ASPECTS OF OPTIMIZATION OF SOIL EROSION CONTROL SYSTEMS

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Abstract: *In recent decades we are witnessing a rapidly expanding areas affected by soil erosion (both hydric and wind erosion) and the disastrous consequences of this natural phenomenon in all continents. Soil degradation is an ancient process that cannot be stopped completely, only controlled, appeared with agriculture, but its extent and impact on the environment are currently more alarming. The negative effects of this process are: reducing the production capacity of ecosystems, global climate change and the environment in general, deterioration of human food resources, undermining economic development. The consequences of erosion on national economies are multiple: direct (agricultural production losses, floods, silting etc.), and indirect: degradation of pastures, that pushing grazing in forests, so their degradation; chaotic modification of runoff drainage regime on slopes which removes required water from vegetation; appearance of rapid floods, producing significant damages; increased river discharges; floods; entrainment, destruction and transportation of particles that form fertile soil horizon. Soil erosion control system include all activities and works which providing the administration of public domain of land, with local / national interest, and their sustainable management. Soil erosion control arrangements, consisting in general from a set of hydrotechnical structures and non-structural measures, produce both a favorable and unfavorable influences on environment. Their different constructive and exploitation solutions exercise a significantly impact on the environment. Therefore the advantages and disadvantages of each solution must be weighed and determined to materialize one or other of them seriously argued. The optimization of soil erosion control systems is needed to meet current and future requirements in the field of rational land management in the context of integrated management. Optimization process of soil erosion control systems includes several components related to environmental protection, technical side and the business side. This paper summarizes the main aspects and possibilities of optimization of existing soil erosion control systems and those that are to be achieved.*

Key words: *soil erosion control, optimization, hydrotechnical structures, non-structural measures.*

INTRODUCTION

In recent decades we are witnessing a rapidly expanding areas affected by soil erosion (both hydric and wind erosion) and the disastrous consequences of this natural phenomenon in all continents. Soil degradation is an ancient process that cannot be stopped completely, only controlled, appeared with agriculture, but its extent and impact on the environment are currently more alarming. The negative effects of this process are: reducing the production capacity of ecosystems, global climate change and the environment in general, deterioration of human food resources, undermining economic development. The consequences of erosion on national economies are multiple: direct (agricultural production losses, floods, silting etc.), and indirect: degradation of pastures, that pushing grazing in forests, so their degradation; chaotic modification of runoff drainage regime on slopes which removes required water from vegetation; appearance of rapid floods, producing significant damages; increased river discharges; floods; entrainment, destruction and transportation of particles that form fertile soil horizon.

Whole country the total erosion is 126 million t/year, and the alluvial effluence is 44,6 mil.t/year, which represents 35%. In terms of the forms of erosion, 84.5% comes from agricultural land (106,8 million t/year), of which the depth erosion participate with 29,8 million t/year (Table 1). (S.C. AQUAPROIECT S.A., 2006)

Table 1

Total soil erosion in Romania

Process name	Total erosion		Coefficient of effluence	Alluvial effluence	
	million t/year	%		million t/year	%
Surface erosion	61,8	49,0	0,26	16,1	36,2
Depth erosion	29,8	23,6	0,46	13,8	31,0
Landslide	15,0	12,0	0,35	5,2	11,6
Erosion from forest fund	6,8	5,4	0,40	2,7	5,9
Bank erosion	12,6	10,0	0,54	6,8	15,3
Total	126,0	100,0	0,35	44,0	100,0

Work necessary for the protection and soil amelioration are based on studies and projects, in design process placing the problem of finding solutions to erosion control in terms of dispersed allotments of arable land, which can be highlighted as at European level, but especially at the national level.

Globally, due to the demarches of different organizations in the world, the focus increasingly more on continuous monitoring of land use for soil conservation, program that combines studies, investigations, projects, methods and techniques to prevent and combat, which having regard to the principles of sustainable development: that meets the needs of the present generation without compromising the opportunity of future generations to meet their own needs.

Table 2 and Figure 1 show the situation of soil erosion control systems in Romania (occupied area and emplacement).

