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STUDY THE POSSIBILITY OF SOLID FLOW VOLUME REDUCTION IN A HYDROGRAPHICAL BASIN

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Abstract: *In general, the effects of solid flow on hydrographical basin can be divided into positive and negative, negative ones with the highest weight. The most important adverse effects of solid flow from the agricultural point of view are: changing or diminishing physical and chemical properties of soils; agricultural production decreased in proportion to worsening soil properties, increased droughts by reducing water retention on slopes and quantitative growth of surface runoff; temporary or permanent removal from agricultural circuit of large areas of land affected by erosion and other degradation processes; difficulties in the operation of irrigation and drainage systems due to clogging of channels and pipe network. environment pollution because through erosion on slopes much of the chemical fertilizers used in agriculture are wash and accumulate in low areas or entering into groundwater and surface waters; increased occurrence of flash floods, favoring the occurrence of landslides. Soil erosion is a natural phenomenon that cannot be stopped completely, but controlled by a series of structural and non-structural measures, this paper aims to explore the possibilities of reducing the volume of solid flow from a hydrographical basin. By arranging ravines and torrents seeking to enforce a set of measures for regulating runoff on slopes and drainage network, in order to restore the whole area of catchment to economic use and erosion control categories, to remove the damage caused by floods. Currently, no yet exist a mathematical model of soil hydric erosion approaching as much by physical phenomenon of slope runoff and solid particles entrainment by water currents, upon which to realize the fundamental physical hydrological model of hydrographical basin. In this paper, for solid flow modeling in a catchment, is used the WEPP program. Based on the obtained results was analyzed the efficiency of solid flow control works, particularly for the cross dam with small height.*

Key words: *hydrographical basin, soil erosion, solid flow, control.*

INTRODUCTION

In general, the solid flow effects on hydrographical basin can be divided into positive and negative, negative ones with the highest weight.

The positive effects of solid flow on a hydrographical basin are: fertilized soils in floodplains of watercourses; the regeneration of exploitable reserves of alluvial materials for construction; ensuring the river beds morphodynamic equilibrium; natural way to achieve corrected flow pathways such as piercing meanders through autodredging, clogging breakwater fields; enhancing high water discharge in beds that have suffered marked erosion processes of deepening the beds.

The negative effects of solid flow on a hydrographical basin are: changing or diminishing physical and chemical properties of soils, agricultural production decreased in proportion to worsening soil properties; increased droughts by reducing water retention on hillslopes and quantitative increase of surface runoff; temporary or permanent removal from agricultural use of large areas of land affected by erosion and other degradation processes; environmental pollution because erosion are washed from the hillslopes and accumulate in low areas or enter in the groundwater and surface water much of the chemical fertilizers used in agriculture; greater damage of land with high slopes by erosion caused by irrigation; increasing the frequency of flash floods; difficulties in the operation of irrigation and drainage systems due to clogging of canals and pipelines networks; promoting landslides occurrence; changing liquid flow transit regime, especially of floods; changing the longitudinal route of rivers due to acceleration and intensification of meandering processes; changing of water quality, with important repercussions for the population and industry; clogging of reservoirs; reducing capacity electricity production from hydropower; possible shutdown of drainage facilities, water capture and control dams; increased erosion processes in tail water; compromising stability or river regularization works – dikes, baring and crossing works; silting of channel networks for navigation, leading change of operating parameters in comparison with the projected values. Causes and the most important effects of soil erosion and solid flow on a watershed are illustrated in Figure 1.

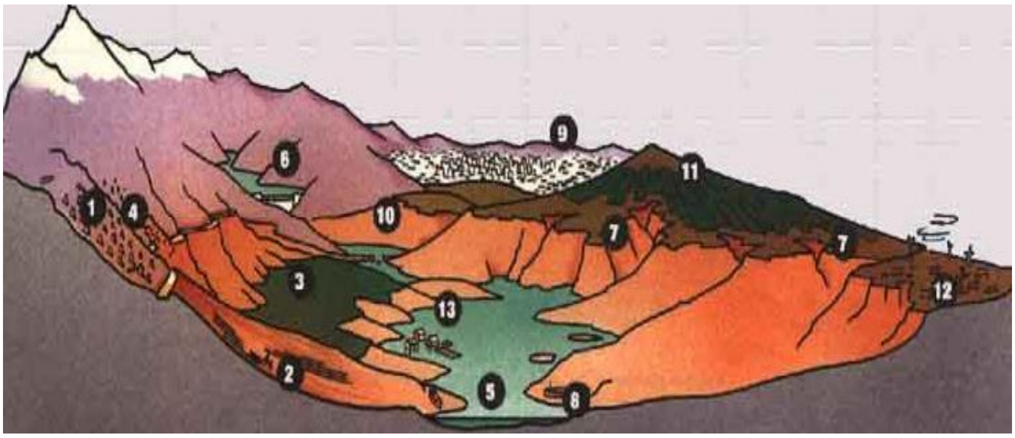

Figure 1: Environmental impacts of erosion and solid leakage (www.fao.org, 2006)

