STUDY THE INFLUENCE OF INITIAL SOIL MOISTURE AND LAND USE ON THE PHENOMENA OF SOLID FLOWS FROM THE SLOPES OF A HYDROGRAPHICAL BASIN

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Abstract: *Current state of theoretical knowledge and mathematical modeling of soil erosion by water processes, sediment transport and their impact on hydrographical basin area is still relatively in an incipient phase. Given the multitude of factors involved in these processes and influence each other, as the extraordinary diversity of the concrete conditions of nature in which such processes occur, is almost impossible for a general theoretical foundation, from which to develop the appropriate calculation tools, useful in the analysis and engineering design activity. Most of the existing relations are obtained either experimentally or in laboratory conditions, either in situ or physical models. However, numerical simulation models emerged in recent decades (WEPP, USLE, RUSLE, etc.) will produce results with practical use. The purpose of this paper is to study the influence of two important factors in the process of solid flow formation on slopes: the initial soil moisture and the use of land. To do this, was used the WEPP (Water Erosion Prediction Project) software. With this program was modeled process of soil erosion in hydrographical basin Manastiur, Timis County, Romania, in different assumptions of torrential rains production, different initial humidity of soil and different land use. Were determined correlations between soil loss and initial soil moisture, and the use of land, respectively. On the basis of the obtained results, we can plan land management that takes into consideration the present situation and the perspectives of an area and harmonizes the interests of all its determining factors (the human factor, the environment, the economic factor etc.). At the same time, we can establish efficient economic and technical solidflow control measures and works (agrotechnical, forest, hydrotechnical measures; structural and non – structural measures), necessary for the abatement of solid flow and the negative effects of soil erosion on the environment. A critical observation is that the WEPP model is applicable only for small basins; the model can only use a single file with climate characteristics, namely the same type of storms or torrential rains through entire area of hydrographical basin (the same rain intensity and duration).*

Key words**:** *hydrographical basin, soil erosion, solid flow, soil moisture, land use*

INTRODUCTION

The ensemble of physical phenomena of soil erosion processes caused by water include the following phases: soil particle detachment by hydrodynamic forces, sediment transport by surface flow and particles deposition.

The sediment formation is due to processes which consist in soil particles detachment and transport on soil surface by external dynamic agents (precipitation, wind etc.) and their deposition at different distances from the detachment place.

The gathering of erosion processes and sediment transport effects in time has as result the modification and the diminution of the chemical and physical features of soils, the appearance of mass movements, especially landslides, the appearance of geomorphological changes of the river courses, while can change their cross and longitudinal profile forms (and also their form in plan), as well as the riverbed characteristics; the reservoir silting, the river bed erosion in the downstream of dams and ecological problems due to the alteration of the original features of the aquatic ecosystems etc.

The factors which determine the erosion development are: climate (precipitations, wind, temperature), relief, soil, vegetation, lytological factors or base rock, and economical and social factors (human factor). (POPOVICI, 1991; BACOV, 1996)

The precipitations affect erosion through raindrop impact, which is a mechanical action of hit between raindrops and surface of soil. Precipitations also affect erosion through surface flow caused by the rains (storms) and the accelerated melting of the snow (on sunlit hillslopes with abrupt slopes).

In the erosion processes a great importance have the torrential rains, storms, because these have an increasing power to dislocate and transport fine soil particles, to form a continuous sheet of water on the inclined areas or a concentrated flow with great force of breaking and transport.

Wind influence on erosion depends on the wind frequency and velocity, the soil structures and textures, the degree of exposition, degree of vegetation cover, the soil humidity, frost – thaw phenomenon etc.

Temperature affects the erosion processes through the frost – thaw phenomenon, which determines the increase of the intensity of rocks desegregation, while, when humidity conditions are favorable, temperature influences through the alteration processes.

The relief is the most important natural factor in the initiation and the maintenance of erosion, as it determines the water flow on hill slopes, as well as the soil loss. The characteristic elements of relief, affecting erosion, are: elevation, slope, form, length and exposition.

The soil influences erosion processes through its resistance to erosion during surface flow as well as through its infiltration capacity. Soil resistance to erosion is mainly determined by cohesion and permeability, in their turn depend the soil structure and texture. An important factor is the initial soil moisture. In case of torrential rains, that cause erosion phenomenon through displacement of soil particles due to rain drop kinetic energy, manifests itself stronger ground with an initial humidity lower than on soil with a higher initial moisture.

Also, initial soil moisture influences the infiltration phenomenon. Rainwater seeps easily into ground with a lower initial moisture, reducing the volume of surface flow, leading to a weaker entrapment of soil particles, while a soil with a higher initial moisture infiltration is lower, thus increasing the volume of surface flow, which eventually lead to a stronger entrapment of soil particles.

