RR} – sediment delivery ratio (function of random roughness, side slope, particle size distribution)

F_{nozzle} – irrigation adjustment factor (if is case)

R_s – rill spacing (m)

w – rill width.

Rill erosion is divided into two parts, detachment and deposition. Rill detachment is predicted when the flow shear stress exceeds the critical shear stress of the soil and when the sediment load is below the calculated sediment transport capacity. For the calculus of $D_r$the following relation is used:

$$D_r = D_c \left(1 - \frac{G}{T_c}\right) (3)$$

where: D_c – detachment capacity by rill flow (kg/s.m^2)

T_c – sediment transport capacity (kg/s.m).

$$D_c = K_r (\tau_f - \tau_c) (4)$$

where: K_r– rill erodibility parameter

τ_f – flow shear stress acting on soil (Pa)

τ_c – critical shear stress of soil (Pa).

Deposition in a rill will be predicted when the sediment load is greater than the sediment transport capacity. For its calculus, we use the following relation:

$$D_r = \frac{\beta V_f}{q} (T_c - G) \ (5)$$

where: V_f – effective fall velocity for the sediment (m/s)

q – flow discharge per unit width (m^2/s)

β – rainfall turbulence coefficient.

The shear stress factor τ for the rill flow is calculated with the help of the following equation:

$$\tau = \gamma R \frac{f_s}{f_t} \sin\alpha \ (6)$$

where: γ – specific weight of water (kg/m^2.s^2)

R – hydraulic radius (m)

α – average slope angle for uniform segment

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f_s/f_t – ratio of friction factor for the soil to total rill friction factor (accounts for shear stress acting on surface cover like residue etc.)

For the calculus of hydraulic radius, a rectangular rill is assumed and the flow depth in the rill is calculated using the Darcy – Weisbach equation:

$$f = \frac{8gRS}{V^2} \quad (7)$$

where: g – gravity (m/s^2)
R – hydraulic radius (m)
S – average slope (%)
V – flow velocity (m/s).

The transport capacity is calculated by applying the full Yalin (1963) equation to the end of an overland flow element (OFE) or hillslope.

$$T_c = k_t \tau_f^{3/2} \quad (8)$$

where: k_t – transport coefficient ($m^{0,5}s^2/kg^{0,5}$), depends on hill slope
τ_f – hydraulic shear stress acting on the soil (Pa).

Hydrology component

The hydrology component of the WEPP model produces four inputs for the erosion component: peak runoff rate, effective runoff duration, effective rainfall intensity, effective rainfall duration.
Infiltration is calculated using the Green - Ampt and Mein – Larson (GAML) equations:
For $F < F_s$:

$$f = i \quad \text{and} \quad F_s = \frac{S \cdot IMD}{i/K_s - 1} \quad \text{for} \quad i > K_s \quad (9)$$
$$\text{no calculation of } F_s \text{ for } i \le K_s$$

For $F \ge F_s$:

$$f = f_p \quad \text{and} \quad f_p = K_s\left(1 + \frac{S \cdot IMD}{F}\right) \quad (10)$$

where: f – infiltration rate
f_p – infiltration capacity
i – rainfall intensity
F – cumulative infiltration volume
F_s – cumulative infiltration volume required to cause surface saturation
S – average capillary suction at the wetting front
IMD – initial moisture deficit
K_s – saturated hydraulic conductivity of soil.

Depresional storage is related by following relation:

$$S_d = 0.112 \cdot r_r + 3.1 \cdot r_r^2 - 1.2 \cdot r_r \cdot S_0 \quad (11)$$

where: r_r – random roughness (m)
S_0 – slope of flow surface.

Peak discharge (P_r) of surface flow is calculated using a kinematic wave model:

$$\frac{\partial h}{\partial t} + \frac{\partial q}{\partial x} = i - f \quad (12)$$

where: i – rainfall intensity (m/s)
f – infiltration intensity (m/s)
h – depth of flow (m)
q – discharge per unit with of plane (m^2/s
t – time (s)
x – distance (m).

$$q = C \cdot S_0^{0.5} h^{1.5} \quad (13)$$

where: C – Chezy coefficient
S_0 – slope value.

Effective duration of rainfall (t_e) (rainfall intensity > infiltration intensity) is calculated using the following relation:

$$t_e = \left[\frac{L}{C \cdot S_0^{0.5} (i - f)^{0.5}}\right]^{1/1.5} \quad (14)$$

where: L – length of the overland flow surface (m).
The effective runoff duration (t_r) is calculated as:

$$t_r = \frac{V_t}{P_r} \quad (15)$$

where: V_t – total runoff volume (m^3)
P_r – peak runoff rate (m^3/s).