Significance of notations: 1 – deforestation; 2 - work agricultural land with high slopes as the steepest slope line, uses inappropriate; 3 - monocultures over large areas of land; 4 - landslides, collapse of rocks; 5 - degradation of the fish population in shallow waters; 6 - reservoirs clogging; 7 - surface and depth soil erosion; 8 - worsening of navigation conditions; 9 - development of large urban agglomerations by population migration from rural to urban areas, due to the inability to meet the needs of living; 10 - destroying bridges and land communication routes during floods; 11 - leaving derelict agricultural land (unprotected); 12 - affecting of poorly protected land by wind erosion; 13 - leaving frequently flooded human settlements.

Destruction of topsoil (soil loss by erosion) is the progressive removal of fertile topsoil and surfacing infertile horizons, reaching even to the parent rock. Aggressive action of water on hillslopes has a double effect: the top layer of fertile soil washing and submitting it to base of the slopes, on the river valleys, lakes and reservoirs, thus degrading the soil on the slopes and at the base of the slopes, and the water quality in the reservoirs. It is estimated that removing a layer 1 cm thick soil per hectare, mean loss of 130 tons of soil, representing an average of almost 3 tons of humus, which results in large decreases in plant production. (BERAR et al, 1983)

Materials from destruction of soil layers are transported by water (by surface runoff and drainage from the beds of torrents, gullies, ruts and rills) and deposited in low slope areas, where water speed drops below the speed of sedimentation of soil particles.

Changing of chemical characteristics of soil - refers to changes in the chemical content of soil horizons. Solid particles entrained by the surface flow from hillslopes have an important role in the transport of chemicals (adsorbed or absorbed) from the soil.

Washing of chemicals from soil can be done in two main ways: through infiltration and surface runoff. Several models were developed to study this process, they are based on the assumption that the concentration of various chemicals in surface runoff decreases from an initial value, as increasing amounts of substances are removed from the upper soil horizons by infiltration and drainage.

Damage of physical and hydrological properties of the soil refers to changing in the physical characteristics of soil and in soil water dynamics. Erosion contributes to the increase soil bulk density in profile, increase of the pH and wilting coefficient, decreasing of soil porosity, of total water capacity of the soil, field capacity, the useful water reserve capacity etc. Annual gradual loss from soil surface horizons are leading to appereance of new horizons with changed physical and hydrological characteristics. Immediate effects of change in soil texture and structure are decreasing degree of aeration of the soil and increase soil bulk density. Most important effects of worsening soil water dynamics, as a primary circulation way of nutrients in the soil, are the decreasing of agricultural production and degradation of land vegetation on hillslopes (NEAMŢU, 1996). Another effect is increased droughts by reducing the amount of water held on the hillslopes and increased surface runoff. With increased awareness of soil washing, soil mechanical composition becomes easier. Decrease of muddy material and humus content, soil colloids and microorganisms wash which containing them, causing continuous reduction of cohesion, higher content of large particles, leading to failure of the soil to erosion easier.

Figure 2 shows the risk of physical degradation of soil, depend to the ratio of the percentage of organic matter and clay content of the soil.

