SOIL EROSION AS A FACTOR OF ENVIRONMENT DEGRADATION IN YUGOSLAVIA

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ABSTRACT

Soil erosion, along with its general consequences (soil loss, water loss, disturbance of runoff regime, torrential floods, reservoir siltation, irrigation and drainage systems siltation, etc.) causes great damages which can be classified as ecological effects. In the process of runoff on eroded slopes, along with soil particles (erosion sediment), all the other substances contained in the eroded soil layer are also removed. After reaching the streams and reservoirs, erosion sediment has the following ecological (and other) adverse effects: a) mechanical pollution of stream and reservoir water, b) chemical pollution of water by manures and fertilizers c) chemical pollution by pesticides. Water erosion is the dominant type of erosion in upland regions of Yugoslavia (about 75% of the total area of Serbia and more then 90% of the total area of Montenegro belongs to hilly-mountainous regions. In the province Vojvodina plains dweler region, the wind erosion is the significant problem. The research showed that average annual losses (influenced by soil erosion) of humus and nutrients in Serbia have a very significant values (580,327.32 t of humus; 40,159.02t of N ; 3,832.62 t of P and 14,367.20 t of K). In this maner the soil erosion cause water contamination. A considerable segment in the protection of water conta-mination, i.e. in the environmental protection, is presented by the consequent and persistent erosion control. All human activities in a watershed or region should be based upon the principles of the erosion co A considerable segment in the protection of water from contamination, i.e. in the ntrol and soil and water, viz. environmental conservation i.e. based on the principles of sustainable develpoment.

Key words: environmental degradation, soil erosion, sustainable development

INTRODUCTION

The soil erosion is on of the most significant factors which endangers the soil and water.Soil erosion is a very complex process of destroying soil particles at the soil surface

(or in stream channels) including their transport from the upper to the lower parts of the watershed, by the energy of overland flow at the slopes or flowing in the streams. Erosion processes and sediment transport are wide spread all over the earth surface affecting many of human activities.The essential economic activities such as: agriculture, forestry, industry, water resources development, civil engineering, etc., have more or less something in common with the erosion and sediment problems. The problems are also present in non-economic activities such as: environment protection, recreation, etc. The economic and social effects of soil erosion and sediment transport are therefore very important.

Soil erosion, along with its general consequences (soil loss, water loss, disturbance of runoff regime, torrential floods, reservoir siltation, irrigation and drainage systems siltation, etc.) causes great damages which can be classified as ecological effects. Ecological effects can be divided into two groups: on-site effects and off-site effects.

On-site effects cause environment degradation due to intensive erosion processes and soil loss.Off-site effects, by erosion, sediment transport through the watershed drainage pattern, is less visible and less studied. In the process of runoff on eroded slopes, along with soil particles (erosion sediment), all the other substances contained in the eroded soil layer are also removed. These substances can be natural (organic and inorganic) and artificial. Natural substances vary depending of geologic and pedologic properties of the slope or eroded region. Most often they are various fertilizers and pesticides applied in agricultural production and they reach the hydrographic network together with erosion sediment. After reaching the streams and reservoirs, erosion sediment has the following ecological (and other) adverse effects: a) mechanical pollution of stream and reservoir water, b) chemical pollution of water by manures and fertilizers c) chemical pollution by pesticides[5].

According to the data of American association for water supply, overland flow from agricultural areas and the input of nutrients is the main cause of water contamination with nitrogen and phosphates.[2] The scale of this problem is illustrated by the fact that in the USA, the annual losses of nitrogen, phosphorus and potassium caused by water erosion amount to about 50 million tons[7].

According to the data of Federal Research Institute for agriculture and soil conservation, in the ex USSR, the input of only 100 $kg \cdot ha^{-1}$ fertilizers in slope soil increases the concentration of nitrogen for 16 %, potassium for 55 % and phosphorus for 92 % in the runoff, compared to the areas where fertilizers were not utilized. If the losses of nutrients are calculated together with the soil loss (suspended sediment), they are much greater, so that one ton of suspended sediment contains 3 kg of nitrogen, 1.7 kg phosphorus and more than 20 kg potassium[7].

The presence of these substances in the streams and storages depends first of all on the intensity of erosion processes in the watershed (sediment yield) and on sediment transport from the watershed. The development of erosion processes in the watershed is conditioned by numerous factors, of which forest vegetation has the strongest influence on the reduction of erosion processes. Sediment transport depends on hydrologic-hydraulic conditions in the stream channel. The paper shows the results of the research of water erosion, sediment transport and transport of organic nutrients and biogenic elements in a small experimental watershed in Serbia.