Vegetation is one of the most important factors influencing erosion. An uncovered soil with vegetation is growing more strongly eroded than covered with small vegetation. Most crops can contribute to erosion because the soil is uncovered by vegetation for long periods of time.

The natural vegetation, such as forests and perennial grass, offers a very good protection of soil, as opposed the cultivated vegetation, which to due the agricultural works, contributes to the acceleration of erosion.

Soil erosion occurs mostly on land have been cultivated or grazed too heavily. Soil strain occurs, provided that certain plants are grown each year, but is not fertilization and nutrients are not returned to the soil.

Intensive cultivation reduces soil fertility and yield decline causes. Is also reduced, soil cohesion, thereby decreasing its resistance to erosion. Pasture damage occurs if one gets too many animals on a given area. Too many animals consume vegetation at a rate faster than its rate of natural regeneration, leaving the soil uncovered with vegetation. (http://www.teaching-soil.eu/ro/toolbox_abcsoil.php)

Forests are the determining factor in maintaining ecological balance, climate and water, representing an ecosystem regeneration capacity of 3-5 times higher than any natural ecosystem. Massive deforestations in the last 80 years, especially after First World War led to a reduction in the area of 9 million hectares to 6.3 million ha of forests, of which 5.5% are now affected by pollution and pests.

Forest vegetation helps to slow surface flow, keeping the bedding, the herbaceous vegetation cover and water retention. Bedding is the main source of nutrients and organic matter return to soil. Massive deforestation for wood capitalization is an essential cause of soil degradation by erosion, especially on hillslopes of hydrographical basins. (http://facultate.regielive.ro/referate/agronomie/agrotehnica_antierozionala_mecanismul_erozi unii_hidrice-42284.html)

Lytological factors or base rocks influence directly erosion processes either, through resistance or the absence of resistance, largely determining the appearance and the development of land degradation, especially gully formation and mass movement.

Social and economic factors (human factor) refer to man's actions which concern land, and which must ensure the rational use of land, intervene with measures of soil conservation on hillslopes diminution of erosion processes, even through man has sometimes contributed directly to the initiation of land degradation processes.

MATERIAL AND METHODS

Current state of theoretical knowledge and mathematical modeling of soil erosion by water processes, sediment transport and their impact on hydrographical basin area is still relatively in an incipient phase. Given the multitude of factors involved in these processes and influence each other, as the extraordinary diversity of the concrete conditions of nature in which such processes occur, is almost impossible for a general theoretical foundation, from which to develop the appropriate calculation tools, useful in the analysis and engineering design activity. Most of the existing relations are obtained either experimentally or in laboratory conditions, either in situ or physical models. However, numerical simulation models emerged in recent decades (WEPP, USLE, RUSLE, etc.) will produce results with practical use.

WEPP model description

WEPP (Water Erosion Prediction Project) (USDA-ARS, 1995) is a 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 a days, the most used model in numerous countries.

The WEPP model may be used in both hillslope and watershed applications. The model is a distributed parameter, continuous simulation, erosion prediction model, 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 most 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).

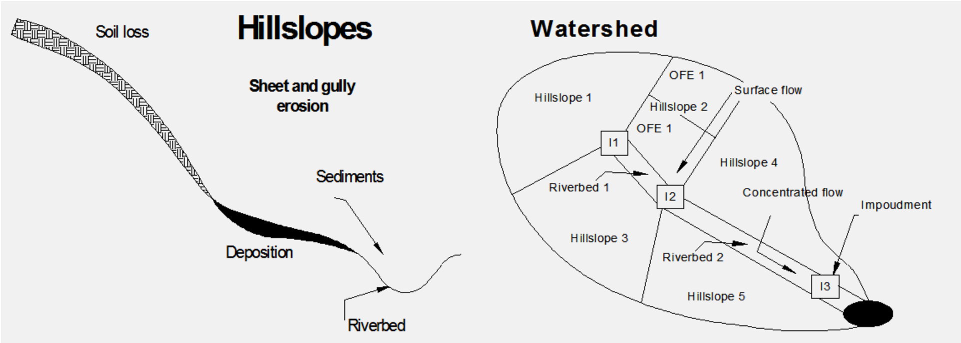

Figure 1: WEPP Model

The model have two basic components:

a). 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).

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. Deposition in a rill will be predicted when the sediment load is greater than the sediment transport capacity.

b). 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 $F < F_s$:

$$f = i \quad \text{and} \quad F_S = \frac{S \cdot IMD}{i / K_S - 1} \quad \text{for} \quad i > K_S \quad (2)$$

no calculation of F_S for $i \le K_S$

For $F \ge F_s$:

$$f = f_p \quad \text{and} \quad f_p = K_S\left(1 + \frac{S \cdot IMD}{F}\right) \quad (3)$$

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.