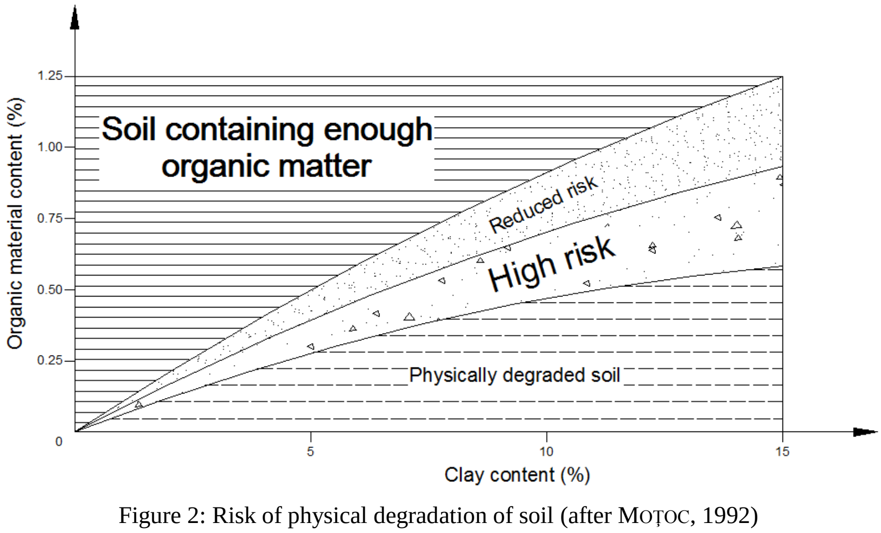

Figure 2: Risk of physical degradation of soil (after MOŢOC, 1992)

Continuous decrease of agricultural production on hillslopes with agricultural use, fruit growing and wine production, refers to the reduction of soil production potential especially since the erosion is advanced, but it occurs differently, depending on soil type and intensity of change in the main physical and chemical properties of surface horizons reached by erosion. Figure 3 shows the decrease in agricultural production depending of the depth of topsoil eroded, respectively of the degree of soil erosion (NEAMȚU, 1996). It can be seen that there is a negative linear correlation between decrease of agricultural production level and eroded soil depth.

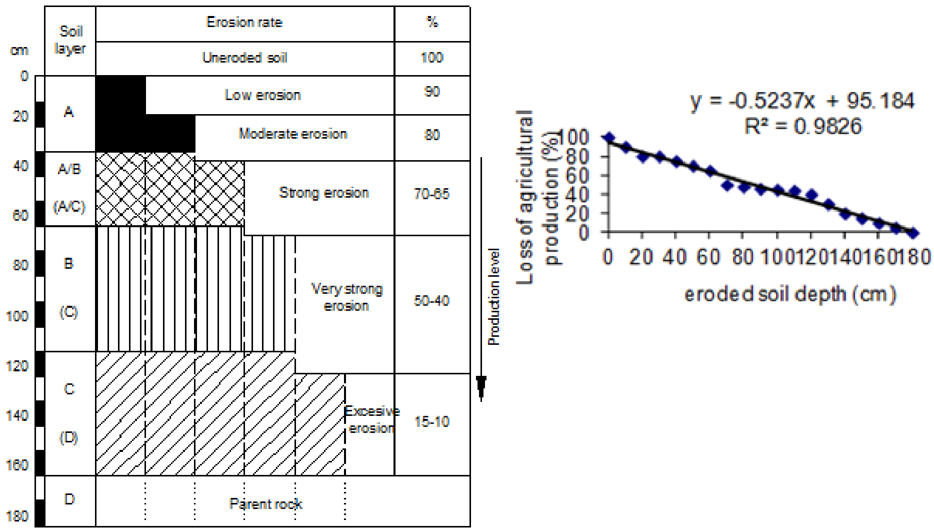

Figure 3: Decrease of agricultural production with eroded topsoil depth

To reduce the volume and effects on hydrographical basin of solid flow are the following categories of works: (BÂCOV, 1996; POPOVICI, 1991, GIURMA, 1997; DI SILVIO, 1998; www.fao.org, 2006):

1. Works on hillslopes (erosion control works) - organizational works (restructuring land use categories: arable, vineyard, fruit trees, lawns etc., ensuring road networks through which to carry reducing transportation costs, internal organization of new categories of use, by creating territorial units of work, corresponding in shape and size, taking into account the achievement of maximum efficiency in agricultural mechanization and soil erosion control; creating the conditions for correct entering of antierosional systems and a corresponding agrotechnics that would ensure prevention and control of soil erosion and increase agricultural production); agro-phytotechnical works (soil preparation work, methods that do not change surface microrelief, tillage methods that modify the surface microrelief in order to disperse and slow leaks, special methods for retaining water in the fields, fertilization, sowing - on the contour line, crop rotation on hillslopes, crop systems after contour lines direction, culture into strips, grass strips, agroterraces, grassing); forestry works and measures (vineyards and orchards, reforestation on land eroded by water); hydroameliorative and hydrotechnical works (horizontal or inclined earth waves and channels, terraces with horizontal or inclined platform, individual terraces with support wall, with picket fences, horizontal or inclined coastal channel outlets in natural or artificial valley).