THE HARMFUL EFFECT OF SEDIMENT IN STREAMS AND RESERVOIRS

The presence of sediment in water makes its purification for purpose of utilization in households, industry and/or agriculture more expensive.

The mechanical contamination of water by the erosion sediment can result in very harmful consequences regarding the ecological balance in a watercourses or reservoirs. In the case of a small concentration of the suspended sediment, i.e. low water murkiness, the sun rays penetrate deeply into the water and stimulate the photosynthesis. Through the murky water, the passing of sunlight is impeded, leading to the decreasing photosynthesis by the water plants and thereby impairing the ecological balance in the watercourse. The sediment deposit in the rivers results in shallowing of the fish breeding sites, thus causing a series of ecological perturbations. The deposition of the dragged and suspended sediment at the bottom of the watercourse causes some of the water plants to disappear, on which fish and other animals in the water feed. Besides, a general deterioration takes place of the life conditions of the river fauna, being reflected drastically upon its reproduction.

The most important ecological effect of the soil erosion and sediment transport consists of introducing the chemical and biological contaminants into river flows. Because of it the water quality drastically deteriorates. According to A. Kurfürst (1992), the increase of application of chemization, viz. application of fertilizers, primarily of mineral ones, is a very significant part in intensifying of agricultural production. The average annual application of fertilizers in 1936/37 amounted to 3.1 kg of nitrogene, 6.6 kg of phosphorus and 3.4 kg of potassium, or summarily 13.1 kg NPK per ha, whereas this application increased considerably for the season 1985/86, i.e. 100.0 kg of nitrogene, 77.2 kg of phosphorus and 76.4 kg of potassium, or summarily 253.6 kg of NPK per ha yearly[6].

The problem of the chemical contamination of water due to water erosion is much more expressed at the steep slopes, where washout of the soil and fertilizers and pesticides along with it is considerably more intensive.

It is considered that the presence of nitrogene and phosphorus has no negative effect upon the industrial utilization of water, but it is no longer suitable for drinking. The presence of the nitrates in the potable water causes some lung diseases. There is no easy and efficient way of elimination of phosphates, nitrates and chlorides from the water. The presence of nutrients washed out from the slopes perturbs the ecological balance in the rivers, natural and artificial lakes. This relates in particular to the lakes (accumulations). The recent lakes are characterized by low content of nutrients (oligotrophic conditions). By incidence of the nutrients such as nitrogene, phosphorus etc. (as a consequence of erosion) the conditions in the lakes, through mesotrophic, become eutrophic ones (the presence of the large quantities of nutrient chemical elements). The eutrophication results in rapid multiplication (blooming) of the water plants leading to the undesired smell and taste, choking of the filters at water intakes, decreasing of the oxygen content in the water and thereby making the survival of fish and other water fauna more difficult.

Nitrogene, phosphorus, potassium and other organic and biogeneous substances mostly arrive as a consequence of the erosion (water and eolic types) in the form of the erosion sediment. According to the data of the American Society of Water Supply Organizations, the surface flows (i.e. the surface erosion) from the agricultural areas is the main cause of contamination of the water by nitrogene and phosphorus (Table I).

For purpose of increasing yields from agriculture, the chemical means are being applied for plant protection against the harmful fughii, insects, for weed and other pests elimination. The substances in question are most frequently very poisonous and very resistant, and they are being deposited in the arable land, in the water, and by the nutrition chain also in the organisms of the wild and tame animals as well as in the human body. As has been shown by the results of the research, only 20-30% of the chemical substances fall upon the leaves of the weed and other plants, and the rest is falling on the soil, from where due to erosion it reaches the watercourses and reservoirs.

Table I. Arrival of the nutrients of different origin into the watercourses and lakes (according to N. Hudson, 1971)

The contamination source	Nitrogene, 10^6 kg·year^{-1}	Phosphorus, 10^6 kg·year^{-1}
Sewage	495-720	90-225
Industrial waste water	>450	*
Draining from agricultural regions 1. arable land 2. not arable land	 675-6750 180-855	 54-540 67.5-337.5
Feces from cattle raising	>450	*
City areas waste waters	49.5-495	5-76.5
Rainfall	13.5-265	1.4-4

** - no data available

The presence of humus in the soil assists in decomposition of these poisonous substances reaching the soil, but since it is the humus horizon to be taken away as the first by erosion, the deposition takes place of the poisonous substances in the soil, wherefrom again by erosion they reach the watercourses and reservoirs. Thus poisoned water becomes a danger for any use, and the life in it (both plant and animal ones) is faced with the problems of how to survive. Therefore true ecological disasters happen ever more frequently.