Table 2

Occupied area of soil improvement arrangements

Evolution of land reclamation arrangements on agricultural land, in the period 1999 - 2009	Area of arrangements for irrigation		Area of arrangements for drainage		Area of arrangements for soil erosion control works	
Anul	ha	%	ha	%	ha	%
1999	3.179.796	36,72	3.201.553	36,98	2.276.909	26,3
2000	3.177.512	35,25	3.201.628	36,12	2.485.374	28,03
2001	3.177.207	36,7	3.201.628	36,98	2.278.490	26,32
2002	3.176.283	36,69	3.201.748	36,98	2.279.904	26,33
2003	3.176.252	36,69	3.201.885	36,98	2.280.336	26,34
2004	6.176.632	36,67	3.202.431	36,97	2.281.335	26,36
2005	3.001.091	37,86	2.851.181	35,97	2.074.913	26,17
2006	3.097.309	36,88	3.085.295	36,73	2.216.577	26,39
2007	3.057.047	37,73	2.911.441	35,93	2.134.250	26,34
2008	3.095.633	36,83	3.085.295	36,72	2.222.287	26,45
2009	3.095,721	36,83	3.085.295	36,71	2.224.469	26,46
±	-84.075		-116.258		-52.440	

Source: Ministry of Agriculture and Rural Development

Status of mentioned works is far from satisfactory, some of which are not functional due to lack of equipment for exploitation, poor maintenance of various parts, lack of funds for maintenance and operation. Therefore, it is necessary rehabilitation and modernization of land reclamation works. (http://www.anpm.ro)

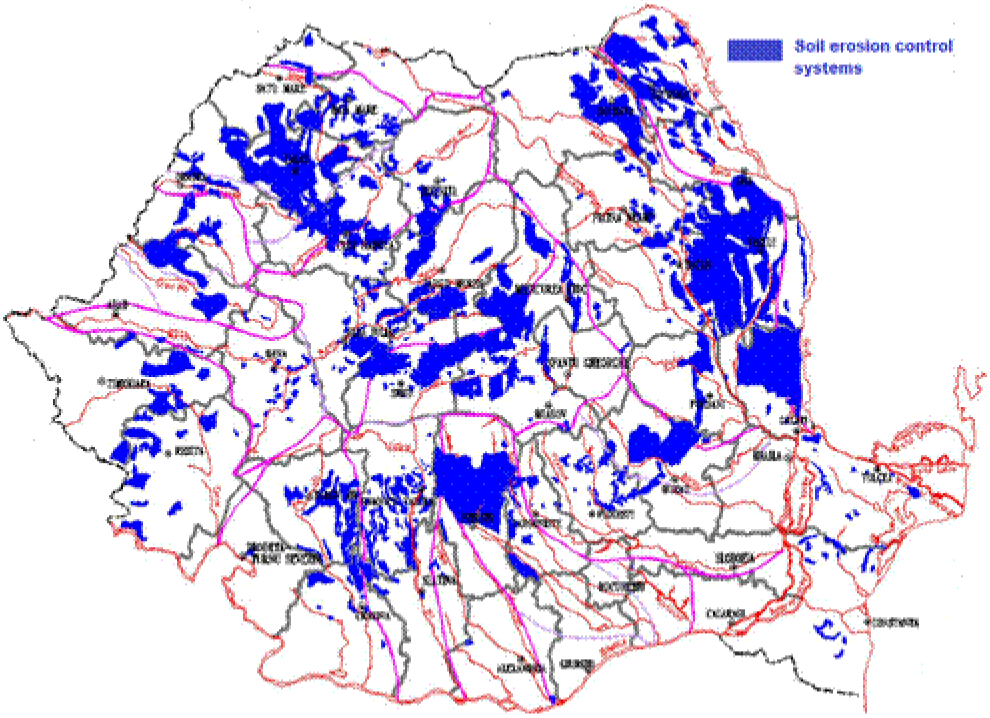

Figure 1: Soil erosion control systems in Romania

Occurred degradations had as causes the wear in time of constructions and overcoming the computational flow during a flood. Unfulfilment on time of current and capital repairs has increased the degradation, leading in some cases to destroy the works.

Soil erosion occurs extensively and in different forms, which may lead to further impoverishment and destruction of the soil and hence the decrease in agricultural production.

Soil erosion control works are executed in a unitary conception and in complex with other land reclamation works (irrigation, drainage, dikes), as well as with the works for water management, hydropower, forestry, land management and environmental protection. (S.C. AQUAPROIECT S.A., 2006)

MATERIAL AND METHODS

A soil erosion control system is the set of activities and works which ensure the management of public domain of land with local / national interest and the qualitative and sustainable management of soil. Soil erosion control system, in generally, consist of one or more of the followings (BÂCOV, 1996; POPOVICI, 1991; GIURMA, 1997; DI SILVIO, 1998):

1. Works on hillslopes (erosion control works) - organizational works (restructuring land use categories, 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 - works in the peak zone and in ravine origin zone; arrangements along the drainage network; hydrotechnical cross structures that can be filtered; longitudinal hydrotechnical works; arrangements in the natural area of deposit of sedimets.