2. Torrential formations arrangement. By ravines and torrents arrangements seeking to enforce a set of measures for regulating runoff from hillslopes and in drainage network in order to restore the whole area of catchment to corresponding economic and erosion control

categories and to remove the damage caused by floods. After application site of works we have: works in the peak zone and in ravine origin zone (branch occlusion and modeling – leveling the area, retention of leakage through horizontal channels, interception and evacuating of leakage through inclined channels and outlets, forestation); arrangements along the drainage network (forestation, grassing, simple slopes, riprap of stone or concrete slabs, retaining walls, contrabanquette for banks); cross construction that can be filtered (wood works - fascine, layers of fascines, fill/packing, wattlework, crest and dams of stone and concrete - dry masonry, gabions, stone masonry cross works – with cement and concrete); longitudinal hydrotechnical works (works to strengthen the banks, river regularization works - to change direction or position of water current); arrangements in the natural area of deposit of silt (evacuation channels, setting deposited alluvial material, creating conditions for flood water evacuation).

3. Other non-construction measures: developing information systems for torrential flood warning and forecasting and decision systems for operative action; implementation and development of the monitoring system of triggers and favoring factors of dangerous phenomena of soil erosion; rethinking hydrotechnical arrangements operating rules; institutional reform, developing legal frameworks for coordination and institutions responsible for developing strategies and operational decisions; developing or updating of regulations, operational action plans and intervention models for various manufacturing scenarios of dangerous erosion (flash floods, mud flow, landslides); developing risk maps (especially for landslides); placing restrictions on building permits for hazardous areas; activities awareness of decision makers at different levels and population located in areas with dangerous erosion phenomena’s risk; developing appropriate economic instruments: the material property insurance through insurance - reinsurance companies, compensation schemes etc.; relocation of settlements and economic objectives from areas with high risk of producing dangerous erosion phenomena’s. (STĂNESCU et al, 2002)

MATERIAL AND METHODS

For the study of possibilities to reducing the solid flow volume in watershed was used WEPP program. The modeling of solid and liquid flow in studied watershed was realized assuming the hypotheses of natural watershed, without solid flow control works and, respectively in the variant of realization of four small high rock fill check dams, than controlling solid and liquid flow into four sections of the studied basin.

The USDA - Water Erosion Prediction Project (WEPP) model represents a new erosion prediction technology based on fundamentals of stochastic weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics. The hillslope or landscape profile application of the model provides major advantages over existing erosion prediction technology. The most notable advantages include capabilities for estimating spatial and temporal distributions of soil loss (net soil loss for an entire hillslope or for each point on a slope profile can be estimated on a daily, monthly, or average annual basis), and since the model is process-based it can be extrapolated to a broad range of conditions that may not be practical or economical to field test. In watershed applications, sediment yield from entire fields can be estimated (figure 4).

Processes considered in hillslope profile model applications include rill and interrill erosion, sediment transport and deposition, infiltration, soil consolidation, residue and canopy effects on soil detachment and infiltration, surface sealing, rill hydraulics, surface runoff, plant growth, residue decomposition, percolation, evaporation, transpiration, snow melt, frozen soil effects on infiltration and erodibility, climate, tillage effects on soil properties, effects of soil random roughness, and contour effects including potential overtopping of contour ridges. The model accommodates the spatial and temporal variability in topography, surface roughness, soil properties, crops, and land use conditions on hillslopes.

In watershed applications, the model allows linkage of hillslope profiles to channels and impoundments. Water and sediment from one or more hillslopes can be routed through a small fieldscale watershed. Almost all of the parameter updating for hillslopes is duplicated for channels. The model simulates channel detachment, sediment transport and deposition. Impoundments such as farm ponds, terraces, culverts, filter fences and check dams can be simulated to remove sediment from the flow. (USDA, 1995)

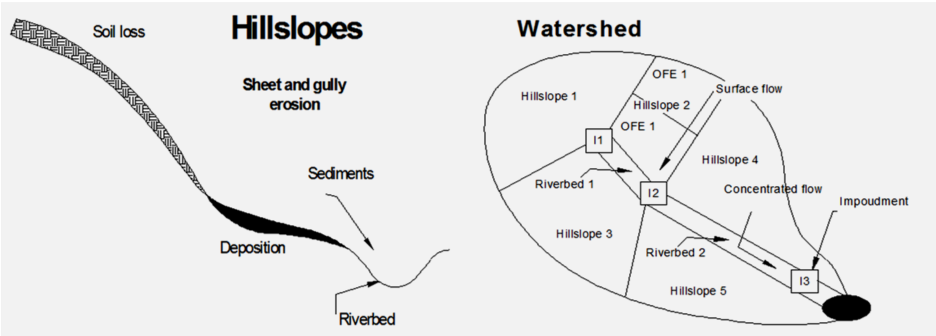

Figure 4: WEPP Model

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 and the location of check dams is shown in figure 5.