The effective rainfall intensity (I_e) (rainfall intensity > infiltration intensity) is calculated as:

$$I_e = \frac{\int I dt}{t_e} \quad (16)$$

where: I – break point rainfall intensity (m/s).

3 Problem Solution

Cenei locality is located in the western part of Romania in Timiş County, near the border with Serbia (fig.2). The location is in a plain area with relatively small slopes up to 5%.[6]

Fig. 2 Cenei location and the analyzed area

The analyzed surface overlaps with parts of the drainange systems Răuți – Sânmihaiu German and Checea – Jimbolia (fig.3).

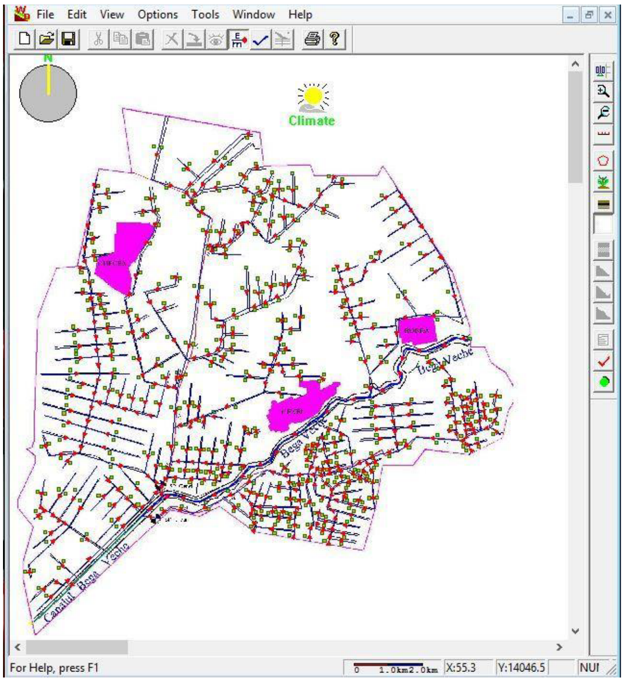

Fig. 3 WEPP model containing the analyzed surface

To create de model were introduced the land surface with slops to the drainage channels (fig.4). For analyzing the surface was essential the correlation between field data consisting in land reclamation works and land surveying.

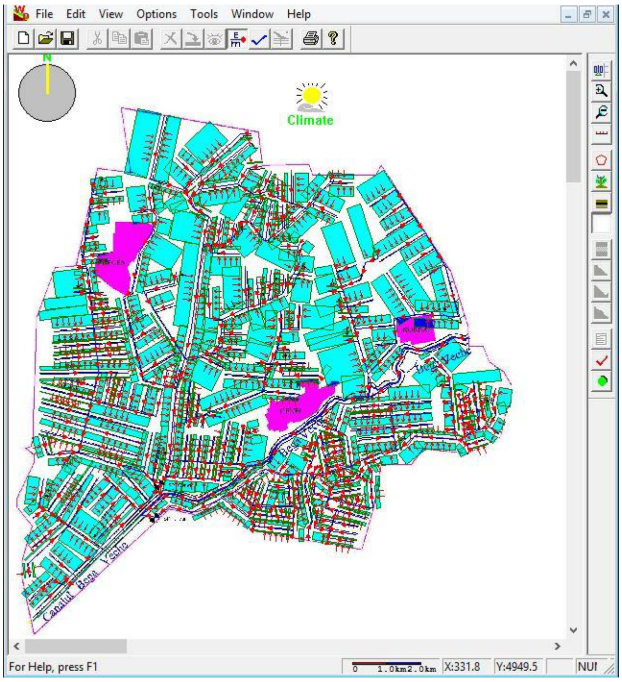

Fig. 4 WEPP model with surfaces and slopes

For obtaining relevant data into the program were entered two types of crops: cereals and corn (fig.5). Essential at this stage was entering the stratification of terrain and soil type for each surface.