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)

In Romania, most soil erosion control systems were achieved before 1990, the main purpose was increase of agricultural production and of land area used for agriculture. In their implementation has not focused on their optimizing, in particular for environment protection. After 1990, due to the economic situation, most of the work specified in soil erosion control remained in early stages of implementation. Works were in progress continued with a slow rate or entered in the stage of conservation.

Currently the focus is on achieving flood protection systems, respectively restoration of abandoned irrigation systems after 1990. This work may be new arrangements or fit into existing soil erosion control systems.

Soil erosion control arrangements produce about environment both a beneficial and unfavorable influence. Different constructive and exploitation solutions of these arrangements exert significantly impact on the environment. Therefore the advantages and disadvantages of each solution must be analyzed and the determination to materialize one or other of them seriously argued. Soil erosion systems optimization is needed to answer current and future requirements in the field of rational land use. (www.library.utt.ro)

Optimization is the activity of selecting, from the set of possible solutions to a problem, the solution that is best compared to a predefined criterion. This definition implies that the following components:

1. A technical problem consisting in a mathematical calculus of solutions;

2. Existence of multiple solutions to the same problem;

3. A criterion for selecting the optimal solution.

The objective function is the mathematical expression of optimization criterion. This should reflect the economic efficiency of the process and at the same time to answer any technical process operation objectives: operational safety and quality compliance.

Optimization can be seen as a ratio between the effects and efforts to achieve these effects. As this ratio have a higher value, the optimization process is more efficient. (NICA, 2001)

Purpose for which is achieved mostly soil erosion control systems are mainly related to soil conservation, rational land use, increase of agricultural production, flood protection, irrigation, drainage.

RESULTS AND DISCUSSIONS

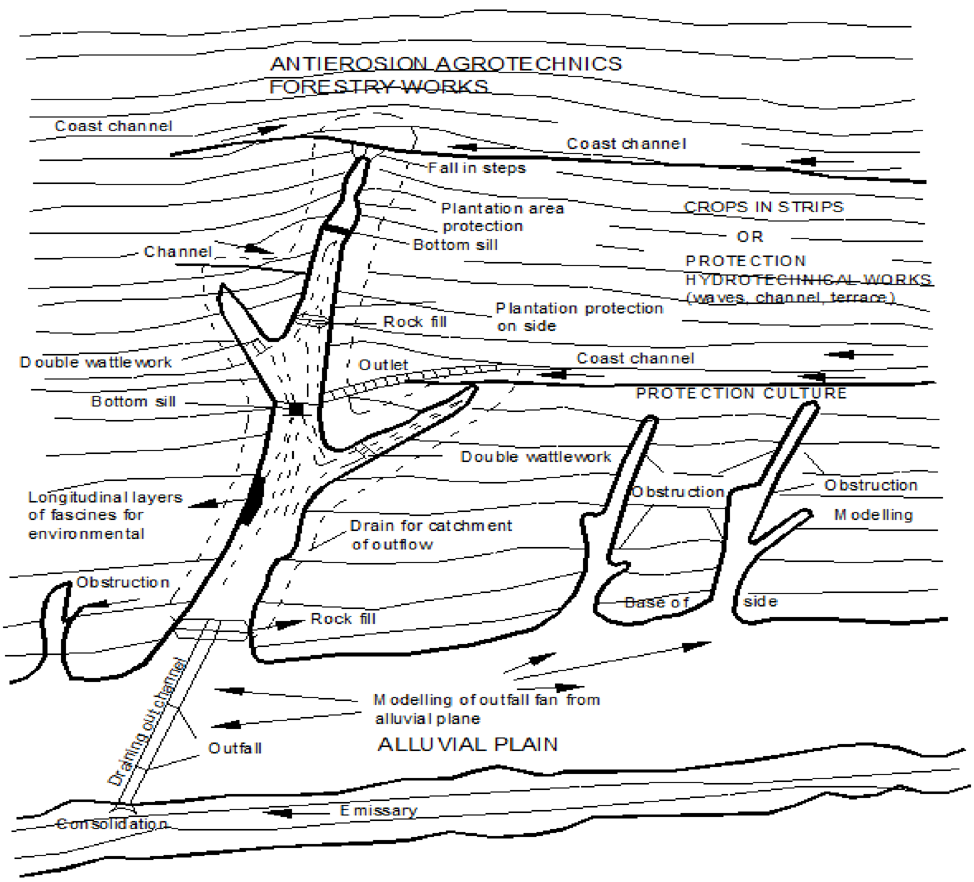

Figure 2: Soil erosion control system (after POPOVICI, 1991)

The optimization of choice of soil erosion control system emplacement. To achievement of soil erosion control systems should be considered that they affect the territory in which they are located (Figure 2), and surrounding areas.