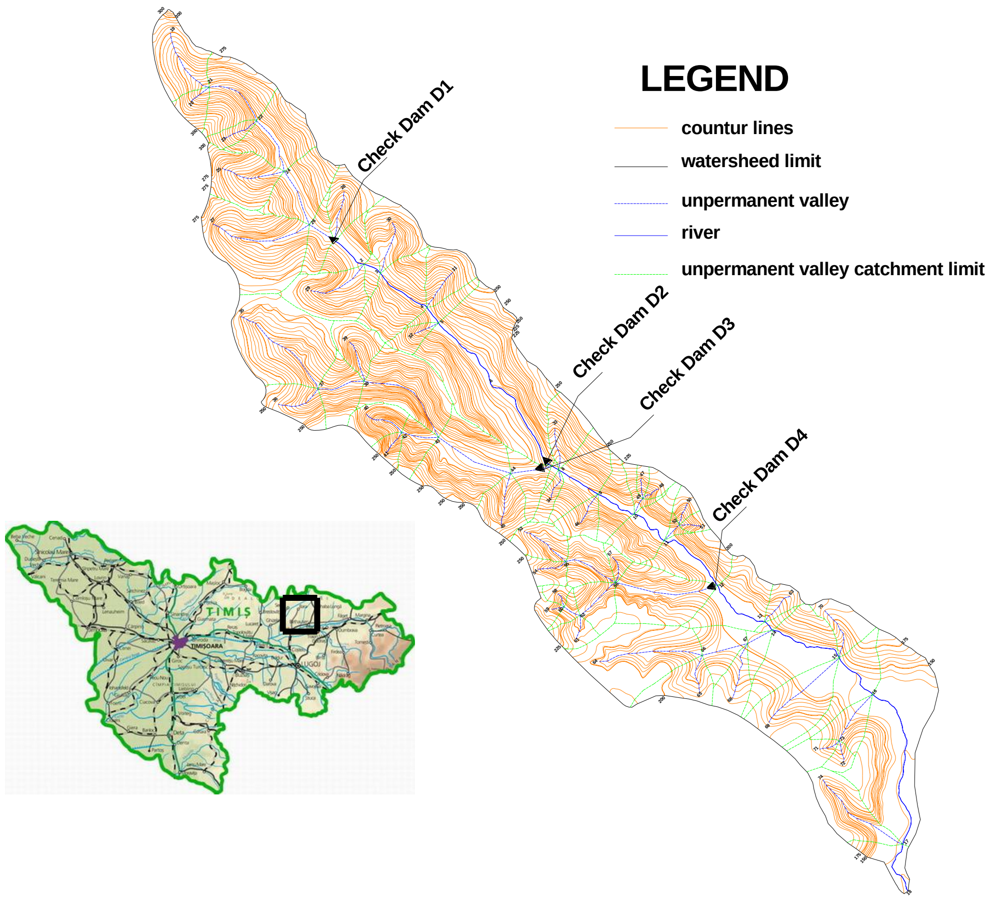

Figure 5: Location of the studied hydrographical basin and area plan of Topla valley