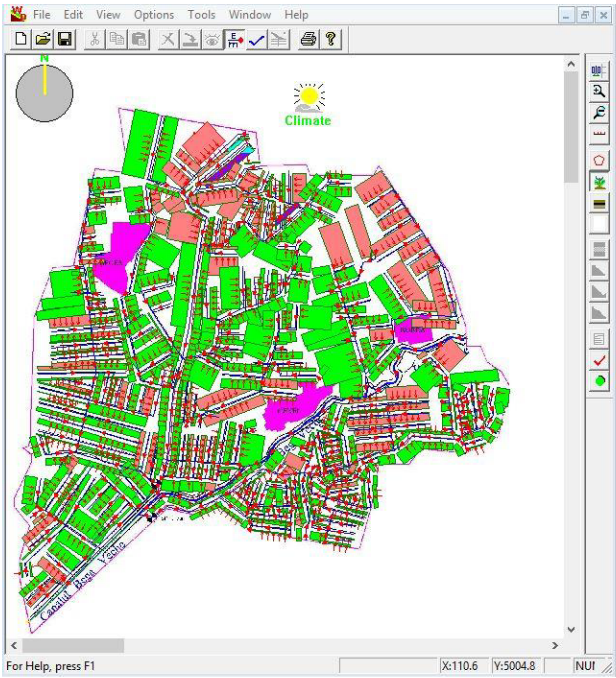

Fig. 5 WEPP model with crop management

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The climate data file was created usingdata from Jimbolia meteorological station or where it was necessary fromTimisoara meteorological station (fig.6).

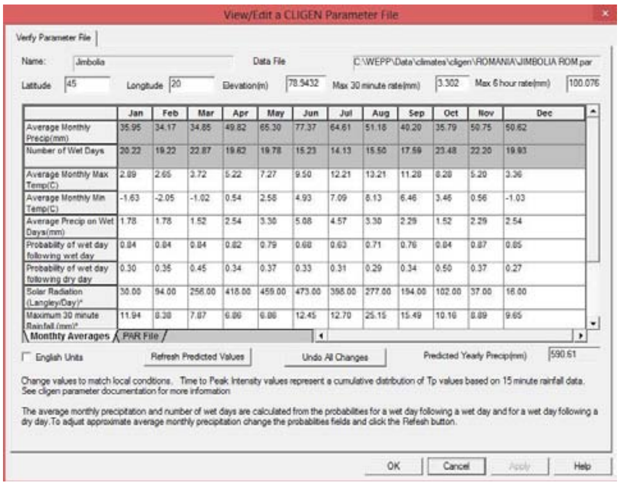

Fig. 6Climate data file for model

The model was run for a one year analysis period for obtaining relevant data of water soil erosion and channelsclogging (fig.7).

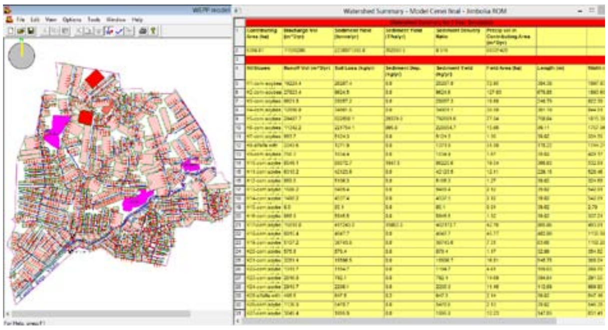

Fig. 7Model results

For analyzing the resultswere extracted data for the most affected surfaces and were obtained tabular and graphic data on the effect of water erosion and sediment transport (fig.8).

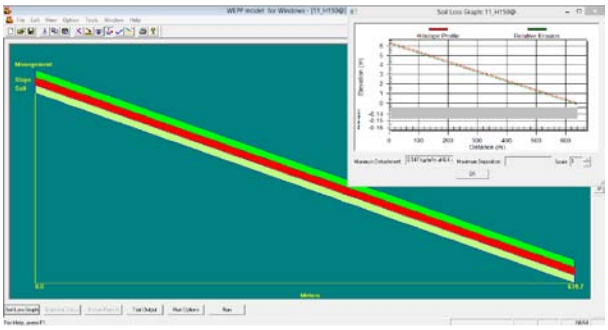

Fig. 8Results on the most affected surface

The results show that across the entire surface of 6350 ha the total sediment yield is 352593 t/ha/yrwith a discharge volume of 11509206 m^3/yr.The precipitation volume in contributing area is about 60331420 m^3/yr.

Main channels have a total sediment yield of 6249 t/yr with a discharge volume of 1335927 m^3/yr.

4 Conclusion

The results show that the phenomenon of water soil erosion affects also the agricultural land with relatively small slopes, but the effect is not so visible.

In time the soil erosion bywater due to the sediment transportation affects the drainage systems by clogging the channels, thereforein order to achieve optimal operation of the drainage system it is necessary to periodicallyintervene.

The effects ofsoil erosion by water can be removed or reduced by periodically applying agricultural works and by establishing the cropsadequate to the studied area that willnot aggravatethe effects.

Similar models were developed for estimating soil erosion by water on hillslopes.

For example the model for establishing soil erosion by water in new USDA erosion prediction technology. Detachment, transport, and deposition processes were represented. The model uses a steady-state sediment continuity equation for predicting rill and interrill processes. The model has capabilities for estimating spatial distributions of net soil loss and is designed to accommodate spatial variability in topography, surface roughness, soil properties, hydrology, and land use conditions on hillslopes[7].

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