In addition to satisfy the uses for which they were designed, site selection for arrangements must follow two important criteria: investment cost as low as, respectively as small negative effects on the population; environment, land use.

When analyzing all existing variants of arrangements, should be imposed the condition that the effects of soil erosion control system implementation can compensate losses due its negative effects on the environmental factors (human settlements, water, air, soil, subsoil, flora and fauna). (CHIRIAC et al., 1976)

The quantitative optimization of soil erosion control system. As optimization criteria can be used to allocate expenses necessary for development and / or operation of one or more watersheds, where is located the soil erosion control system.

The objective function is:

$$z = \min \sum_{i=1}^{n} (C_i + P_i)$$

where: n - time period (month, year), C_i - expenditures of different soil erosion control measures during the period i (costs of maintenance, operation and investment), Pi - losses.

Decision variables x_i can be reported soil loss and surface runoff. Restrictions result from soil conditions, hydrological and hydrogeological conditions of the studied area.

The qualitative optimization of soil erosion control system. Soil erosion affect the water quality of rivers. Water quality management models include sources of pollution (point sources and diffuse sources - chemicals from the hillslopes, fertilizers washing) and their effects on surface water and uses, respectively the measures taken to reduce negative effects.

As optimization criteria can be used the necessary expenses for wastewater treatment in a river basin and the cost of water treatment for drinking, from the same river basin.

Decision variables x_i are levels of treatment in i points, located along a stream.

The objective function is:

$$z = \min \left(\sum_{i=1}^{m} B_i + \sum_{j=1}^{n} A_j\right)$$

where: B_i - the cost of soil erosion control works in adjacent watershed, A_j - the cost of water treatment for drinking in the point j.

Optimization of soil erosion control systems from point to view of environmental protection. In accordance with the statement of the United Nations Conference in June 1972 in Stockholm, the "environmental impact" means any effect of a activities product on environment, such as: fauna and flora health and safety, soil, air, water, climate, landscape and historical monuments or other structures, on the interaction between these factors, effects on cultural heritage or socio-economic conditions resulting from alterations to those factors.

Hydrotechnical arrangements (including soil erosion control measures) in generally, and hydrotechnical structures in particularly, produce on the environment both a positive and a negative impacts. Regardless of the implemented measures, their negative impact on the environment cannot be removed completely. Therefore it was concluded that this quantitatively and qualitatively decrease may only issue, finally reaching a convenient impacts, widely accepted, by potentiating the beneficial effects and reducing harmful effects, thus protecting the important elements of the environment.

In frame of soil erosion control systems, special attention should be given to reducing the negative environmental impact of hydrotechnical constructions made in the beds of ravines.

Effects of hydrotechnical structures, in soil erosion control arrangements, on environment are: clearing vegetation on the site of constructions; partial or total destruction of flora and fauna; flooding some areas due to losses from the partial or total construction damage.

Measures that can be taken to reduce harmful effects on the environment are: to ensure all possible conditions for the survival of fauna and flora by taking these considerations into account in phase of system design, replacement and reparation of damaged hydrotechnical structures, execution in time of current and capital repairs.

These measures are actually the optimization of existing soil erosion control works, in terms of environmental protection.

In case of new arrangements, all environmental factors should be included in their design phase. Different constructive solutions have a significantly different impact on the environment. Therefore the advantages and disadvantages of each solution must be weighed and decision to materialize one or other of them seriously argued.

General concept of soil erosion control systems design must respect criteria that minimize the ecological balance damage, which include:
- the priority objective must be the environment protection and biodiversity conservation, taking into account the conservation and protection of habitats and species of community interest;
- the constructions must be "elastic" type, capable to support large, differentiated deformations;
- allow free and natural water flow, especially during floods, and in case of ice, float or solids existence in water table;
- the constructions must to be properly founded on natural ground to avoid damage caused by advancing erosion under construction body, including in water withdrawal period;
- allow phased implementation of works, ensuring time tracking of morphological processes and performance parameters of the project;
- design of arrangements will be considered the limits allowed for hydromorphological, physic-chemical and biological indicators of ecosystems, to achieve the main goal of environmental targets;
- deviations from these criteria can be justified only to defend the population and/or economic objectives with social value.