SOIL EROSION AND SEDIMENT TRANSPORT IN YUGOSLAVIA

Water erosion is the dominant type of erosion in upland regions of Yugoslavia (about 75% of the total area of Serbia and more then 90% of the total area of Montenegro belongs to hilly-mountainous regions.

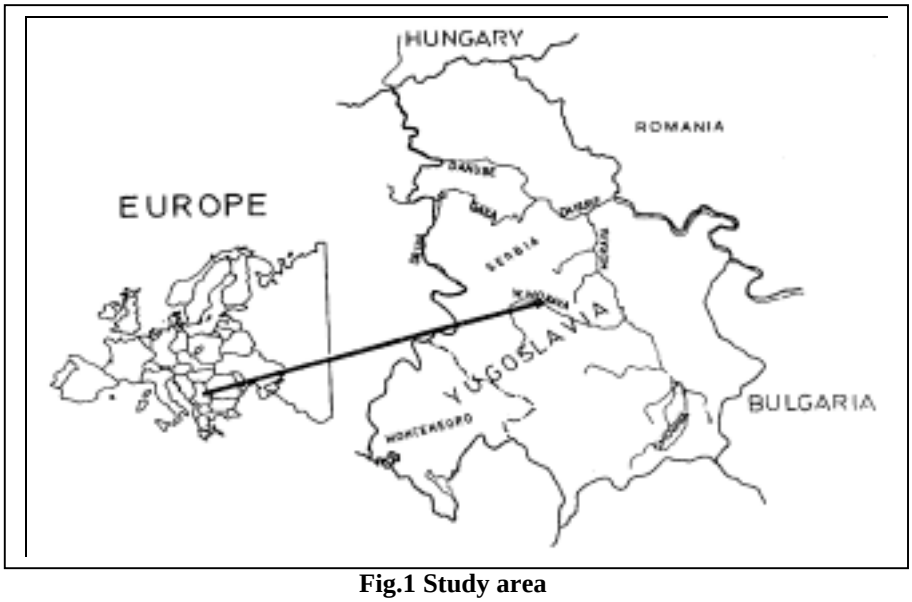

Fig.1 Study area

In the province Vojvodina plains dweller region, the wind erosion is the significant problem. Water erosion depends on a number of physical-geographical and antropogeneaus factors, consequently in order to define the state of water erosion in Yugoslavia have been analyzed: parent rock, composition relief, climate, vegetal cover (land use). All the factors presents the favorable conditions for water erosion processes. The survey of water erosion in Yugoslavia has been given based on the data of erosion in the Republics (Table II). As the consequence of such natural conditions 86.41% of teritory of Serbia is under erosion processes of different intensities, whereas 95.10% of territory of Montenegro is attacked by soil erosion (in Yugoslavia 87.59% of the territory is under erosion processes)[1].

Table II The rate of erosion in Yugoslavia

Republic	Total area km^2	Attacked by erosion	
		km^2	%
Serbia	88,361.0	76,354.43	86.41
Montenegro	13,812.0	13,135.20	95.10
Yugoslavia	102,173.0	89,489.63	87.59

Fig.2 Soil erosion in the Južna Morava river watershed

Table III Gross erosion and sediment transport in Yugoslavia

Republic	Gross erosion		Annual sediment transport	
	Total	Specific	Total	Specific
	$m^3 \cdot y \cdot r^{-1}$	$m^3 \cdot yr^{-1} \cdot km^{-2}$	$m^3 \cdot yr^{-1}$	$m^3 \cdot yr^{-1} \cdot km^{-2}$
Serbia	37,249,975	421.57	9,350,765.0	105.80
Montenegro	3,799,352	273.08	2,101,600.0	152.20
Yugoslavia	41,149,327	401.76	11,452,365.0	112.10

The above scope of water erosion in Yugoslavia is the consequence of natural features and antropogeneous impact.

The share of certain categories of destructiveness, i.e. intensity of erosion processes in stream channel and in watershed, has been calculated from the erosion map for Serbia prepared according to S.Gavrilovic`s classification. Unfortunately, the map of erosion has not been produced for Montenegro, so the data are not available. From the erosion map it can be seen that 35.55% of the area in Serbia has been attacked by erosion of the I, II, and III categories (excessive, intensive and medium erosion), which illustrates the significance of the problem and the amount of damage erosion causes to economy and to the society in general.