For the study we 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

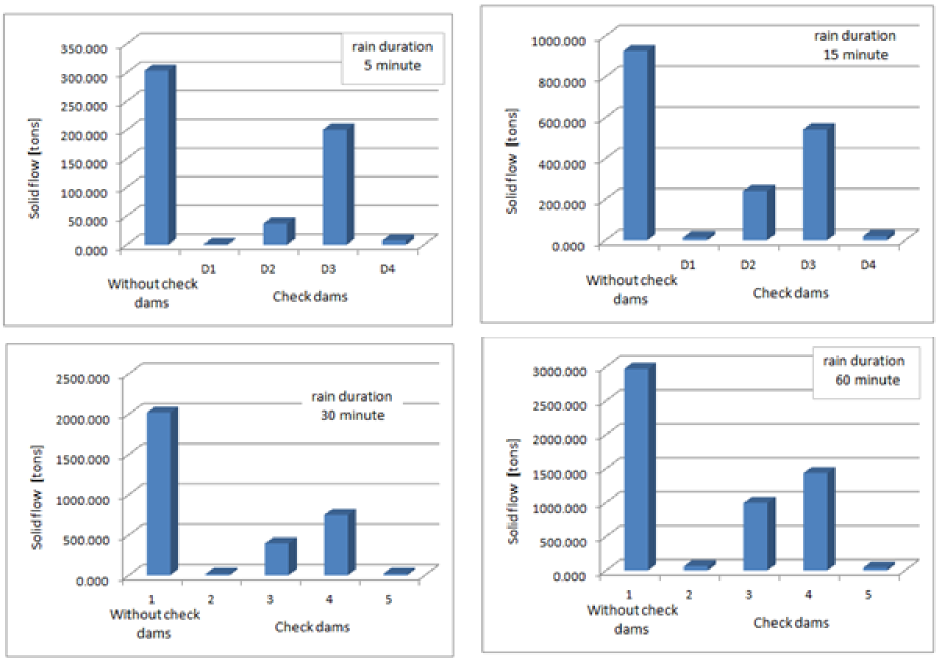

Figure 6: Solid flow amounts from studied watersheed

Solid flow modeling results in studied hydrographical basin can be seen in Figure 6. The graphs show the amount of solid material derived from the hydrographical basin in variant of natural watershed, without solid flow control works and, respectively in the variant of realization of four small height rock fill check dams, than controlling solid and liquid flow into four sections of the studied basin, in all the four hypotheses of producing heavy rains.

It can be seen that the largest contribution to solid material retention is given in all four modeling assumptions by dam D3. The explanation is that this dam controls the largest area of the basin, respectively the land use in this area.

The smallest contribution has D1 dam, he controlling solid flow in the river basin edge where solid leakage have insignificant values due to well-developed forest land cover, which protects the soil.

Similarly, the dam D4 controlled sub-surface is quite small and it is located downstream of other dams, the amount of sediment retained is relatively small, the bulk being retained by dams from upstream.

Figure 7 shows the quantity of solid material derived from the hillslopes of hydrographical basin after retained a part of them by the four small height rock fill check dam. It can be seen that the four dams to retain all the assumptions of producing heavy rain more than 60% of the total sediment.

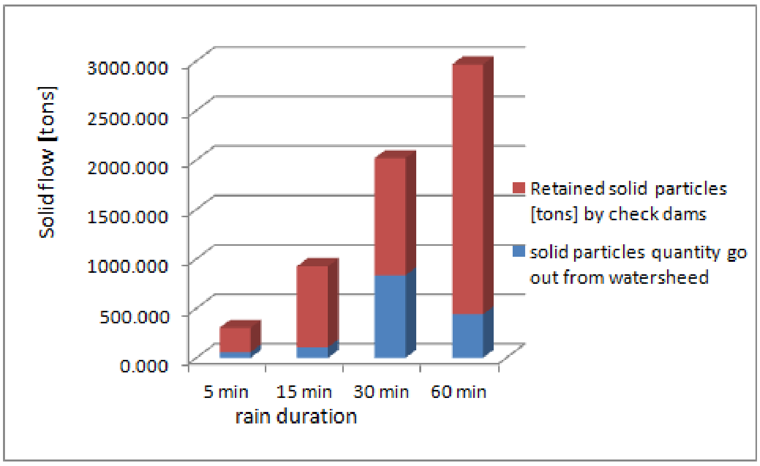

Figure 7: Solid flow amounts wich are retained by check dams and which going aut from watersheed

CONCLUSIONS

Assess whether the control works of torrential formations and torrential basins helps to reduce erosion and decrease the amount of solid material derived from the slopes of a catchment can be done by calculating some indicators such as hydrological effect, anti-erosion effect, hydrological efficiency coefficient and anti-erosion efficiency coefficient. The higher values of these indicators show that the contribution of control works with the solid and liquid leakage reduction is more important. These indicators can be calculated for a single control work, for a certain kind of work, and the whole system of fitting drainage network and catchment.

Also be taken into account investment costs to achieve such works, respectively their operating costs.

The final decision on setting up a hydrographical basin with liquid and solid flow control works and with soil erosion control works should be based on technical and economic calculation, comparing costs with the costs of damages in variant in which the watershed is not equipped with this kind of control works.

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