To reduce the impact on environment exist the following solutions:
- use of local materials for proper integration of construction works in landscape;
- ecological rehabilitation / reconstruction measures, that will override on integration measures in environment, will result in a decrease of impact supposed by project implementation. (www.library.utt.ro; www.studiidemediu.ro; ROMANIAN GOVERNMENT, 2008)

Technical optimization of soil erosion control systems. To achieve a real optimization of soil erosion control systems is necessary to analyze all the components of systems in order to bring them operating at maximum performance.

Once this analysis is done and identifying the causes that restrain functionality at maximum capacity, is possible to determine the measures to be taken to ensure the functioning of these components to maximum efficiency or replace them if necessary.

It examines the behavior in time of construction, the state of degradation of them, if the equipment operates on designed characteristics and yields, if not affected by time (obsolescence of equipment), if not appeared in the meantime new technologies with a higher projected yield for existing conditions. (COGĂLNICEANU, 1987)

Assess whether the arrangement works of torrential formations and torrential basins contributes to the reduction of soil erosion processes can be done by calculating the following indicators (POPOVICI, 1991):

- Hydrologic effect $E_{H\,p\%}$ (m^3/s):

$$E_{Hp\%} = Q_{1p\%} - Q_{2p\%}$$

where: $Q_{1p\%}$ - maximum discharge of runoff corresponding to rain with p% probability in studied hydrographical basin

$Q_{2p\%}$ - maximum discharge of runoff in the same hydrographical basin, after a certain period of time after execution of the works, in case of rain the same probability.

- Antierosional effect E_A (m^3/an):

$$E_A = V_1 - V_2$$

where: V_1 – average annual volume of sediments, carried in a particular section, before execution of soil erosion control work

V_2 - average annual volume of sediments, carried in a same section, after a certain period of time after execution of the soil erosion control work.

- Hydrological efficiency coefficient $K_{H\,p\%}$

$$K_{Hp\%} = E_{Hp\%} / Q_{1p\%}$$

- Antierosional efficiency coefficient K_A:

$$K_A = E_A / V_1$$

The higher values of these indicators, indicates that the contribution of soil erosion control works to solid and liquid runoff reduction is important. These indicators can be calculated for one work, for a certain kind of work, and for the whole system of arrangements of the drainage network and watershed.

Economical optimization of soil erosion control systems. This optimization process aimed to obtaining maximum benefit for generating funds to recover investment costs and operating and maintenance costs of the system.

Operating and maintenance cost recovery is a minimum support condition for soil erosion control arrangements.

In taking of investment decision, it is important to evaluate the economic impact of various soil erosion control arrangements, it is necessary to perform a cost-benefit analysis for each possible solution.

The evaluation of these investments can be described as having four basic steps:
• arrangement quality performance evaluation;
• estimating the associated costs;
• characterization of different solutions in terms of cost and efficiency;
• achieving comparative economic analysis of different arrangement solutions.

In the allocation of capital resources, some investments are considered as "strategic investment", ie they are necessary for the national economy or to protect the public and social-economic facilities against effects of floods, environmental pollution or drought. Another group of investment is required by law, they have little or no recovery rate of capital and they are not selected based on economic criteria. (B.I.R.D., 2009)

CONCLUSIONS

Climate change, dangerous hydrological phenomena's (floods, torrential rains, droughts, pollution) which occur more frequently in last year's, respectively the current economic context impose a necessity of optimizing soil erosion control systems, especially because population growth determine the increasing of food demand from agricultural production.

Rational management of the soil can be achieved by the combination of activities and technologies to obtain simultaneously: bioproductivity, food security and soil quality, economic viability and social acceptability. This can be done if it acts primarily on the main objective - the protection of soil quality. Maintaining long-term productive capacity of the soil, increasing the fertility and combating desertification are primary strategic task of all countries.

Optimizing of soil erosion control systems is a very important process; both at the design stage (new arrangements) and in the operational phase of these works (new and existing arrangements).

Optimization process of soil erosion control systems includes several components related to environmental protection, technical side and the economical side. The first two components can be implemented separately, but cannot be separated in any form of economic component.

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