Sediment transport related to gross erosion (total erosion production), is also considerable (Table III)[1]. Damage caused by erosion initially is the loss of the upper fertile soil horizon, coupled with loss of organic and mineral nutrients from steep and ploughed land, leading to inadequate air and water relations in the soil.

The data on gross erosioin and sediment transport have been obtained from the map of erosion for Serbia, whereas for Montenegro the data are given on the basis of torrent catastre:in both cases the method by S. Gavrilović has been applied. Total average annual gross erosion in Yugoslavia amounts o 41,149,327.0 m^3, i.e. specific annual gross erosion amounts to 401.76 $m^3 \cdot km^{-2}$ while annual sediment transport is 11,453,365.0 m^3 and specific annual sediment transport is 112.10 $m^3 \cdot km^{-2}$. If annual gross erosion is turned into equivalent hectares of soil 20 cm thick, it can be concluded that every year 20,525 ha is endangered

Table IV Mean annual losses of humus and nutrients with suspended sediment

Watershed	Period	Mean annual losses in $kgha^{-1}$					
		Humus	N	P	K	Ca	Mg
Dubošnički Potok	1986-1988	84,98	6,12	1,14	3,52	27,09	13,94
Lonjinski Potok	1984-1988	39,55	1,90	0,37	2,37	4,53	3,20
Đurinovac Potok	1984-1988	68,80	3,16	0,97	3,93	8,40	6,80
Lještarska Dolina	1981-1985	73,63	6,73	1,29	9,32	18,55	16,08

In Yugoslavia, erosion regions with the most disastrous torrents are in Serbia, e.g.: the gorges Grdelička Klisura and Ibarska Klisura, Vranjska Kotlina valley as well as the watershed of the river Timok.

The damage caused by water erosion results from detaching and transporting the fertile soil horizon slopes, as well as from torrential flows. Erosion removs organic and mineral nutrients from the top soil, the soil structure is destroyed leading to the disturbance of soil characteristics of air and water relationship.

Table IV shows mean annual losses of humus and nutrients as the consequence of water erosion in four experimental watersheds in Serbia[4][5]. The largest value of losses was recorded in the waterheds of torrents Dubošnički potok and Lještarska Dolina, where the soil erosion and sediment transport has been more intensive than in the other two watersheds.

Wind erosion also causes losses of humus and nutrients together with wind erosion sediments.

Table V shows the values of average annual losses of humus and nutrients with the suspended sediment in Serbia (based of research in the experimental watersheds in Central Serbia and wind erosion experimental stations in Vojvodina)[3].

The result of research show that the losses of humus and nutrients are, first of all, determined by the intesity of erosion and the quantity of gross erosion. The losses was also affected by the level of protection works and soil conservation. In addition to the impacts of water erosion, great losses of humus and nutrients are also result of wind erosion.

Fig. 3 Gully erosion on the arable land in the Južna Morava river watershed

The soil erosion (by water and wind) and sediment transport in addition to ather damages, also cause the nature resources damages (soil loss, water loss and pollution, degradation of landscape etc.).

Table V Average annual losses of humus and nutrients with the suspended sediment in Serbia

Region erosion type	**Area (km^2)**	**Losses of humus and nutrients ($t\ yr^{-1}$)**			
		Humus	**N**	**P**	**K**
Central Serbia -Water erosion	66850.0	352793.84	18050.85	2714.31	13076.84
- Vojvodina - Wind erosion	21506.0	227533.48	22108.17	1118.31	1290.36
TOTAL	88361.0	580327.32	40159.02	3832.62	14367.20

The result of research show that the losses of humus and nutrients (as a water polluter) are first of all, determined by the intensity of erosion and the quantity of gross erosion. The losses was also affected by the level of protection works and soil conservation.. The soil erosion (by water and wind) and sediment transport in addition to other damages, also cause the environment (nature resources) degradation (soil loss, water loss and pollution, degradation of landscape etc.).

CONCLUSIONS

As the conclusions it can be say: the soil erosion(by water and wind) and the sediment transport, in addition to other damages like soil loss, the loss of humus and biogeneous elements (soil impoverishment),water loss etc. also cause the environmental damages in the form of mechanical and chemical contaminations of the water in streams and reservoirs into which the sediment arrives together with the accompanying elements. The contamination scale can be very significant, depending on intensity of soil erosion.
A considerable segment in the protection of water from contamination, i.e. in the environmental protection, is presented by the consequent and persistent erosion control. All human activities in a watershed or region should be based upon the principles of the erosion control and soil and water, viz. environmental conservation i.e. based on the principles of sustainable develpoment .

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