Description of studied area

The studied territory – Manastiur hydrographical basin – is situated in the depression between Zarandului and Poiana Ruscai Mountains, at the borderline between Lipova Plateau and the Occidental Field. From a genetic perspective, the studied perimeter is characterized by a piemontane accumulative relief; the relief consists of Pliocene river deposits. The morphogenetic processes are particularly subject to the activity of the hydrographical network, which generated a choline hill like relief, with altimetry values between 120 and 300 m. Relief asymmetry shows how this has evolved, at least during the Quaternary, mostly under the influence of the basic level of Bega river. On the whole, the relief presents a general inclination from the north-east to the south-west, with the following components: piemontan hills on the north, terraces on the south and central part, a river meadow in the central part.

The hillslopes generally have a complex profile, with slopes between 2– 50 %. Ravines are frequent on the hillslopes with large and medium slopes, and landslides are isolated, not stretching on large areas.

Erosion processes are most intensified on hillslopes with south, south-east, east and south-west exposition, and they are also most increased when land is used for agricultural purposes, in comparison with pasture and hay fields. The occurrence of deep hydric erosion forms is also due to the unreasonable human intervention (unjustified fallow and exacerbated deforestation). (OSPA, 1982)

As regards vegetation, the territory belongs to the area of deciduous tree forests, like the oak tree, with the following forms of vegetation: natural wood vegetation, shrubs, cultivated wood vegetation, natural grass vegetation, leguminous vegetation, herbage and plants in crop. Land uses concern: forests, trees, pastures, hay fields and arable land, the corresponding surfaces not being exactly known.

In order to model the phenomena related to solid runoff we chose the sub-basin of Topla river, with a length of 11,56 km, a surface of 2357,40 ha; containing 56 sectors of secondary valleys, with a total length of 31,58 km and 184 small sub-basins corresponding to these secondary valleys; the plan of the area, with the separation on sub-basins corresponding to each valley, is shown in figure 2.

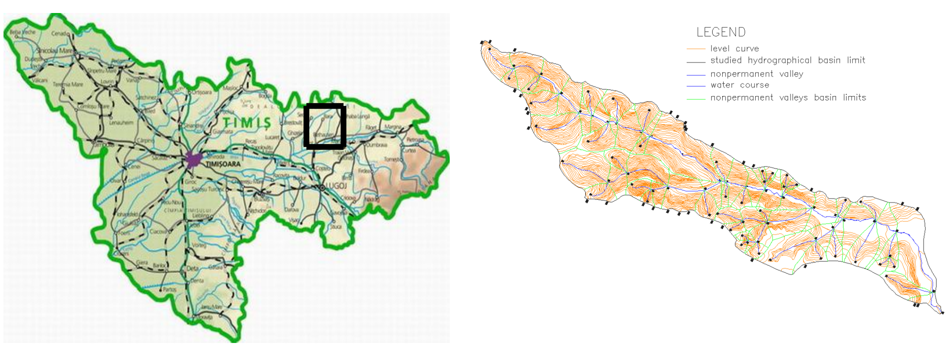

Figure 2: Location of the studied hydrographical basin and area plan of Topla valley

For the study of influence of initial soil moisture and land use on the phenomena of solid flows we chose one hillslope from studied hydrographical basin (with area 60,66 ha, hillslope length 473 m, width 1283 m, average slope 12,69 %) and considered the following hypotheses:

- the constant intensity of the rain on the entire surface of the hillslope;
- the same soil type for the entire hillslope - *Typic Hapludalfs* (with more subtypes), of a middle and heavy texture (reduced permeability), being part of the hydrological group C;
- soil use is the same all over the hillslope surface;
- there are no human works to control soil erosion.

The soil characteristics are shows in table 1. (OSPA, 1982)

Table 1

Soil characteristics

Layer	Depth (inch)	Sand (%)	Clay (%)	Organic (%)	CEC (meq/100 g)	Rock (%)
1	5,906	37,2	21,2	1,800	11,4	0,0
2	14,170	38,1	20,9	1,670	10,9	0,0
3	26,770	31,0	30,5	0,800	14,4	0,0
4	34,250	28,8	36,2	0,001	19,3	0,0
5	40,550	29,3	32,0	0,001	18,6	0,0
6	51,180	34,4	31,3	0,001	18,3	0,0

WEPP model was applied for the calculus of the soil loses on hillslope during the torrential rain, in four hypotheses (which have resulted from the torrential rain distribution charts with the 10% assurance and having a duration of 5, 15, 30, 60 minutes, elaborated on the basis of measurements and statistical processing of the meteorological data on the Bega hydrographical basin area (table 2). (BACOV et al., 1988)

Table 2

Characteristics of torrential rains

Storm Amount (mm)	Storm duration (hr)	Max intensity (mm hr^{-1})	% Duration to Peak Intensity
15,00	0,08 (5 min)	189,375	20
23,30	0,25 (15 min)	94,132	20
28,80	0,50 (30 min)	58,176	20
42,00	1,00 (60 min)	42,420	20

RESULTS AND DISCUSSIONS

In figure 3 are shows the variation of soil losses (solid flows) in those four hypotheses of torrential rains producing, in function with initial soil moisture of studied area, for different type of land use.

From the results obtained by running the WEPP program in the 4 hypotheses to produce torrential rain, for different initial soil moisture can be observed:

- between all studied correlations (linear, logarithmic, polynomial of different degrees, exponential) between the initial soil moisture and soil specific losses, the best proved to be the exponential, it having the highest correlation coefficient;
- lowest soil loss occurring on land use of pasture and straw plant, and highest soil loss occurring on degraded pastures and weed plant crops;
- for land use of pasture and straw plants are not significant variations of soil loss for an initial moisture of 20% and 100% when torrential rains lasting 5 and 15 minutes, significant growth took place when torrential rain lasting 30 and 60 minutes;

- a relatively uniform increase in the amount of soil loss is observed in degraded pasture, in which event occurring and the largest loss of soil.

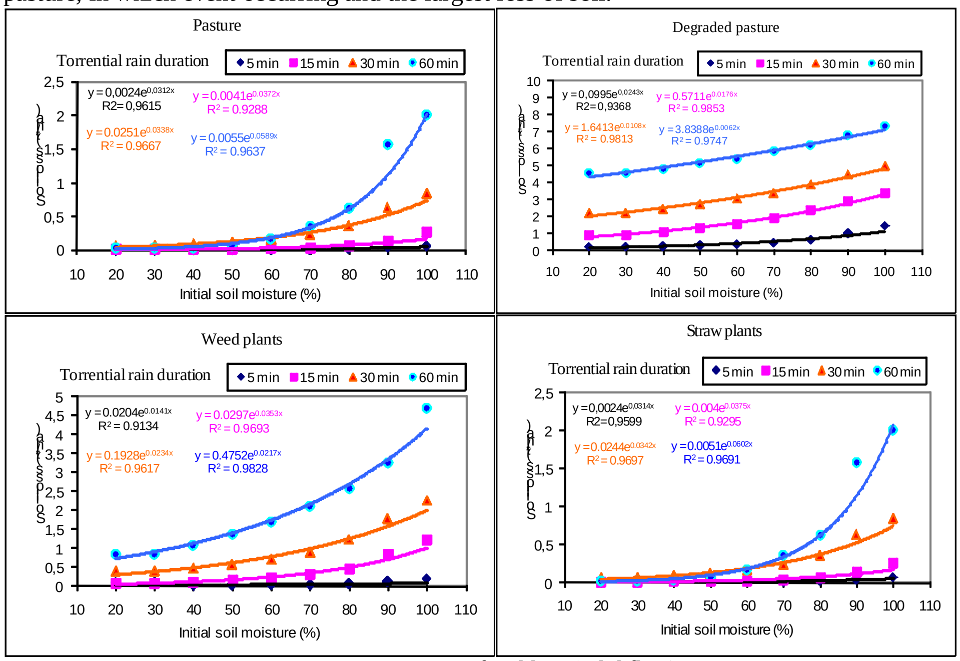

Figure 3: Variation of soil loss (solid flow)

CONCLUSIONS

The overland flows, determined by the torrential rains, on the hillslope surfaces, which determine solid flow, very much depend on the initial soil moisture. The higher the initial soil moisture gets the greater the volume of overland flow, and implicitly, of the solid flow becomes.

For a short duration of torrential rains, in case of hillslopes covered with well-developed forests, overland flow and solid flow are insignificant. This is a reason for which is not considered in the study the forest land use.

On the basis of the obtained results, we can plan land management that takes into consideration the present situation and the perspectives of an area and harmonizes the interests of all its determining factors (the human factor, the environment, the economic factor etc.). At the same time, we can establish efficient economic and technical solid flow control measures and works (agrotechnical, forest, hydrotechnical measures; structural and non – structural measures), necessary for the abatement of solid flow and the negative effects of soil erosion on the environment.

A critical observation is that the WEPP model is applicable only for small basins; the model can only use a single file with climate characteristics, namely the same type of storms or torrential rains through entire area of hydrographical basin (the same rain intensity and duration).(BEILICCI et al., 2009)

In future is necessary to develop of complex prediction models for solid and liquid flow in hydrographical basins imposes the creation of multidisciplinary research teams for the modeling of hydrological, pedological and soil erosion processes. The development of a model for the complex processes that occur on hillslopes supposes a compromise between the processes that we wish to incorporate into the model and the processes that we know from the available data.

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